City of Norman
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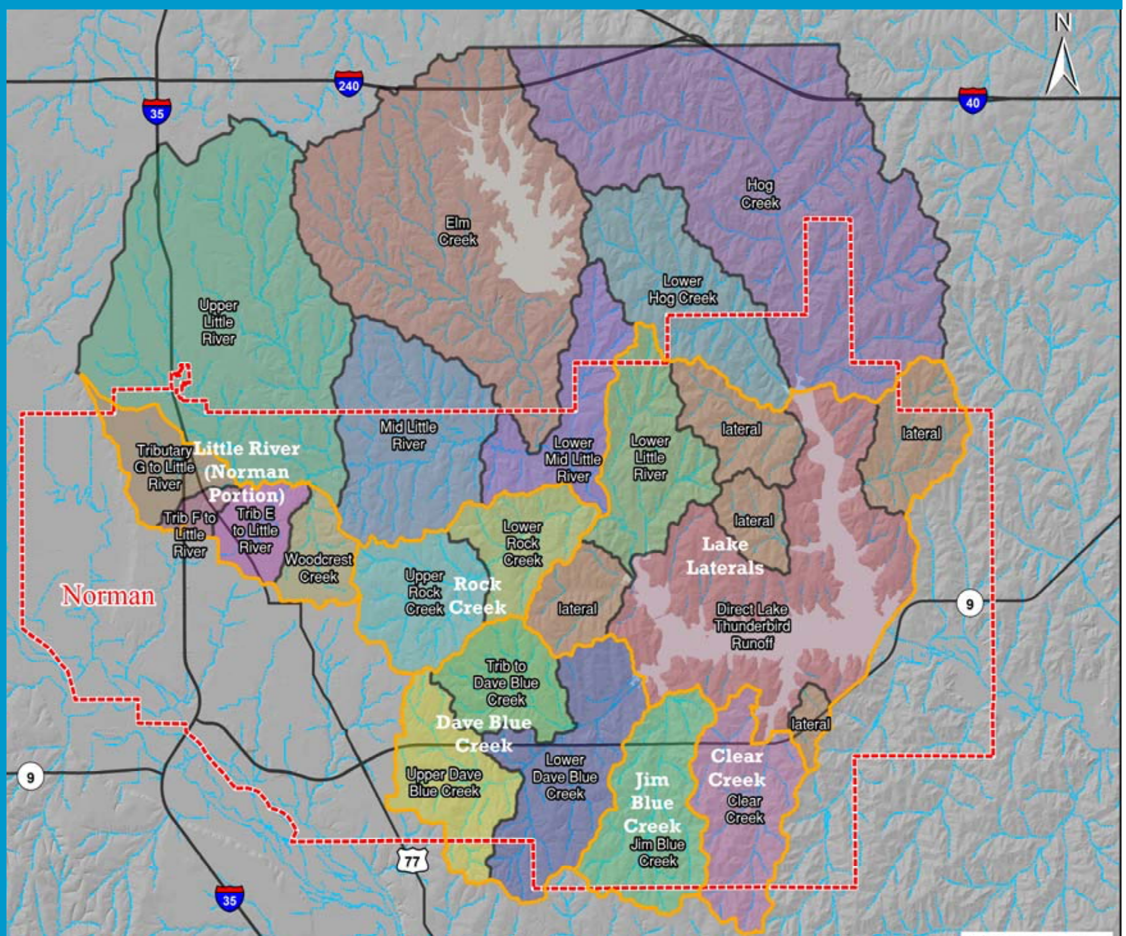
City of Norman, OK Lake Thunderbird Compliance Plan and Monitoring Plan



October 27, 2015

GBM[c] & Associates
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Introduction

In November 2013 the City of Norman received notification from the Oklahoma Department of Environmental Quality (ODEQ) that a Total Maximum Daily Load (TMDL) completed for Lake Thunderbird had been approved by EPA (EPA approval date was 11-13-2013). The City of Norman along with the City of Moore and Oklahoma City (Figure ES-1) are all within the Lake Thunderbird Watershed and are required to comply with this TMDL. The ODEQ letter required that Norman, as a Phase 2 MS4 Permittee, "incorporate all Total Maximum Daily Load (TMDL) requirements applicable to the storm water discharges into the City's Storm Water Management Program (SWMP)" and that the SWMP be modified within 24 months from the date of EPA approval (of the TMDL). The SWMP is to be modified in accordance with "Appendix E" of the Lake Thunderbird TMDL, which is titled "*MS4 Stormwater Permitting Requirements and Presumptive Best Management Practices (BMP) Approach.*"

This document provides the requirements of Appendix E compiled into two documents, a TMDL Compliance Plan and a Monitoring Plan. The Compliance Plan outlines the steps Norman will take to meet the TMDL requirements and the Monitoring Plan provides the framework for assessing progress towards meeting the goals of the Compliance Plan.

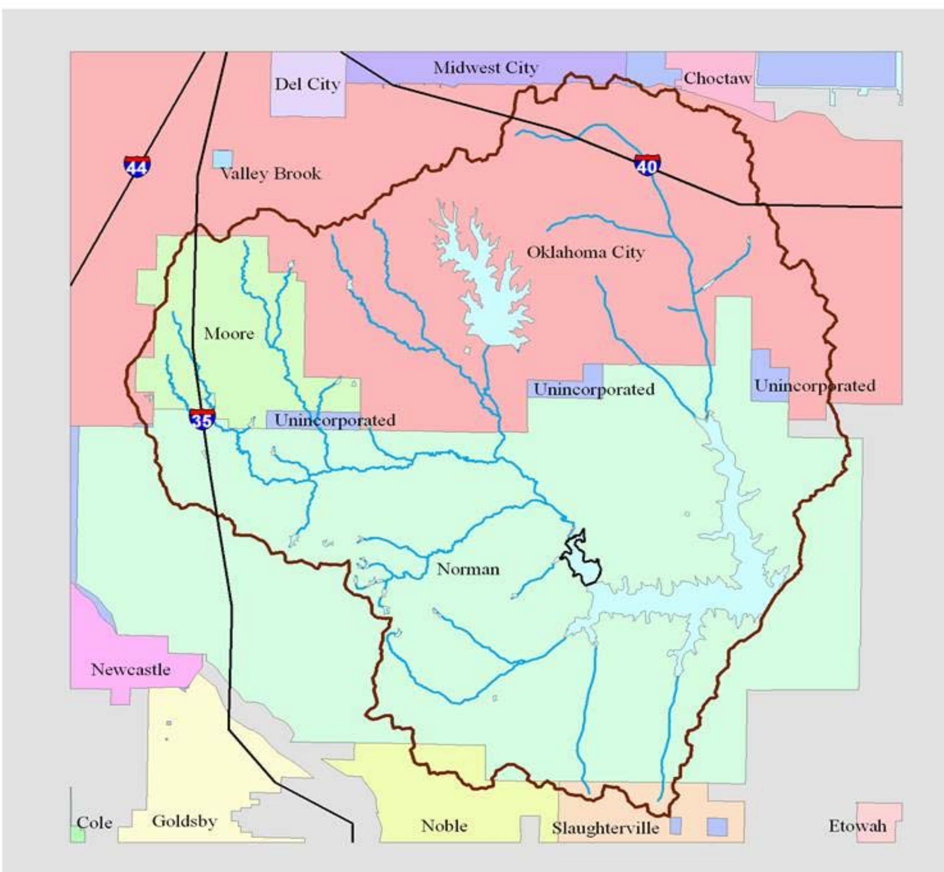

Figure ES-1. Lake Thunderbird Watershed Communities.

Approach

To achieve the WLA allocated to the City of Norman MS4 program, and meet the requirements of the TMDL, reductions of sediment, nitrogen and phosphorus are required. A watershed assessment was completed using a combination of GIS land use analysis, watershed modeling and unified stream assessments to help identify watershed issues, sources of pollution and to prioritize problem sub-watersheds. All this information was analyzed first from an overall watershed perspective (all of the Lake Thunderbird Watershed), then the focus was narrowed to examine just the Norman portion of the watershed.

The WLA and reduction requirements allotted to the City of Norman and the other MS4's on an average basis, are provided in the Table ES-1.

Table ES-1. WLA and Required Pollutant Reductions for the MS4's on an Average Annual Basis[1].

Pollutant	LTA Annual Load (lb)	Moore WLA (lb/Year)	Norman WLA (lb/Year)	OKC WLA (lb/Year)	LTA 35% Reduction	Moore Required Reduction (lb/Year)	Norman Required Reduction (lb/Year)	OKC Required Reduction (lb/Year)
TN	259,120	67,604	105,255	86,287	90,692	23,046	35,881	29,415
TP	50,900	14,715	19,866	16,319	17,815	5,011	6,765	5,557
TSS	25,336,800	5,493,018	10,689,596	9,151,652	8,867,880	1,872,570	3,644,083	3,119,798

[1]These average values can be converted to maximum daily load (MDL) values (for comparative purposes) using the same procedure presented in Section 5.5 of the TMDL report (Dynamic Solutions, 2013).

The TMDL Compliance Plan is largely based on the HSPF modeling completed for the TMDL by Dynamic Solutions using data from 2008 to 2009. Load reductions required to meet Norman's WLA were determined by applying various BMPs to the base HSPF model outputs for different land uses in each of Norman's sub-watersheds. HSPF modeling was used to address mostly structural BMPs applied to urban\suburban and rural land. In addition to the HSPF modeling, the Watershed Treatment Model developed by the Center for Watershed Protection (Caraco, 2013) was also used to determine potential reductions from non-structural BMPs.

Watershed Assessment

An assessment of the Lake Thunderbird Watershed was completed to supplement the information from the TMDL report and the HSPF modeling. The focus of the assessment was to better pin-point which sub-watersheds have potentially been contributing the most sediment and nutrients to Lake Thunderbird and the most probable major sources of those non-point source (NPS) pollutants within each sub-watershed. The assessment utilized GIS resources and field based unified stream assessment (USA) methodologies. The last sections of this assessment focus on specific findings for the City of Norman MS4 portion of the Lake Thunderbird Watershed. This narrower focus was accomplished by utilizing the watershed delineations found in the City's Storm Water Master Plan and grouping them into 6 sub-watersheds to create watershed sizes that were logical and manageable (Figure ES-2). The sub-watersheds depicted in the Figure are those that Norman has complete control over.

Priority Sub-Watershed Ranking

A priority matrix was developed to aid in determining which sub-watersheds were contributing the most sediment and nutrients to Lake Thunderbird and most in need of being addressed.

Scores were assigned to sub-watersheds based on a ranking of the top five sub-watersheds with the greatest apparent impacts (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.).

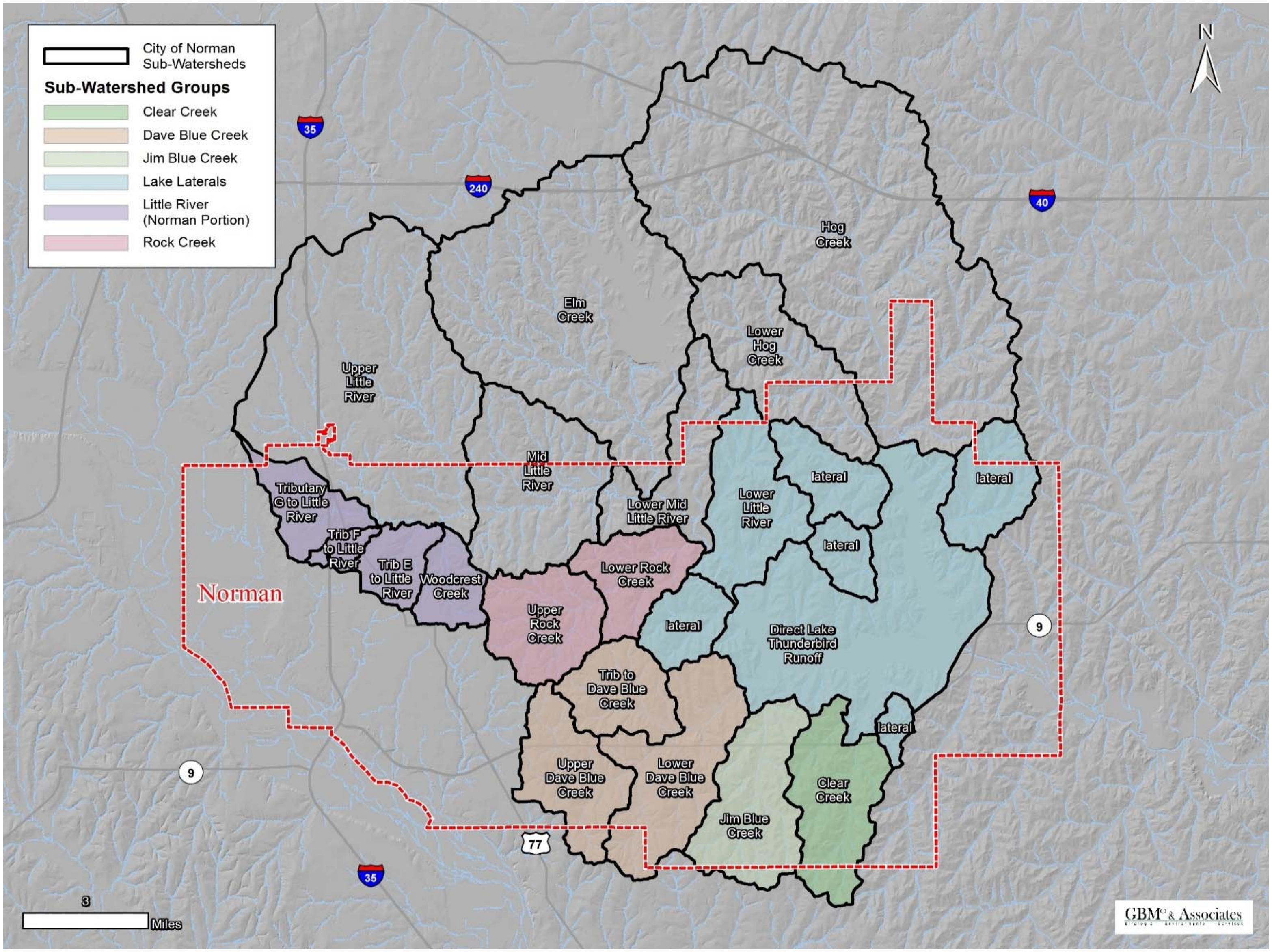

Figure ES-2. Norman MS4 Portion of the Lake Thunderbird Watershed and its Associated Sub-Watersheds.

This detailed matrix analysis aids in defining where priority areas are and what the key sources of pollution may be (Table ES-2).

Table ES-2. Total Scores and Matrix Ranking.

Severity Rank	Sub-watershed	Score
1	Little River (Norman portion)	30
2	Rock Creek	27
3	Dave Blue Creek	26
4	Jim Blue Creek	16
5	Lake Laterals	12
6	Clear Creek	10

According to the matrix ranking, the three key sub-watersheds within the Norman portion of the watershed most in need of source reductions are Little River, Rock Creek and Dave Blue Creek. These areas should be the focus of the first round of BMP implementation (Figure ES-3).

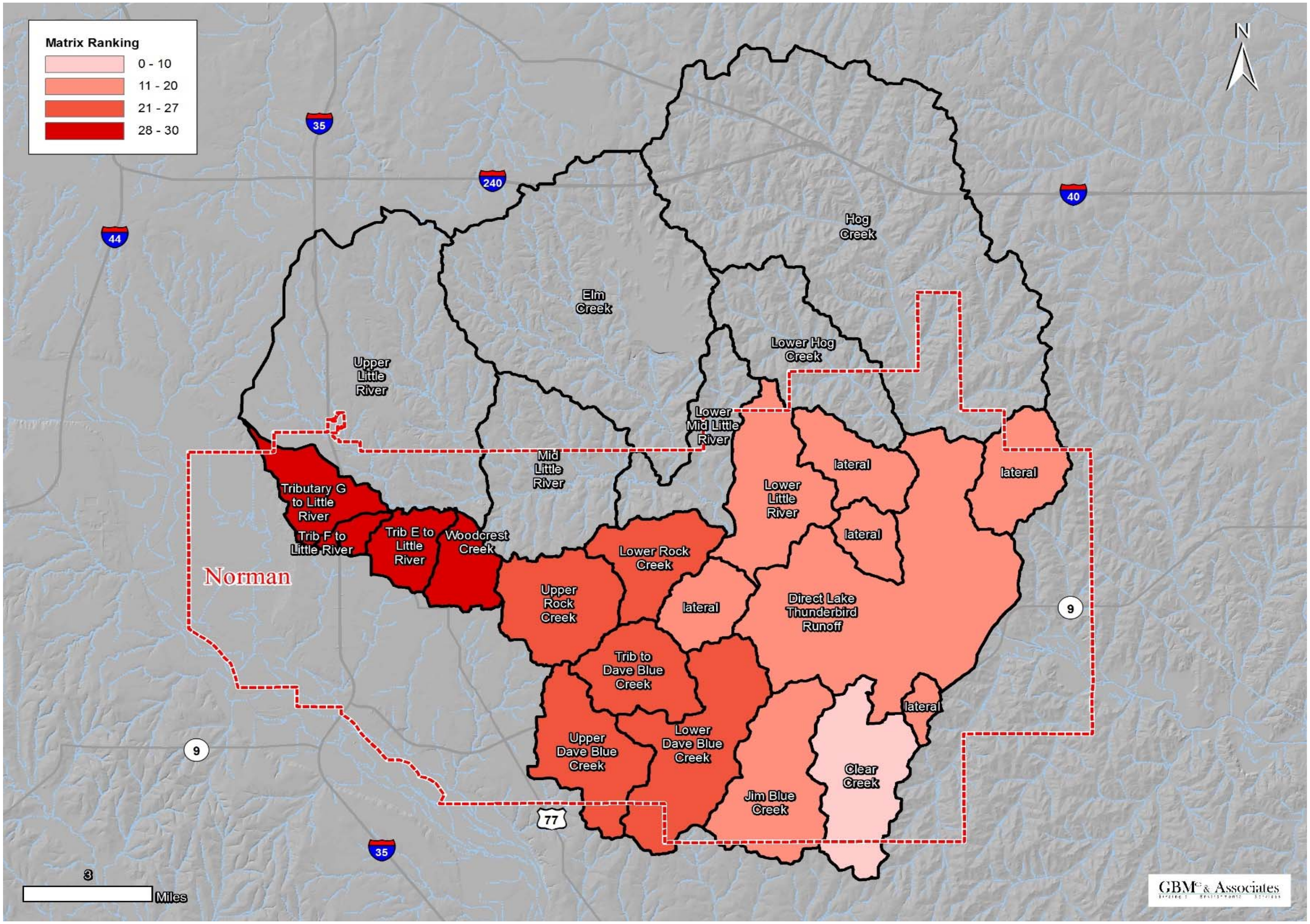

Figure ES-3. Ranking of Critical Sub-Watersheds According to the Priority Matrix.

Management Measures Already Implemented by Norman

The City of Norman has been implementing many good storm water management measures over the past few years. Several of these management measures have great potential to reduce pollutants in storm water. The City's Storm Water Master Plan (March, 2009) outlines many of their efforts including improving drainage and creation of several ordinances to protect streams and Lake Thunderbird. These ordinances have been written and approved by the City Council and are described briefly below.

- Water Quality Protection Zone Ordinance
- Storm Water Management Ordinance(s)
  - Detention/Retention
  - Illicit Discharge Detection and Elimination
  - SSO/CSO Identification and Reduction
- Fertilizer Ordinance(s)

Modeling NPS Load Reduction Potential

Two water quality models were used to determine the potential of different management practices to reduce TSS and nutrients in the Norman portion of the Lake Thunderbird Watershed. The Center for Watershed Protections Watershed Treatment Model (WTM) was used to model non-structural BMPs. The EPA supported HSPF model (Bicknell, 2001), which contributed to the development of the TMDL, was used to model urban/suburban BMPs and rural BMPs.

Non-structural BMPs

The WTM is used in this plan exclusively as a tool to determine which non-structural (education based and City program based) BMPs most effectively reduce TSS and nutrients in each sub-watershed. BMPs evaluated with the WTM include:

- Residential Lawn Care Education
- Pet Waste Education Programs
- Street Sweeping
- Catch Basin Cleanouts
- Septic System Education Programs
- Sanitary Sewer Overflow Repair

Structural BMPs

The latest version of HSPF and the base model UCI file, which was used to develop the TMDL, were used to evaluate structural (requiring construction and/or installation on the ground) BMP removal rates from various land uses in the Norman portion of the Lake Thunderbird Watershed. HSPF addresses load reductions from BMPs on a land use by land use basis.

These land use applications are provided in Table ES-3. A goal to apply BMPs on approximately 25% of each respective land use was established. This goal is based on practicality and the reality that to achieve BMP implementation on more than 25% of an area is unreasonable and likely unattainable.

Table ES-3. Percent of each Land Use to which a Particular BMP was applied.

Land use[1]	BMP Group	% Land use Applied
Urban/Suburban (URLD, URML, URHD)	Detention	25
	Bioswale	25
Commercial (URCOM)	Detention	25
	Bioswale	25
	Rain garden/barrel	15
Rangeland (RNGE)	Cover Crops	25
Row Crops (AGRL)	Cover Crops	25
Pasture/Hay (PAST)	Grazing	25
Grass-open space (BERM)	Bioswale	25

[1]Each land use category includes the code used in HSPF for that land use.

Other BMPS

In addition to the traditional non-structural and structural BMPs discussed in the preceding sentences other key BMP recommendations are discussed below.

Construction Storm Water

Storm water runoff from construction activity can significantly impact water quality in receiving streams. ODEQ regulates discharges of storm water runoff from construction related activity through General Permit OKR10. Through City ordinances, the City of Norman imposes regulations to reduce the impacts of construction activity within areas of its jurisdiction.

Unpaved Roads Management

Potential reductions of pollutants through implementation of good unpaved road BMPs on 50% of the unpaved roads in the MS4 watershed can have a significant impact on load reductions.

Riparian Buffers Restoration

Riparian vegetated buffers are lacking or limited in several reaches of Lake Thunderbird Watershed. Riparian buffers are critical to the health of a stream system and serve to reduce pollutant loads transported to stream systems from adjacent land uses and they reduce or prevent stream bank erosion. Riparian areas throughout the Lake Thunderbird Watershed should be restored or enhanced

Stream Bank and Channel Stabilization

Several of the streams in the Lake Thunderbird Watershed are exhibiting significant stream bank erosion at several locations. It is recommended that efforts be implemented to reduce and prevent stream bank and bed erosion within City of Norman controlled areas of the Lake Thunderbird Watershed. These efforts include measures designed to reduce erosive peak storm flows as discussed in other sections of this report as well as stream bank stabilization and/or remediation efforts where practicable. Where stabilization and/or remediation efforts are implemented, prioritization of efforts should be based on a cost-benefit approach.

Load Reduction Summary

A summary of the load reductions that would be achieved through this Compliance Plan are provided in Tables ES-4-6. Load reductions for sediment are primarily gained from stream bank stabilization, urban area BMPs and construction storm water improvement (Figure ES-4). However, load reductions for nutrients (nitrogen and phosphorus) are primarily gained from urban BMPs and rural BMPs (Figures ES 5 and 6).

Table ES-4. Summary of Annual Sediment Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/ Practice (lb/yr)
Annual Average Reduction Required for Norman: 3,644,083							
Non structural	31,548	53,731	31,832	2,874.0	2,721.0	16,562.0	139,268
Urban/Suburban	91,764.0	334,065.0	117,153.0	22,909.0	29,812.0	101,477.0	697,180
Rural	26,125.0	26,825.0	53,377.0	12,986.0	12,952.0	39,437.0	171,702
Unpaved Road Maintenance	17,447.0	755.0	11,654.0	5,906.0	8,901.0	31,496.0	76,159
Construction SW	88,573.5	400,221.0	97,321.5	40,459.5	22,963.5	28,431.0	677,970
Riparian Restoration	316.0	180.0	707.0	616.0	502.0	671.0	2,992
Stream Restoration	469,703	563,644	469,703	140,911	140,911	93,941	1,878,812
Totals	725,477	1,379,421	781,748	226,661	218,762	312,015	**3,644,083**

Table ES-5. Summary of Annual Nitrogen Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Annual Average Reduction Required for Norman: 35,881							
Non structural	513.0	863.9	648.5	465.0	440.0	2,678.0	5,608.4
Urban/Suburban	2,216.0	7,918.0	1,901.0	178.0	232.0	797.0	13,242.0
Rural	1,791.0	1,577.0	3,381.0	835.0	911.0	2,717.0	11,212.0
Unpaved Road Maintenance	5.3	0.2	3.6	1.8	2.7	9.6	23.2
Construction SW	27.1	122.5	29.8	12.4	7.0	8.7	207.5
Riparian Restoration	0.1	0.1	0.2	0.2	0.2	0.2	0.9
Stream Restoration	1,396.8	1,676.1	1,396.8	419.0	419.0	279.4	5587.0
Totals	5,949	12,158	7,361	1,911	2,012	6,490	**35,881**

Table ES-6. Summary of Annual Phosphorus Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Annual Average Reduction Required for Norman: 6,765							
Non structural	71.3	136.7	91.3	77.0	73.0	442.0	891.3
Urban/Suburban	2,542.0	9,356.0	2,008.0	150.0	196.0	673.0	14,925.0
Rural	1,099.0	978.0	2,076.0	507.0	562.0	1,678.0	6,900.0
Unpaved Road Maintenance	2.8	0.1	1.9	1.0	1.4	5.1	12.3
Construction SW	14.3	64.5	15.7	6.5	3.7	4.6	109.3
Riparian Restoration	0.1	0.0	0.1	0.1	0.1	0.1	0.5
Stream Restoration							
Totals	3,729	10,535	4,193	742	836	2,803	**22,838**

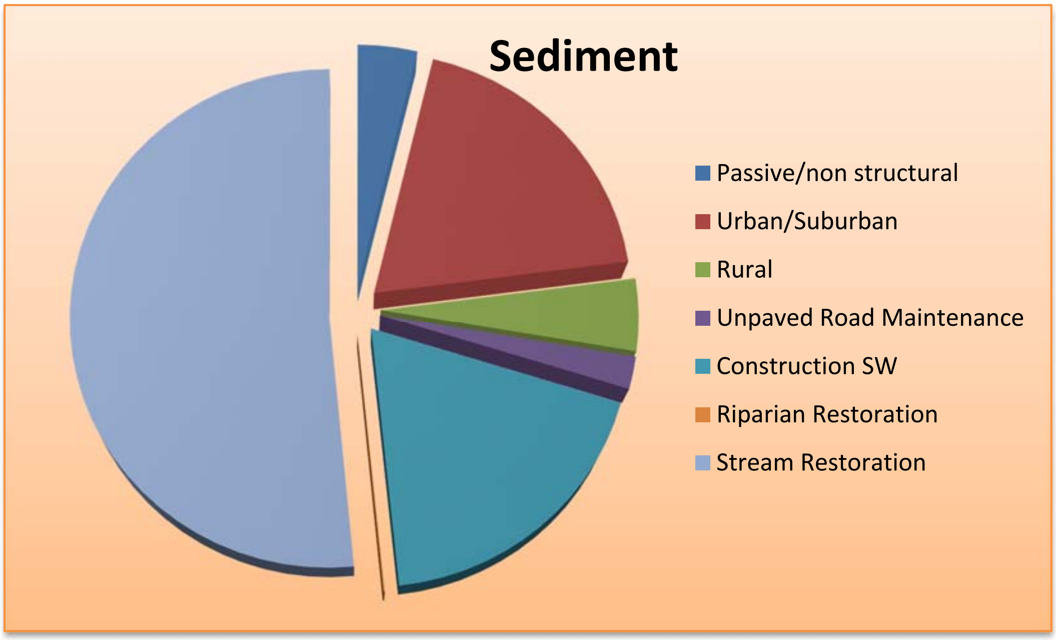

Figure ES-4. Sediment Reductions from Various Implementation Efforts.

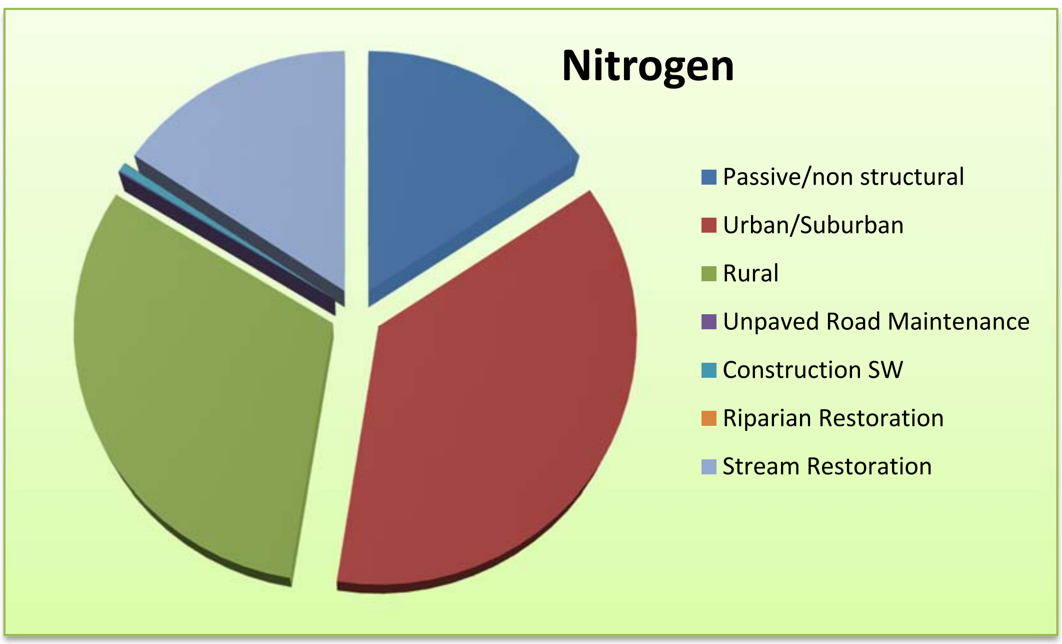

Figure ES-5. Nitrogen Reductions from Various Implementation Efforts.

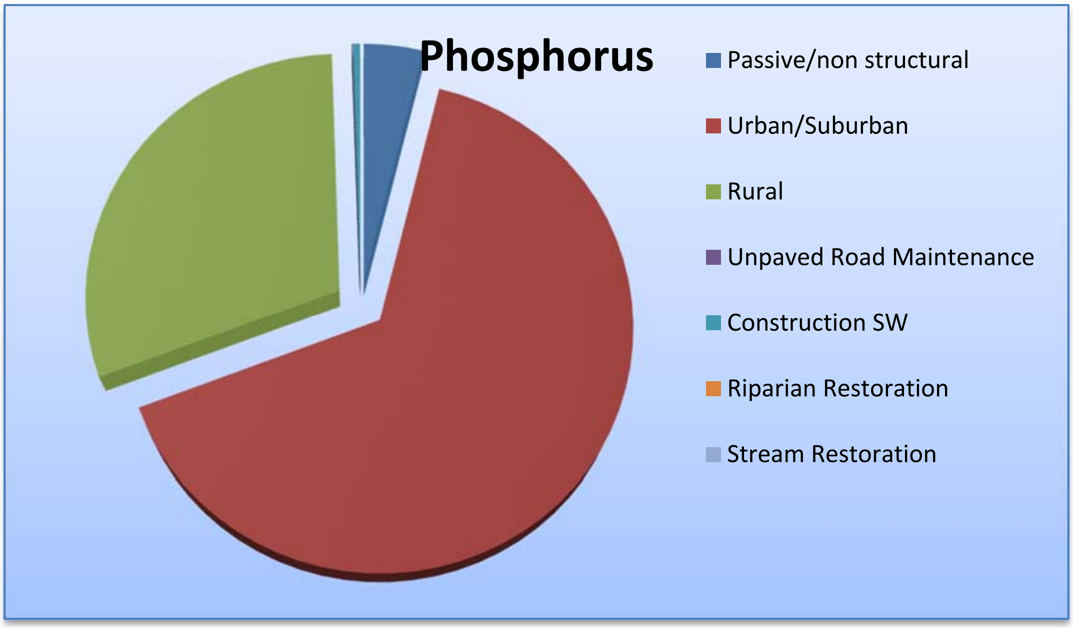

Figure ES-6. Phosphorus Reductions from Various Implementation Efforts.

Implementation

The implementation portion of this TMDL Compliance Plan is designed to direct watershed management activities, including: BMP implementation to achieve load reductions, monitoring water quality to track goal attainment, continuing education efforts, etc. The Compliance Plan should be reviewed and updated at least every 5 years to ensure it is still relevant to the current conditions of the watershed and is in line with the data that has been collected over the past 5 years of monitoring. In order to help ensure success of the plan it is necessary to have a schedule prioritizing implementation and listing the tasks that need to be accomplished. The schedule provides 15 years for actions to be accomplished that will result in attainment of the pollutant load reductions assigned to the City of Norman MS4.

The basic strategy to attain these goals is to begin monitoring immediately, address education and other non-structural BMPs in the first five years. Years five through ten will be used to reassess the loading status and the Compliance Plan applicability, and to phase in implementation of rural and structural BMPs. Full attainment of the TMDL by the end of 2031 is anticipated.

Table ES-7. Implementation Schedule[1].

Action Item	Target Date for completion[1]
Begin Compliance Plan implementation	January 1, 2016[2]
Begin monitoring according to the Monitoring strategy	March 1, 2016[2]
Develop strategy to implement passive BMPs	June 30, 2016
Implement education based BMPs	December 31, 2016
Develop Strategy to Address Construction Storm Water	December 31, 2016
Implement Construction Storm Water Plan	June 30, 2017
Implement other non-structural BMPs	October 30, 2017
Review past three years of monitoring data, set baseline and adapt Compliance Plan as needed	June 30, 2019
Develop Strategy to implement rural BMPs	December 31, 2019
Develop Strategy to implement urban/suburban structural BMPs	June 30, 2020
Work with landowners and implement Riparian Buffer Restorations	December 31, 2020
Review past five years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2021
Implement first phase of rural BMPs in priority sub-watersheds	December 31, 2022
Implement first phase of urban/suburban BMPs in priority sub-watersheds	December 31, 2023
Implement second phase of rural BMPs in priority sub-watersheds	December 31, 2024
Review past ten years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2026
Implement second phase of urban/suburban BMPs in priority sub-watersheds	December 31, 2026
Restore/stabilize stream banks in priority sub-watersheds	December 31, 2028
Implement third phase of urban/suburban BMPs	December 31, 2029
Restore/stabilize remaining stream banks	December 31, 2030
Review past 15 years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2031
Implementation complete and TMDL met	July 1, 2031[3]

[1] Participation by landowners and funding are an unknown and could have a significant effect on the schedule and implementation success.
[2] Following approval by ODEQ
[3] Success based on results of final review of data and measurable milestone achievement.

Monitoring

A synopsis of the plan is provided here. Norman will monitor water quality through sample collection, physio-chemical measurement and flow gauging at key sub-watershed locations representing upper watershed areas where urbanization is greatest and lower watershed areas that are more rural. Monitoring will occur at each key sub-watershed station on a monthly basis, with a minimum of four samples focused on high flow events. New stream gauges (water level loggers) will be installed in key sub-watersheds and rating curves developed to calculate loading in those sub-watersheds. The Norman MS4 will use loading data (TSS, TN (as NO3-NO2-N and TKN), TP) collected in the future to compare to the loading data collected historically in their program and data collected during TMDL development. Annual loading from the Norman MS4 will be calculated from monitoring data and compared to their WLA to determine compliance. Load reductions or increases will be determined using the loading data, control charts and trend analysis. Norman may use control charts and trend analysis to gauge if the watershed loading is responding positively or negatively to load reduction efforts.

BMP effectiveness will be monitored in at least two of three ways:

1. Implementation of BMPs on the ground, and
2. Modeling of reductions from BMPs implemented, or
3. Monitoring of sub-watershed loads.

In addition, a rotating storm water outfall sampling program will be implemented such that 40% of large outfalls (36 inch or greater) will be sampled at least once annually. Monitoring parameters will be the same for these outfalls as for the sub-watershed monitoring locations.

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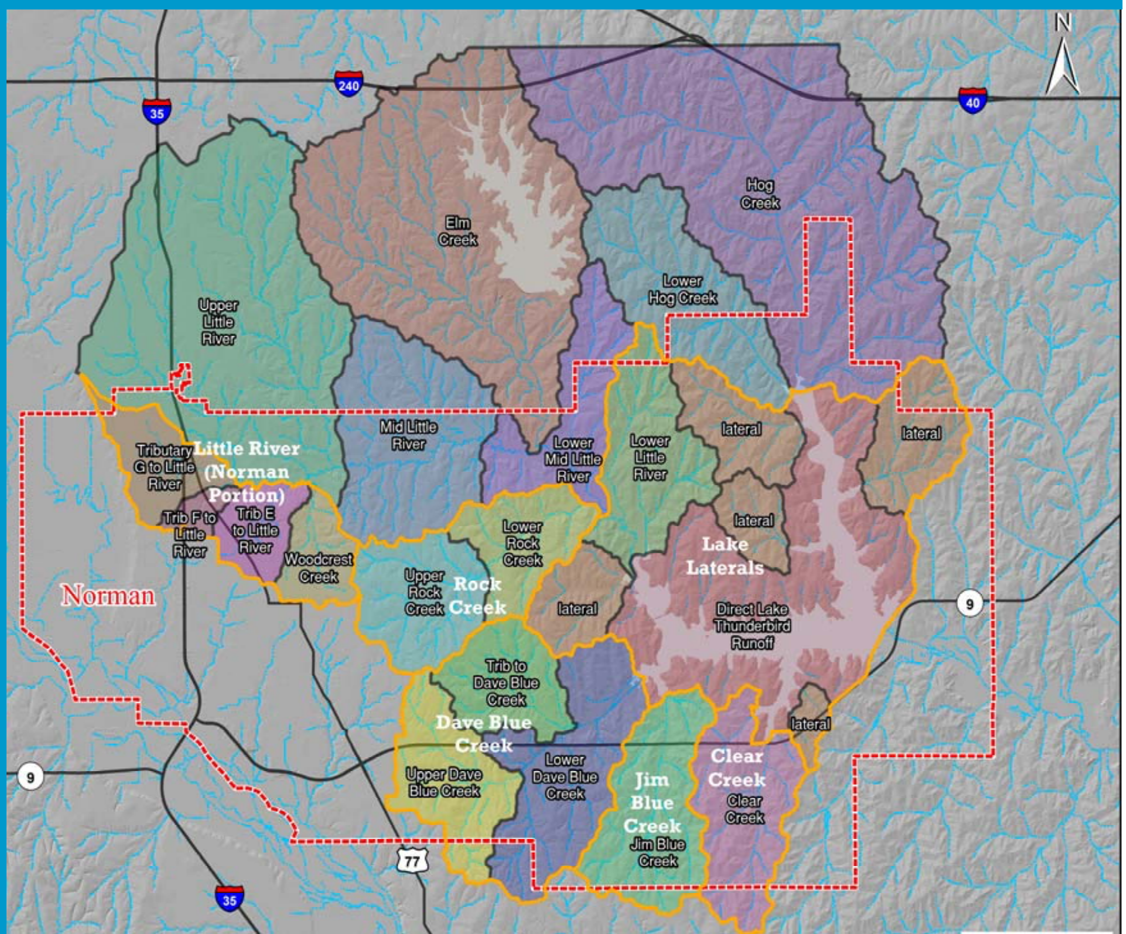

October 27, 2015

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Strategic Environmental Services

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TMDL Monitoring Plan - City of Norman

Prepared for:

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Norman, OK

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October 27, 2015

CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION AND BACKGROUND

The City of Norman received a total maximum daily load (TMDL) final report from Oklahoma Department of Environmental Quality (ODEQ) on November 10, 2013. The objective of the Lake Thunderbird TMDL is to reduce loads of nutrients and sediment such that the waterbody attains all applicable Water Quality Standards designated uses and criteria. If successful, Lake Thunderbird will be removed from the 303(d) list for Oklahoma. Currently Lake Thunderbird is not maintaining the designated uses of Fish and Wildlife Propagation ï Warm Water Aquatic Use for both Dissolved Oxygen and Turbidity, and Public and Private Water Supply for Chlorophyll-Ŭ. The TMDL established a wasteload allocation (WLA) for the City of Norman MS4 program area. To meet the requirements of the TMDL the City developed a TMDL Compliance Plan to reduce sediment and nutrients to a level that achieves the WLA.

The TMDL Compliance Plan was developed based upon a watershed assessment; which was completed using a combination of GIS land use analysis, watershed modeling, and unified stream assessments to help identify watershed issues, sources of pollution, and to prioritize problem sub-watersheds. All this information was analyzed first from an overall watershed perspective (all of the Lake Thunderbird Watershed), then the focus was narrowed to examine just the Norman MS4 portion of the watershed. Watershed modeling was used to determine potential reductions of nutrients and sediment from implementation of recommended best management practices (BMP). Two land use based models, Hydrologic Simulation Program Fortran (HSPF) and The Watershed Treatment Model (WTM), were used to estimate possible reductions in each sub watershed that could be achieved following application of structural and non-structural BMPs.

This monitoring plan is a required component of TMDL compliance. Appendix E of the Lake Thunderbird TMDL provides that ñwithin 24 months of EPA approval of [the TMDL], each permittee shall prepare and submit to the DEQ either a TMDL monitoring plan or a commitment to participate in a coordinated regional monitoring program. Norman has elected to develop a TMDL Monitoring Plan.

Appendix E specifies that the monitoring plan include the following:

- Evaluation of any existing storm water monitoring program related to the TMDL.
- Monitoring goals, types, and sampling and analytical methods.
- Maps of discharge points with drainage areas, and TMDL monitoring sites.
- Consideration of methods for evaluating storm water pollutant loading from construction and industrial sites.

- Inclusion of sampling at storm water points discharging to surface waters of the state from conveyances measuring at least 36 inches at their widest point (one representative sample from 50% of these points is required).
- List of parameters appropriate to the TMDL to be sampled.

The Monitoring Plan shall be fully implemented within three years of EPA TMDL approval and used to periodically evaluate the effectiveness of BMPs to attain the wasteload allocations.

The Monitoring Plan establishes a water quality monitoring program that will be used to track TMDL Compliance. The City of Norman will use water quality sample data (TSS, TN (as NO3-NO2-N and TKN), TP) and flow data to calculate and track pollutant loading and guide Compliance Plan implementation efforts. Load reductions or increases will be determined using the loading data, control charts, and trend analysis. Implementation of the Compliance Plan will reduce export of pollutants such as nitrogen, phosphorus, and sediments into Lake Thunderbird and should be evident in the sample data and trend analysis over time.

The Monitoring Plan's compliance with Appendix E requirements is demonstrated as follows:

1. Norman does not currently have an existing storm water monitoring program related to the TMDL reduction goals.
2. The goals of the Monitoring Plan are as follows:
    a. Collect data of high quality in accordance with the QAPP.
    b. Collect sufficient data to more accurately define baseline loading of nutrients and TSS.
    c. Collect sufficient data to evaluate trends and to evaluate the effectiveness of BMPs as they are implemented.
    d. Collect sufficient data to evaluate the need for Compliance Plan revision (e.g., if progress in reducing pollutant loads cannot be demonstrated).
    e. Collect sufficient data to demonstrate attainment of the WLA assigned to Norman.
3. Monitoring types, sampling and analytical methods are provided in the Monitoring Plan and in the QAPP.
4. Maps of monitoring sites, and a descriptive list of monitoring locations, are provided in the Monitoring Plan and the QAPP.
5. Consideration of methods for evaluating pollutant loads from construction and industrial sites is described in Section 2.4 of the Monitoring Plan.
6. Major storm water discharge monitoring is described in Section 2.3 of the Monitoring Plan.
7. Parameters to be analyzed are found in the Monitoring Plan and the QAPP.
8. The QAPP is attached to the Monitoring Plan.
9. A Monitoring Plan implementation schedule is found in Section 7.0 of the Plan.

2.0 WATER QUALITY MONITORING

In order to track pollutant load decreases, an ongoing monitoring program will be established that addresses the physical, chemical and biological condition of Norman© portion of the Lake Thunderbird watershed. The Norman MS4 portion of the watershed that was the focus of the Compliance Plan will be the watershed, where the monitoring plan will be applied.

Ten TMDL monitoring stations will be established to represent ten of the Lake Thunderbird Sub-watersheds (Figure 1). Stations were chosen based on access and watershed representation (Table 1). In addition, major discharge points (significant storm water outfalls) will be sampled on a rotating basis during storm events (Figure 2). An overall map of all sampling locations relative to Normans major roadways is provided in Figure 3. The following sections provide a description of the tasks that will be performed by the City of Norman (or their contractor). Table 3 provides an implementation and milestone schedule. A Quality Assurance Project Plan (QAPP) has been developed to guide these written activities and contains the important details required of a monitoring program. The QAAP is provided as Attachment A.

2.1 Water Quality Monitoring at TMDL Monitoring Stations

Water quality samples will be collected monthly at each of the 10 designated TMDL monitoring stations shown on Figure 1 and 3. At a minimum 4 of the monthly sampling events per year will be representative of storm water associated with streamflow elevation (see QAPP Section B.1. Figure 3). Storm event monitoring will help identify which watersheds are major nutrient and TSS contributors and provide a better measure of actual loading to Lake Thunderbird. All storm sampling events should occur during the latter half of the rise in the stream flow hydrograph and as close to the peak in the hydrograph as possible. Once the storm hydrograph has dropped 25% below the peak a sample can no longer be considered a storm sample.

All samples will be taken as grab samples (filled from stream water at one moment in time) and will be collected from the main flow area in the stream channel at each station. Samples will be collected below the water© surface where possible but in such a way as to prevent picking up bottom sediments. Water samples will be delivered to the laboratory for analysis. Samples will be analyzed for total phosphorus, total nitrogen (NO3-NO2-N and TKN), and TSS. Additional parameters may be added as necessary. Water samples will be collected by Norman MS4 or their designated contractor. During each sample event in-situ parameters will be analyzed at each station and flow (see Section 2.2) will be measured. In-situ parameters shall consist of pH, temperature, dissolved oxygen, specific conductance and turbidity. In-situ parameters will be measured at the time of sample collection using a portable field meter(s). Field meters will be calibrated following the SOPs which generally adhere to manufacturer's recommendations. A summary of the sampling requirements is included in Table 2.

Hourly rainfall amounts will be recorded from the nearest weather stations in the area. Rainfall data from 2-3 weather stations (determined by the monitoring team) that bracket the sub-watershed(s) will be used where possible. Rainfall amounts will aid in associating nutrient and sediment loading with a particular storm event. Rainfall amounts will also aid in determining the size and intensity of rainfall needed to generate sufficient runoff to allow collection of storm samples in the future.

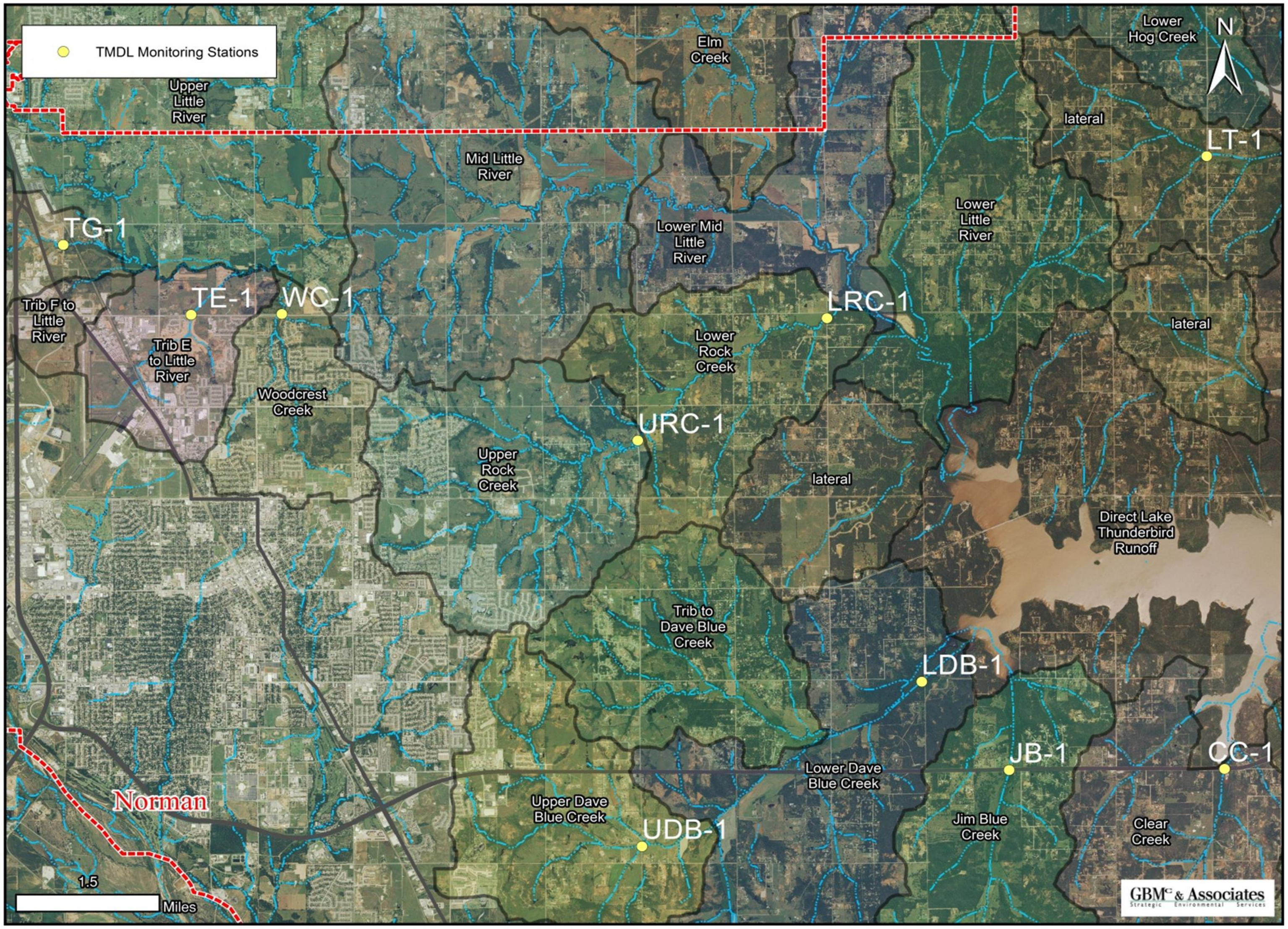

Figure 1. Map of the Anticipated Project TMDL Monitoring Stations.

Table 1. Description of TMDL Monitoring Stations.

Station Name	Waterbody	Lat.	Long.	Location Description	Chemical Monitoring
TG-1	Little River Tributary	35º 17ô22.87ò N	97º 28ô36.04ò W	24th Ave. NW approximately 410 feet south of West Indian Hills Road Intersection	Monthly Sampling for each station. Minimum of 4 of the monthly samples per year shall be during storm event after the flow has begun to rise in the stream with hydrograph as close as possible to peak but not after the hydrograph has dropped 25% below the peak. Grab samples will be collected at each site and will be analyzed for total nitrogen, total phosphorous and TSS. PH, temperature, dissolved oxygen, specific conductance and turbidity will be tested at the time of sample collection. Grab samples shall be collected from the main flow area and, when possible, at least six inches below the water surface. Field meters shall be calibrated following SOPs which generally adhere to manufacturerôs recommendations. Refer to the Monitoring Report and QAPP documents for details on data collection, sampling, reporting and quality control requirements. Include all findings in the required monthly report. See Note 1 for flow monitoring requirements.
TE-1	Little River Tributary	35º 15ô42.84ò N	97º 27ô11.73ò W	US HWY 77/West Tecumseh Road approximately 1750 feet east of 12th Ave. NW	
WC-1	Woodcrest Creek	35º 15ô42.65ò N	97º 26ô11.89ò W	US HWY 77/West Tecumseh Road approximately 1300 feet east of Porter Ave.	
URC-2	Upper Rock Creek	35º 14ô33.09ò N	97º 22ô11.62ò W	48th Avenue NE approximately 3350 feet north of East Robinson Street	
LRC-1	Lower Rock Creek	35º 15ô40.06ò N	97º 20ô08.22ò W	72nd Avenue NE approximately 245 feet south of East Tecumseh Road	
LT-1	Lake Laterals	35º 17ô10.61ò N	97º 15ô54.54ò W	120th Avenue NE approximately 3700 feet north of East Franklin Road	
UDB-1	Upper Dave Blue Creek	35º 11ô21.42ò N	97º 20ô49.46ò W	SH-9/East Imhoff Road approximately 1760 feet east of 60th Ave. SE	
LDB-1	Lower Dave Blue Creek	35º 12ô14.60ò N	97º 19ô04.97ò W	84th Avenue SE approximately 1.02 miles north of SH-9	
JB-1	Jim Blue Creek	35º 11ô21.96ò N	97º 18ô09.52ò W	SH-9/East Imhoff Road approximately 680 feet west of 96th Ave. SE	
CC-1	Clear Creek	35º 11ô21.65ò N	97º 15ô44.55ò W	SH-9/East Imhoff Road approximately 815 feet east of 120th Ave. SE	

<u>Note 1: Flow Monitoring</u> - Level measuring gages will be installed at all monitoring stations listed in table above. The level measuring gages continuously measure stream stage and record the data every 15 minutes. Cellular telemetry stations shall be installed in conjunction with the gauges at each main stem stream station, where cell signals are available, to allow real time access to stage data via the internet. The flow data can also be used to determine if the grab samples for laboratory analysis were collected during the appropriate point in the hydrograph range.

Manual flow measurements shall be taken in first 6 sampling events using the velocity-area method at each monitoring station listed in table above to develop a rating curve for that gage. Rating curves are developed by graphing flow measurements versus stream stage (depth) over a range of flow conditions (low to high) and developing a regression relationship. The regression relationship shall be developed by the contracting agency with no less than six manual flow measurements and submitted for review and accuracy. The regression equation resulting from the correlation is then used to calculate flow from the stage measurements. Flow will be measured manually using a portable velocity meter while wading in-stream according to SOP 5.0, which is based on the USGS Velocity-Area method. Stream flow which is measured for each sample event shall be used along with concentration data to calculate loads of the pollutants measured at each monitoring station.

2.2 Flow Monitoring at TMDL Monitoring Stations

Level measuring gages will be installed at all TMDL monitoring stations. The level measuring gages continuously measure stream stage and record the data every 15 minutes. Cellular telemetry stations should be installed in conjunction with the gauges at each main stem stream station, where cell signals are available, to allow real time access to stage data via the internet. The flow data can also be used to determine if the grab samples for laboratory analysis were collected during the appropriate point in the hydrograph range.

Five manual flow measurements (minimum) using the velocity-area method will be needed at each TMDL monitoring station to develop a rating curve for that gage. Rating curves are developed by graphing flow measurements versus stream stage (depth) over a range of flow conditions (low to high) and developing a regression relationship. The regression equation resulting from the correlation is then used to calculate flow from the stage measurements. Flow will be measured manually using a portable velocity meter while wading in-stream according to SOP 5.0, which is based on the USGS Velocity-Area method. Stream flow which is measured for each sample event is used along with concentration data to calculate loads of the pollutants measured at each monitoring station.

2.3 Water Quality Monitoring at Major Discharge Points

In addition to the monthly monitoring at the TMDL monitoring stations, the major discharge points (shown in Figure 2) that discharge directly to surface waters of the state within the Norman MS4 portion of the Lake Thunderbird watershed will be sampled on a rotating basis. Major discharge points are defined in Appendix E of the TMDL as ña pipe or open conveyance measuring 36 inches or more at its widest cross section.ò There are 14 major discharge points in the Norman MS4 that discharge into The Lake Thunderbird Watershed (Figures 2 and 3). The 14 major discharge points that have been identified will be sampled only when a storm water runoff event occurs. There will be a rotating schedule for sampling the discharge points that will be determined by the monitoring team. Each year 40% of the sites will be sampled, which allows each site to be sampled twice during the 5-year permit cycle. The same *in-situ* parameters (temperature, pH, dissolved oxygen, specific conductance and turbidity) will be measured at all of these sites as well as analyzed for total phosphorus, total nitrogen, and TSS just as the TMDL monitoring sites. Hourly rainfall amounts should be recorded from the nearest weather stations in the area for each event. Rainfall amounts will aid in determining the size and intensity of rainfall necessary to produce levels of nutrient and sediment loading for a particular storm event. A summary of the sampling requirements is included in Table 2. Table 3 presents a list of major outfalls with their location and type information

Table 2. Summary of Sample Design.

Station I.D.	Parameters Being Analyzed[1]	Number Samples Per Station Annually
TMDL Monitoring Stations to be sampled monthly	pH, temperature, dissolved oxygen, specific conductance, turbidity, total phosphorus, total nitrogen, TSS and flow	12
Major Discharge Points to be sampled during storm events	pH, temperature, dissolved oxygen, specific conductance, turbidity, total phosphorus, TSS and total nitrogen	1[2]

[1]See QAPP for analytical details.
[2]Stations will be sampled on a rotating basis. Not all stations will be sampled in a given year See Section 2.3.

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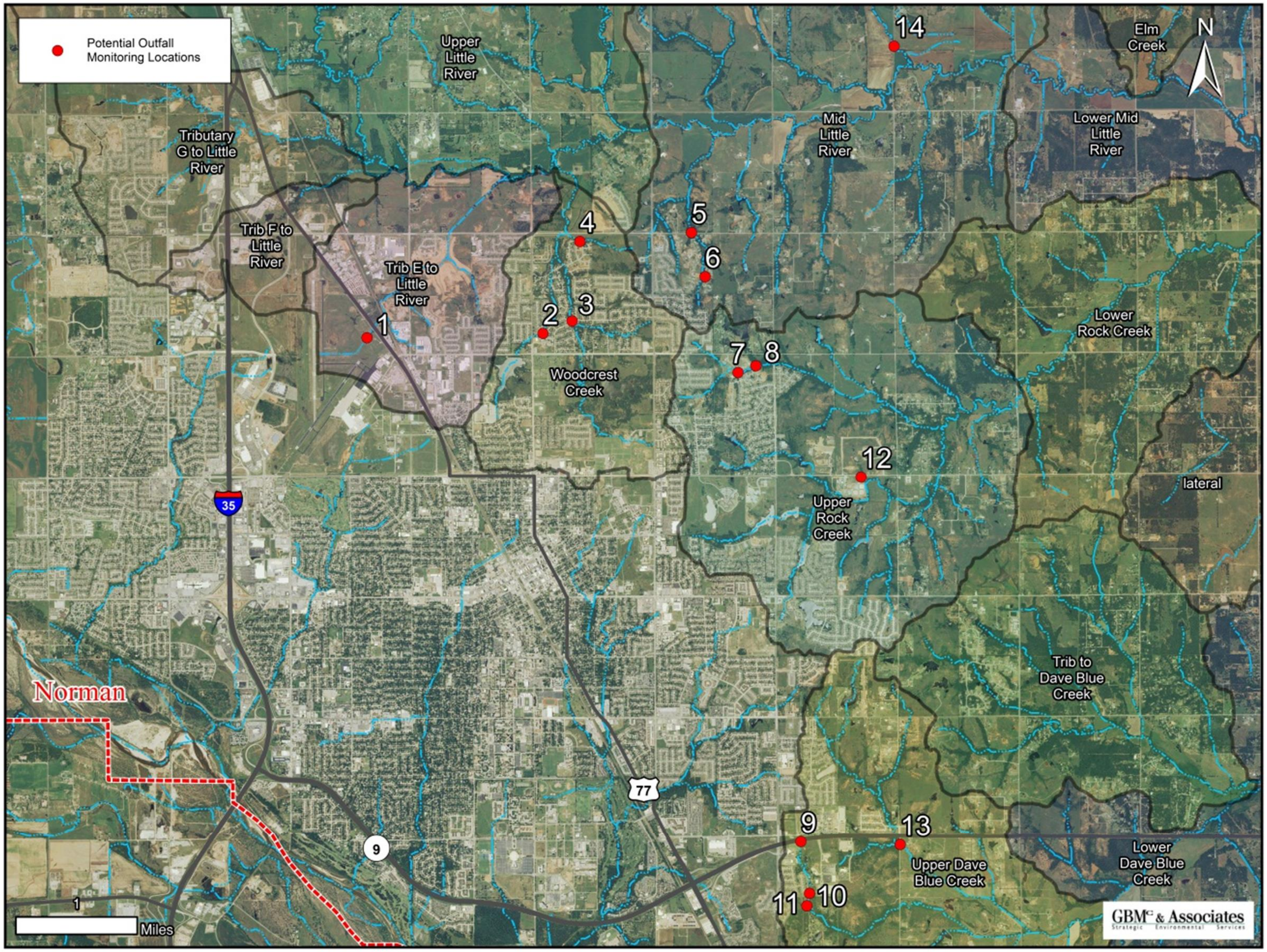

Figure 2. Identified Major Discharge Points to Sample when a Storm Water Runoff Event Occurs.

Table 3. Location of Major Outfalls.

Site #	Lat.	Long.	Outlet Location	Description	Sample Collection Frequency
1	35º 15ô27.80ò N	97º 27ô32.27ò W	Crossing 12th Ave. NW approx. 1510 feet south of West Tecumseh Road	36ò RCP	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
2	35º 14ô59.63ò N	97º 26ô22.90ò W	Approx. 220 feet west of Woodside Dr. Cul-de-sac (from Center of Cul- de-sac)	Pond Outlet	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
3	35º 15ô04.89ò N	97º 26ô07.58ò W	Approx. 50 feet north of Sequoyah Trail Bridge between Willow Creek Dr. and Winding Creek Dr.	2-8ôx8ôRCB	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
4	35º 15ô39.13ò N	97º 26ô03.22ò W	Approx. 135 feet NW of intersection of Nauwinet Way and Nantucket Blvd.	48ò RCP	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
5	35º 15ô42.73ò N	97º 25ô04.70ò W	Crossing East Tecumseh Road apprx. 1770 feet east of 12th Avenue NE	54ò CGMP	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
6	35º 15ô23.51ò N	97º 24ô56.73ò W	Crossing Santa Rosa Ct. approx.. 480 feet south of Hollister Trail intersection	36ò RCP	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
7	35º 14ô42.34ò N	97º 24ô40.61ò W	Approx. 65 feet east of Hallbrook Dr. from 175 feet south of Turtle Creek Dr.	36ò RCP	Once each year listed below 2016, 2018, 2020, 2022, 2024, 2026, 2028, 2030
8	35º 14ô45.19ò N	97º 24ô31.24ò W	Approx. 215 feet NW of the center of Bates Ct. cal-de-sac	Concrete Channel	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
9	35º 11ô20.24ò N	97º 24ô09.16ò W	Crossing SH-9 approx. 1000 feet east of 24th Ave. SE	7ôx5ôRCB	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
10	35º 10ô57.86ò N	97º 24ô04.95ò W	Approx. 270 feet south of the center of cul-de-sac of Stonebridge Ct.	Concrete Channel	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
11	35º 10ô52.71ò N	97º 24ô06.26ò W	Approx. 765 feet east of the intersection of Langley Ct. and Langley Dr.	48ò RCP	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
12	35º 13ô57.13ò N	97º 23ô36.44ò W	Crossing East Robinson Street approx. 3710 feet east of 24th Ave. NE	36ò RCP	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
13	35º 11ô18.80ò N	97º 23ô17.43ò W	Crossing 36th Avenue SE approx. 365 feet south of SH-9	Concrete Channel	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031
14	35º 17ô02.32ò N	97º 23ô17.72ò W	Crossing 36th Avenue NE approx. 2825 feet north of East Franklin Road	120ò CGMP	Once each year listed below 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031

Note 2: Storm event monitoring at Outfalls - Samples from no two sites shall be collected during one storm event. In stream sample collection shall be during storm event as close as possible to the peak of the hydrograph but not after the hydrograph has dropped 25% below the peak. For pipe or spillway outfalls sampling can occur anytime during discharge but preferably using the nearest stream hydrograph as a guide and following the same hydrograph stage practice Norman Mesonet station shall be used to record hourly rainfall amounts for each event. Grab samples will be collected at each site and will be analyzed for total nitrogen, total phosphorous and TSS. PH, temperature, dissolved oxygen, specific conductance and turbidity will be tested at the time of sample collection. Grab samples shall be collected below the water surface and field meters shall be calibrated following SOPs which generally adhere to manufacturerôs recommendations. Refer to the Monitoring Report and QAPP documents for details on data collection, sampling, reporting and quality control requirements. Include all findings in the required monthly report.

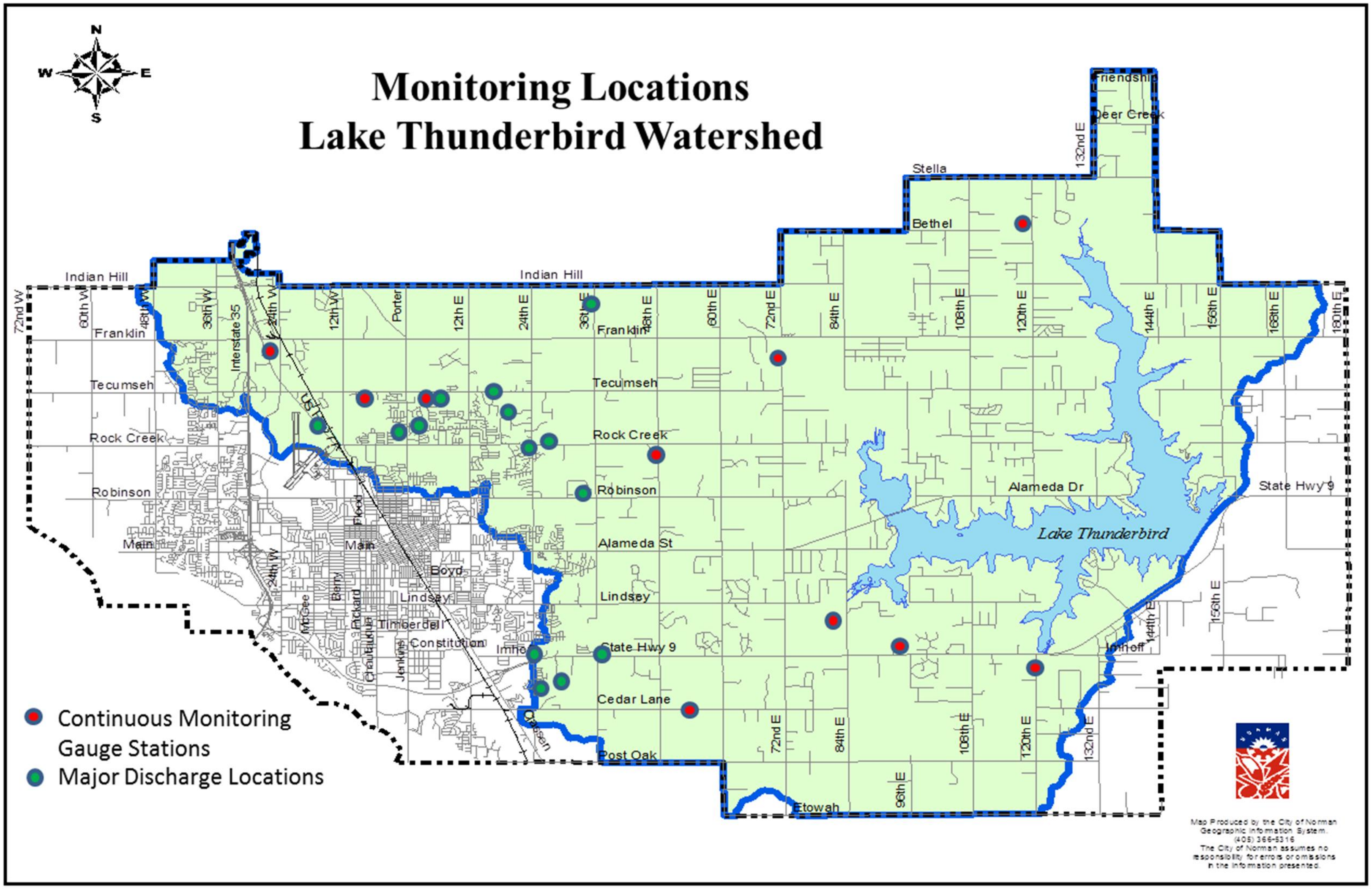

Figure 3. All Monitoring Stations Depicted Relative to Major Roadways.

2.4 Construction and Industrial Site Monitoring

Prior to full implementation of the Monitoring Plan, Norman will review and consider options for monitoring of construction and industrial sites. These options are currently thought to consist of a demonstration project conducted by Norman to monitor active construction locations on a site specific basis, or to require that site operators develop and implement a site monitoring plan in conjunction with the construction activity. Review of Storm Water Pollution Prevention Plans on construction and industrial sites will also be considered. Norman will work with ODEQ regarding options to best evaluate loading from construction and industrial sites. Please refer to Section 8.4 of the Compliance Plan for further information on Norman's approach to construction storm water.

3.0 BIOLOGICAL ASSESSMENT

The Oklahoma Conservation Commission (OCC) prepared a Watershed Based Plan (WBP) for Lake Thunderbird. In this plan they made several recommendations for pollutant reduction as well as suggested partnerships with the OCC to accomplish some of the suggestions in the WBP. The City of Norman will work to develop a partnership with the Oklahoma Conservation Commission (OCC) to complete bi-annual biological monitoring within the Lake Thunderbird watershed. The biological monitoring will consist of semi quantitative macroinvertebrate collections and qualitative habitat assessments. Macroinvertebrate sampling completed by the OCC is anticipated to be completed at critical stations (Rock Creek, Little River and Dave Blue Creek). The OCC biological monitoring consists of twice yearly (winter and spring) sampling of macroinvertebrates at each of the chosen sites on a bi-annual (every other year) basis. The OCC monitors several reference streams that can be used for aquatic community structure comparison and calculating metrics.

Concurrently with the biological monitoring, the OCC field staff will perform a visual qualitative habitat assessment for each sampling event. This information is essential to assessing aquatic community health and structure and for determining availability of suitable habitat for aquatic organisms. Norman MS4 may add additional habitat assessment sites in the future. This will be negotiated between OCC and Norman MS4 which will be based upon a need to have additional physical/biological information.

4.0 WATERSHED MODELING

A component of the compliance and monitoring program is BMP tracking. Watershed modeling is a tool that can be used to track BMP reduction potential as new BMPs are implemented. The TMDL Compliance Plan is largely based on the Hydrologic Simulation Program Fortran (HSPF) modeling completed for the TMDL. Load reductions required to meet the TMDL assigned waste load allocations (WLA) for Norman were determined by applying various best management practices (BMPs) to the base HSPF model outputs for different land uses in each of Norman's sub-watersheds. HSPF modeling was used to address mostly structural BMPs applied to urban\suburban and agricultural land. In addition to the HSPF modeling, the Watershed Treatment Model developed by the Center for Watershed Protection (Caraco, 2013) was also used to determine potential reductions from passive/non-structural BMPs. These models will be used on an as needed basis to aid in tracking BMP implementation and potential pollutant load reductions.

5.0 DATA ANALYSIS

The analytical monitoring data collected will be used in conjunction with the flow data to calculate constituent loading. Monitoring data will be analyzed annually to help direct the efforts of the Compliance Plan and make adjustments where necessary (i.e. adaptive management). Upon completion of the first three years of monitoring the data from each monitoring station will be combined with the data collected during the TMDL and analyzed together to establish a baseline for concentration and load. This baseline will serve as the "current" condition for which future data will be compared. After 5 years of data has been compiled, statistical analysis, including trend analysis, will be used to track the effectiveness of the Compliance Plan in improving water quality within the watershed and in pursuit of WLA attainment. In addition, major discharge point monitoring data will be used to identify areas with high concentrations of nutrients and TSS that may need additional attention. The data will be used to guide the Compliance Plan efforts through identifying key concerns and critical areas in need of attention. After 5 years of data collection, it is expected that the monitoring data will begin to reveal annual load and concentration reductions that can be tied to Norman's progress in implementing BMPs in the watersheds. A biological baseline will also be established using the first three years of data. Future biological data will be compared with the baseline data and/or reference streams to indicate the biological health of the critical stream segments.

6.0 QUALITY ASSURANCE

A formal Quality Assurance Project Plan (QAPP) is attached to this Monitoring Plan and it specifies the data quality objectives, data quality conditions and accommodations for all monitoring activities. Chain of Custody records, adequate field forms, and training of field personnel will be the responsibility of Norman MS4.

Any significant changes to this monitoring program or Compliance Plan will be made in writing and submitted to the ODEQ staff for review and approval. Comments and inquiries on the scope of TMDL Monitoring Plan should be made to the City of Norman.

7.0 RECORDKEEPING

A schedule of Monitoring milestones is provided in Table 4. An annual report will be submitted each year for the Compliance Plan and includes a TMDL implementation report. The TMDL implementation report will include relevant information gathered as part of the City of Norman monitoring efforts. Also in the implementation report will be relevant actions taken by Norman MS4 that affect storm water discharges to Lake Thunderbird watersheds that are related to TMDL Compliance.

Table 4. Monitoring Implementation and Milestone Schedule

ACTION	RESPONSIBLE PARTIES	MILESTONE	FREQUENCY
FLOW MNITORING			
Establish flow gages	City or designated contractor	March 2016	Once
Monitor flow	City or designated contractor	January 2016	Continuous
Maintain gage	City or designated contractor	Spring 2016	As needed
CHEMICAL MONITORING			
High flow monitoring	City or designated contractor	Spring 2016	4/year/station
Base flow monitoring	City or designated contractor	Spring 2016	8/year/station
Major Outfalls	City or designated contractor	Spring 2016	5-6 outfalls/year
CONSTRUCTION AND INDUSTRIAL SITE MONITORING			
Construction Site	City or designated contractor	Summer 2016	As needed
Industrial Site	City or designated contractor	Summer 2016	As needed
BIOLOGICAL ASSESSMENT			
Macro invertebrates	OCC, staff	Spring 2016	3 sites, (two seasons), bi-annually
HABITAT ASSESSMENT			
HA with Biol. Assess.	OCC, staff	Spring 2016	3 sites, (two seasons), bi-annually
ADMINISTRATIVE			
Report data	City or designated contractor	January 2017	Annual or as requested

Attachment A

Quality Assurance Project Plan (QAPP)

I. PROJECT MANAGEMENT (GROUP A)

A1 TITLE AND APPROVAL SHEET

Title: TMDL Monitoring Plan for Lake Thunderbird – City of Norman

Completed By: GBM[c] & Associates and Olsson Associates

QAPP Approved by:

Scott Sturtz City Engineer City of Norman	______________ Signature ______________ Date
Joe Willingham Storm Water Engineer City of Norman	______________ Signature ______________ Date
Aaron Milligan Storm Water Pollution Specialist City of Norman	______________ Signature ______________ Date
Monitoring Supervisor	______________ Signature ______________ Date
QA Assurance Officer	______________ Signature ______________ Date
Field Team Leader/Sampler	______________ Signature ______________ Date
Sampler	______________ Signature ______________ Date

Effective Date:______________________

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II. DATA GENERATION AND ACQUISITION (GROUP B)

FIGURES

TABLES

Appendix

A3 DISTRIBUTION LIST

The following list of individuals and their respective organizations will receive a finalized, signed, USEPA Region VI approved QAPP, and copies of subsequent revisions from the City of Norman:

Individual	Organization
Scott Sturtz	City of Norman- City Engineer ___________________
Joe Willingham	City of Norman - Storm Water Engineer
Aaron Milligan	City of Norman - Storm Water Pollution Specialist Signature
Monitoring Supervisor	City or designated contractor
QA Officer	City or designated contractor
Field Team Leader/Sampler	City or designated contractor
Sampler	City or designated contractor

A4 PROJECT/TASK ORGANIZATION

Scott Sturtz City Engineer City of Norman	Responsible for management and implementation of the Compliance Plan.
Joe Willingham Storm Water Engineer City of Norman	Responsible for coordination of monitoring plan and analysis of the water quality data.
Aaron Milligan Storm Water Pollution Specialist City of Norman	Responsible for coordination of monitoring plan and analysis of the water quality data.
Monitoring Supervisor	Responsible for scheduling sampling and coordination of field teams.
QA Assurance Officer	Responsible for the quality of the analytical lab analysis.
Field Team Leader/Sampler	Responsible for sampling TMDL monitoring stations and major discharge points.
Sampler	Responsible for sampling TMDL monitoring stations and major discharge points.

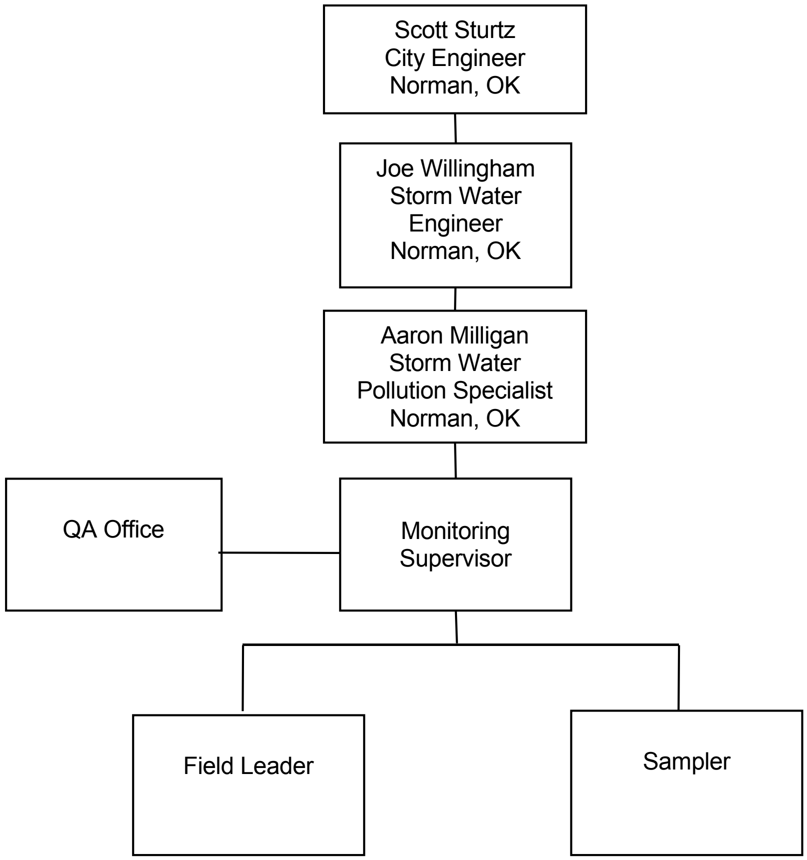

Figure 1. Organizational chart.

A5 PROBLEM DEFINITION/BACKGROUND

Study Objective – This QAPP has been developed to support the City of Norman's TMDL Compliance Plan for Lake Thunderbird. The objective of the TMDL Compliance Plan is to reduce loads of nitrogen, phosphorus, and suspended sediments such that Lake Thunderbird attains all applicable Water Quality Standards designated uses and criteria. If successful, Lake Thunderbird will be removed from the 303(d) list for Oklahoma. Currently Lake Thunderbird is not maintaining the designated uses of Fish and Wildlife Propagation – Warm Water Aquatic Use for both Dissolved Oxygen and Turbidity, and Public and Private Water Supply for Chlorophyll-α. The Lake Thunderbird watershed is 256 square miles in size, located in Cleveland County, Oklahoma. The watershed contains portions of the cities of Norman, Moore, and Oklahoma City. Land slope is generally mild; overall 86% of the watershed contains slopes less than 5 degrees. The top three land cover percentages in the watershed were grassland/herbaceous 37%, deciduous forest 34% and developed urban land at 18%.

A watershed assessment was completed using a combination of GIS land use analysis, watershed modeling and unified stream assessments to help identify watershed issues, sources of pollution and to prioritize problems in the sub watersheds. All this information was analyzed first from an overall watershed perspective (all of the Lake Thunderbird Watershed), then the focus was narrowed to examine just the Norman portion of the watershed (Figure 2). Watershed modeling was used to determine potential reductions of nutrients and sediment from recommended best management practices (BMP) being implemented. Two land use based models, Hydrologic Simulation Program Fortran (HSPF) and The Watershed Treatment Model (WTM), were used to estimate reductions in each sub watershed when structural and non-structural BMPs are applied.

Revisions and updates to the Compliance Plan will be based largely from the results of the Monitoring Plans and this QAPP. The Norman MS4 will use loading data (TSS, TN (as NO2-NO3-N and TKN), TP) collected per this QAPP to compare to the loading data collected historically in their program and data collected during TMDL development. Load reductions or increases will be determined using the loading data, control charts and trend analysis. Implementation of the Compliance Plan will likely reduce export of pollutants such as nitrogen, phosphorus and suspended sediments into Lake Thunderbird and the monitoring results will validate those load reductions.

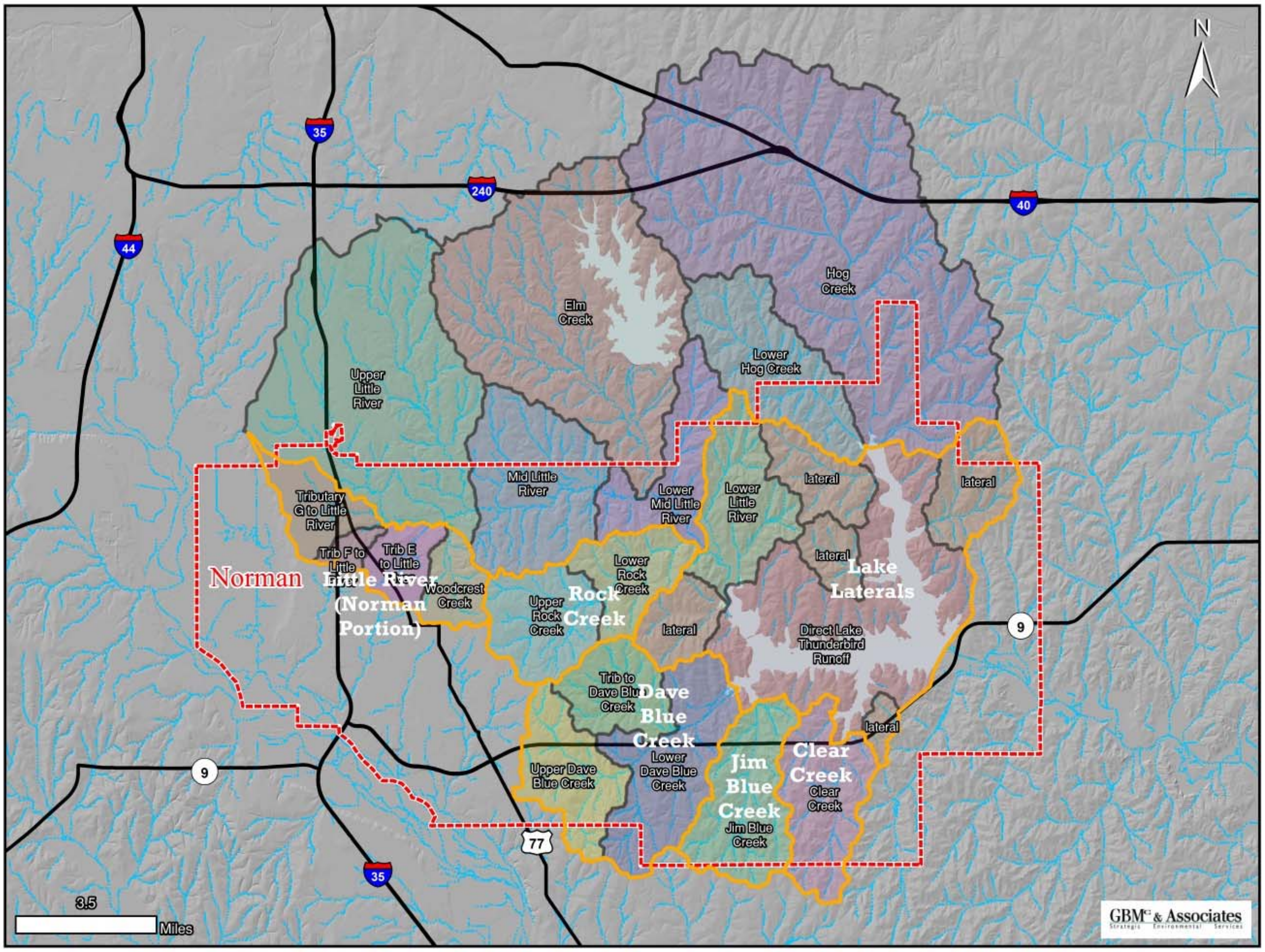

Figure 2. City of Norman watersheds and sub watersheds that drain to Lake Thunderbird.

A6 PROJECT/TASK DESCRIPTION

The following tasks support the process and procedures to collect sufficient data in order to assess water quality and constituent loading in the Lake Thunderbird Sub-watersheds.

Task 1 – Water Quality Monitoring at TMDL Stations

A water quality monitoring study will be completed by the Norman MS4. Sample locations will focus in sub-watersheds with the greatest apparent impacts as described in the Compliance Plan (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.). Ten TMDL monitoring stations in the Lake Thunderbird sub-watersheds will be sampled monthly.

During each sampling event, *in-situ* parameters will be analyzed and samples will be collected for laboratory analysis. *In-situ* parameters shall consist of pH, temperature, dissolved oxygen, specific conductance, and turbidity. Samples delivered to the laboratory will be analyzed for total phosphorus, total nitrogen, and TSS. Data collected for this project will be used to track pollutant loading and guide Compliance Plan implementation efforts.

Task 2- Flow Monitoring at TMDL Stations

Measurement of flow at each monitoring station is necessary to calculate pollutant loading. Level measuring gages should be installed at each of the TMDL monitoring stations to provide a continuous measurement of flow. A rating curve will be developed for each level gauge during the first year of monitoring. The rating curve allows flows measured manually during each sample event to be related to stage data collected by the level gauge. This relationship (a rating curve) can then be used to calculate flow from only the stage data in the future. Cellular telemetry stations will be installed on each main stem stream station to allow real-time access to data via the internet. This data will be used to more effectively calculate pollutant loading in the sub-watersheds. Stream flow will be measured manually using the velocity-area method at each station during sample events unless the station has a functioning gauge.

Task 3- Water Quality Monitoring at Major Discharge Points

In addition to the monthly monitoring at the TMDL monitoring stations, the major discharge points that discharge directly to surface waters of the state within the TMDL watershed will be sampled on a rotating basis. A major discharge point, often referred to as a storm water outfall, is a conveyance or pipe measuring 36 inches or greater. Discharge point locations were determined by using the storm water drain GIS data from the City of Norman. The 14 major discharge points will be sampled only when a storm water runoff event occurs. There will be a rotating schedule for sampling the discharge points. Each year 40% of the sites will be sampled, which allows each site to be sampled twice during the 5-year permit cycle. The same *in-situ* parameters will be measured at all of these sites as well as analyzed for total phosphorus, total nitrogen, and TSS just as the TMDL monitoring sites.

Task 4 – Study Report

An annual report will be submitted each year for the Compliance Plan and includes a TMDL implementation update report. The TMDL implementation report will include the status, actions, and milestones of the TMDL Compliance and Monitoring Plan for the City of Norman. Also in the implementation report will be those relevant actions taken by Norman MS4 that affect storm water discharges to Lake Thunderbird watersheds that are related to the TMDL Compliance Plan.

Project Schedule

The following table illustrates a timeline of tasks to be completed during the Project. This schedule may be amended, if necessary, due to field conditions; unforeseen natural occurrences, and extended regulatory reviews. Any additional modifications to the project schedule will be communicated as early in the process as practicable.

Schedule:

Task No.	Task Description	Start Date	Completion Date
1	QAPP approval	November 1, 2015	December 31, 2015
2	Monitoring Begins	January 1, 2016	January 30, 2016
3	Ongoing monthly monitoring	January 1, 2016	December 30, 2020
4	Compliance Plan (Review)	June 1, 2021	June 30, 2021

A7 DATA QUALITY OBJECTIVES FOR MEASUREMENT DATA

Water Quality Monitoring

Sample collection techniques are based on those recommended by EPA for specific media types in various guidance documents. Use of accepted methodology ensures that the results are comparable. The completeness criteria for this project are that 90% of the samples from each media provide usable results. That is, through the collection, handling and analysis process there is an allowance that 10% of the samples (maximum) could be lost, contaminated or rendered unusable due to field technician or laboratory error.

Sample handling bias will be assessed using field blanks. A field blank will be collected once during each year of the study and all parameters will be analyzed. The data quality objectives for sample handling are as follows:

QC test	Frequency	Results	Objective
Field blanks	Once annually	Accuracy bias	< 120% MDL

Representativeness of samples collected is assured by collecting a field duplicate sample at a rate of 10% (minimum) of samples collected. One field duplicate sample (minimum) will be collected for each sampling event. Field duplicates within +/- 30% of each other are considered to prove the representativeness of collection techniques.

An overview of data quality objectives for the laboratory is provided in the table below. EPA approved methods will be utilized and the laboratory will be certified in the State of Oklahoma or hold an equivalent national certification (NELD, etc.). Specific laboratory quality assurance and quality control requirements are provided in detail in Section B5.

Sample Analysis

Parameter	Source/Method	Units	MDL
Total Phosphorus as P	SM4500-P BE	mg/L	0.02
TKN	EPA 351.2	mg/L	1.0
Nitrate-Nitrite as N	EPA 300.1	mg/L	0.05
TSS	SM2540D-1997	mg/L	5.00

A8 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

All personnel participating in water quality studies have been trained by experienced scientists/engineers to complete the necessary tasks or are in the process of being trained with appropriate oversight. Personnel participating in water quality studies shall be familiar with the SOPs appropriate to that particular study and the QAPP. Personnel participating in studies conducted pursuant to specific procedures specified by a regulatory authority (e.g., a state or federal environmental agency) shall be familiar with those specific procedures.

Norman MS4 will oversee all sample collections. All field technicians will be trained for proper sample handling, preventative maintenance, calibration and sample custody procedures. Norman MS4 is responsible for assuring that all field technicians are properly trained.

The Analytical Laboratory is responsible for related laboratory testing. All technicians are trained in the appropriate techniques and familiar with the appropriate SOPs.

A9 DOCUMENTATION AND RECORDS

Study Report

A bound field logbook will be maintained documenting field activities during the study. Log book entries shall include, dates of field activities, type of activities completed, list of samples collected, and general observations pertinent to the study. Field data, including sample collection, will be recorded in a field log book or on a field data sheet designed specifically for the field activity. Entries will include: date and time of sample collection, name of person collecting samples, problems encountered, and date and time of sample delivery. Logbooks and field data sheets will be kept at the Norman MS4 office except when in the field. Copies will be made of all entries at the Norman MS4 office following completion of field activities.

All data collected during scientific studies should be checked by the team leader for completeness and accuracy. Field data forms should be complete and initialed by the completing scientist and the reviewing scientist.

Data entry to spreadsheets and databases along with spreadsheet calculations shall be checked for accuracy at a rate of 10% (minimum) of the entries and calculation cells. Copies of the checked data and spreadsheets should be initialed by the reviewer and retained in the records.

All calculations should be detailed in the body of written reports, or shown on Norman MS4 Calculation Pages. Good notes regarding calculations should be kept and filed in the project notebook.

All scientific reports shall be peer reviewed and/or reviewed by the Project Manager prior to approval submittal.

All laboratory data shall be reported in normal turnaround time to Norman MS4 in both hard copy and electronic format. Data will be stored at Norman MS4 for a minimum of 5 years.

The QAPP will be updated as necessary following an adaptive management protocol. The Project Manager is responsible for providing updates to all of the parties listed in Element A3.

II. DATA GENERATION AND ACQUISITION (GROUP B)

B1 SAMPLING PROCESS DESIGN

A water quality monitoring study will be completed in the Norman Portion of the Lake Thunderbird sub-watersheds.

Table B1.1 provides the locations of the TMDL monitoring stations that will be utilized during the study and describes the location of the stations (Figure 2).

Table B1.1. Description of TMDL Monitoring Stations.

Station I.D.	Lake Thunderbird Station Description
TG-1	Trib G of Little River on 24th Ave NW between W Franklin Rd and Hwy 77
TE-1	Trib E of Little River on Hwy 77 near Black Mountain Way
WC-1	Woodcrest Creek on Hwy 77 near Prescott Dr
URC-2	Upper Rock Creek on 48th Ave NE near Bruehl Lane
LRC-1	Lower Rock Creek on 72nd Ave NE between E Tecumseh Rd and Laramie Rd
LT-1	Lake Thunderbird and Laterals on 120th Ave NE near Gander Ln
UDB-1	Upper Dave Blue on Hwy 9 near Blue Creek Dr
LDB-1	Lower Dave Blue on 84th Ave SE between E Lindsey St and Blue Jay Rd
JB-1	Jim Blue Creek on Hwy 9 near 96th Ave SE
CC-1	Clear Creek on Hwy 9 between 120th Ave SE and E Imhoff Rd

Task 1 – Water Quality Monitoring at TMDL Stations

Water quality samples will be collected at each designated TMDL monitoring station monthly (Figure 3). At minimum 4 of the monthly sampling events should occur during a storm event in each sub-watershed, or the morning after the event, when flows are still elevated. This will indicate which watersheds are major nutrient and TSS contributors and provide a better measure of actual loading to Lake Thunderbird. All storm sampling events should occur during approximately the latter half of the rise in the stream flow hydrograph and as close to the peak in

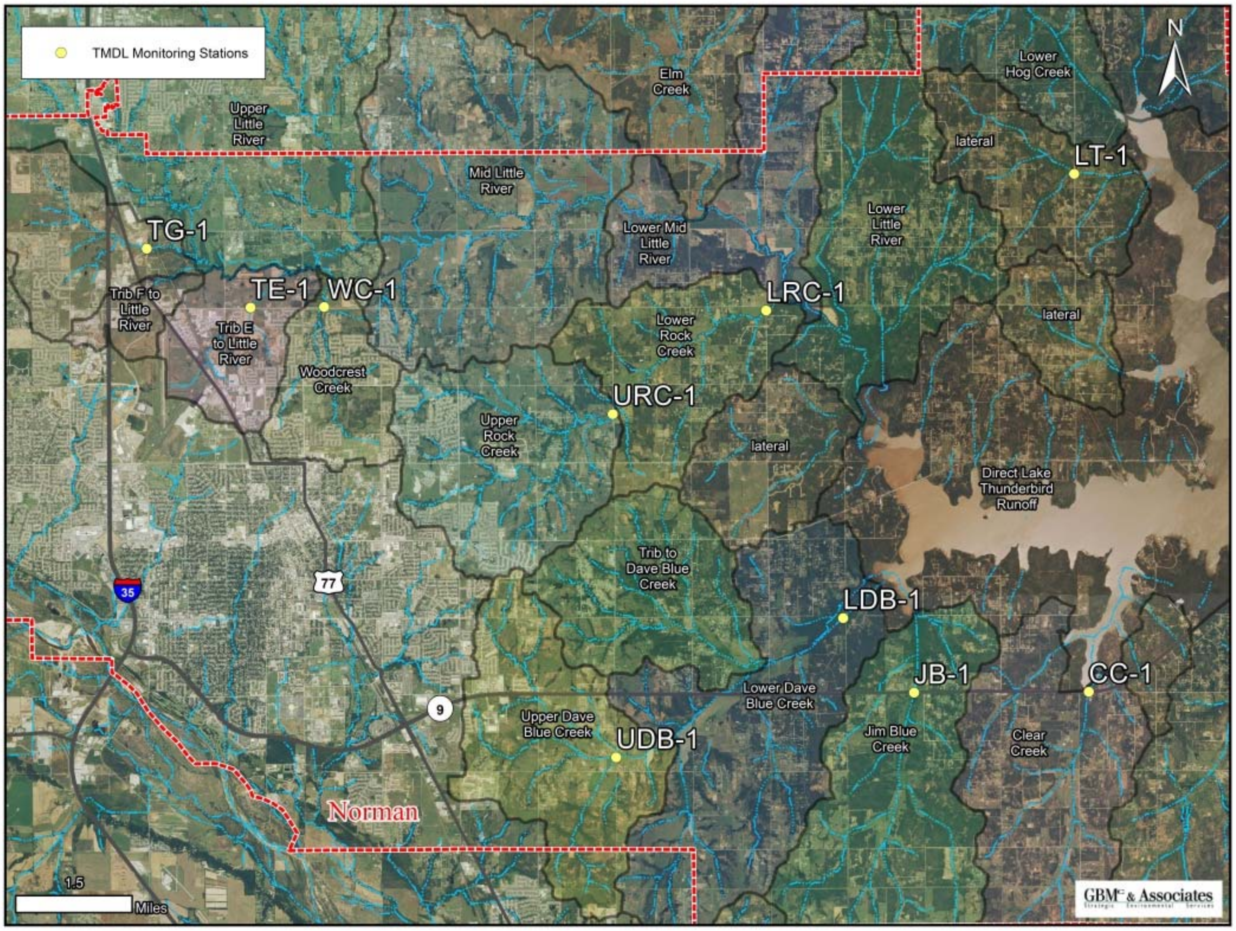

Figure 3. TMDL Monitoring Stations to be Sampled Monthly.

the hydrograph as possible (Figure 4). Once the storm hydrograph has dropped 25% below the peak a sample can no longer be considered a storm sample. Each sample will be collected as a grab sample and will be collected from the main flow area in the channel at each station. Water samples will be delivered to the laboratory for analysis. Samples will be analyzed for total phosphorus, total nitrogen (NO3-NO2, TKN), and TSS. Hourly rainfall amounts should be recorded from the nearest weather stations in the area. Rainfall amounts will aid in associating nutrient and sediment loading for a particular storm event. Rainfall amounts will also aid in determining the size and intensity of rainfall needed to collect a storm sample in the future. Additional parameters may be added as necessary. Water samples will be collected by Norman MS4 or their contractor.

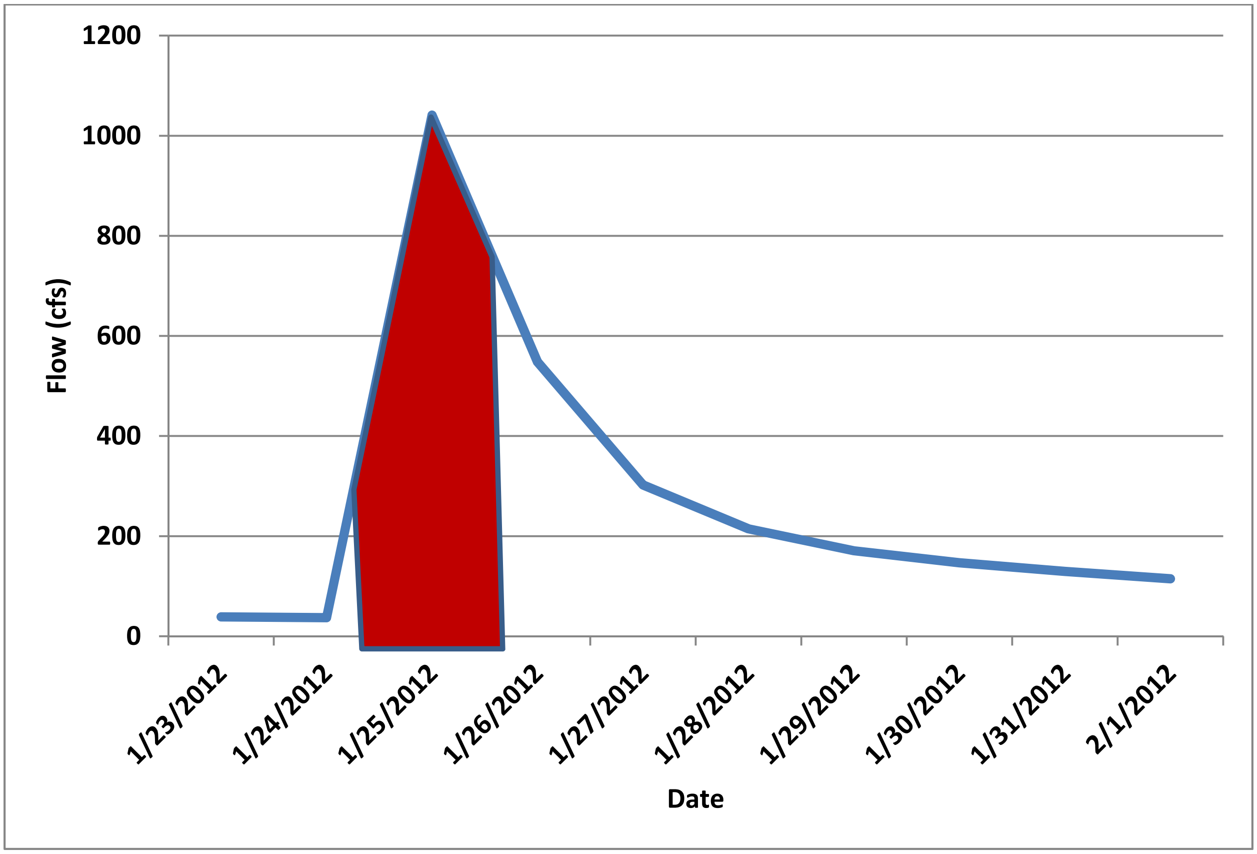

Figure 4. Example of Storm Water Sampling Window, Red Fill Indicates when a Storm Sample will be taken.

During each sample event, *in-situ* parameter measurements will be taken and flow will be measured. *In-situ* parameters shall consist of pH, temperature, dissolved oxygen, specific conductance and turbidity. *In-Situ* parameters will be measured by Norman MS4 or their contractor. A summary of the experimental design is included in Table B1.2.

Task 2- Flow Monitoring at TMDL Stations

Level measuring gages will be installed at all monitoring stations. Five manual flow measurements (minimum) using the velocity-area method will be needed to develop a rating curve. Rating curves are developed by graphing flow measurements versus stream stage (depth) to create a regression relationship. The equation resulting from the regression is used to calculate the flow from stage measurements. Gages will continuously measure stream stage and record the data every 15 minutes. Cellular telemetry stations should be installed on mainstem stream stations where cell signals are available, to allow real time access to stage data. Flow will be measured using a portable velocity meter while wading in-stream according to SOP 5.0, which is based on the USGS Velocity-Area method. Flow data will be collected to develop a rating curve, and during each sample event for use with concentration data to calculate pollutant loads.

Task 3- Water Quality Monitoring at Major Discharge Points

In addition to the monthly monitoring of the TMDL monitoring stations, the major discharge points that discharge directly to surface waters of the state within the TMDL watershed will be sampled on a rotating basis. The 14 major discharge points (Figure 5) will be sampled only when a storm water runoff event occurs. There will be a rotating schedule for sampling the discharge points. Each year 40% of the sites will be sampled, which allows each site to be sampled twice during the 5-year permit cycle. The same *in-situ* parameters will be measured at all of these sites as well as analyzed for total phosphorus, total nitrogen, and TSS just as the TMDL monitoring sites. Hourly rainfall amounts should be recorded from the nearest weather stations in the area for each event. Rainfall data from 2-3 weather stations that bracket the sub-watershed(s) should be used if possible. Rainfall amounts will aid in determining the size and intensity of rainfall necessary to produce the amount of nutrient and sediment loading for a particular storm event.

Table B1.2. Summary of Sample Design for Calendar Year.

Station I.D.	Parameters Being Analyzed	Number Samples Per Station each year
TMDL Monitoring Stations to be sampled monthly	pH, temperature, dissolved oxygen, specific conductance, turbidity, total phosphorus, total nitrogen TSS and flow	12
Major Discharge Points to be sampled during storm events on a rotating basis	pH, temperature, dissolved oxygen, specific conductance, turbidity, total phosphorus, TSS and total nitrogen	1*

*Sampling for major outfalls occurs on a rotating basis with 40% of stations sampling 1/yr.

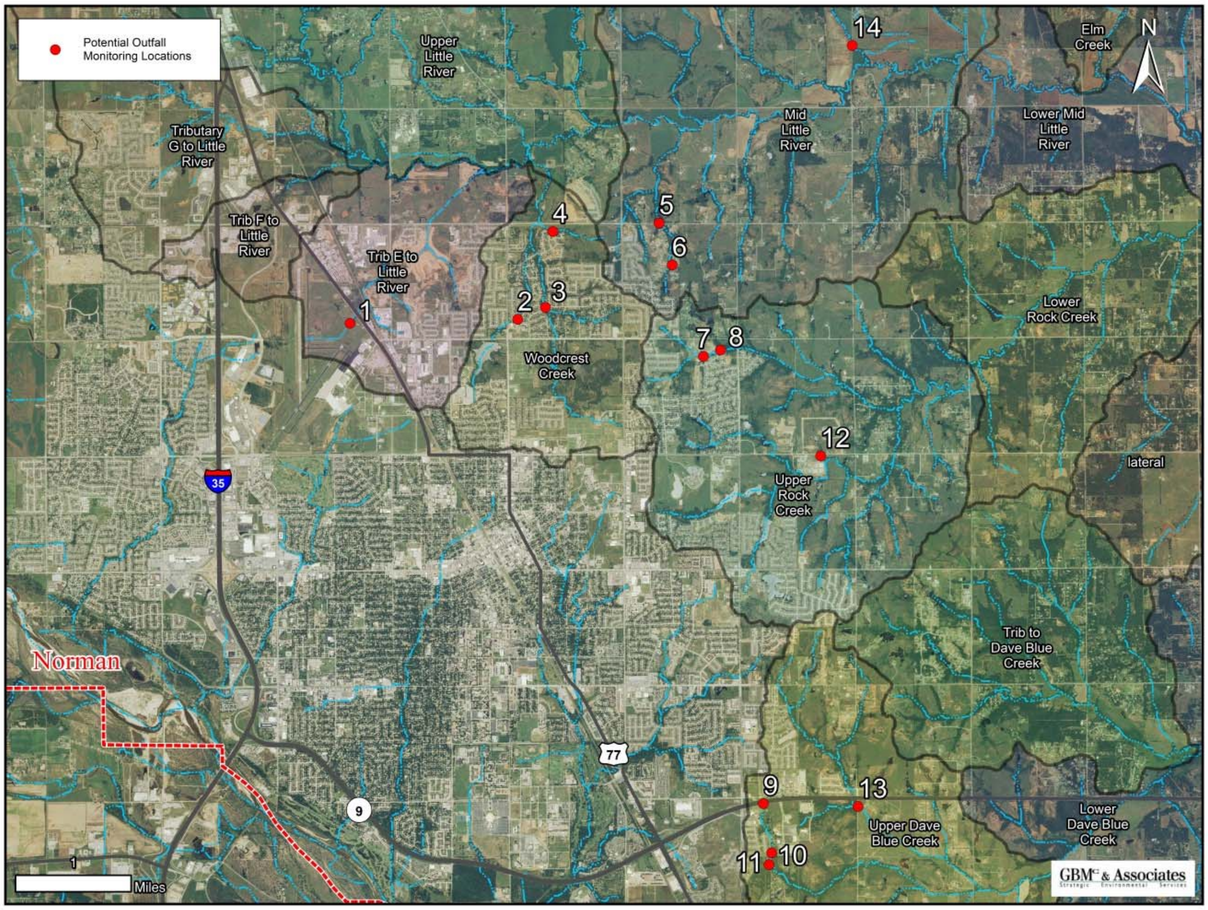

Figure 5. Potential Major Discharge Point to Sample when a Storm Water Runoff Event Occurs.

B2 SAMPLING METHODS REQUIREMENTS

The following section provides details of the sampling methodology and procedures that will be utilized during the water quality monitoring study. Table B1.1 provides a summary of the water samples to be collected for analysis and Table B2.2 provides a summary of sampling methodologies to be used during the study. Standard Operating Procedures (SOP's) in this section are provided in Appendix A.

Trained personnel will conduct the field sampling and other associated activities at each sample location. Notes will be kept in field notebooks and/or specific field data forms that record information collected during the study, unusual observations, and a log of each day's activities. All data forms, calibration logs, field notes, and other study documentation will be reviewed by the Project Manager for completeness and accuracy. Concerns over field data collection success or required deviations to SOP will be reported to the project Quality Assurance Officer for review. Any deviations to the methodologies described in this QAPP will be recorded and presented, in detail (including an assessment of potential effect on data), in the final project report.

Water Quality Monitoring

TMDL water samples will be collected monthly by Norman MS4 or the designated contractor. Water samples delivered to the laboratory will be analyzed for total phosphorus, TKN, nitrate-nitrite-N, and TSS. Grab samples for each parameter will be collected from the main flow area of the stream following the procedure described in Section B1 and the SOP. If additional samples or samples from other media are collected similar protocols will be followed.

Samples will be analyzed in the laboratory according to the procedures outlined in the 40CFR Part 136. Table B2.1 summarizes the samples taken, the analytical method, the preservative, and the holding time. A laboratory certified in the State of Oklahoma or holding acceptable national certification shall conduct all chemical analyses. The contracted laboratory will serve as the laboratory of record for the analytical analyses.

During each sample event *in-situ* parameters will be analyzed. Samples will be collected for laboratory analysis from each sample station. *In-situ* parameters shall consist of pH, temperature, dissolved oxygen, specific conductance and turbidity. *In-situ* parameters will be measured at the time of sample collection using a portable field meter(s). Field meters will be calibrated following the SOP which generally adheres to manufacturer's recommendations.

Table B2.1. Summary of TMDL Water Samples Taken for Analytical Analysis.

Parameter	Number Samples/Event	Analytical Method	Preservative	Holding Time
Total Phosphorus as P	10	SM4500-P BE-1997	6°C, H_2SO_4	28 Days
TKN	10	SM4500-NH3 D-1997	6°C, H_2SO_4	7 Days
Nitrate-Nitrite as N	10	EPA 300.1	6°C, H_2SO_4	48-hours
TSS	10	SM2540D-1997	6°C	7 Days

SM = Standard Methods for the Examination of Water and Wastewater.

Level measuring gages will be installed at all monitoring stations. Gages will continuously measure stream level (stage) and record the data every 15 minutes. Stream gage data will be used to calculate flow using the rating curve calculation. Cellular telemetry stations will be installed at all main stem stream stations where cell signals are available to allow real-time access to data. Flow will be measured using a portable velocity meter while wading in-stream according to SOP 5.0, which is based on the USGS Velocity-Area method. Flow data will be used to calculate pollutant loads using monitoring (concentration) data, it is imperative that flow be measured at all TMDL monitoring stations whenever samples are collected.

In addition to the monthly monitoring of the TMDL monitoring stations, the major discharge points that discharge directly to surface waters of the state within the TMDL watershed will be sampled on a rotating basis. The 14 major discharge points will be sampled only when a storm water runoff event occurs. There will be a rotating schedule for sampling the discharge points. Each year 40% of the sites will be sampled, which allows each site to be sampled twice during the 5-year permit cycle. The same *in-situ* parameters will be measured at all of these sites as well as analyzed for total phosphorus, total nitrogen, and TSS just as the TMDL monitoring sites. Hourly rainfall amounts will also be recorded from the nearest weather stations.

Table B2.2. Summary of Sampling Methods.

Sample Type	QAP SOP Number	Sampling Equipment	Field Processing Protocol	Storage Vessel	Preservative	Designated Record Sheet (Y / N)
Flow	SOP 5.0	Flow meter Depth Rod Measuring tape	n/a	n/a	n/a	Y
Water	SOP 12.0	Sample Bottles	Label and Store in Ice Chest	Lab Provided Bottles	Various (see Table B2.1)	Y
In-situ	SOP 1.0, 2.0, 3.0, 4.0, 14.0	Field Meters	Calibrate, Measure in Main Channel	n/a	n/a	Y

B3 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

All samples will be placed in the appropriate clean containers supplied by the laboratory. Each sample container will be labeled with the sample I.D., date, time, and initials of collector(s). Samples will be placed in ice chests and maintained at ≤6º C for delivery to the laboratory in a timely manner conducive to maintenance of regulatory holding times. Chain of Custody (COC) forms that include information on each sample (location ID, date, time, preservative, and collector) delivered to the laboratory for analysis will be completed. Each COC form will be signed by each person handling the samples from collection in the field to receipt in the laboratory. The COC form will include all required information (see SOP 12.0) and will be checked for completeness prior to submission of samples to the laboratory.

B4 ANALYTICAL METHODS REQUIREMENTS

Water Quality Analysis

All procedures used for analyzing chemical parameters of water quality for reporting purposes will follow methods approved per 40CFR Part 136.

Analytical methods are listed below, along with specific performance requirements. All analytical measurements will be completed by a laboratory certified in the State of Oklahoma or equivalent national certification. All analytical methods will be conducted under the laboratories Quality Assurance Plan in which there is a specific SOP for each method. Analytical method SOPs will be made available upon request. All methods fall under the specific quality control requirements outlined in the Quality Assurance Plan. Any failure in the analytical systems will be the responsibility of the laboratory to apply necessary corrective action.

Failures in the QA system encountered by the laboratory shall be reported to the project Quality Assurance Officer (QAO) as soon as reasonably possible.

Table B4.1. Summary of Analytical Methods.

Parameter	Source/Method	Units	RL
Total Phosphorus as P	SM4500-P BE-1997	mg/L	0.02
TKN	EPA 351.2	mg/L	1.0
Nitrate-Nitrite as N	EPA 300.1	mg/L	0.05
TSS	SM2540D-1997	mg/L	5.00

B5 QUALITY CONTROL REQUIREMENTS

Field Sampling

Field duplicate samples for each constituent (total phosphorus, TKN, nitrate-nitrite-N, and TSS) shall be collected at a minimum frequency of 10% of the samples collected for the entire study. A minimum of one duplicate sample will be collected for each sampling event. Field duplicate samples shall vary by no more than 30% relative percent differences (RPD) or the sample results will be considered suspect. In the event an RPD exceeds 30%, the Project QAO will investigate the incident to determine the cause of the exceedance and what action, if any, is necessary.

Sample handling bias will be assessed using field blanks for each constituent. Field blanks will be collected once during the study. The data quality objective for sample handling is as follows:

QC test	Frequency	Results	Objective
Field blanks	Once every event	Accuracy bias	< 120% MDL

Exceedence beyond the 120% of MDL will require an investigation by the Project QAO to determine the cause of the exceedence and what action, if any, is necessary.

Analytical Laboratory

The laboratory will validate analytical data by use of blanks, laboratory controls, spikes, spike duplicates and sample duplicates. Laboratory blanks measure the amount of each respective analyte contributed from the analytical procedure. A laboratory blank is considered out of control for a specific analyte if the value exceeds the higher of either the minimum detection limit (MDL) or 5% of the measured concentration in the sample. A laboratory control measures the ability of the laboratory to recover an analyte from a blank matrix. The laboratory spike sample is used to evaluate the laboratory's ability to recover an analyte in the sample matrix. The QC exceedence criteria for laboratory controls and spikes is based on upper and lower control limits derived from the laboratory's method specialized limits. The laboratory spike and sample duplicate is used to evaluate the laboratory's precision (ability to attain similar analytical results from duplicate samples). A RPD is calculated for the spike and/or sample duplicate. The RPD is compared to method specialized limits to determine QC exceedance. Any significant excursion from one of the QC parameters will result in repeat of the analysis in question. Should repeat analyses still fall outside the allowed control range an investigation by the laboratory as to the cause of the QC excursion and a report of the corrective actions taken will be reported to the project QAO.

Specific laboratory quality control requirements for each analytical method are listed for each parameter in Table B5.1.

Table B5.1. Summary of Laboratory QA Requirements.

Parameter	Source/Method	LCS Recovery (%)	Matrix Spike Recovery (%)	Matrix Spike RPD (%)
Total Phosphorus as P	SM4500-P BE-1997	85-115	80-120	15
TKN	EPA 351.2	85-115	80-120	15
Nitrate-nitrite as N	EPA 300.1	85-115	80-120	15
TSS	SM2540D-1997	n/a	n/a	15[1]

[1] Sample duplicate RPD

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

Equipment cleaning and maintenance procedures will follow manufacturer recommendations. Records of maintenance of field sampling equipment will be kept in a record book listing name of technician, date and type of maintenance. Portable field meters should be calibrated in the lab at least twice/month (every other week) to monitor readiness and ensure proper functionality. Each day during a field trip equipment will be inspected before use (during calibration, etc.) to ensure functionality. All equipment will be inspected and cleaned immediately following a field trip and stored in a safe place to allow its future readiness.

Where appropriate, calibration and performance tests are described in the SOP of the respective application. Generally, all equipment will be utilized per the manufacturer's directions. If during the course of the field activities, equipment fails to conform to known QA/QC requirements, the equipment will be repaired or replaced with similar equipment that will meet QA/QC requirements.

B7 INSTRUMENT CALIBRATION AND FREQUENCY

Field meters will be calibrated prior to each sampling event. DO probes will be corrected for barometric pressure and calibrated to 100% saturation. Calibration of pH probes will be completed following a two point calibration using either a pH 4, pH 7, or pH 10 calibration solution. Turbidity meter readings will be checked against standards, and if a reading is more than 20% off the known value, the meter will be calibrated following the SOP. Specific conductance will be checked against known standards, and if the meter is more than 20% off the known value, the meter will be calibrated following the SOP. All meter calibrations will be completed following the SOPs which are provided in the Appendix to this document.

B8 INSPECTION/ACCEPTANCE REQUIREMENTS FOR SUPPLIES AND CONSUMABLES

Supplies and consumables used for this project will include sample bottles, preservative, laboratory reagents necessary for the tests performed and calibration standards. All sample bottles will be new clean bottles of a style and material consistent with analytical requirements. All consumables will be purchased new. All lab supplies and consumables will be approved by the Project Manager or the Lab Manager. All chemicals and reagents will be dated and inspected for proper expiration date when purchased and prior to use. All supplies will be inspected when purchased and any damaged or open containers or packaging will be refused.

B9 NON-DIRECT MEASUREMENTS

Historical watershed and lake monitoring data collected by the Norman MS4 and by other reputable government agencies (ODEQ, OCC, USGS, OWRB, etc.) will be evaluated for use in this study. Table B9.1 outlines the data that will be used, where it will be used in the study and the acceptance criteria for its use.

Table B9.1. Summary of Use of Non-Direct Data (existing) Data in the Study.

Data Description	Use in Study	Acceptance Criteria
Norman MS4 watershed monitoring data	Watershed assessment	Meets same rigors as that outlined in this QAPP to the extent necessary to allow comparison to current study data.
Water quality and flow data collected by government agencies (ODEQ, OCC, OWRB, USGS)	Watershed assessment	Meets same rigors as that outlined in this QAPP to the extent necessary to allow comparison to current study data.

B10 DATA MANAGEMENT

Upon conclusion of all activities at a given study location, the QAPP/monitoring plan should be reviewed to ensure all necessary data was collected. The field team should review all completed data forms and sample labels for accuracy, completeness, and legibility, and make a final inspection of samples. If information is missing from the forms or labels, the team leader should fill in the missing information prior to proceeding to the next study location. Any missing and/or compromised samples should be collected immediately. A field notebook should be maintained by the field team leader (at a minimum) to document field activities, data collected, deviations from method, and general observations and information related to the study. Every person should maintain individual field logs to document activities and observations during daily activities.

All data collected during scientific studies should be checked by the team leader for completeness and accuracy. Field data forms should be complete and initialed by the completing scientist and the reviewing scientist. All field data sheets and log books will be kept at Norman MS4 and maintained for a period of 5 years.

All field data will be entered to spreadsheets (or databases) or scanned into pdf files for electronic storage. Data will be stored electronically in project files on a secure network. The network is backed up daily. Data entry to spreadsheets and databases along with spreadsheet calculations shall be checked for accuracy at a rate of 10% (minimum) of the entries and calculation cells. Copies of the checked data and spreadsheets should be initialed by the reviewer and retained in the records. All calculations should be detailed in the body of written reports, or shown on the Calculation Pages. Good notes regarding calculations will be kept and filed in the project notebook.

Norman MS4 is responsible for the compilation of all data (*in-situ*, bioassessment, analytical, etc.) collected during the study. Analytical results as well as QA/QC results will be reported in electronic format to the Project Manager. This data will be stored on the MS4 network for a minimum of five years after the end of the project.

All deliverables (scientific reports, QA/QC reports, etc.) developed as part of this study shall be peer reviewed and/or reviewed by the Project Manager.

III. ASSESSMENT AND OVERSIGHT

C1 ASSESSMENTS AND RESPONSE ACTIONS

Data will be reviewed by the Norman MS4 QA Officer to evaluate the QAPP and its implementation. The review will include the following objectives:

a) collection of samples
b) corrective actions

Laboratory performance may be checked using external audit samples. The Norman MS4 QA Officer will be the internal individual responsible for detecting any errors or malfunctions and performing corrective actions. If errors are detected or anomalous data is suspected, the data will be traced back through the acquisition process until the error is found. In the event that no error is found, the data will be considered appropriate for reporting. If an error is found and cannot be resolved, then the effected data will be discarded.

C2 REPORTS TO MANAGEMENT

Reports will be made to the Project Manager by the laboratory detailing significant occurrences related to the project including number of samples taken, surveys completed, operational problems, and corrective actions. Quality Assurance reports will be made to the Project Manager by the Field Coordinator and the laboratory detailing all QA problems and corrective actions. Copies of all reports will be maintained at the Norman MS4 office for a period of five years.

IV. DATA VALIDATION AND USABILITY

D1 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

Water quality results will be rejected if they fall outside of the standard deviation for the respective parameter as outlined in Section A7. The review, validation and verification of the analytical data are the responsibility of the contracted laboratory. The review, validation and verification of field data and lab results for reporting are the responsibility of Norman MS4 or their designated contractor.

D2 VALIDATION AND VERIFICATION METHODS

The field and lab data will be combined in the spreadsheets and reported to the Project Manager. Norman MS4 or their designated contractor will validate and verify the data in the reports to be correct by checking all entries against lab results and field notebook entries.

D3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Laboratory data quality objectives and their fulfillment will be assessed immediately after the analyses are performed. Data found to be outside objectives will be reanalyzed immediately if possible and discarded if not meeting laboratory objectives and assessment in Element B5.

Sample handling data quality objectives will be assessed by adherence to SOPs and analysis of field duplicates and blanks. Sample handling quality objectives will be assessed annually and reported in the final report.

Sampling data quality objectives will be met by designing the sampling protocol so that the error involved in sampling is equal to or less than the prescribed objective. The objectives will be assessed by analysis of field duplicates. They should agree with each other within 30 percent.

Any deviations from the objectives will be reported to Norman MS4 or their designated contractor and attempts will be made to determine and fix the causes of the data not meeting objectives.

APPENDIX

SOPs

(General SOPs for key activities are provided as an additional aid to the field methodology. They are not intended to address all possible equipment options or field conditions that could be encountered)

1.0 pH Meter Calibration SOP

Purpose

This SOP describes the methods for calibration and use of portable pH meters (capable of 2-point calibration) such as the Orion® Star Series pH meter and YSI Multi Probe System (MPS). This SOP should not supersede manufacturer's specific recommended calibration procedures. Field forms used for meter calibration and measurement recording are attached to these SOPs.

Procedure

Orion® Star Series (or similar pH meter)

Calibration

1. Be sure that the electrode (probe) is properly attached and that a good battery is installed.

2. Turn the meter on and check the read-out for any warning messages ("Low Bat.", etc.) If problems occur refer to the owners manual for help.

3. Record the proper information (date, time, etc.) on the Calibration Field Form (attached) or in a field logbook.

4. Remove the probe protection cap, rinse and place the probe in pH buffer solution 7.00 (yellow in color) submerging the end to ***at least 1 inch***. Allow the meter to adjust to the buffers pH for approximately 1 minute.

5. Press the Calibration button on the meter to begin the calibration process. The display should read "CAL.1" along with the pH reading.

6. When the meter has accepted the buffer the **pH** will stop flashing. Press the Calibration button to accept the value and proceed to the next calibration point "CAL.2"

7. Remove the probe from the 7.00 buffer and rinse with distilled water to remove any excess buffer solution.

8. Place the probe in the second buffer solution, 4.01 (pink) or 10.01 (blue), whichever best brackets the expected pH range to be measured, and stir it gently.

9. When the meter has accepted the value the **pH** will stop flashing as in step 6 above. Press “Save” to accept this value. Record this number on the pH Calibration Record sheet.

10. The display will immediately show the slope, a number that should be between 92% and 102%. Record this number on the pH Calibration Record sheet. If the slope is larger or smaller than this range the meter should be recalibrated.

11. A calibration check should be done once the meter is calibrated. This is done by rinsing the probe with distilled water and then placing it in the pH 7.00 buffer solution and taking a reading. Make sure the measure symbol is lit, if not press the “Measure” button to return to measurement mode. When the **pH** stops flashing record this reading on the pH Calibration Record form. If the reading is between 6.90 and 7.10 then the original calibration remains valid. If the measurement falls outside this range then the meter should be recalibrated.

12. Gently shake or rinse off excess liquid from the probe. The meter is now ready for use.

13. The pH meter should be calibrated once per day on days that it is used. The pH meter should have its calibration checked once for each sampling trip or once every 10 samples whichever is greater. This is done simply by placing the probe in the pH 7.00 buffer solution and taking a reading. Record this reading on the pH Calibration Record form. If the reading is between 6.90 and 7.10 then the original calibration remains valid. If the measurement falls outside this range then the meter should be recalibrated. Furthermore, if the battery or probe is ever disconnected from the meter during use, a new calibration would be required.

YSI MPS

1. Be sure that the pH electrode (probe) is properly attached and that a good battery is installed.

2. Turn the meter on and check the read-out for any warning messages (“Low Bat.”, etc.) If problems occur refer to the owners manual for help.

3. Record the proper information (date, time, etc.) on the Calibration Field Form (attached) or in a field logbook.

4. Press the On/off key to display the run screen then press the Escape key to display the Main Menu screen.

5. Use the arrow key to highlight the Calibrate selection and press Enter.

6. Use the arrow keys to highlight the pH selection and press Enter to display the pH calibration screen.

7. Select the 2-point option to calibrate the pH sensor using two calibration standards then press Enter. The pH Entry Screen is displayed.

8. Remove the transport/calibration cup from the end of the probe and place the probe in pH buffer solution 7.00 (yellow in color) so that the sensor is completely immersed, ***approximately 30 mL.***

9. Screw the transport/calibration cup on the threaded end until securely tightened. Gently rotate and/or move probe module up and down to remove any bubbles from the pH sensor.

10. Use the keypad to enter the calibration value of the buffer being used and press Enter. The pH calibration screen is displayed. Allow at least one minute for temperature equilibration before proceeding.

11. Observe the reading under pH, when the reading shows no significant change for approximately 30 seconds, press Enter. The screen will indicate that the calibration has been accepted and prompt you to press Enter to Continue.

12. Press Enter. This returns you to the Specified pH Entry Screen. Rinse the probe module, transport/calibration cup and sensors in distilled water.

13. Repeat steps 8 through 11 using the second pH buffer solution, 4.01 (pink) or 10.01 (blue), whichever best brackets the expected pH range to be measured.

14. Press Escape to return to Main Menu. Use the keypad and select Run.

15. A calibration check should be done once the meter is calibrated. This is done simply by placing the probe in the pH 7.00 buffer solution and taking a reading. Record this reading on the pH Calibration Record form. If the reading is between 6.90 and 7.10 then the original calibration remains valid. If the measurement falls outside this range then the meter should be recalibrated.

16. Gently shake or rinse off excess liquid from the probe. The meter is now ready for use.

17. The pH meter should be calibrated once per day on days that it is used. The pH meter should have its calibration checked once for each sampling trip or once every 10 samples whichever is greater. This is done simply by placing the probe in the pH 7.00 buffer solution and taking a reading. Record this reading on the pH Calibration Record form. If the reading is between 6.90 and 7.10 then the original calibration remains valid. If the measurement falls outside this range then the

meter should be recalibrated. Furthermore, if the battery or probe is ever disconnected from the meter during use, a new calibration would be required.

pH Measurements

Orion® Star Series (or similar pH meter)

1. Place the probe in the liquid to be analyzed and stir it gently. The probe should be submerged so that the sensor is ***at least 1 inch*** into the liquid.

2. Press the "Measure" button to begin. The measure symbol will flash until the reading is stable. When the **pH** stops flashing record the reading to the nearest tenth of a unit.

3. Be sure to turn off the meter when the final pH measurement has been taken and recorded.

YSI MPS

1. Select Run from the main menu to display run screen.

2. With probe sensor guard installed, completely immerse all sensors into sample.

3. Allow the meter to stabilize and record the pH reading to the nearest tenth of a unit.

Meter Maintenance/Storage

Orion® Star Series (or similar pH meter)

1. Store the meter in a safe dry place.

2. Keep the probe cover on the probe when not in use and between measurements.

3. A small piece of sponge or paper towel soaked in pH buffer 7.00 should be placed in the bottom of the probe cover to keep the probe surface wetted with the buffer. The probe should **never** be allowed to dry out.

4. Use only "Low Maintenance Triode" ATC probes with the Star series pH meters (model # 9107BNMD or equivalent.)

YSI MPS

1. Store the meter in a safe dry place.

2. Keep a moist sponge in the transport/calibration cup and keep sealed when not in use and between measurements. The probes should **never** be allowed to dry out.

Quality Assurance/Quality Control

1. Meters are calibrated biweekly (at a minimum) to ensure proper function and accuracy.

2. Values measured during biweekly calibrations are compared between meters to verify accuracy.

3. Duplicate measurements should be taken at a rate of 10% (minimum) of samples analyzed.

2.0 Dissolved Oxygen (D.O.) Meter Calibration SOP

Purpose

This SOP describes the methods for calibration and use of the portable YSI Model 58 and Model 85 D.O. meters as well as the YSI MPS or similar meter. This SOP should not supersede manufacturer's recommended calibration procedures. Field forms used for meter calibration and measurement recording are attached to these SOPs.

Procedure

Calibration

Model 58

1. Be sure that the oxygen probe is properly attached to the meter and that the end of the probe is affixed in storage bottle containing a piece of wet sponge or towel to keep the probe moist, and to provide a water-saturated air environment.

2. Turn the meter on and check the read-out for the "LOBAT" warning, and for the normally observed display readings. If problems occur refer to the owners manual for help.

3. Record the proper information (date, time, etc.) on the Dissolved Oxygen Calibration Record sheet or in a field logbook.

4. Set the D.O. meter to "ZERO" and use the "O2 ZERO" knob to adjust the display to 0.0. If the meter will not adjust to zero refer to the owners manual for guidance.

5. Perform a Calibration according to one of the following procedures:

   Winkler Titration (verification calibration)

   a) Fill a container with at least 500 mL distilled water (or tap water if distilled not available) and allow it to acclimate. It can be aerated overnight to achieve 100% oxygen saturation if desired.
   b) Fill each of two BOD bottles with the water from the container by gently submerging them into the container.
   c) Add one each of the HACH manganous sulfate and alkaline iodide-azide powder pillows to each bottle. Cap the bottles and invert them 15-20 times to mix the solution thoroughly.
   d) Allow the bottles to settle until a precipitate appears in the bottom half of the bottle. This will usually take 3-5 minutes.

e) Add one HACH sulfamic acid powder pillow to each BOD bottle. Invert the bottles until all the precipitate has been dissolved.
f) Using a graduated cylinder measure and place 200 mL of the solution into a flask.
g) Add 1 mL of HACH starch indicator to the flask. The solution should turn black.
h) Using a burette filled with sodium thiosulfate (at room temperature) titrate the solution in the flask drop-wise until the solution turns clear.
i) Record the starting and ending volumes from the burette.
j) Repeat this titration (steps f-I) for a second flask filled with fresh solution.
k) Subtract ending volumes from starting volumes to arrive at the volume used for each titration. The volume used is equivalent to the dissolved oxygen content of the water in mg/L.
l) If the D.O. values from the two titrations differ by more than 5%RPD then the titrations should be repeated.
m) Remove the D.O probe from the storage bottle and place it in the container holding the water. It must be submerged at least 1 inch below the waters surface. Set the meter to the "0.1 mg/l" measurement mode. Swirl the probe gently and slowly in the water.
n) Calibrate the meter to the average of the two dissolved oxygen measurements by turning the "O2 CALIB" knob until the display reads the corresponding D.O. concentration. Record the final calibrated value.

Air Calibration (Standard Calibration)

a) Set the meter to the temperature measurement mode ("TEMP…").
b) Record the temperature of the probe in the storage bottle on the record form or in a field logbook.
c) Refer to the attached table presenting Solubility of Oxygen in Water values (also on back of meter) and find the solubility of oxygen at the corresponding temperature.
d) Record the appropriate barometric pressure or altitude (use pressure when available).
e) Refer to the attached table presenting Calibration Values at Various Pressures and Altitudes (also on back of meter) and record the "CALIB VALUE" in % saturation at the corresponding pressure or altitude.
f) Using the solubility of oxygen value and the % saturation value as a decimal calculate the calibration value by multiplication (i.e. at an altitude Of 1413 ft. and a temperature of 20°C the calibration value would be 8.64 mg/L or 8.6 mg/L).
g) Set the meter to the D.O. measurement mode ("0.1 mg/l") and adjust the display using the "O2 CALIB" knob to read the calibration value as calculated.
h) Record the final calibrated value on the record form or in a field logbook.

Model 85

1. Turn on the meter and make sure the meter is in the D.O. mode (will display mg/L).

2. Wet the sponge in the calibration/storage chamber and insert the probe into the chamber.

3. Allow the D.O. and Temperature readings to stabilize (up to 15 minutes).

4. Press the up arrow and down arrow buttons simultaneously.

5. When prompted to do so, enter the local altitude in hundreds of feet by scrolling up or down with the up or down arrow buttons.

6. Press enter when the correct altitude is displayed. Base altitude on barometric pressure when possible, as it will have an affect on the calibration. See “Air Calibration” above for details.

7. When the percent reading is stable, press enter. Save will be displayed on the screen for a few seconds, then the meter will return to the normal operation mode.

NOTE: Each time either of the meters is turned off they should be recalibrated.

YSI MPS

Air Calibration (Standard Calibration)

1. Be sure that the D.O. electrode (probe) is properly attached and that a good battery is installed.

2. Turn the meter on and check the read-out for any warning messages (“Low Bat.”, etc.) If problems occur refer to the owners manual for help.

3. Record the proper information (date, time, etc.) on the Calibration Field Form (attached) or in a field logbook.

4. Press the On/off key to display the run screen then press the Escape key to display the Main Menu screen.

5. Use the arrow key to highlight the Calibrate selection and press Enter.

6. Use the arrow keys to highlight the Dissolved Oxygen selection and press Enter to display the DO calibration screen.

7. Highlight the DO % selection and press Enter. The DO Barometric Pressure Entry Screen is displayed.

8. Place approximately 3 mm (1/8 inch) of water in the bottom of the transport/calibration cup or ensure the sponge is “dripping” wet and engage only 1 or 2 threads of the transport/calibration cup to the probe module to ensure the DO sensor is vented to the atmosphere. Make sure the DO and temperature sensors are **not** in an upright position and immersed in the water.

9. Use the keypad to enter the current local barometric pressure either measured by the YSI556 or from the NWS/NOAA for your area. Barometer readings from the NWS/NOAA are generally corrected to sea level and must be uncorrected before use. For field DO calibrations, use the following equation to correct National Weather Service & NOAA sea level corrected barometric pressure to absolute barometric pressure:

   $BP \sim SLBP - 2.5(A/100)$

   SLBP = sea level BP
   A = altitude in feet above sea level

10. Press Enter. The DO % saturation calibration screen is displayed. Allow approximately ten minutes for the air in the transport/calibration cup to become saturated and for temperature to equilibrate before proceeding.

11. Observe reading under DO %. When the reading shows no significant change for approximately 30 seconds, press Enter. The screen will indicate that the calibration has been accepted and prompt you to press Enter to Continue. Record the resulting % saturation value, which should be between 95% and 105%.

12. Press Enter to return to the DO calibration screen then press Escape to return to the calibrate menu.

13. Gently shake or rinse off excess liquid from the probe. The meter is now ready for use.

Winkler Titration (verification calibration)

1. DO calibration in mg/L may also be carried out using a known concentration of dissolved oxygen.

2. Go to the DO calibrate screen and highlight the DO mg/L selection. Press Enter.

3. Repeat the calibration steps (a. through m.) under Model 58 Winkler Titration.

4. Observe the DO mg/L reading after the reading has stabilized for approximately 30 seconds. Record calibration reading then press Enter. The screen will indicate that the calibration has been accepted and prompt you to press Enter to Continue.

5. Press Enter to return to the DO calibration screen and press Escape to return to the calibrate menu. Rinse probe and sensors in distilled water.

D.O. Measurements

Model 58 and 85

1. Set the meter to the D.O. measurement mode. Place the probe in the liquid to be analyzed and stir it gently and slowly to keep water passing over the probe membrane. The probe should be submerged ***at least 1 inch*** into the liquid.

2. Allow the meter to stabilize on a reading (should take less than one minute). Once the meter has stabilized record the reading.

3. If the meter will not stabilize check the probe for air bubbles. If bubbles are found shake the probe firmly but not violently a couple of times and re-measure. If problems still occur, probe maintenance is necessary.

4. The meter should be placed in the “ZERO” mode between measurements to conserve battery life. Be sure to turn off the meter when the final D.O. measurement has been taken and recorded.

YSI MPS

1. Select Run from the main menu to display run screen.

2. With probe sensor guard installed, completely immerse all sensors into sample.

3. Allow the meter to stabilize and record the DO reading to the nearest tenth a mg/L.

Meter Maintenance/Storage

1. Store the meter in a safe dry place.

2. Keep the probe cover on the probe when not in use and between measurements.

3. A small piece of sponge or paper towel soaked in clean water should be place in the bottom of the probe cover to keep the probe surface moist. The probe should **never** be allowed to dry out.

4. The probe membrane should be replaced at a minimum every 6 months or whenever the meter fails to perform to standard.

5. Use only YSI replacement parts and probes with the meter.

Quality Assurance/Quality Control

1. Meters are calibrated biweekly (at a minimum) to ensure proper function and accuracy.

2. Values measured during biweekly calibrations are compared between meters to verify accuracy.

3. Duplicate measurements should be taken at a rate of 10% (minimum) of samples analyzed.

3.0 Conductivity Meter Calibration and Measurement SOP

Purpose

This SOP describes the methods for calibration and use of portable YSI Model 30 meter, the Model 85 conductivity meter, and the YSI MPS or similar meter. This SOP should not supersede manufacturer's recommended calibration procedures. Field forms used for meter calibration and measurement recording are attached to these SOPs.

Procedure

Calibration and Bi-Weekly Accuracy Checks

Model 30, Model 58 and YSI MPS

Calibration of YSI Model 58 and Model 85 conductivity meters is performed by the manufacturer and is rarely needed. However, the accuracy of the meter should be monitored bi-weekly and before each use. The bi-weekly monitoring of accuracy should be recorded in the calibration log book, along with date/time performed and name of person performing task.

Accuracy Check

1. Turn the instrument on and allow it to complete its self test procedure.

2. Bi-weekly the instrument should be checked for accuracy using a standard of 200 uS/cm (±10%). The meter should be set to measure specific conductance. The steps listed below under "Conductivity Measurements" should be followed for checking conductivity accuracy. This standard check should be recorded in the calibration log book.

3. YSI conductivity meters are calibrated a minimum of once a year or when there is reason to believe the instrument is reading incorrectly (outside the range of the standard ±10% in uS/cm during the accuracy check).

Calibration Model 30 & 85

1. To calibrate, select a calibration solution, which is most similar to the sample you will be measuring. The following should serve as a guideline:

   for sea water choose a 50 mS/cm conductivity standard,

for fresh water choose a 1 mS/cm or 500 mS/cm conductivity standard, and
for brackish water choose a 10 mS/cm conductivity standard.

2. Place at least 3 inches of solution in a clean glass beaker.

3. Insert the probe into the beaker deep enough to completely cover the oval shaped hole on the side of the probe. Do not rest the probe on the bottom of the container -- suspend it above the bottom at least 1/4 inch.

4. Allow at least 60 seconds for the temperature reading to become stable.

5. Move the probe vigorously from side to side to dislodge any air bubbles from the electrodes.

6. Press and release the up and down keys (∧,∨) at the same time. The CAL symbol will appear at the bottom left of the display to indicate that the instrument is now in Calibration Mode.

7. Use the up or down arrow key to adjust the reading on the display until it matches the value of the calibration solution you are using.

8. Once the display reads the exact value of the calibration solution being used press the ENTER key once. The word "SAVE" will flash across the display for a second indicating that the calibration has been accepted.

YSI MPS Calibration

1. Select Calibrate from the main menu and use the arrow keys to highlight the Conductivity selection.

2. Press Enter and then highlight the Specific Conductance selection, press Enter.

3. The Conductivity Calibration Entry Screen is displayed. Place approximately 55 mL of conductivity standard into dry or pre-rinsed transport/calibration cup.
   Note: It is ideal to pre-rinse with a small amount of standard that can be discarded.

4. When calibrating, select a calibration solution, which is most similar to the sample you will be measuring. The following should serve as a guideline:

   for sea water choose a 50 mS/cm conductivity standard,
   for fresh water choose a 1 mS/cm or 500 mS/cm conductivity standard, and
   for brackish water choose a 10 mS/cm conductivity standard.

5. Carefully immerse the sensor into the solution and gently rotate to remove any bubbles from the conductivity cell. Screw the transport/calibration and securely tighten.

6. Use the keypad to enter the calibration value of the standard being used. Be sure to enter the value in **mS/cm at 25ºC**, press Enter.

7. The Conductivity Calibration Screen is displayed. Allow at least one minute for temperature equilibration before proceeding.

8. Observe the reading under Specific Conductance until no significant change or for approximately 30 seconds, press Enter. After calibration has been accepted, press Enter to continue.

9. Press Enter and then press Escape to return to calibrate menu. Rinse probe and sensors with distilled water. Gently shake or rinse off excess liquid from the probe. The meter is now ready for use.

Conductivity Measurements

Model 58 and Model 85

1. Press the "ON/OFF" button to turn the meter on. The meter will go through a self-test procedure, which will last for several seconds. The cell constant will be displayed when the self-test is finished. Consult the Operations Manual if an error is displayed during the self-test.

2. Select the mode of measurement on the meter by pressing and releasing the "MODE" button on the meter. Specific conductance is typically measured in field studies. The following are the modes of measurement capable of the YSI 30 meter:

   Conductivity - measurement of the conductive material in the liquid sample without regard to temperature. Displayed when the large numbers on the display will be followed by the respective units, and the temperature units will not be flashing.

   Specific Conductance - temperature compensated conductivity which automatically adjusts the reading to a calculated value which would have been read if the sample had been at 25°C. Displayed when the large numbers on the display will be followed by the respective units, and the temperature units will be flashing.

   Salinity - A calculation done by the instrument electronics, based upon the conductivity and temperature readings. Displayed when large numbers on the display will be followed by ppt.

3. Insert the probe into the solution being measured for conductivity, making sure that the probe is inserted deep enough to cover the hole located on its side. If possible, refrain from touching any solid located in the solution, and hold the probe at least 1/4 inch from the bottom and sides of any container used to hold the sample. The probe should also be vigorously shaken in the solution to dislodge any air bubbles, which may be adhered.

NOTE: The YSI meters are factory calibrated, and retain the last calibration conducted. This means that once batteries are installed, or when the meter is turned on, you are ready to begin taking measurements.

YSI MPS

1. Select Run from the main menu to display run screen.

2. With probe sensor guard installed, completely immerse all sensors into sample.

3. Allow the meter to stabilize and record the Conductivity reading.

Meter Maintenance/Storage

Always rinse the conductivity cell with clean water after each use.

Cleaning the conductivity cell

1. Dip the cell in cleaning solution of 1:1 isopropyl alcohol and 10N HCl, and agitate for two to three minutes.

2. Remove the cell from the cleaning solution.

3. Use a nylon brush to dislodge any contaminants from inside the electrode chamber.

4. Repeat steps one and two until the cell is completely clean. Rinse the cell thoroughly in deionized water.

5. Store the conductivity cell in the meter storage chamber.

Quality Assurance/Quality Control

1. Meters are calibrated biweekly (at a minimum) to ensure proper function and accuracy.
2. Values measured during biweekly calibrations are compared between meters to verify accuracy.

3. Duplicate measurements should be taken at a rate of 10% (minimum) of samples analyzed.

4.0 Temperature Measurement/Check SOP

Purpose

This SOP describes the methods for the measurement of temperature using various instruments including the Orion Star Series pH meter, YSI MODEL 58 DO meter, YSI MODEL 30 conductivity meter, YSI MODEL 85 combination meter and YSI MPS as well as other meters with temperature capability. This SOP should not supersede manufacturer's recommended calibration procedures. Field forms used for meter calibration and measurement recording are attached to these SOPs.

Procedure

Accuracy Check for all Instruments

1. Insert the probe for the corresponding instrument into a container holding water, and allow the temperature reading to stabilize.
2. Record the temperature displayed on each respective instrument in the calibration log book along with date/time and individual performing the task.
3. Compare the actual temperature of the water measured with a certified calibrated thermometer to the temperature measured by the respective instruments.
4. If the temperature relative percent difference exceeds 20%, then do not use that particular meter for temperature analysis.

Temperature Measurement

Orion Star Series pH meter

1. Connect the combination pH/temperature electrode to the meter.
2. Turn the meter on, and allow it to go through its self-test.
3. Insert the probe into the solution to be measured.
4. The temperature read out is located in the upper left of the LCD on the meter.

HACH EC10 pH/mV/temperature meter

1. Connect the combination pH/temperature electrode to the meter.
2. Turn the meter on, and allow it to go through its self-test.
3. Insert the probe into the solution to be measured.
4. The temperature read out is located in the prompt line followed by ATC.

YSI Model 30 Conductivity meter and YSI Model 85 Combination meter

1. Turn the meter on.
2. Insert the probe into the solution to be measured.
3. The temperature read out is located in the lower right of the LCD on the meter.

YSI Model 58 Dissolved Oxygen meter

1. Turn the meter to temperature mode.
2. Insert the probe into the solution to be measured.
3. The temperature read out is located on the screen.

YSI MPS

1. Select Run from the main menu to display run screen.
2. With probe sensor guard installed, completely immerse all sensors into sample.
3. Allow the meter to stabilize and record the Temperature reading.

Quality Assurance/Quality Control

1. Meters are calibrated biweekly (at a minimum) to ensure proper function and accuracy.
2. Values measured during biweekly calibrations are compared between meters to verify accuracy.
3. Duplicate measurements should be taken at a rate of 10% (minimum) of samples analyzed.

5.0 Flow Measurements SOP

Purpose

This SOP describes the procedure used in the determination of water flow, which is necessary for the calculation of water volume passing through a given water body.

No single method for measuring discharge is applicable to all types of stream channels. The preferred procedure for obtaining discharge data is based on "velocity-area" methods (e.g., Rantz and others, 1982; Linsley et al., 1982). For streams that are too small or too shallow to use the equipment required for the velocity-area procedure, two alternative procedures are presented.

Stream discharge is equal to the product of the mean current velocity and vertical cross sectional area of flowing water. Discharge measurements are critical for assessing pollutant loading and reaeration rates used for dissolved oxygen modeling, as well as, other characteristics that are very sensitive to stream flow differences. Discharge will be measured at a suitable location within the sample reach that is as close as possible to the location where chemical samples are collected so that these data correspond. Field data forms for recording measurements are attached to these SOPs.

Procedure

Velocity Area Procedure

Because velocity and depth typically vary greatly across a stream, accuracy in field measurements is achieved by measuring the mean velocity and flow cross-sectional area of many increments across a channel. Each increment gives a subtotal of the stream discharge, and the whole is calculated as the sum of these parts.

A Marsh McBirney Model 201 Portable Water Current Meter (or equivalent) will be used whenever conditions allow. The site selected for flow measurements will be chosen on the basis of the most uniform streambed cross-section. This facilitates the best measurements since non-uniform streambeds may cause errors in velocity and depth. Manmade structures (bridges and culverts) may be used as flow measurement sites, but are not ideal.

Discharge measurements are generally made at only one carefully chosen channel cross section within the sampling reach. It is important to choose a channel cross section that is as much like a canal as possible, void of obstructions, as this provides the best conditions for measuring discharge by the velocity-area method. Rocks and other obstructions may be removed to improve the cross-section before any measurements are made. However, because removing obstacles from one part of a cross-section affects adjacent water velocities, you must not change the cross-section once you commence collecting the set of velocity and depth measurements.

The procedure for obtaining depth and velocity measurements is outlined below:

1) Locate a cross-section of the stream channel for discharge determination that exhibits as many of these qualities as possible: Segment of stream above and below cross-section is straight, depths mostly greater than .5 feet, and velocities mostly greater than 0.5 feet/second. Do not measure discharge in a pool, when possible. Flow should be relatively uniform, with no eddies, backwaters, or excessive turbulence.

2) Stretch a tape measure across the stream perpendicular to its flow, with the "zero" end of the rod or tape on the left bank, as viewed when looking downstream. Tightly suspend the measuring tape across the stream, approximately one-foot above water level and secure at both ends.

3) Record the total wetted distance indicated by the tape from the left descending bank (LDB) to the right descending bank (RDB).

4) Attach the velocity meter probe to the calibrated wading rod that indicates depth and holds the flow probe at 60% depth. Check to ensure the meter is functioning properly and the correct calibration value is displayed. If necessary the meter and probe can be calibrated according to the instructions in the QA/QC section of this SOP (which is based on manufacturer's recommendations).

5) Divide the total wetted stream width into equally sized intervals, generally one foot wide (minimum of ten measurement locations, but never less than 1/2 foot increments).

6) Stand downstream of the tape and to the side of the midpoint of the first interval (closest to the LDB).

7) Place the wading rod in the stream at the midpoint of the interval. Record the distance from the left bank (in feet) and the depth indicated on the wading rod (in tenths of a foot) on the Flow Measurement Form.

8) Stand downstream of the probe to avoid disrupting the stream flow. If the water depth is less than or equal to 2.5 ft., adjust the position of the probe on the wading rod so it is at 60% of the measured depth below the surface of the water (Meador et al., 1993). The probe is set at the 60% depth by adjusting the foot scale on the sliding rod with the tenth scale on the depth gauge rod. If the water depth is greater than 2.5 ft., take measurements at 20% and 80% of the depth from the water surface. The average of these two readings is considered the water velocity for the respective measurement point. To set the probe at the 20% depth, first multiply the water depth by two, and then use the calculated number to line up the

foot scale as with the 60% depth. The same method is used for the 80% depth, except the calculated value is the water depth divided by two.

9) Face the probe upstream at a right angle to the cross-section. Do not adjust the angle of the probe, even if local flow eddies hit at oblique angles to the cross-section.

10) Wait 20 seconds to allow the meter to equilibrate then measure the velocity. Record the value on the Flow Measurement Form. For the electromagnetic current meter (e.g., Marsh-McBirney), use the lowest time constant scale setting on the meter that provides stable readings.

11) Move to the midpoint of the next interval and repeat Steps 6 through 8. Continue until depth and velocity measurements have been recorded for all intervals.

12) Record the data from each measurement on the Discharge Flow Recording form.

Timed Filling Procedure

In channels too "small" for the velocity-area method, discharge can be determined directly by measuring the time it takes to fill a container of known volume. "Small" is defined as a channel so shallow that the current velocity probe cannot be placed in the water, or where the channel is broken up and irregular due to rocks and debris, and suitable cross-section for using the velocity area procedure is not available. This can be an extremely precise and accurate method, but requires a natural or constructed spillway of free-falling water. If obtaining data by this procedure will result in a lot of channel disturbance or stir up a lot of sediment, wait until after all biological and chemical measurements and sampling activities have been completed.

Choose a cross-section of the stream that contains one or more natural spillways or plunges that collectively include the entire stream flow. A temporary spillway can also be constructed using a portable V-notch weir, plastic sheeting, or other materials that are available onsite. Choose a location within the sampling reach that is narrow and easy to block when using a portable weir. Position the weir in the channel so that the entire flow of the stream is completely rerouted through its notch. Impound the flow with the weir, making sure that water is not flowing beneath or around the side of the weir. Use mud or stones and plastic sheeting to get a good waterproof seal. The notch must be high enough to create a small spillway as water flows over its sharp crest.

Make sure that the entire flow of the spillway is going into the bucket. Record the time it takes to fill a measured volume on the Field Measurement Form. Repeat the procedure five times. If the cross-section contains multiple spillways, you will need to do separate determinations for each spillway. If so, clearly indicate which time and volume data replicates should be averaged together for each spillway; use additional field measurement forms if necessary.

Neutrally-Buoyant Object Procedure

In streams too shallow to use the velocity-area method the neutrally-buoyant object method may be employed. This procedure involves measuring the time it takes a floating object to pass a known stream distance. This is done using buoyant objects that float low in the water such as key limes, sticks, or small rubber balls. The following steps should always be followed to ensure accurate results.

1. Mark off on the stream bank the starting and ending points. These should be far enough apart to allow at least 10 seconds of drift time between them. Record the distance between the two points in feet to the nearest 0.1 foot.

2. Place the buoyant object in the water upstream of the starting point and begin timing on a stopwatch when the object reaches the start line.

3. Record the elapsed time till the object crosses the end line, in seconds to the nearest 0.1 seconds.

4. Repeat steps two and three at least three times to develop an average time of passage in seconds.

5. Average velocity is equal to distance divided by average elapsed time.

6. Measure cross sectional depths and width in the middle of the flow path to acquire a cross sectional wetted area. This can be used along with the average velocity to determine flow in cubic feet per second.

Observations and Calculations

Discharge is usually determined after collecting water chemistry samples. Although discharge is part of the physical habitat indicator, it is presented as a separate section.

Flow data will be recorded on the Discharge Flow Recording forms or on a field computer. Any additional observations will be recorded in field notebooks. Calculations will be performed using hand held calculators to determine flow volume in CFS. The calculated volume will be evaluated for reasonableness and may be repeated if there are questions regarding the flow accuracy. A sketch of the stream cross section can be added to the flow form, especially if there were critical conditions that may have impacted the flow measurement.

The following calculations are used to calculate flow/discharge:

a. Calculate Area (A) by multiplying Width (W) X Depth (D).
b. Calculate discharge (Q) by multiplying Velocity (V) by Area (A).
c. Calculate total Area (A) and Discharge (Q) in each respective column.

d. Calculate average Velocity (V) by dividing summed Discharge (Q) by summed area or by taking an average of each velocity measurement.

QA/QC Stream flow Current Velocity Meters

Field teams will be using an electromagnetic type meter (e.g., Marsh McBirney Model 201 D, or equivalent). General guidelines regarding performance checks and inspection of current meters are presented below. If required the operating manual for the specific meter will be referenced for information as necessary.

Periodically or prior to field studies, the meter is calibrated to a zero value using a bucket of quiescent water and the following routine. The probe is placed in the bucket and allowed to sit for 30 minutes with no disturbance. The velocity value obtained should be 0.0 $\pm$ 0.1. The meter is adjusted to zero if the value is outside this range.

Duplicate flow measurements are taken for at least one in ten sites where flow is measured. Duplicates do not have to be taken at the same exact location but should be in the same reach to avoid potential water gains or losses. A relative percent difference (RPD) is calculated, and must be less than 20% to be within control parameters. Any values exceeding 20% are investigated to determine the cause and the need for corrective action. When possible flow measurement values are compared to gauging station data or data from fixed flow meters as a QA check

12.0 Sample Collection and Custody

Purpose

This SOP describes the materials and methods necessary for the routine collection of water and wastewater samples for the analysis of various conventional and unconventional pollutants. It also gives guidance for the completion of the COC forms necessary for each set of samples collected for laboratory analysis. This SOP provides general guidance and should not be a substitute for a study specific work plan and/or Quality Assurance Project Plan.

Procedures

Sample Collection

1. Clean sample bottles should be supplied by the laboratory or a reputable scientific supply company. Be sure to have an extra set of sample bottles on hand on each field trip.

2. Check all bottles prepared by the lab to ensure the proper analyses are covered with the correct type of preservation.

3. A duplicate sample for a given analyte shall be taken, 1 for every 10 samples collected. That is, a duplicate sample will be collected 10% of the time. A duplicate sample is simply a second sample taken from the same location immediately following the original sample. The duplicate sample serves as a quality control check for the sample sources (stream water, etc.) variability, and the sampling methodology repeatability.

4. A field blank shall be collected 10% of the time (1 in 10 samples) when metals or organic chemicals are being analyzed. A field blank is simply a sample bottle filled with deionized water (blank water) on-site at the study location to represent any potential contamination present at the site or in the sampling techniques.

5. A trip blank should be collected at the rate of 1 per 10 samples when metals or organic chemicals are being analyzed. A trip blank is a bottle filled in the lab with deionized water to verify blank water and sample bottle purity.

6. Use appropriate safety precautions while collecting the samples (i.e., wear latex gloves, Tyvek® suits, etc.) as necessary.

7. Place a label on the sample bottle, prior to collecting the samples, and record the following information on the label using a permanent marker (e.g., Sharpie®):

   a. sample identification,
   b. date of collection,
   c. time of collection,
   d. initials of collectors, and
   e. parameters to be analyzed (NH_3-N, Total Cu, etc.)

8. Fill each bottle per site completely, and place the cap securely each bottle.

When filling sample bottles be sure to choose a representative sample location which is accessible in a manner as to prevent bottom and/or attached solid materials from entering the sample bottle. Samples should be taken in flowing water where possible. Samples should be taken from below the water surface if depth allows.

9. Place the bottle in an ice filled ice chest to keep the sample cool (4°C±2). If the ice chest(s) will be shipped to a laboratory, ice should be placed in a plastic bag(s) to prevent possible sample contamination from melting.

10. Record sample information on the Field Data Form or in a field notebook, along with any pertinent observations. If available, record instantaneous flow at the time of sample collection. This is important if the samples are from an NPDES discharge or other regulatory monitored system.

11. Measure any necessary in-situ parameters (pH, temperature, dissolved oxygen, specific conductivity) and record on the appropriate field form or in a field notebook.

12. When sampling is complete a COC form should be completed.

13. Take note of sample holding times and make an effort to return samples to lab as soon as possible.

Chain of Custody (COC)

1. A COC form (attached) must be filled out for all samples submitted to the laboratory for analysis.

2. The COC form must be filled out with a ballpoint pen, and signed in the appropriate locations by each individual receiving the sample(s).

3. The following information ***must be completed*** on each COC form:

   a. company/facility,
   b. contact name,
   c. address,
   d. phone number,
   e. sample id,
   f. sample description (where taken),
   g. date (from sample bottle),
   h. time (from sample bottle),
   i. number of containers,
   j. preservative,
   k. parameters to analyze at lab,
   l. sampler(s),
   m. shipment method,
   n. turnaround time required,
   o. coc form completed by,
   p. coc form checked by, and
   q. relinquished by.

4. Each completed COC form shall be photocopied and the copy filed.

5. If shipping ice chests to a laboratory, the original COC form should be placed in a ziplock bag and then taped to the inside top of the ice chest for shipment.

6. At the lab the COC form will be received and signed. A copy of the COC form should be returned by the lab, along with the analysis results, when completed.

14.0 Turbidity Meter Calibration SOP

Purpose

This SOP describes the methods for calibration and use of the portable HACH Model 2100P Turbidimeter (or equivalent meter). This SOP should not supersede manufacturer's specific calibration procedures. Field forms used for meter calibration and measurement recording are attached to these SOPs.

Calibration

Calibration of the 2100P Turbidimeter should be completed annually or when the Gelex® standards fall outside the acceptable range >± 10%.

Procedure

1. Prepare formazin 20, 100, and 800 NTU calibration dilutions immediately before calibrating. The solutions are made with a well mixed 4000 NTU stock solution and high quality dilution water (<0.5 NTU) as follows:

    - Dilution water--Deionized water. The deionized water should have a turbidity reading <0.5 NTU.
    - 20 NTU--Add 0.5 mL stock solution to a 100 mL volumetric flask and bring to volume.
    - 100 NTU--Add 2.5 mL stock solution to a 100 mL volumetric flask and bring to volume.
    - 800 NTU--Add 20 mL stock solution to a 100mL volumetric flask and bring to volume.
    - (The 4000 NTU solution is stable for up to a year, but dilutions deteriorate more rapidly.)

2. Use the same sample cuvette for each different dilution reading. Rinse the clean cuvette with dilution water three times; then fill to the line with dilution water.

3. Place the instrument on a flat surface. Then insert the sample cuvette into the cuvette compartment with the orientation mark on the cuvette aligned with the mark on the front of the compartment. Close the lid and press I/O.

4. Turn the signal average off by pressing the Signal Average key until off is indicated. Then press calibrate (CAL). CAL and S0 should be displayed on the screen along with the value for the S0 standard for the last calibration.

5. Press READ. After the count down is completed, the blank value will be displayed, then the display will advance to the next standard. Remove the sample cuvette.

(In case of error, refer to manual.)

6. S1 and 20 NTU will be displayed on the screen.
7. Rinse the sample cuvette 3 times with the well mixed, 20 NTU standard. Then fill the cuvette to the line with the 20 NTU standard.
8. Clean the outside of the cuvette with a soft, lint-free cloth removing water spots and fingerprints. Then apply a thin film of silicone oil and spread the oil evenly over the outside surface with a soft cloth.
9. Insert the sample cuvette into the cuvette compartment with the orientation mark on the cuvette aligned with the mark on the front of the compartment.
10. Close the lid and press READ. After the count down is completed, the standard value will be displayed, then the display will advance to the next standard. Remove the sample cuvette.
11. Repeat steps 6 through 10 for the S2 and S3 samples (100 and 800 NTU, respectively.)
12. After S3 has been read, the display will show S0. Remove the sample cuvette. Press CAL to accept the calibration.
13. Once the calibration has been accepted, the instrument will automatically proceed to measurement mode.

    (If any errors occur during calibration, revert to manual for explanation.)

Calibration Verification

The 2100P Turbidimeter does not require calibration before every measurement. Gelex® Standards are used for routine calibration checks. Routine calibration checks should be performed bi-monthly. If the Gelex® standards read more than 5% from their recorded value, the meter should be recalibrated.

Procedure

Assigning values to the Gelex® standards

1. Calibrate the meter as described above.
2. Select the automatic range mode using the RANGE key.
3. Turn the signal average off by pressing the SIGNAL AVERAGE key until SIG AVG is not displayed on the screen.

4. Clean the outside of the Gelex® vile with a soft, lint-free cloth removing water spots and fingerprints. Then apply a thin film of silicone oil and spread the oil evenly over the outside surface with a soft cloth.

5. Insert the 0-10 NTU Gelex® standard into the cuvette compartment with the orientation mark on the vile aligned with the mark on the front of the compartment. Close the compartment lid.

6. Press READ and record the displayed value after the lamp signal is no longer displayed on the screen.

7. Remove the vile and mark the value on the band near the top of the vile with a permanent marker.

8. Repeat steps 3 through 6 for the other Gelex® standards.

9. The values for each Gelex® standard should be reassigned each time a new calibration is performed.

Checking meter calibration

1. The Gelex® standards should be used as a routine check for instrument calibration. If the standards do not read within 5% of the assigned value, the instrument should be recalibrated before use, and new values assigned to the Gelex® standards.

2. Place the instrument on a flat surface.

3. After turning the instrument on, select the automatic range mode using the RANGE key.

4. Turn the signal average off by pressing the SIGNAL AVERAGE key until SIG AVG is not displayed on the screen.

5. Clean the outside of the Gelex® vile with a soft, lint-free cloth removing water spots and fingerprints. Then apply a thin film of silicone oil and spread the oil evenly over the outside surface with a soft cloth.

6. Insert the 0-10 NTU Gelex® standard into the cuvette compartment with the orientation mark on the vile aligned with the mark on the front of the compartment. Close the compartment lid.

7. Press READ and record the displayed value after the lamp signal is no longer displayed on the screen.

8. Remove the vile and compare the value on the band near the top of the vile with the recorded value. If the recorded value is within 5% of the value marked on the vile, continue to step 8. Otherwise recalibrate the instrument.

9. Repeat steps 3 through 6 for the other Gelex® standards.

Turbidity Measurements

Procedure

1. Collect a representative sample of the liquid to be analyzed in a clean container. Rinse the clean sample cuvette three times with the sample water and fill to the line with sample, taking care to prevent the formation of air bubbles and not leave fingerprints on the sides of the cuvette.

2. Clean the outside of the cuvette with a soft, lint-free cloth removing water spots and fingerprints. Then apply a thin film of silicone oil and spread the oil evenly over the outside surface with a soft cloth.

3. Place the instrument on a flat surface and turn it on by pressing I/O.

4. Insert the sample cuvette into the cuvette compartment with the orientation mark on the cuvette aligned with the mark on the front of the compartment and close the lid.

5. Select automatic range by pressing the RANGE key until AUTO RNG is displayed.

6. Turn the signal average off by pressing the SIGNAL AVERAGE key until SIG AVG is not displayed on the screen.

7. Press READ and record the turbidity value after the lamp symbol is no longer displayed on the screen.

Meter Maintenance/Storage

1. Store the meter in the designated portable carrying case.

2. The meter should not be stored or left in a "dirty" condition.

3. The sample cuvette, silicone oil, and Gelex® standards should be stored in clean state in the proper boxes in the portable carrying case.

4. The 4000 NTU stock solution should be stored in a refrigerator at 5^0 C.

Quality Assurance/Quality Control

1. Meters are calibrated biweekly (at a minimum) to ensure proper function and accuracy.

2. Duplicate measurements should be taken at a rate of 10% (minimum) of samples analyzed.

Field Data Form

FIELD MEASUREMENT RECORD (Date__________________) **REVIEWED BY:_________________**

Station/Depth	Date	Time	Field Crew	Temp C°	DO mg/l	Sp. Cond. uS	pH su	ORP	Turb. (ntu)	Sample # of Containers Sed./Soil	Water	Notes

* Indicates calibration check was made

V1.3 08/04/2005

Discharge/Flow Measurement Form

Station:		
Waterbody:		
Date:		
Crew:	Start Time:	Recorder:
	End Time:	GH. Change: ______________in
	Staff/Gage:	______________hrs.
Width:	Area:	Velocity:
Disch/Flow:	Method:	No Secs:
Meter No:	Max Vel:	Min Vel:

ORIENTATION:

Wading, Boat, Upstream, Downstream, Side Bridge _______ ft/mi,

above, below gage, and ______________________

Measurement rated: excellent good fair poor based on the following

conditions: Cross section ____________________________________

Flow_______________________ Weather_______________________

Other______________________ Air ___________ºF @ ___________

Gage______________________ Water_________ºF @ ___________

Observer ____

____

Control ____

____

Remarks/Observations:

(1) Distance from initial point	(2) Width (W)	(3) Depth (D)	Obstruction(s) (logs, rocks, other)	(4) Avg. Velocity At Point (V)	Method Depth (0.2, 0.6, or 0.8)	(5) Area (A)	(6) Discharge (Q)
TOTALS							

Completed By________ Checked by___________ Reviewed by____________

V1.1 01/2012

Discharge Flow Measurement Form
Continued

(1) Distance from initial point	(2) Width (W)	(3) Depth (D)	Obstruction(s) (logs, rocks, other)	(4) Avg. Velocity At Point (V)	Method Depth (0.2, 0.6, or 0.8)	(5) Area (A)	(6) Discharge (Q)
TOTALS							

1) Distance from initial point	(2) Width (W)	(3) Depth (D)	Obstruction(s) (logs, rocks, other)	(4) Avg. Velocity At Point (V)	Method Depth (0.2, 0.6 or 0.8)	(5) Area (A)	(6) Discharge (Q)
TOTALS							

Completed By________ Checked by___________ Reviewed by____________

Chain of Custody

CLIENT INFORMATION		BILLING INFORMATION		SPECIAL INSTRUCTIONS/PRECAUTIONS:
Company:		Bill To:		
Project Name/No.:		Company:		
Send Report To:		Address:		
Address:				Parameters for Analysis/Methods
		Phone No.:		
Phone/Fax No.:		Fax No.:		

Sample ID	Sample Description	Date	Time	Matrix S=Sed/Soil W=Water	Number of Containers	Composite or Grab										
Preservative	(Sulfuric acid =S, Nitric acid =N, NaOH =B, Ice =I)															

Sampler(s):	Shipment Method:	Turnaround Time Required:
COC Completed by:_______________ Date: ____________ Time: ________		COC Checked by:________________ Date:___________ Time:________
Relinquished by:_________________ Date:____________ Time:_______		Received by: ___________________ Date:___________ Time:________
Relinquished by:_________________ Date:____________ Time:_______		Received in lab by:_______________ Date:___________ Time:________
LABORATORY USE ONLY:	Samples Received On Ice?: YES or NO	Sample Temperature:________________

V1.2 10/16/15

Calibration Field Form

Dissolved Oxygen Meter Air Calibration Record						
Date/Time:	Calibrators Initials:	Meter:	100 % Air Saturation (mg/l)	Altitude (ft)	Barometric Pressure (mm Hg)	Comments:

pH Meter Calibration Record						
Date/Time:	Calibrators Initials:	Meter:	Standard (4, 7, 10):	Slope:	7.00 Buffer Check	Comments:

Conductivity Meter Calibration Record					
Date/Time:	Calibrators Initials :	Meter:	Standard:	Meter Cond:	Comments:

Turbidity Meter Calibration Record									
Date/Time:	Calibrators Initials :	Meter:	Gel Standard:			Meter Reading			Comments:
			0-10	0-100	0-1000	0-10	0-100	0-1000	

Temperature Meter Calibration Record					
Date/Time:	Calibrators Initials:	Meter:	Thermometer Temperature °C:	Meter Temperature °C:	Comments:

City of Norman
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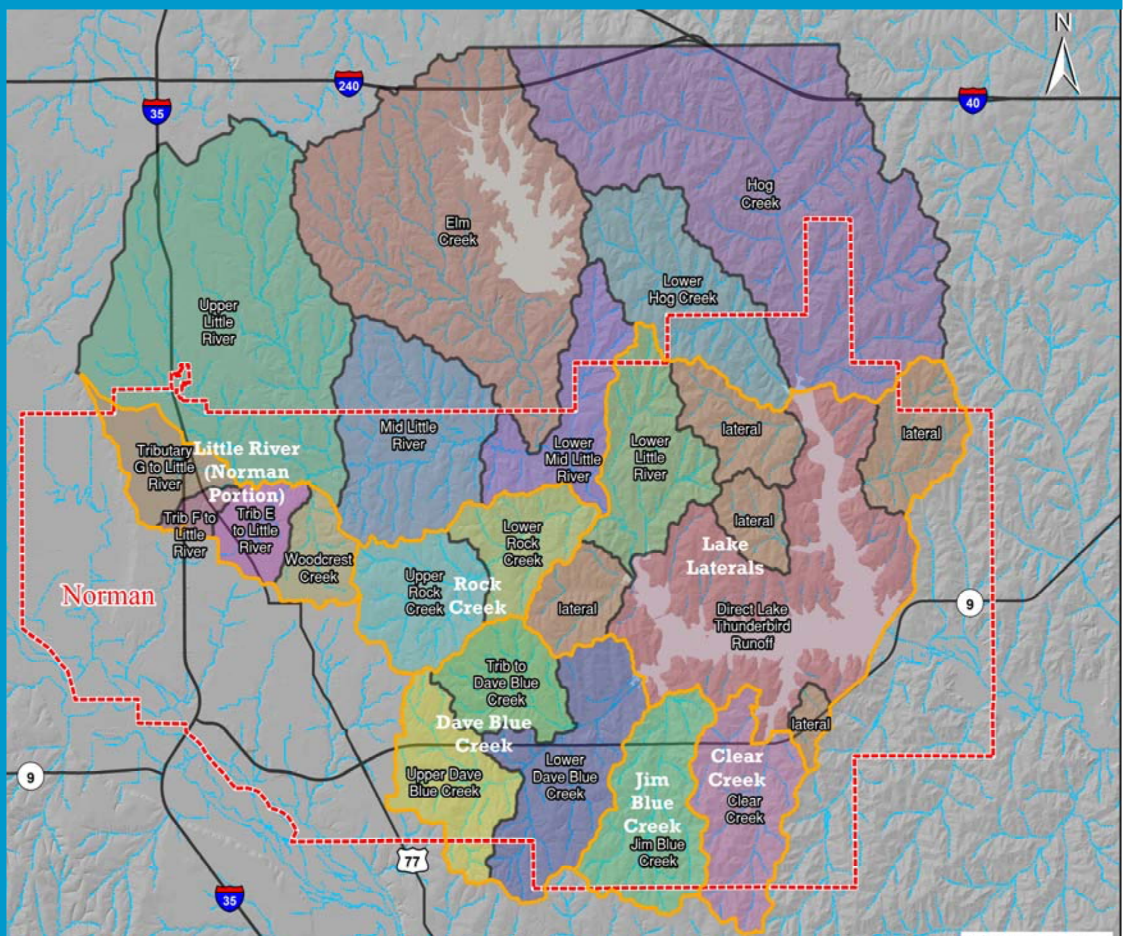
TMDL Compliance Plan
City of Norman, OK



October 27, 2015

GBM^c & Associates
Strategic Environmental Services

OLSSON ASSOCIATES

CONTENTS

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FIGURES

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TABLES (cont)

APPENDICES

Acronyms

BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
COMCD	Central Oklahoma Master Conservancy District
HSPF	Hydrologic Simulation Program Fortran
LID	Low Impact Development
MDL	Maximum Daily Load
MRLC	Multi-Resolution Land Characteristic Consortium
MSGP	Multi-Sector General Permits
NED	National Elevation Dataset
NLCD	National Land Cover Database
NPS	Non-Point Source
NRCS	National Resources Conservation Service
ODEQ	Oklahoma Department of Environmental Quality
ODOT	Oklahoma Department of Transportation
OWRB	Oklahoma Water Resources Board
OCC	Oklahoma Conservation Commission
SPC	Stream Planning Corridor
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic
SWAT	Soil and Water Assessment Tool
SWMP	Storm Water Management Program
SWPPP	Storm Water Prevention Pollution Plan
TMDL	Total Maximum Daily Load
USGS	U.S Geological Survey
USDA	United States Department of Agriculture
USA	Unified Stream Assessment
WTM	Watershed Treatment Model
WQPZ	Water Quality Protection Zone
WLA	Waste Load Allocation

1.0 Introduction

In November 2013 the City of Norman received notification from the Oklahoma Department of Environmental Quality (ODEQ) that a Total Maximum Daily Load (TMDL) completed for Lake Thunderbird had been approved by EPA (EPA approval date was 11-13-2013). The ODEQ letter required that Norman, as a Phase 2 MS4 Permittee, ñincorporate all Total Maximum Daily Load (TMDL) requirements applicable to the storm water discharges into the Cityôs Storm Water Management Program (SWMP)ò and that the SWMP be modified within 24 months from the date of EPA approval (of the TMDL). The SWMP is to be modified in accordance with ñAppendix Eò of the Lake Thunderbird TMDL, which is titled ñ*MS4 Stormwater Permitting Requirements and Presumptive Best Management Practices (BMP) Approach.*ò

Appendix E provides an approach for development of a TMDL Compliance Plan. The Compliance Plan shall include, at a minimum, the following:

1. An evaluation to identify potential significant sources of TSS, nutrients, and organic matter entering the MS4. Following the evaluation of the sources the permittee is to develop and implement a program to reduce those pollutants discharged from its MS4 system.
2. The permittee is to demonstrate understanding of the TMDL requirements and have a strategy to meet the required waste load allocation (WLA). Approaches listed in Appendix E, including BMPs, to be considered in meeting the WLA include the following:
    a. Retrofitting developed areas with structural BMPs.
    b. BMP implementation to prevent additional storm water pollutants in new or re-development areas.
    c. Implementation of non-structural BMPs for source control (fertilizer application restrictions, nutrient testing requirements, stream riparian buffer protections, City ordinances).
    d. Implementation of non-structural BMPs to treat existing loads (street sweeping).
    e. Development and implementation of water quality trading programs.
3. Enhancement of construction site storm water control, compliance inspections, adoption of ordinances.
4. A schedule for achieving the WLA.
5. Implementation and tracking of BMPs including both structural and non-structural using BMP summary sheets that provide sufficient information to document pollutant reduction, efficiency, maintenance, and the necessary calculation processes.
6. Educational programs directed at pollutant reductions.
7. Development of a pollutant monitoring and tracking program (included with this document).

The purpose of this Compliance Plan, prepared for the City of Norman, is to provide the information specified in Appendix E in order to achieve the required WLA in an efficient, science-based manner.

1.1 Approach

To achieve the WLA allocated to the City of Norman MS4 program, and meet the requirements of the TMDL, reductions of sediment, nitrogen and phosphorus are required. A watershed assessment was completed using a combination of GIS land use analysis, watershed modeling and unified stream assessments to help identify watershed issues, sources of pollution and to prioritize problem sub-watersheds. All this information was analyzed first from an overall watershed perspective (all of the Lake Thunderbird Watershed), then the focus was narrowed to examine just the Norman portion of the watershed.

The Hydrologic Simulation Program Fortran (HSPF) modeling completed as the foundation for the TMDL provides pollutant loading on an average annual basis. The TMDL report (Dynamic Solutions, 2013) provides long term average loading in the watershed and then establishes the WLA for each MS4 as a maximum daily load (MDL). The HSPF modeling determined that a 35% reduction in loading was necessary on an average annual basis to comply with the water quality standards. In order to determine the reductions that are required on an average annual basis it was necessary to calculate WLA on an average annual basis. The WLA and reduction requirements allotted to the City of Norman and the other MS4ös, on an average annual basis, are provided in Table 1. A reduction of 35,881 lbs of nitrogen, 6,765 lbs of phosphorus and 3,644,083 lbs of TSS (sediment) will be the reduction targets for the City of Norman TMDL Compliance Plan. In this compliance plan the terms TSS and Sediment are used interchangeably and they both refer to sediment carried with flow to the lake.

Table 1. WLA and Required Pollutant Reductions for the MS4's on an Average Annual Basis.

Pollutant	LTA Annual Load (lb)[1]	Moore WLA (lb/Year)	Norman WLA (lb/Year)	OKC WLA (lb/Year)	LTA 35% Reduction[2]	Moore Required Reduction (lb/Year)	Norman Required Reduction (lb/Year)	OKC Required Reduction (lb/Year)
TN	259,120	67,604	105,255	86,287	90,692	23,046	35,881	29,415
TP	50,900	14,715	19,866	16,319	17,815	5,011	6,765	5,557
TSS	25,336,800	5,493,018	10,689,596	9,151,652	8,867,880	1,872,570	3,644,083	3,119,798

[1]LTA loading is total from Table 5.1 of the report.
[2]LTA reduction includes the WLA and the LA (~2.6%) portion

This TMDL Compliance Plan is largely based on the HSPF modeling completed for the TMDL by Dynamic Solutions using data from 2008 to 2009. Load reductions required to meet Normanös WLA were determined by applying various BMPs to the base HSPF model outputs for different land uses in each of Normanös sub-watersheds. HSPF modeling was used to address mostly structural BMPs applied to urban\suburban and agricultural land. In addition to the HSPF modeling, the Watershed Treatment Model developed by the Center for Watershed

Protection (Caraco, 2013) was also used to determine potential reductions from non-structural BMPs.

2.0 Background

Lake Thunderbird, as completed in 1965, is a 6,070 acre reservoir constructed and owned by the U.S. Bureau of Reclamation. Volume of the lake was 119,967 acre-feet as constructed. The lake was created by impounding the Little River and Hog Creek for purposes of providing flood control, water supply, recreation, and fish / wildlife habitat. Lake Thunderbird is located east of Norman in Cleveland County and provides water supply for Norman, Midwest City, and Del City under authority of the Central Oklahoma Master Conservancy District (COMCD). The lake is heavily used for recreation.

2.1 Overview of Previous Studies

Various water quality and modeling studies have been completed for Lake Thunderbird and the Thunderbird Watershed during the past 15 years. The Oklahoma Water Resources Board (OWRB) has completed annual water quality studies of the reservoir beginning in 2000 and continuing through the present time. The reports prepared following these studies generally indicate that the lake has excessive nutrients, algae, and turbidity.

During 2001 the OWRB performed bathymetric mapping of the reservoir. This mapping determined that the surface area of the reservoir had been reduced to 5,439 acres and the volume reduced to 105,838 acre-feet. The OWRB reported that the reservoir sedimentation rate was estimated at 393 acre-feet per year, compared with the Bureau of Reclamation 100-year estimate of 350 acre-feet per year. The observed rate was only 12% higher than the original estimated rate (OWRB, 2002).

The most recent available OWRB report for Lake Thunderbird reflects data collected during 2013. The OWRB report contained information regarding Chlorophyll- Ŭ (Chl- Ŭ) levels in the lake. Chl- Ŭ concentration is used to estimate algal biomass in lakes and other aquatic systems, and the OWRB report suggests that algae may have declined during 2012 and 2013. In the closing remarks section of the report the OWRB states that ñthe 2012 calendar year represented the first year since 2007 that peak Chl- Ŭ had been reduced, and 2013 represented another large reduction in peak Chl- Ŭ from 2012. Significant nutrient reduction from the surrounding watershed, particularly in the Little River area is critical to bring Chl- Ŭ within Oklahoma Water Quality Standards of 10 εg/L.ò (OWRB, 2014). Improvements in the lake are more likely the result of operation of a supersaturated dissolved oxygen system which is designed to oxygenate the lakes hypolimnion that is normally without oxygen during certain periods. This oxygenation serves to preclude the release of sediment phosphorus, which the OWRB noted had been reduced following operation of the supersaturated dissolved oxygen system.

Modeling of the watershed was completed by Vieux (2007) using the Soil and Water Assessment Tool (SWAT) model and by ODEQ/Dynamic Solutions, LLC in 2013 using an HSPF model in preparation of the Lake Thunderbird TMDL. Vieux reported that the results of his modeling indicated that the largest phosphorus loads were coming from urbanized areas of Oklahoma City and Moore. The greatest sediment loads were coming from Moore, followed by Norman and then Oklahoma City. Vieuxøs modeling further estimated that the average phosphorus loads being delivered from the watershed to the lake were between 18,000 kg/yr and 23,000 kg/yr (approximately 39,600 lb/yr to 50,700 lb/yr).

The HSPF modeling completed by ODEQ / Dynamic Solutions for the TMDL estimated that the total annual phosphorus load delivered by the watershed in 2008-2009 was 23,087 kg/yr (50,878 lb/yr). Calculated loading rates for sediment, CBOD, TOC, Total Nitrogen, and Total Phosphorus were all highest in the Upper Little River sub-watershed that corresponds to the City of Moore. The TMDL yielded similar results to Vieuxøs study.

In 2008, the Oklahoma Conservation Commission (OCC) prepared a Watershed Based Plan for the Lake Thunderbird Watershed. The OCC Plan establishes a framework for watershed management for the Lake. Additionally, the OCC contracted with the University of Oklahoma for a demonstration / education project utilizing low impact development building techniques that was completed on a neighborhood scale in 2014.

2.2 Water Quality Standards

Lake Thunderbird receives protective Water Quality Standards in accordance with OAC785:45, which contains both designated beneficial uses and criteria necessary to support those uses. Uses designated for the lake include Fish and Wildlife Propagation, Public and Private Water Supply, and Primary Body Contact Recreation. In 2010 the lake was added to EPA 303(d) list and was designated as a sensitive water supply.

The 2014 303(d) list for Oklahoma shows that Lake Thunderbird is not maintaining the designated uses of Fish and Wildlife Propagation ï Warm Water Aquatic Use for both Dissolved Oxygen and Turbidity, and Public and Private Water Supply for Chlorophyll-Ŭ.

The objective of the Lake Thunderbird TMDL is to reduce loads of nutrients (phosphorus and nitrogen) and sediment such that the waterbody attains all applicable Water Quality Standards designated uses and criteria.

3.0 Watershed Description

The Lake Thunderbird Watershed is 256 square miles (163,840 acres) in Cleveland and Oklahoma Counties. The watershed contains portions of the cities of Norman, Moore, and Oklahoma City (see Figure 1). Land use reported in the TMDL consists primarily of grassland/herbaceous at 38% and deciduous forest at 35%. Developed urban land use makes up 16% of the watershed. This data was from the 2006 National Land Cover Database (NLCD). More recent Land Use and Land Cover Data was obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database (NLCD, 2011). Small changes were present when land cover was examined using more recent NLCD information. The top three land cover percentages were grassland/herbaceous at 37%, deciduous forest at 34% and developed at 18%, showing that both grassland and forest decreased slightly, and developed area increased 2% during the period covered by the 2006 and 2011 NLCD updates. Land cover/use characteristics of the overall watershed from the 2011 NLCD are shown in Table 2.

Table 2. Summary of Lake Thunderbird Watershed Land Use Characteristics.

Land Use	Percentage	Square Miles	Acres
Grassland/Herbaceous	37%	94	60,182
Deciduous Forest	34%	88	56,084
Developed, Open Space	8.9%	23	14,513
Developed, Low Intensity	5.2%	13	8,584
Open Water	4.8%	12	7,812
Developed, Medium Intensity	3.4%	8.6	5,493
Pasture/Hay	3.3%	8.3	5,333
Cultivated Crops	2.0%	5.2	3,325
Developed, High Intensity	0.7%	1.9	1,225
Barren Land (Rock/Sand/Clay)	0.47%	1.2	763
Evergreen Forest	0.20%	0.51	324
Woody Wetlands	0.05%	0.14	89
Emergent Herbaceous Wetlands	0.04%	0.11	72
Shrub/Scrub	0.02%	0.06	40
Totals	100%	256	163,840

Figure 1 shows the land uses for the overall Lake Thunderbird Watershed, surrounding lands, and the Norman MS4 boundary in 2011.

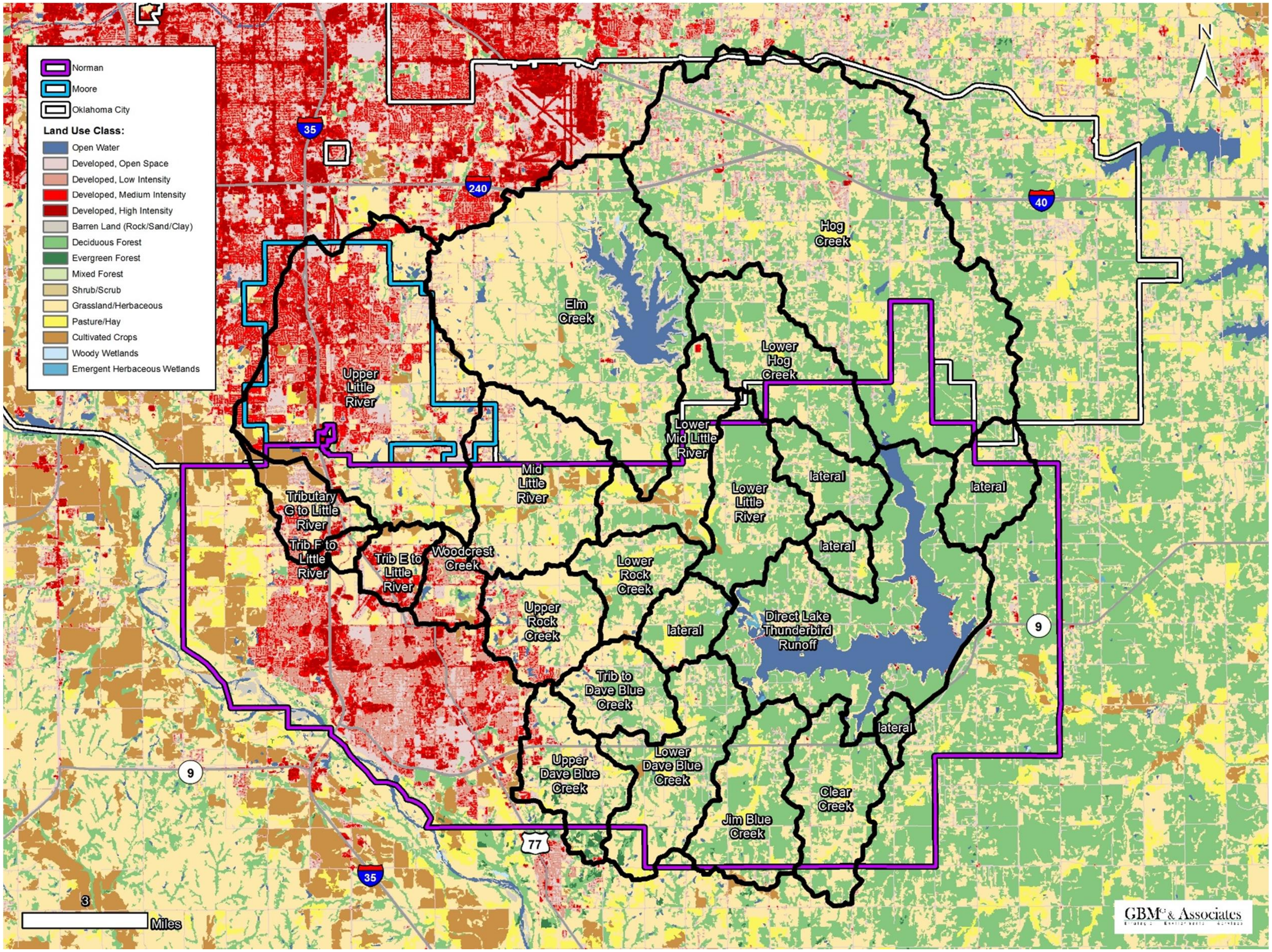

Figure 1. Land Uses for the Overall Lake Thunderbird Watershed, Surrounding Lands, and the Norman MS4 Boundary

3.1 Land Slope

A land slope analysis was also completed for the Lake Thunderbird Watershed, and the results summary is provided in Table 3. Land slope is generally mild; overall 86% of the watershed contains slopes less than 5 degrees. The largest slope category for the watershed is the 3 ï 5 degree range which correlates to a 5.2% to 8.8% slope. Slope was derived from U.S. Geological Survey (USGS) National Elevation Dataset (NED) n36w098 1/3 arc-second 2013 using ESRI ArcGIS Spatial Analyst ï Slope Tool.

Figure 2 provides the general distribution of land surface slope in the Lake Thunderbird Watershed.

Table 3. Summary of Land Slope Analysis.

Slope Range (Degrees)	Percent of Total Watershed
0 - 1	21
1 - 2	19
2 - 3	18
3 - 5	27
5 - 7	11
7 - 9	2.7
9 - 12	0.78
12 - 17	0.14
17 -52.8	0.02

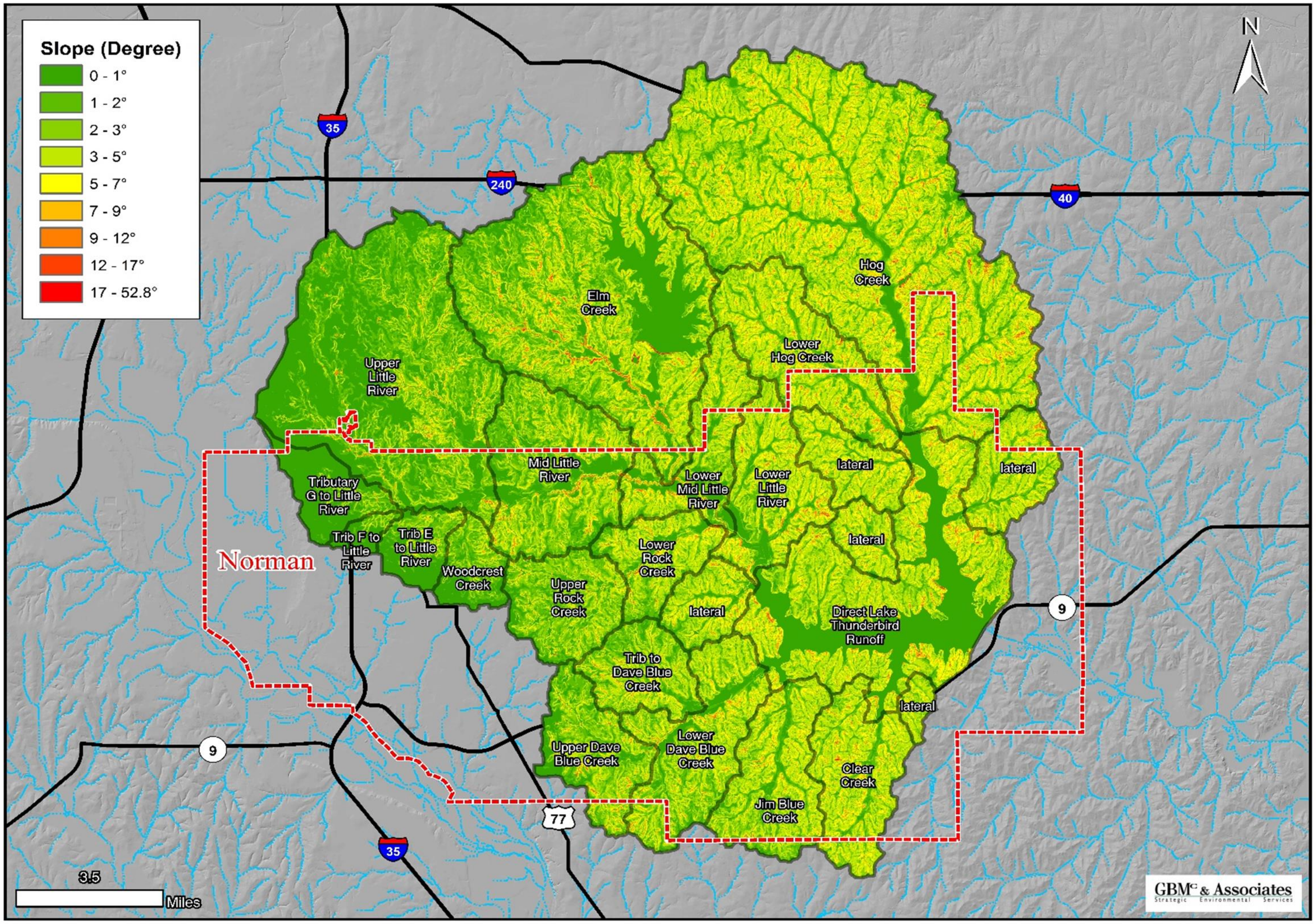

Figure 2. Land Surface Slope in the Lake Thunderbird Watershed.

3.2 Soils

Soils data was obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database for Oklahoma County, Oklahoma (September, 2014) and Soil Survey Geographic (SSURGO) database for Cleveland County, Oklahoma (December, 2013).

Soils on the land surface in the watershed are primarily dominated by the Stephenville-Darsil-Newalla complex, which accounts for 20.1%. Harrah fine sandy loam makes up about 9.3%. The top ten most common soils in the Lake Thunderbird Watershed together comprise approximately 60% of the overall watershed and are shown in Table 4. The distribution of various soil types is shown in Figure 3.

Table 4. Summary of Soils Analysis.

Soil MUNAME	Percent Contribution %
Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes.	20.1
Harrah fine sandy loam, 5 to 8 percent slopes.	9.3
Stephenville-Darsil complex, 1 to 5 percent slopes.	5.4
Renfrow-Huska complex, 3 to 5 percent slopes, eroded.	4.1
Harrah fine sandy loam, 5 to 8 percent slopes, eroded.	3.6
Kingfisher-Ironmound complex, 1 to 5 percent slopes.	3.2
Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes, eroded.	3.1
Grainola-Ashport complex, 0 to 8 percent slopes.	2.8
Grainola-Ironmound complex, 5 to 12 percent slopes.	2.4
Tribbey fine sandy loam, 0 to 1 percent slopes, frequently flooded.	2.3

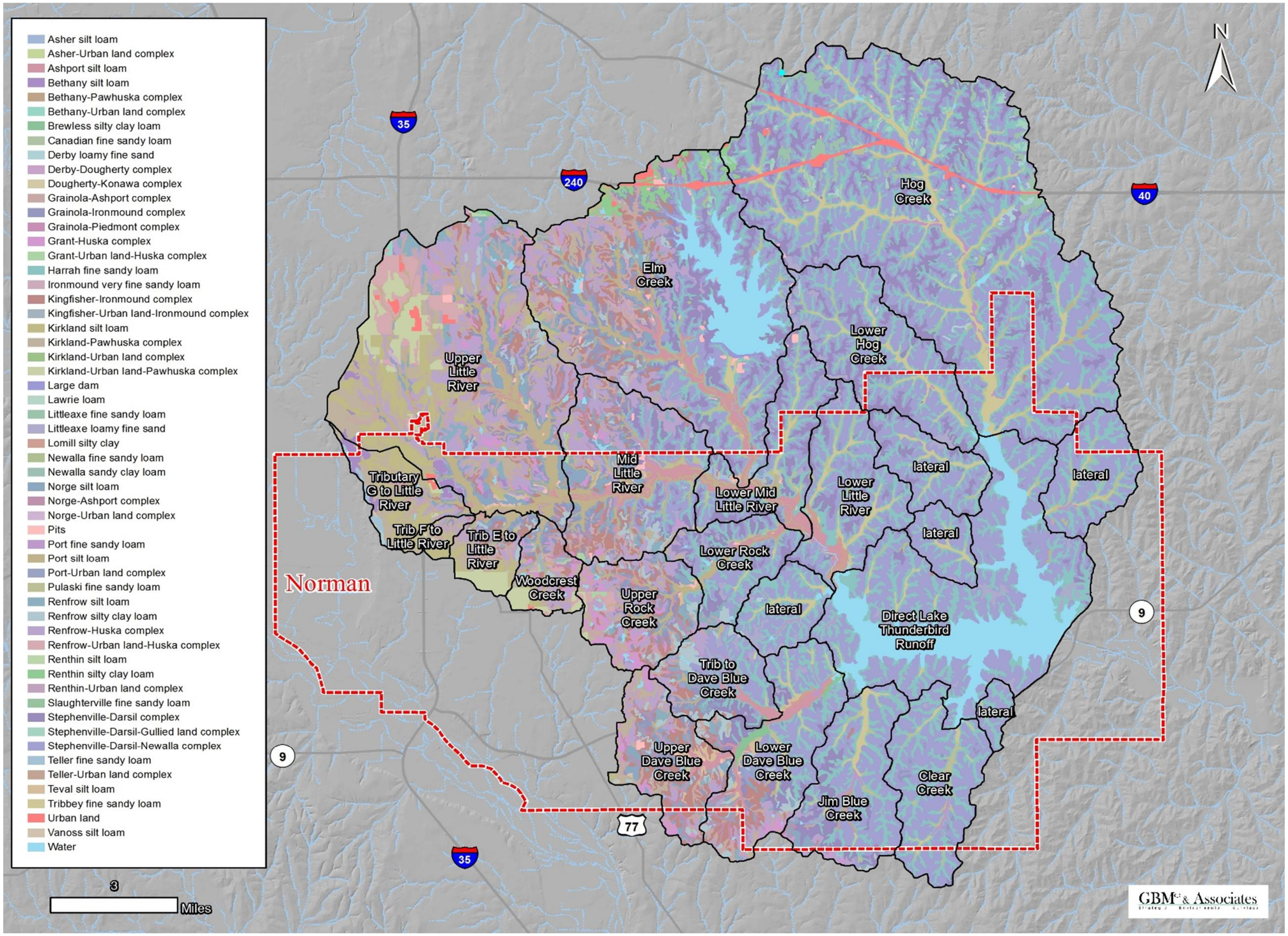

Figure 3. Soil Types in the Lake Thunderbird Watershed.

4.0 Watershed Assessment

An assessment of the Lake Thunderbird Watershed was completed to supplement the information from the TMDL report and the HSPF modeling. The focus of the assessment was to better pin-point which sub-watersheds have potentially been contributing the most sediment and nutrients to Lake Thunderbird and the most probable major sources of those non-point source (NPS) pollutants within each sub-watershed. The assessment utilized GIS resources and field based unified stream assessment (USA) methodologies. The following sections provide a brief description of our assessment methods and summary of our findings. The last sections of this assessment present our specific findings for the City of Norman MS4 portion of the Lake Thunderbird Watershed.

It is important to note that suggested improvements for this compliance document are designated in watersheds that are located entirely within the limits of City of Norman jurisdictional control. The City of Norman will have the option to place BMPs in watersheds that are partially located in the City of Norman Jurisdictional control.

4.1 GIS Non-point Source Assessment

A desktop assessment of the Lake Thunderbird Watershed was completed using GIS resources including soils maps, land use, aerial photographs, etc. The assessment was focused on identifying possible non-point sources of pollutants that could be transported to the stream system during storm runoff events. The entire assessment described in Section 4 was completed on a sub-watershed basis, using the 12-digit HUC watershed delineations (Figure 4). Since the watershed assessment reached beyond the limits of the City of Norman it was necessary to use HUC naming designations for this section (Section 4) of this document. The naming convention in all other sections of this document will follow the City of Norman adopted naming convention for watersheds.

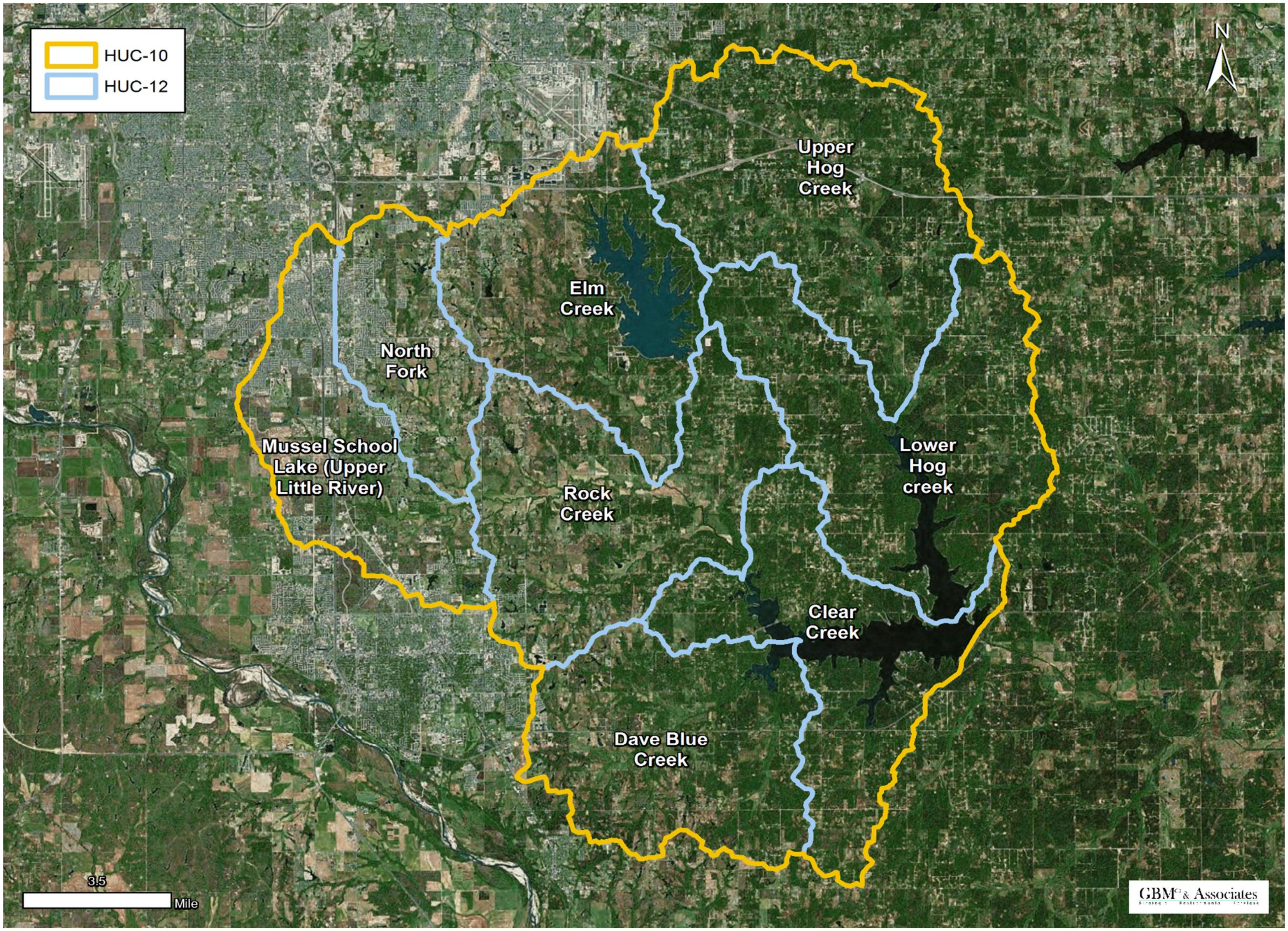

Figure 4. HUC-12 Sub-Watersheds Used for Assessment.

4.1.1 Land Use by Sub-watershed

Land use was evaluated using 2006 land-use land cover data (same data used in the 2013 TMDL Report) from the United States Geological Survey (Table 5). Land use is an important attribute in a watershed analysis. The percent of pasture, row crops, and developed (urban) areas were used in this assessment and can provide great insight into a watershed's potential for NPS pollution. The three sub-watersheds that had the most potential impact from agriculture (pasture + row crops) land uses were upper Little River, Rock Creek and North Fork Little River. The three sub-watersheds with the highest potential impacts from urban land uses were the upper Little River, North Fork Little River and upper Hog Creek.

Table 5. Land Use/Cover Shown as Percentages.

Land Cover Type	Dave Blue Creek	North Fork Little River	Little[1] River (upper)	Clear Creek	Rock Creek	Upper Hog Creek	Lower Hog Creek	Elm Creek
Open Water	1.81	1.04	1.27	14.03	0.94	0.45	6.26	1.16
Developed, Open Space	7.89	15.42	11.55	6.61	7.43	16.34	6.87	6.58
Developed, Low Intensity	2.01	19.21	22.64	0.68	3.94	3.32	0.34	2.02
Developed, Medium Intensity	0.87	13.85	19.83	0.24	1.28	0.81	0.09	0.74
Developed, High Intensity	0.10	1.40	4.72	0.07	0.07	0.08	0.04	0.31
Total Developed (Urban)	**10.87**	**49.88**	**58.74**	**7.60**	**12.72**	**20.54**	**7.35**	**9.64**
Deciduous Forest	37.02	3.97	3.66	48.19	28.25	40.10	59.47	21.00
Evergreen Forest	1.42	0.00	0.03	0.02	0.00	0.04	0.00	0.02
Shrub/Scrub	0.10	0.00	0.00	0.05	0.00	0.00	0.03	0.00
Rangeland/ Herbaceuous	43.34	38.40	24.26	28.12	48.57	34.69	25.53	63.92
Hay/Pasture	4.62	2.52	3.24	1.59	5.75	4.14	1.34	2.34
Cultivated Crops	0.74	3.98	8.59	0.03	3.73	0.00	0.00	1.82

[1]Little River (upper) is same as Mussel School Lake depicted in Figure 4.

In addition to the traditional land use categories, a special category labeled "developing area" was created and delineated using high resolution aerial photography. This category reflects the area of land surface that had been recently cleared and is undergoing some sort of development (construction activity). It is possible for construction sites to transport large loads of sediment and nutrients even with implementation of some BMPs. This assessment was completed using aerial photography from 2014 (to match current field observations) and for 2008, to match the time frame in which the HSPF model was run for the TMDL. In 2008, during the timeframe the HSPF model was run, the majority of development was occurring in the North Fork Little River, the upper Little River and the Rock Creek sub-watersheds. In 2014, the percent development was lower but still mostly in the same three sub-watersheds. Developing area data determined from aerial photography is provided in Table 6.

Based on field observations in the watershed made during fall 2014 and spring 2015, it was apparent that there was a significant amount of land currently undergoing development of some type. In many cases the areas were large and the soil and erosion control features appeared to be only minimally effective.

Table 6. Developing Area Data Determined from Aerial Photography.

Watershed Name	Total Watershed Area (ac)	Total Developing Area 2008 (ac)	2008 % Watershed Developing	Total Developing Area 2014 (ac)	2014 % Watershed Developing
Clear Creek	20080.2	49.8	0.25	36.3	0.18
Dave Blue Creek	20644.8	147.6	0.72	125.7	0.61
Elm Creek	13339.7	0.0	0.00	17.4	0.13
Lower Hog Creek	26102.7	40.6	0.16	71.0	0.27
Little River (upper)[1]	15830.2	902.6	5.70	691.6	4.37
North Fork Little River	10648.7	701.8	6.59	324.7	3.05
Rock Creek	23221.7	668.6	2.88	237.3	1.02
Upper Hog Creek	27054.7	540.8	2.00	204.9	0.76

[1]Little River (upper) is referred to as Mussel School Lake on Figure 4.

4.2 Unified Stream Assessment

A variation of the USA protocol (Kitchel and Schueler, 2004) was completed on Lake Thunderbird Watershed in each sub-watershed in 2014, with additional information collected from the Norman portion of the watershed in 2015. This visual-based field assessment protocol consists of dividing a stream section into manageable reaches and evaluating, on foot, each reach in its entirety. The evaluation is a screening level tool intended to provide a quick characterization of stream corridor attributes that can be used in determining the most significant problems in each stream reach from a physical, ecological, chemical and hydrologic perspective. General categories of stream corridor characteristics assessed are:

1. Hydrology
2. Channel morphology
3. Substrate
4. Aquatic habitats
5. Land use
6. Riparian buffer
7. Water/sediment observations
8. Stream impacts (non-point source related including bank erosion)
9. Floodplain dynamics
10. Geomorphic attributes
11. Restoration/retrofit opportunities

Figure 5 shows stream reaches where USA data was collected.

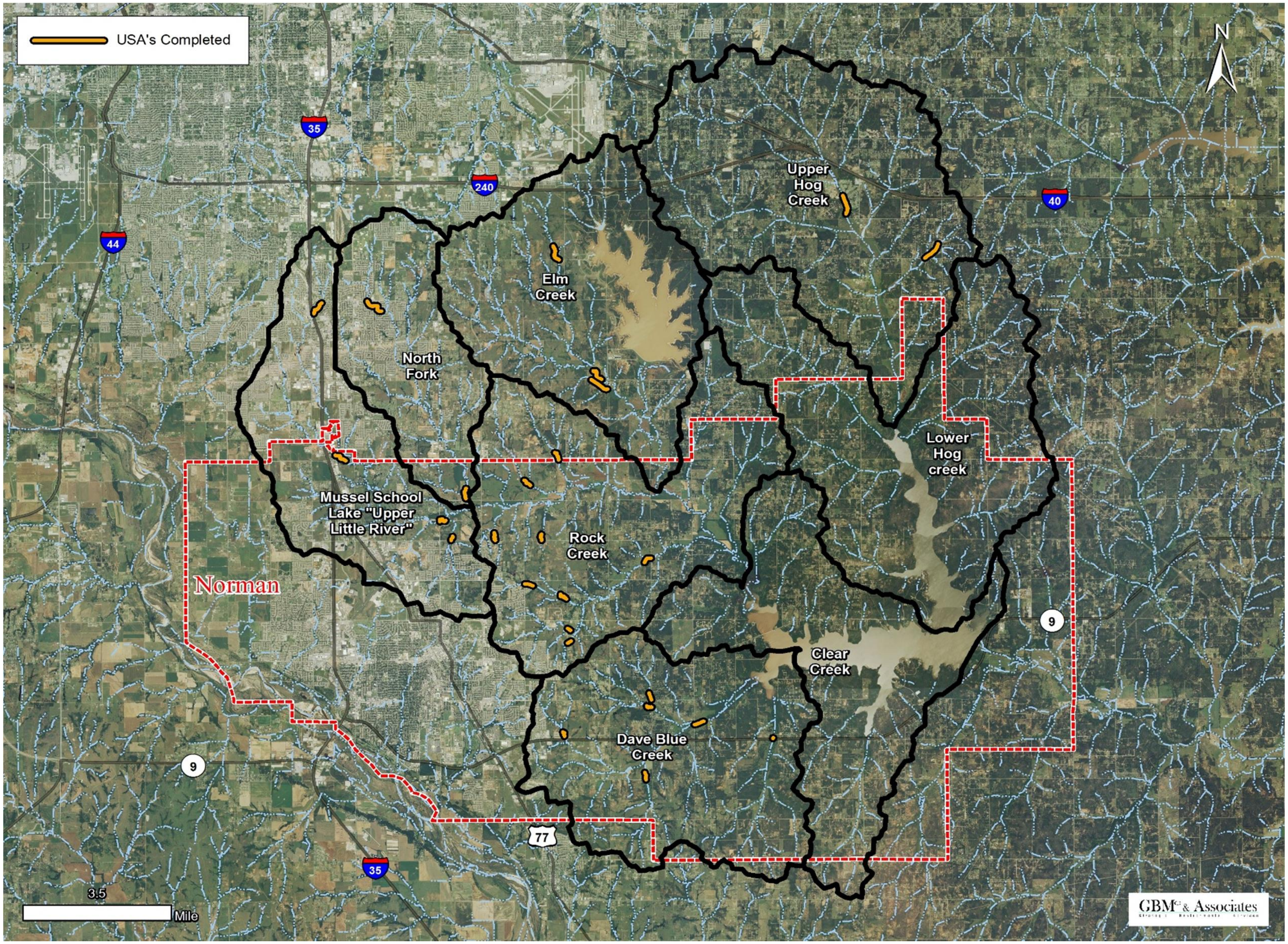

Figure 5. Stream Reaches where USA Data was Collected.

4.2.1 Geomorphology and Channel Stability

Fluvial geomorphology refers to the interrelationship between the land surface (topography, geology and land-use) and stream channel shape (morphology). When the force of running water is exerted on the land surface it can have significant effects on the morphology of stream channels. A stable stream, or one said to be in "equilibrium", is one where water flows do not significantly alter the channel morphology over short periods of time. The most important flow level in defining the shape of a stream is its bankfull flow (or effective discharge) (Rosgen, 1996). Bankfull discharge is the stage at which water first begins to enter the active flood plain. A detailed geomorphic assessment of the entire Lake Thunderbird Watershed was beyond the scope of this project. However, several geomorphic attributes were estimated during the USA's completed during the fall 2014 and spring 2015, and are helpful in assessing channel stability (Rosgen, 1996 and 2006). Table 7 provides a summary of the channel dimensions measured during the USA's as well as key stability issues noted.

Table 7. Summary of Geomorphic Characteristics.

Parameter (approximate/ estimated)	Station Identification						
	Dave Blue Creek	Hog Creek	Little River (upper)	North Fork Little River	Rock Creek	West Elm Creek	Little River (middle)
Bankfull depth (ft)[1]	1.3	3.1	2.2	4.0	1.4	4.0	2.2
Bankfull width (ft)[1]	17	9.3	23	19	12.5	24	20
Top of bank width (ft)[1]	26.5	14	33	28.5	30	36	35
Substrate size class	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay
Width:Depth ratio	13.1	3.0	10.5	4.8	8.9	6.0	9.1
Entrenchment Ratio	1.6	2.2	1.5	1.5	2.3	1.4	1.8
Overall stream bank erosion hazard	Extreme	High	Very High	Very High+	Extreme	Very High	Extreme
Channel stability issues	Deepening and widening	Channelization	Deepening	Deepening and Bank erosion	Bank erosion	Deepening and Bank erosion	Bank erosion

[1]Dimesions based on approximate measurements made using range finder or tape measure and survey rod.

Channel instability can affect stream dimension in two primary ways, through agradation or degradation (Rosgen, 1996 and 2006). These are frequently manifested as channel widening (bank erosion) and channel entrenchment (deepening) by way of bed erosion (Figure 6). Both of these instability characteristics were observed in the Lake Thunderbird Watershed. Tables 8 and 9 provide an estimate of the potential sediment and nutrient loading (on an annual basis) from each sub-watershed or stream corridor that may be caused by these types of channel instability issues.

Each instance of bank erosion perceived as moderate risk or greater was tagged with a GPS coordinate and the length of the affected bank measured or estimated. The severity of bank erosion was then characterized using a bank erosion hazard index (BEHI) developed by Dave Rosgen (Rosgen, 2006). The BEHI uses several characteristics of the eroded bank (height, vegetated protection, bank angle, soil composition, etc) to calculate an overall score that relates to level of erosion hazard. The possible levels are low, moderate, high, very high, and extremely high.

An estimate of the potential sediment loading from bank erosion was calculated for each sub-watershed based on the BEHI data collected during the USA. The proportion of each USA reach that was experiencing active bank erosion at a moderate or greater level was determined. This proportion was extrapolated to the entire main stream channel in that sub-watershed to arrive at a total length of stream bank affected. Affected stream length was multiplied by average eroding bank height and by a conservative annual bank loss rate of 0.25 feet for each sub-watershed. Volume was then converted to pounds of soil adjusted for gravel content. The nutrient content of the soil was taken from analysis of five stream bank soil samples collected from various drainages in the Lake Thunderbird Watershed (soil data provided in Appendix A) to arrive at loading for nutrients. Stream bed erosion was estimated using a similar procedure substituting bankfull width for bank height.

Stream bank erosion is very prominent in the Lake Thunderbird Watershed (Figure 7). Bank erosion and/or bed erosion are believed to be major sources of sediment and nutrients in each of the sub-watersheds. Several of the sub-watersheds in the Lake Thunderbird Watershed had greater than 20% of their major stream length experiencing active erosion at a moderate level or greater. Active bank erosion can add thousands of tons of sediment and associated nutrients to the stream system during high flow events. These sediment and nutrient loads will ultimately be deposited into Lake Thunderbird.

Figure 6. Entrenched Channel in Little River Watershed.

Table 8. Stream Bank Erosion.

Stream[1]	Sediment/soil (lbs/year)	Nitrogen (lbs/year)	Phosphorus (lbs/year)[2]
Clear Creek	939,204	287	151
Dave Blue Creek	1,640,903	502	265
Little River (middle)[2]	11,672,233	3,572	1,882
Elm Creek	846,819	259	137
Hog Creek	494,353	151	80
Jim Blue Creek	895,716	274	144
Little River (upper)	5,469,170	1,674	882
North Fork Little River	6,664,378	2,039	1,074
Rock Creek	5,134,032	1,571	828
West Branch Hog Creek	273,363	84	44
West Elm Creek	4,774,241	1,461	770

[1] Erosion estimates are presented on a stream by stream basis. Main stem streams were evaluated.
[2] Little River (middle) is in the Rock Creek sub-watershed.
[3] See Figure 5 for location of watersheds.

Table 9. Stream Bed Erosion (Resulting from Channel Entrenchment).

Stream[1]	Sediment/soil (lbs/year)	Nitrogen (lbs/year)[3]	Phosphorus (lbs/year)[3]
Clear Creek	5,632,275	1,723	908
Dave Blue Creek	9,837,125	3,010	1,586
Little River (middle)[2]	0[3]	0	0
Elm Creek	0	0	0
Hog Creek	3,409,621	1,043	550
Jim Blue Creek	5,369,769	1,643	866
Little River (upper)	25,932,290	7,935	4,180
North Fork Little River	20,189,332	6,178	3,255
Rock Creek	0	0	0
West Branch Hog Creek	1,885,425	577	304
West Elm Creek	35,631,499	10,903	5,744

[1] Erosion estimates are presented on a stream by stream basis. Main stem streams were evaluated.
[2] Little River (middle) is in the Rock Creek sub-watershed.
[3] Streams with a ñ0ò were not substantially entrenched.
[4] See Figure 5 for location of watersheds.

Figure 7. Stream Bank Erosion in the North Fork Little River Drainage (left) and Rock Creek Drainage (right).

In addition to bank and bed erosion, some gully erosion that has the potential for a large amount of sediment transport was observed throughout the watershed (Figure 8). The total amount of sediment loss from a single gully erosion area identified entering Rock Creek was calculated to be approximately 330,000 pounds.

Figure 8. Gully Erosion from Storm Water Conduit off Pasture into Creek.

4.2.2 Riparian Buffer Impacts

Urbanizing areas frequently encroach on stream corridors by stripping riparian vegetation to the edge of the stream bank to make room for buildings and manicured lawns. In addition, row crops and pasture land use can be associated with impact to riparian buffers as nearby stream forest is cleared to create larger fields and pastures, and as cattle grazing encroaches on the stream banks. Impacted riparian buffer from cattle overgrazing or frequent stream access was assessed during the USAõs and not found to be a large scale problem in the watershed. However, impacted riparian buffers from urbanization, pasture and row crop creation (and loss of buffer from bank erosion) were commonly observed problems. Therefore, each main stem named stream (identified per National Hydrographic Database) in the associated sub-watershed was examined through aerial photography to determine how many linear feet of stream were affected by loss of riparian buffer. These lengths were then divided by the total length of named stream in that sub-watershed to represent the percent of stream with impacted riparian buffers (Table 10).

Table 10. Riparian Buffer Impacts.

Stream[1]	Total Length (ft)	Impacted Length (ft)	Percent Impacted (%)
Clear Creek	23082.95	2789.41	12.1
Dave Blue Creek	40328.73	3925.58	9.7
East Elm Creek	13386.34	2303.74	17.2
Elm Creek	8342.22	1198.35	14.4
Hog Creek	63588.46	38279.79	60.2
Jim Blue Creek	22014.15	3421.74	15.5
Little River (upper)	125693.99	24171.01	19.2
North Fork Little River	52656.83	19125.29	36.3
Rock Creek	42144.37	1756.92	4.2
West Branch Hog Creek	35162.64	17179.00	48.9
West Elm Creek	47032.21	5809.51	12.4
Willow Branch	17669.20	3728.88	21.1

[1]Riparian buffer estimates are taken from main stem streams in each sub-watershed.

4.2.3 Unpaved Roads

Unpaved roads (gravel or dirt) are common in the Lake Thunderbird Watershed. During storm events these roads can transport significant loads of sediment into adjacent streams. The magnitude of the sediment load varies depending on many factors including: proximity to streams, condition of the road, slope, and the design of the road. Unpaved roads can be designed to include BMPs that reduce erosion and transport of sediment. General observation (and analysis provided for the Norman portion of the watershed in Section 4.5.3) suggests that unpaved roads could be a significant contributor to the sediment load entering Lake Thunderbird.

4.2.4 Other Findings

Other potential sources of sediment and nutrients identified most frequently during the USA were storm water outfalls and stream crossings. Storm water outfalls mostly included culverts entering streams from road side ditches or obvious drainage pathways exiting pastures directly into the creek. Both types of outfalls allow for direct transport of sediment and nutrients into the stream system. Stream crossings were typically ATV or farm trails that can serve as conduits for storm water much like a storm water outfall. Stream crossings also can be sites of active channel erosion due to the crossing of motorized vehicles that impact the stream banks and channel substrates.

4.3 Priority Sub-Watershed Ranking

A priority matrix was developed to aid in determining which sub-watersheds were contributing the most sediment and nutrients to Lake Thunderbird and most in need of being addressed. Each of the major impact assessment categories were considered, including: HSPF sediment loading, HSPF nutrient loading, percent agriculture (pasture+row crops), amount of impacted riparian buffers, amount of bank erosion, amount of stream bed erosion, and percent developing area. HSPF model results from the TMDL report (Dynamic Solutions, 2013) were utilized in the matrix. Model predicted sediment and nutrient loading were evaluated on a sub-watershed basis to arrive at the sub-watershed ranking that appears in the matrix.

Scores were assigned to sub-watersheds based on a ranking of the top five sub-watersheds (Table 11) with the greatest apparent impacts (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.). For our matrix ranking the greatest apparent impact received 5 points, second 4 points, third 3 points, etc. These were then tallied for all 8 assessment parameters. The higher the total score the higher the priority for implementation of BMPs. Table 12 provides a summary of the score totals for each sub-watershed.

Table 11. Matrix Ranking and Scoring of Assessment Parameters.

Sub-watershed	HSPF Sediment Loading	HSPF Nutrient Loading	% Agriculture	% Developing land area	% Urban	Bank erosion	Bed Erosion	Impacted riparian	Total Score
N. Fork Little River	5	4	3	5	4	4	3	3	31
Little River (upper)[1]	4	5	5	4	5	3	4	2	32
Elm Creek	3	2	1			2	5	1	14
Rock Creek	2	3	4	3	2	5			19
Little River (middle)[2]	1	1	*	*	*	*	*	*	2
Upper Hog Creek	*	*	*	2	3	*	*	5	10
Dave Blue Creek	*	*	2	1	1	1	2	*	7
Clear Creek	*	*	*	*	*	*	1	*	1
Lower Hog Creek	*	*	*	*	*	*	*	4	4

*Not in top 5.

[1] Little River (upper) is also known as Mussel School Lake.

[2] Little River middle is part of the Rock Creek 12-digit HUC in Figure 4. It is separated out in this matrix to reflect contributions upstream of Norman.

Table 12. Total Scores and Matrix Ranking.

Severity Rank	Sub-watershed	Score
1	Little River (upper)	32
2	N. Fork Little River	31
3	Rock Creek	19
4	Elm Creek	14
5	Upper Hog Creek	10
6	Dave Blue Creek	7
7	Lower Hog Creek	4
8	Little River (middle)	2
9	Clear Creek	1

According to the matrix ranking, the five key sub-watersheds of the overall Lake Thunderbird Watershed in most need of source reductions are Upper Little River, North Fork Little River, Rock Creek, Elm Creek and Upper Hog Creek. Of these five, only Rock Creek is under the control of Normanös MS4 program. Section 4.5.4 of this plan will revisit this scoring matrix, focusing on only the sub-watersheds under the influence of the City of Normanös MS4 program.

4.4 Historical Streamflow Analysis at USGS Gauges

The USGS has no permanent gauging stations above Lake Thunderbird. Two temporary stations were installed in or around 2012 by the USGS but neither were operated for more than 6 months, and the data is all considered ñpreliminaryò to this day. Therefore, no long term or short term reliable data exists concerning annual stream flow characteristics or peak flow dynamics in the Lake Thunderbird Watershed.

4.5 Narrowing the Assessment to the Norman MS4

The focus of this more detailed assessment is narrowed down to the Norman portion of the watershed and allows for a more efficient and accurate identification of potential non-point sources and provides information that may allow sub-watersheds to be prioritized for BMP implementation. This narrower focus was accomplished by utilizing the watershed delineations found in the Cityös Storm Water Master Plan and grouping them into 6 larger sub-watersheds to create watershed sizes that were logical and manageable (Figure 9). The sub-watersheds depicted in Figure 9 are those that Norman has management authority over. Portions of sub-watersheds along the northern boundary of the MS4 are within Normans planning area, but will display water quality influenced greatly by impacts in their upper watershed outside of Normanös control. These areas would be difficult to properly monitor for WLA compliance and are not considered in the analysis.

4.5.1 Land Uses

Land use was evaluated for this more focused analysis using the more recent 2011 MRLC NLCD data (Table 13). The three sub-watersheds that had the most potential impact from rural (pasture + row crops) land uses were Little River (Norman portion), Jim Blue Creek and Rock Creek. The three sub-watersheds with the highest potential impacts from urban (developed) land uses were the Little River (Norman portion), Rock Creek and Dave Blue Creek.

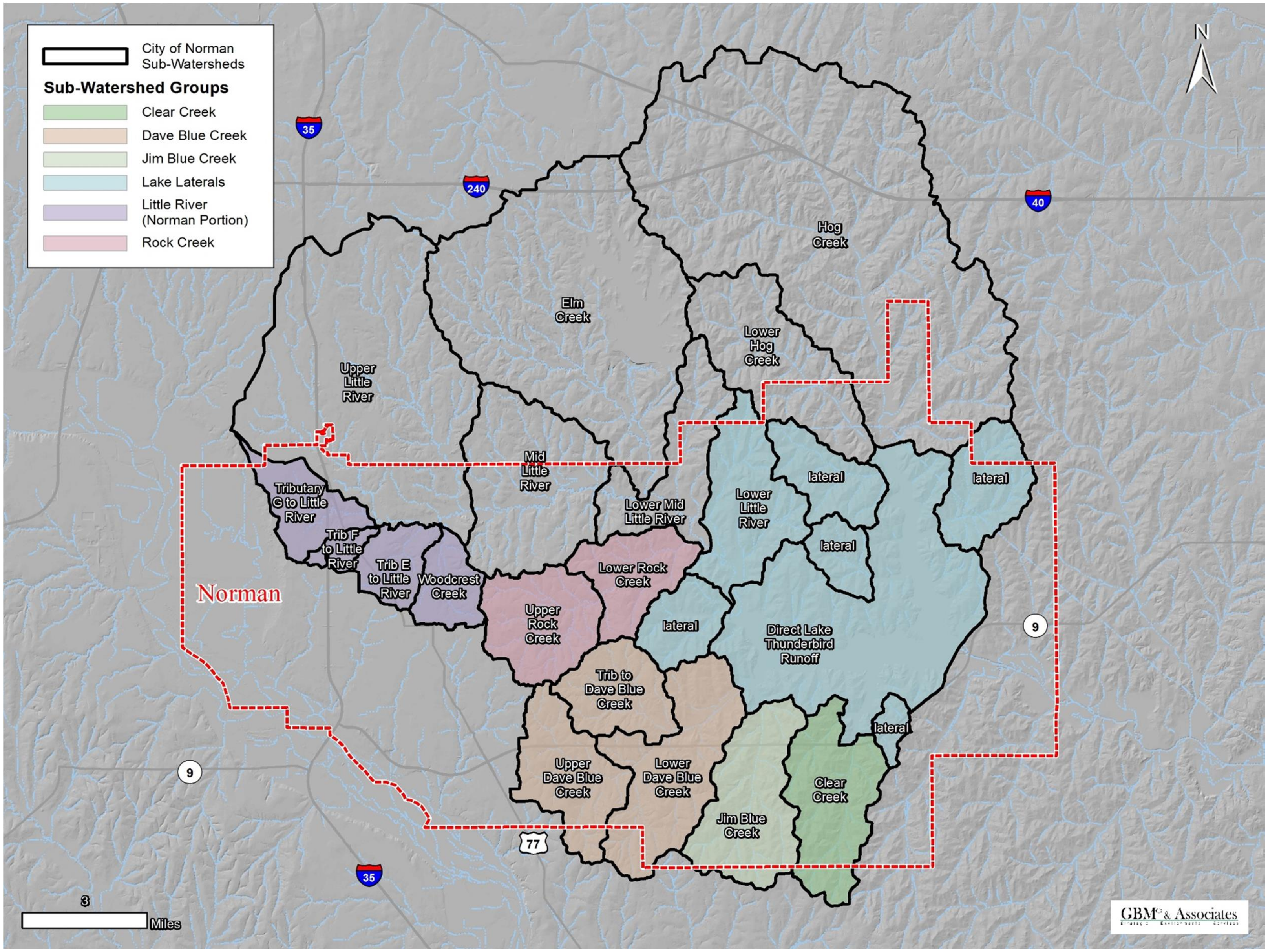

Figure 9. Norman MS4 Portion of the Lake Thunderbird Watershed and its Associated Sub-Watersheds.

Table 13. Land Use Analysis of Norman MS4 Sub-Watersheds.

Sub-watersheds	Little River					Rock Creek			Dave Blue Creek				Direct Lake Thunderbird Run-off and Laterals							Clear Creek	Jim Blue
LULC	Trib F (2.0)[1]	Woodcrest Creek	Tributary G to Little River	Trib E (31.0)[1]	Overall WS %	Upper Rock Creek (7.0)	Lower Rock Creek	Overall WS %	Trib to Dave Blue Creek	Upper Dave Blue Creek	Lower Dave Blue Creek	Overall WS %	30.0[1]	14.0[1]	11.0[1]	Lake Thunderbird Laterals	20.0[1]	Lower Little River	Overall WS %	Overall WS %	Overall WS %
Open Water	0.6	2.5	1.1	1.2	1.4	3.3	0.5	2.1	1.4	1.2	0.5	1.0	0.0	0.2	0.0	28.8	0.9	0.1	5.0	0.0	0.2
Open Space (developed)	11.2	12.3	13.7	11.1	12.1	9.2	6.4	8.0	8.5	8.5	8.7	8.6	10.5	8.3	6.3	4.6	5.9	7.2	7.1	6.2	5.9
Developed (low-high intensity)	40.6	48.5	31.9	28.2	34.5	18.2	1.0	10.7	1.7	9.8	1.4	4.0	0.9	0.7	0.3	1.0	1.3	0.5	0.8	1.1	0.9
Barren land	0.0	0.1	0.5	0.3	0.3	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	4.0	7.1	2.9	7.0	5.6	13.7	37.4	24.0	32.6	22.2	39.7	32.7	53.7	62.0	68.1	48.5	43.3	58.6	55.8	50.3	52.1
Grassland	39.8	24.6	29.1	40.1	33.6	51.0	46.4	49.0	50.4	53.7	44.1	48.5	32.2	28.6	24.4	16.6	38.6	31.4	28.6	40.2	33.4
Pasture/Hay	2.4	0.7	1.2	3.3	2.0	2.5	6.5	4.2	4.8	3.4	5.0	4.5	2.6	0.0	0.9	0.0	9.5	1.5	2.4	2.2	6.4
Row Crops	1.3	4.2	19.6	8.8	10.4	1.9	1.7	1.8	0.5	1.0	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0
Wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.4	0.1	0.2	0.0	0.0
Total Area (acres)	638	1910	2569	3827	8944	4237	3241	7478	3317	4311	6522	14151							31,325	5146	5437

[1]Labeled according to the City of Norman SWMP or label assigned if not specifically named in the SWMP.

4.5.2 Live Stock Numbers

Numbers of agricultural animals were estimated in the watershed from the county agricultural census data for cattle and calves. For cows the number of ñall cattle and calvesò for Cleveland county was used, along with the number of acres of pasture in each county, to calculate number of cows per acre. Cows were assumed to be evenly spread over the pastures in the counties affected. A cows/acre number was then applied to each sub-watershed using the number of acres of pasture determined through the land use analysis. Cattle estimates are provided in Table 14.

Table 14. Agricultural Animal Estimates per Sub-Watershed.

	Sub-watershed					
	Rock Creek	Little River (Norman Portion)	Dave Blue Creek	Jim Blue Creek	Clear Creek	Lake Laterals
All Cattle/Calves	321	384	608	234	221	1346

4.5.3 Unpaved Roads

Unpaved roads (gravel and dirt) are common in the Lake Thunderbird Watershed. There are over 100 miles of public and private unpaved roads in the Norman portion of the watershed. The City of Norman will pave majority of public roads and will work with private owners to encourage the stabilization of private drives and roads. During storm events these roads can transport significant loads of sediment into adjacent streams. The magnitude of the sediment load varies depending on many factors including: proximity to streams, condition of the road, slope and the design of the road. Unpaved roads can be designed to include BMPs that reduce erosion and transport of sediment.

Miles of unpaved road were determined from Oklahoma Department of Transportation (ODOT) GIS road layers (Statewide County ODOT Road Network, 2013) for each sub-watershed in the Norman portion of Lake Thunderbird Watershed. A summary of this data is provided in Table 15. Sediment loading for each mile of unpaved road was estimated based on a recent study completed in Pennsylvania by the Center for Dirt and Gravel Road Studies (Bloser, 2012). The Center for Dirt and Gravel Road studies (The Center) is the author of the nationally recognized manual on environmentally sensitive maintenance on dirt and gravel roads (USEPA-PA-2005). This manual is recommended nationwide by the USEPA and the US Forest Service. The Centers study determined the load of sediment transported for several different unpaved road types and conditions that would result from a 0.6 inch rain event occurring over 30 minutes. For purposes of the Lake Thunderbird Watershed assessment an average rate of sediment transport was set at 485 lb/mile of unpaved road per rain event. The 485 lb/mi sediment rate was the average of the runoff rate from roads with average maintenance and traffic levels and roads that had been recently topped with fresh aggregates which produce much lower levels of sediment runoff. These conditions were chosen to provide conservative sediment loading estimates. Six rain events (>1.0 inch) were assumed to occur each year and each rain event would result in 485 lb of sediment per mile of road (Table 15). Sub-watersheds with the highest potential loading of sediment from unpaved roads are Lake Laterals, Rock Creek and Dave Blue Creek.

Table 15. Summary of Unpaved Roads in Lake Thunderbird Watershed[1].

	Rock Creek	Little River (Norman Portion)	Dave Blue Creek	Jim Blue Creek	Clear Creek	Lake Laterals	Total
Unpaved Roads (mi)	24.0	1.0	16.0	8.1	12.2	43.3	104.6
TSS Load Annually (lbs)	69,789	3,020	46,616	23,623	35,606	125,986	304,640

[1]Values provided in this table are rounded to a minimum of 2 significant digits.

4.5.4 Construction Storm Water

The scope of this study did not include site specific evaluation of water quality impacts from construction sites in the Norman area. However, throughout the study period impacts and potential threats to water quality from construction activity were noted. Observations made included large cleared areas left unstabilized or those that had inadequate or unmaintained structural controls. Utility work was also observed numerous times with no best management practices in place, including dewatering efforts which were obviously contributing sediments.

As stated, large unstabilized tracts of land were observed during the study. These tracts were generally associated with the addition and/or expansion of residential neighborhoods. During field study dates in November 2014 to April 2015, these tracts were left with no ongoing construction activity nor any stabilization efforts implemented. A review of historical aerial photography shows that this practice is commonplace and the timeframes are substantial.

Calculations were performed to estimate the increase in storm water discharge and the potential sediment/nutrient loss due to land clearing. The change in runoff coefficient from forest or pastureland to cleared land results in an estimated runoff increase of 2.3 times as much storm water. The associated sediment and nutrient loss with this change in land use is significant.

Soil loss due to erosion was calculated using the Universal Soil Loss Equation and site specific information from the Little River watershed. Calculations showed an estimated annual loss of 5.47 tons/acre/year for a construction site due to surface water erosion assuming no controls are in place. For a 20 acre construction site this correlates to 110 tons of soil, 67 lbs of Nitrogen, and 35 lbs of Phosphorus per year. In contrast, data available from the NRCS (2010) estimated soil losses from Oklahoma farmland at a rate of 2.51 tons/acre/year. Similar evaluation using RUSLE2 Model resulted in a range of values that bracketed 5.47 ton/acre/year. Therefore, the reasonably conservative 5.47 tons/acre/year was utilized for soil loss estimation.

GIS data was utilized to estimate the amount of area currently under development within the Norman portion of the Lake Thunderbird Watershed. According to most recent aerials, Little River watershed has 366 acres under development, Dave Blue watershed has 126 acres, and there are 81 acres under development in the Rock Creek watershed. If left uncontrolled, this represents a potential load of approximately 6,300,000 lbs of sediment, 1,900 lbs of Nitrogen, and 1,000 lbs of Phosphorus per year. A summary of pollutant loading potential from construction storm water is provided in Table 16.

Table 16. Summary of Potential Loading from Uncontrolled Construction Sites[1].

Pollutant	**Rock Creek**	**Little River (Norman Portion)**	**Dave Blue Creek**	**Jim Blue Creek**	**Clear Creek**	**Lake Laterals**	**Total**
Sediment (lb/year)	885,735	4,002,210	973,215	404,595	229,635	284,310	6,779,700
Nitrogen (lb/year)	271	1225	298	124	70.3	87.0	2,075.3
Phosphorus (lb/year)	143	645	157	65.2	37.0	45.8	1,093

[1]Values in this summary table are rounded to a minimum of two significant digits.

In addition to the soil loss from land use change, the increased run-off also results in higher peak flows in stream channels that cause increased stream bank erosion, contributing more sediment and nutrients to the system. Control of these excess runoff volumes is critical to maintain stream system stability.

4.5.5 Stream Bank Erosion

Additional USAǒs were completed in the Norman portion of the Lake Thunderbird Watershed to supplement the earlier USAs that were completed watershed wide. Results of the USA and BEHI calculations showed the Little River watershed (Norman portion and middle portion in the MS4 boundary) exhibited the greatest risk for erosion and accompanying sediment/nutrient loads. Stream segments of the Little River and its tributaries showed between 50 to 100% of reach lengths observed were affected by bank erosion. Bank erosion was characterized from high to extreme using the BEHI classification index. Stream reaches observed in this watershed were classified as Entrenched due to the ratio between the bankfull depth and width.

The BEHI procedure showed significant bank erosion within the Rock Creek watershed. Overall, the rankings were lower than the Little River Watershed. However, reaches observed showed a large percentage of affected stream length including one reach with 90% of banks exhibiting Moderate bank erosion. On average, the Rock Creek watershed showed approximately 40% of banks affected with erosion characterized as High. Streams in this watershed were classified as Slightly Entrenched to Moderately Entrenched.

Of the three key Norman MS4 watersheds where USAõs were completed, the Dave Blue Watershed showed the least impact due to bank erosion. However, while streams appeared to be in better overall condition compared to other watersheds in the area, there were still areas with significant bank erosion and scour. BEHI calculations showed an average of 17% of the banks evaluated were affected by bank erosion. The erosion hazard was characterized as Very High to Extreme for these stream segments. Streams in the watershed were found to be Moderately Entrenched. Currently, this watershed is the least developed and further urbanization has the potential to increase peak storm flows and erosion in the watershed.

Bank and bed erosion are significant sources of sediment and nutrient load to streams and watersheds. Calculations were completed (as an example) to estimate the loads introduced to the watershed by one 500-ft section of stream with 10-ft high banks. Using a conservative erosion rate of 0.25 ft per year, the amount of sediment loss translates to 1,250 ft^3 or 57.4 tons of sediment per year. Using the average concentrations from samples collected during the study, this amount of nutrient associated with this sediment totals 35.1 lbs of Total Nitrogen and 18.5 lbs of Total Phosphorus for one bank of a 500-ft long stream segment. Considering the amount of affected stream bank within the watershed, this calculation illustrates the necessity to prioritize stabilization and/or remediation of stream banks. A summary of pollutant loading potential from stream bank erosion is provided in Table 17. Explanation of how those estimates were calculated is provided in Section 4.2.1. The HSPF modeling completed for the TMDL (Dynamic Solutions, 2013) uses loading caused by channel scour to account for stream bank erosion. The resulting annual sediment load predicted from HSPF for sour, from the entire Lake Thunderbird Watershed, is approximately 2,000,000 lbs. Based on our calculations (Table 17) this could be a gross underestimation of bank erosion.

Table 17. Summary of Potential Loading from Stream Bank Erosion.

Pollutant	**Rock Creek**	**Little River (Norman Portion)**	**Dave Blue Creek**	**Jim Blue Creek**	**Clear Creek**	**Lake Laterals[1]**	**Total**
Sediment (lb/year)	3,024,354	7,098,086	2,716,995	895,716	939,204	939,204	15,613,559
Nitrogen (lb/year)[2]	925	2157	831	274	287	287	4,761
Phosphorus (lb/year)[2]	488	1136	438	144	151	151	2,508

[1] No USA data was collected in lake laterals, but these areas are expected to be similar to Clear Creek or Jim Blue Creek.

[2] Nitrogen and phosphorus calculated from average nutrient content of soil samples, 0.00306 lb/lbN and 0.000161 lb/lb P.

4.5.6 Norman MS4 Priority Sub-Watershed Ranking

Many factors play into determining which sub-watersheds should be prioritized and which types of impacts within the sub-watersheds should be addressed first. To aid in this analysis a matrix was developed to consider each of the impact assessment categories including: HSPF sediment loading, HSPF nutrient loading, percent agriculture (pasture+row crops), amount of impacted riparian buffers, amount of bank erosion, amount of unpaved roads, and percent developing area. HSPF model results from the TMDL report (Dynamic Solutions, 2013) were utilized in the matrix. Model-predicted sediment and nutrient loading were evaluated on a sub-watershed basis to arrive at the sub-watershed ranking that appears in the matrix.

Scores were assigned to sub-watersheds (Table 18) based on a ranking of the top five sub-watersheds with the greatest apparent impacts (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.) For this matrix ranking the greatest apparent impact received 5 points, second 4 points, third 3 points, etc. These were then tallied for all 8 assessment parameters. The higher the total score the higher the priority for implementation of BMPs. Table 19 provides a summary of the score totals for each sub-watershed.

Table 18. Matrix Ranking and Scoring of Assessment Parameters.

Sub-watershed	HSPF Sediment Loading	HSPF Nutrient Loading	% Agriculture	% Developing land area (active construction)	% Urban	Bank erosion	Unpaved Roads	Impacted riparian	Total Score
Rock Creek	4	4	3	3	4	4	4	1	27
Little River (Norman)	5	5	5	5	5	5	0	0	30
Dave Blue Creek	3	3	2	4	3	3	3	5	26
Jim Blue Creek	2	2	4	2	1	1	1	3	16
Clear Creek	1	1	0	0	2	2	2	2	10
Lake Laterals	0	0	1	1	0	1	5	4	12

Table 19. Total Scores and Matrix Ranking.

Severity Rank	Sub-watershed	Score
1	Little River (Norman portion)	30
2	Rock Creek	27
3	Dave Blue Creek	26
4	Jim Blue Creek	16
5	Lake Laterals	12
6	Clear Creek	10

According to the matrix ranking, the three key sub-watersheds within the Norman portion of the watershed most in need of source reductions are Little River, Rock Creek and Dave Blue Creek. These areas should be the focus of the first round of BMP implementation.

5.0 Pollution Source Assessment

Pollution sources in the Lake Thunderbird Watershed were assessed with emphasis on non-point sources, which was the focus of the TMDL and this compliance plan.

5.1 Point Sources

There are no NPDES wastewater dischargers in the Lake Thunderbird Watershed. There are 14 NPDES Multi-Sector General Permits (MSGP) for industrial storm water discharges in the watershed (Dynamic Solutions, 2013). However, only four of these are within the Norman MS4 boundary (Dynamic Solutions, 2013).

5.2 Non-point Sources

The portion of the Lake Thunderbird Watershed that is in the City of Norman MS4 boundary was evaluated. The critical Norman sub-watersheds where the most TSS and nutrients originate were assessed and discussed in Section 4.0. Figure 10 provides a map of the ranking of critical sub-watersheds, which will be the main focus of load reduction goals for the watershed. Based on the assessment findings (Sections 4.0) potential sources of pollution and their risk level in each of the sub-watersheds delineated and analyzed are presented below. Risk level was assigned based on matrix scoring (see Table 18 and Table 19), field observations and interpretation of GIS data.

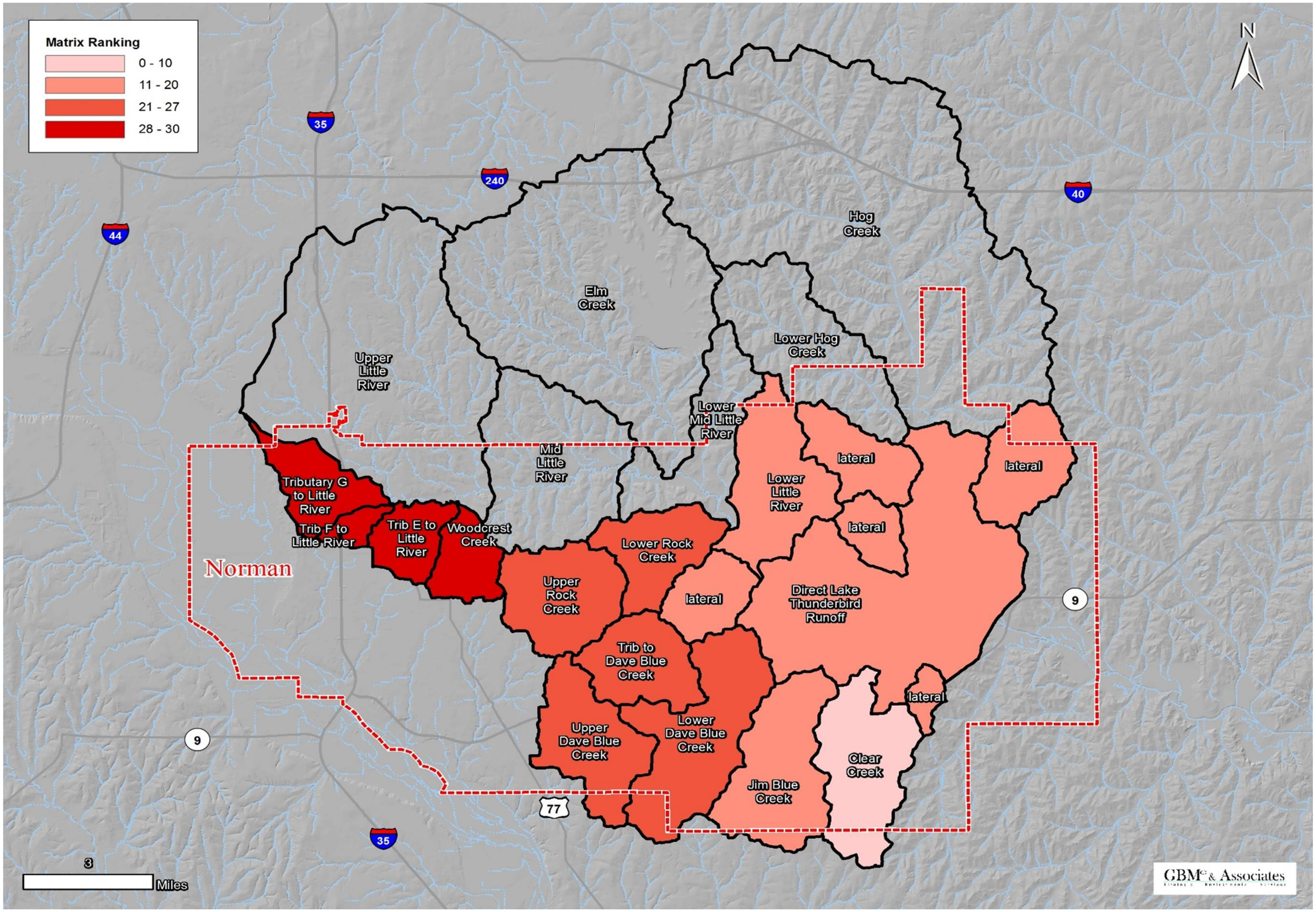

Figure 10. Ranking of Critical Sub-Watersheds According to the Priority Matrix.

Upper Rock Creek ï This is in the headwaters portion of the Rock Creek sub-watershed and is mostly composed of developed (urban and suburban) and grassland (rangeland) land uses. Potential non-point sources identified in the Upper Rock Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 20.

Table 20. Potential Non-Point Sources Identified in Upper Rock Creek.

Non-point source (Upper Rock Creek)	Severity/Risk
Commercial areas	Moderate - High
Residential areas	Moderate - High
New construction	High
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Septic tanks	Low - Moderate
Un-paved roads	Moderate
Row Crops	Low

Lower Rock Creek ï This sub-watershed is also in the middle portion of the overall lake watershed and is mostly composed of rangeland and pasture. Cattle pasture is more prominent in this sub-watershed than in other nearby sub-watersheds. Potential non-point sources identified in the Lower Rock Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 21.

Table 21. Potential Non-Point Sources Identified in Lower Rock Creek.

Non-point source (Lower Rock Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Moderate
Cattle	Moderate
Fertilized pastures and hay operations	Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Septic tanks	Low - Moderate
Un-paved roads	Moderate
Row Crops	Low

Little River Tributaries (Tribs G, F, E and Woodcrest) ï This is the northwest corner of Norman and is mostly composed of urban, suburban and commercial land uses. Potential non-point sources identified in the Little River Tributary (Tribs G, F, E and Woodcrest) sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 22.

Table 22. Potential Non-Point Sources Identified in Little River Tributaries.

Non-point source (Little River Tribs)	Severity/Risk
Commercial / Industrial areas	Moderate - High
Residential areas	Moderate - High
New construction	High
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Row Crops	Low - Moderate

Upper Dave Blue Creek - This sub-watershed drains the southern portion of Norman. The land-use is primarily grassland, developed (urban and suburban), and forest. Potential non-point sources identified in the Upper Dave Blue Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 23.

Table 23. Potential Non-Point Sources Identified in Upper Dave Blue Creek.

Non-point source (Upper Dave Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low ï Moderate
New construction	Moderate
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate - High
Septic tanks	Low
Un-paved roads	Moderate
Row Crops	Low

Lower Dave Blue Creek and Tributary to Dave Blue - These sub-watersheds drain mostly rural areas southeast of Norman. The land-use is primarily grassland, forest and some pasture/hay. Potential non-point sources identified in the Upper Dave Blue Creek and Dave Blue Tributary sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 24.

Table 24. Potential Non-Point Sources Identified in Lower Dave Blue Creek and Tributary.

Non-point source (Lower Dave Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Low
Cattle	Low ï Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

Jim Blue Creek - This sub-watershed drains mostly rural areas southeast of Norman. The land-use is primarily forest and grassland, with some pasture/hay. Potential non-point sources identified in the Jim Blue Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 25.

Table 25. Potential Non-Point Sources Identified in Jim Blue Creek.

Non-point source (Jim Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Low
Cattle	Low ï Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

Clear Creek - This sub-watershed drains mostly rural areas south of Lake Thunderbird. The land-use is primarily forest and grassland. Potential non-point sources identified in the Clear Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 26.

Table 26. Potential Non-Point Sources Identified in Clear Creek.

Non-point source (Clear Creek)	Severity/Risk
Commercial areas	Very Low
Residential areas	Very Low
New construction	Very Low
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Very Low

Lake Thunderbird Direct and Laterals - This large sub-watershed is made up of all the smaller tributaries (laterals) and drainages that enter directly into Lake Thunderbird. The sub-watershed drains mostly rural areas near the lake. The land-use is primarily forest and grassland, with some pasture/hay. Potential non-point sources identified in the Thunderbird direct and lateral sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 27.

Table 27. Potential Non-Point Sources Identified in Thunderbird Laterals.

Non-point source (Lake Thunderbird Laterals)	Severity/Risk
Commercial areas	Very Low
Residential areas	Very Low
New construction	Low
Cattle	Low – Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

6.0 Modeling Non-Point Source (NPS) Load Reduction Potential

Two water quality models were used to determine the potential of different management practices to reduce TSS and nutrients in the Norman portion of the Lake Thunderbird Watershed. The Watershed Treatment Model (WTM) developed by the Center for Watershed Protection was used to model non-structural BMPs. The EPA supported HSPF model (Bicknell, 2001), which contributed to the development of the TMDL, was used to model urban/suburban BMPs and rural BMPs. Each sub-watershed was modeled independently to arrive at a predicted load reduction potential with multiple management measures applied.

Both models (HSPF and WTM) are generally considered land-use based models that utilize annual rainfall, soil hydrologic groups and land-use categories to calculate primary pollutant loading in a watershed.

6.1 WTM Modeling for Non-Structural BMPs

The WTM model was used to assess potential load reductions from non-structural BMPs. A summary of the land use calculated for each sub-watershed of concern then entered into the WTM is provided in Table 28. The WTM is used in this plan exclusively as a tool to determine which non-structural BMPs most effectively reduce TSS and nutrients in each sub-watershed. BMPs evaluated with the WTM include:

- Residential Lawn Care Education
- Pet Waste Education Programs
- Street Sweeping
- Catch Basin Cleanouts
- Septic System Education Programs
- Sanitary Sewer Overflow Repair

Each non-structural BMP required additional land use data specific to each sub-watershed. The additional land use data included number of housing units, impervious surface area that drains to a storm drain, and miles of sanitary sewer lines which were calculated for each sub-watershed. Based upon the area of each sub-watershed, and the total number of housing units and area of Cleveland County; a proportion calculation was used to determine the number of housing units in each sub-watershed (Table 29). In the Storm Water Master Plan prepared by PBS & J, cumulative impervious surface area for each watershed was included. The impervious surface area in each sub-watershed was calculated using the total impervious surface area of the larger watershed from the Storm Water Master Plan and the area of each sub-watershed as a proportion (Table 29). Half of the total impervious surface area accounted for City roads; the area that remained was split into residential and parking lots for modeling purposes. City and residential roads were summed to determine the impervious surface draining to storm inlets (Table 29). The City of Norman provides an interactive GIS map with all sewer lines included. The map was integrated into GIS and force mains, gravity mains, and lateral sanitary sewage lines were summed for each sub-watershed in the City limits (Table 29). Impervious surface area, impervious surface area draining to storm inlets, and miles of sanitary sewer line were not calculated for rural watersheds as they are outside the City of Norman. Rural areas do not have their sewage piped to the City treatment facility, they do not receive street sweeping provided by the City, nor would the storm water runoff drain to a storm inlet. Therefore Jim Blue, Clear Creek, and Lake Thunderbird and laterals will not receive street sweeping, catch basin cleanout, or sanitary sewer overflow repairs as BMPs in the WTM.

Other data were required to evaluate certain BMPs. Much of this data is not directly available for the Norman area (such as fertilizer overuse rate by residents, pet waste management habits, etc.) so other reputable sources of data (Center for Watershed Protection is a primary source) were utilized and referenced in Section 8.1. Where no data was available conservative assumptions were made, particularly in the case of BMPs where public education and response is a component.

Table 28. Summary of WTM Inputs for Land Use in Each Sub-Watershed.

Land Use (acres)	Land Use in Sub-watersheds					
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue
LDR[1]	46.5	49.8	216.0	1,184.2	509.4	411.6
MDR[1]	2.9	3.6	19.4	1,158.0	98.6	168.8
HDR[1]	0.0	1.1	9.0	295.6	9.0	27.3
Forest	2,833.1	2,589.9	17,515.7	471.5	1,912.2	4,462.8
Rural[2]	2,543.2	2,498.7	11,994.8	5,012.8	4,708.0	8,928.9
Water	11.1	2.4	1,570.3	122.4	141.1	151.3
Total area	5,436.8	5,145.5	31,325.5	8,944.5	7,478.2	14,150.6

[1] LDR stands for low density residential, MDR stands for medium density residential, and HDR stands for high density residential

[2] Rural land loading calculations are the default rates in the model, they include pollutants from grazed cattle, fertilizer used for hay and other common uses of rural land.

Table 29. Summary of Inputs for Other Land Use Categories in each Sub-Watershed.

Source	Other Land Use Categories in Sub-watersheds					
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue
Housing units	1,650	1,562	9,508	2,714	2,269	4,295
Impervious surface area (acres)[1]	--	--	--	609	1,056	626
Impervious surface draining to storm inlets (acres)[1]	--	--	--	457	792	470
Sanitary sewer lines (miles)[1]	--	--	--	84.4	38.5	14.0

[1]Areas outside of public services (storm, sewer, sanitary sewer, etc.) are omitted.

6.2 HSPF Modeling for Urban/Suburban and Rural BMPs

HSPF is a widely used watershed model that can evaluate point source and non-point source loading of pollutants, transport, and their effect on water quality. It is one of the few models supported by both the USEPA and the USGS. The latest version of HSPF and the base model UCI file, which was used to develop the TMDL, were used in this report to evaluate BMP removal rates from various land uses in the Norman portion of the Lake Thunderbird Watershed. The HSPF model addresses load reductions from BMPs on a land use by land use basis. Each BMP is set-up in the model with BMP type, type of land use the BMP is effective for, and the percentage of that land use area (acres) that it is applied to. The model also allows the pollutant (sand, silt, clay, nitrate, phosphate, etc.) removal efficiency to be added to the BMP set-up. However, the HSPF model does not adjust the loading rate from a given land use based on removal efficiency. HSPF applies a BMP by simply adjusting the area of that land use that creates loading, (i.e. if a grazing BMP is applied to 25% of pasture then 25% less pasture produces pollutant loading in that model reach).

To simplify application of BMPs to the HSPF base model and allow removal efficiencies to play a direct role in the reductions, the modelô s land use loading output file was generated using HSPEXP+. The land use loading output file breaks out each land use area in acres, provides a loading rate (t/year, lb/year, etc.) for each pollutant for that land use type, and produces a total annual pollutant load by land use for that reach/sub-watershed. This modeling output data was then used to evaluate pollutant reductions for various BMPs on a land use basis by taking both the percent area on which BMPs were implemented and BMP reduction efficiency into account. For example, an urban BMP was applied to 25% of the Urban high density land-use (P:109URHD), achieving a 66% reduction of sediment (Table 30). This level of sediment reduction is calculated as (0.25 x 12acres) * (0.66 x 0.044 tons/acre/year) to arrive at 0.08712 tons reduced (Table 30). An example of how BMPs were implemented with the land use data is provided in Table 30.

Table 30. Example of HSPF Land Use Sediment Loading Output and BMP Application.

Reach	Land-use	Area (ac)	Rate (tons/ac/year)	Total Load (tons/year)	Urban BMP (25% area/66% Reduction (tons)
RCHRES 65 - Rock Creek	P:101 WATR	186	0.018	3.38	n/a
RCHRES 65 - Rock Creek	P:102 BERM	477	0.298	141.91	n/a
RCHRES 65 - Rock Creek	P:103 FRSD	1742	0	0.003	n/a
RCHRES 65 - Rock Creek	P:104 RNGE	3880	0.073	285.05	n/a
RCHRES 65 - Rock Creek	P:105 URML	218	0.048	10.40	1.73
RCHRES 65 - Rock Creek	P:106 PAST	353	0.133	46.99	n/a
RCHRES 65 - Rock Creek	P:107 AGRL	166	0.088	14.61	n/a
RCHRES 65 - Rock Creek	WETN	0	NaN	0	n/a
RCHRES 65 - Rock Creek	P:109 URHD	12	0.044	0.53	0.087
RCHRES 65 - Rock Creek	FRSE	0	NaN	0	n/a
RCHRES 65 - Rock Creek	UCOM	0	NaN	0	n/a
RCHRES 65 - Rock Creek	P:112 URLD	1	0.045	0.045	0.0074
RCHRES 65 - Rock Creek	I:101 URML	218	0.304	66.20	10.93
RCHRES 65 - Rock Creek	I:102 URHD	46	0.723	33.25	5.49
RCHRES 65 - Rock Creek	I:103 UCOM	5	0.786	3.93	0.65

Land uses where BMPs were applied in the HSPF model include developed land (urban, suburban and commercial), open space turf grass areas, rangeland (also called grassland), pasture/hay land and row crops/cultivated fields. BMPs were applied in groupings to allow flexibility in BMP selection. BMPs in each grouping are provided in Table 31. Removal efficiencies for the BMPs listed in Table 31 were obtained from averaging removal efficiency from the literature (Appendix B).

Table 31. BMPs by Land Use and Group.

Land use	Group	BMP	Removal Efficiency (%)			Group Removal Efficiency (%)		
			N	P	Sed	N	P	Sed
Urban/Suburban, Commercial	Detention	Wetlands	25	49	69	25	40	66
		Wet ponds	29	59	72			
		Dry extended detention	10	19	65			
		Bioretention	35	32	60			
Urban/Suburban, Commercial, Open Space/Bermuda Grass	Bioswales	Bioswales	35	38	47	26	25	41
		Wet swales	29	24	32			
		Vegetated open channels	15	13	45			
Urban/Suburban (Commercial)	Rain gardens and barrels	Rain gardens	13	23	28	13	23	28
		Rooftop disconnection	13	23	28			
Rangeland	Cover crops[1]	Cover crops	33	22	15	33	22	15
Row Crops/Cultivated Fields	Cover crops	Cover crops	33	22	15	31	25	24
		Conservation Tillage	29	28	32			
Pasture/Hay	Grazing	Rotational grazing	10	24	30	21	12	15
		Alternative water sources	33	0	0			

[1]Cover crops on rangeland refers to minimizing bare soil through planting a perennial grass that will grow densely or by planting annual grasses (cover crops) to fill in gaps.

In order for the HSPF model to predict potential load reductions from each land use and each BMP applied, it was necessary for a reasonable portion of each land use to have a particular BMP applied to it. These land use applications are provided in Table 32. A goal to apply BMPs on approximately 25% of each respective land use was established. This goal is based on practicality and the reality that to achieve BMP implementation on more than 25% of an area is unreasonable and likely unattainable.

Table 32. Percent of each Land Use to which a Particular BMP was applied.

Land use[1]	BMP Group	% Land use Applied
Urban/Suburban (URLD, URML, URHD)	Detention	25
	Bioswale	25
Commercial (URCOM)	Detention	25
	Bioswale	25
	Rain garden/barrel	15
Rangeland (RNGE)	Cover Crops	25
Row Crops (AGRL)	Cover Crops	25
Pasture/Hay (PAST)	Grazing	25
Grass-open space (BERM)	Bioswale	25

[1]Each land use category includes the code used in HSPF for that land use.

7.0 Management Measures Already Implemented by Norman

The City of Norman has been implementing many good storm water management measures over the past few years. Several of these management measures have great potential to reduce pollutants in storm water. The City's Storm Water Master Plan (2009) outlines many of their efforts including improving drainage and creation of several ordinances to protect streams and Lake Thunderbird. These ordinances have been written and approved by the City Council and are described briefly below.

7.1 Water Quality Protection Zone Ordinance

Water Quality Protection Zone (WQPZ) is provided in Section 19 of the Code of the City of Norman for streams in the Lake Thunderbird Watershed. This ordinance went into effect in June 2011. A WQPZ is a zone along a stream consisting of "…vegetated strip of land, preferably undisturbed and natural, extending along both sides of a stream and its adjacent wetlands, floodplains or slopes." A WQPZ is sometimes referred to as a riparian buffer zone or strip and is designed to protect stream banks from erosion and to filter pollutants entering the stream from storm water run-off. The width of the zone is required by the code to be the greater of:

a. 100 feet from the top of bank on either side; or
b. The width designated by a stream planning corridor (SPC) in the Storm Water Master Plan (2009); or
c. The FEMA floodplain; or
d. A reduced width based on use of engineered solutions such as implementation of a structural control to reduce nitrogen, phosphorus and sediment loading based on the accepted low impact development manual.

A low impact development (LID) manual was reviewed and adopted by the City for use in conjunction with this ordinance. The manual is based on the Wichita/Sedgwick County Storm Water Manual utilized by the City of Wichita, KS.

7.2 Storm Water Management Ordinance(s)

Detention/Retention

Storm water detention /retention basins are a valuable tool of controlling peak storm flows and reducing erosion. The 2009 Storm Water Master Plan for Norman states that there are 290 or more retention facilities, detention facilities, or other water bodies (ponds) present in the City of Norman MS4. The City of Norman Engineering Design Criteria specifies that development plans incorporate permanent storage for storm runoff, promote storm water infiltration, and reduce erosion and sediment transport. The limits of the City of Norman Water Quality Protection Zone (WQPZ) is shown in Figure 11.

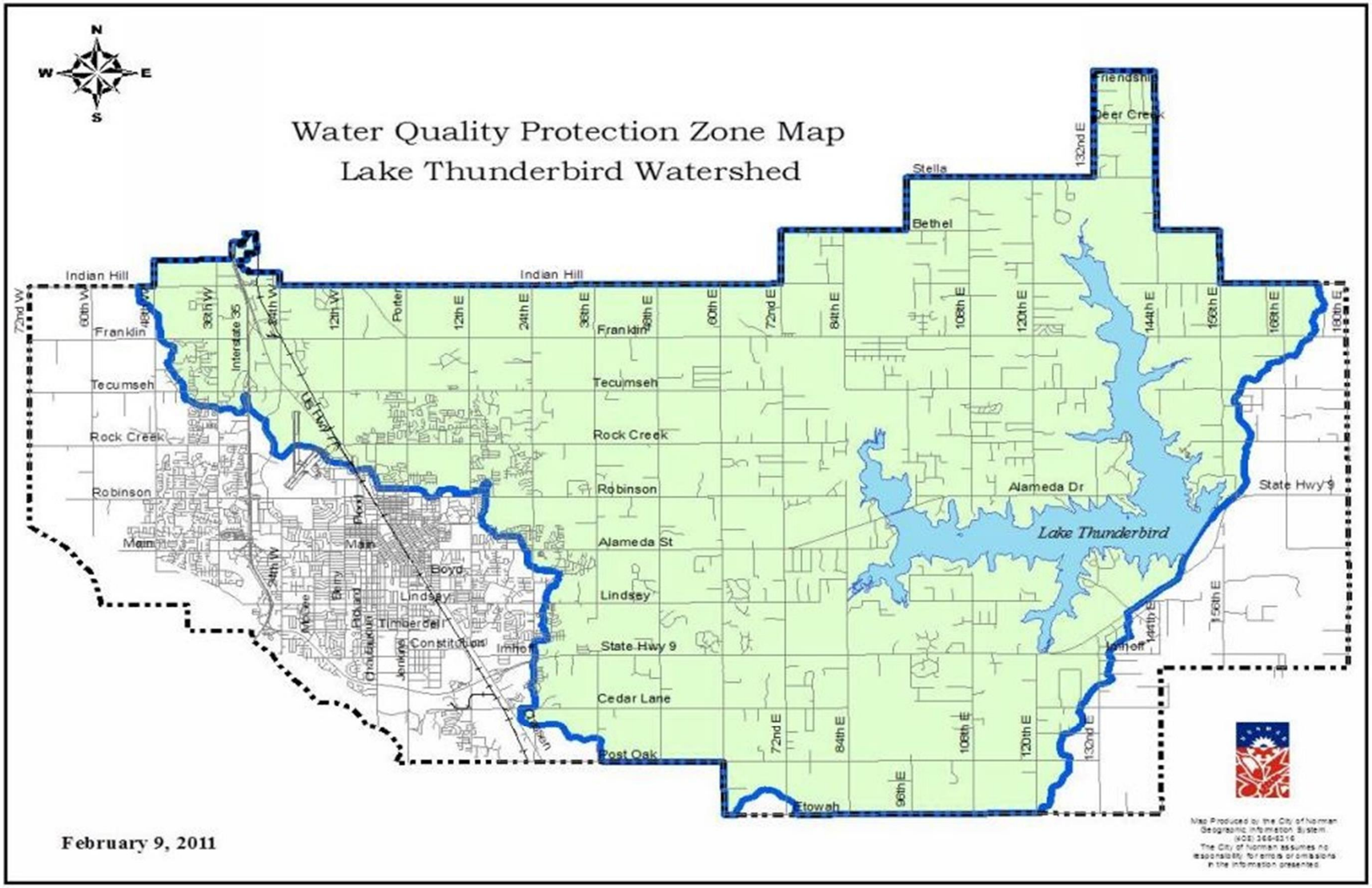

Figure 11. Limits of City of Norman Water Quality Protection Zone Program.

Illicit Discharge Detection and Elimination

The City also has a Storm Water Pollution ordinance (Section 6000) to control introduction of pollutants into the MS4 from storm water and which prohibits illicit discharges. The ordinance also provides for ñé legal authority for inspection, surveillance and monitoringé ò The guidelines provided in this ordinance are commonly referred to as ñillicit discharge detection and eliminationò. The Cityõs program for illicit discharge includes a list of allowed discharges, prohibited discharges, spill reporting, discharge sampling, inspection and enforcement (including notices of violation and prosecution). The current program has goals to inspect all identified outfalls and detention ponds annually. Visual inspection of major creek channels occurs at a rate of approximately 25% per cycle. Illicit dischargers are currently identified through:

- outfall and pond inspection
- creek channel inspection, and
- citizen reporting (via phone, website, email or in person)

The Cityõs current illicit discharge detection and elimination program appears adequate and no changes are recommended at this time.

7.3 Fertilizer Ordinance(s)

The City has adopted an ordinance governing use of manufactured fertilizer. This ordinance controls when phosphorus containing fertilizer may be applied, where it may be applied and how it is applied. The ordinance does not allow manufactured fertilizer containing any amount of phosphorus or a compound containing phosphorus to be applied to turf within the City with the following exceptions: 1) Manufactured fertilizer containing phosphorus may be applied within the first six months of turf establishment from seed or sod. 2) Naturally occurring phosphate in unadulterated natural or organic fertilizing products can be applied. 3) Fertilizer may be applied to soil that has been tested in a certified laboratory and shown to have phosphate levels of Ò10ppm, in which case fertilizer application should not exceed the laboratory recommended application rate.

The ordinance includes the following key components

- Prohibited conduct ï including application in wet or pending rainfall conditions, applying fertilizer within 25 feet of a waterbody and placement of any yard waste in a waterbody or storm drain.
- Soil testing ï required prior to application
- Education outreach ï provide public readily available information related to this ordinance and their responsibilities.
- Requirements for commercial sales within the City of Norman.
- Storage requirements
- Registration for commercial applicators.
- Inspections ï by City of Norman

7.4 Additional Efforts

In addition to the ordinances discussed above the City has staff inspectors that are tasked with identifying issues and enforcing storm water requirements within the MS4 boundary. The issues that these inspectors address are illicit discharge detection and elimination, construction storm water enforcement, drainage system inspection, maintenance and education.

8.0 Recommended NPS Reduction Measures

The following sections provide recommendations for management of the Norman portion of the Lake Thunderbird Watershed through education, BMP implementation, protection, enhancement, and restoration. A description and summary of each BMP's use ("BMP Summary Sheets") is provided in Appendix C. BMP Summary Sheets are from the Center for Watershed Protection, Urban Sub-watersheds Restoration Manual (Schueler et al., 2007; Novotney and Winer, 2008 and Schueler et al., 2005), or the USEPA National Management Measures for the Control of Non-Point Pollution from Agriculture (USEPA, 2003).

8.1 Non-Structural BMPs

The first effort to reduce sediment and nutrient loading to Lake Thunderbird should be implementation of non-structural BMPs. This type of BMP requires little to no construction effort but can be completed through education, maintenance/good housekeeping, ordinances and inspection/enforcement efforts. The WTM modeling presented in Section 6 was focused on non-structural BMPs. A brief explanation of each BMP is described below. Tables 33-35 present the possible load reductions that can be achieved by implementing and/or enforcing these BMPs.

8.1.1 Residential Lawn Care Education

Bright green grassed lawns are often a result of fertilization practices. Surveys indicate that 50-70% of home owners that fertilize their lawns are considered over-fertilizers (Swann, 1999). Over-fertilization causes nutrient runoff that has potential to cause eutrophication downstream (Barth 1995a and 1995b). A residential lawn care education program would inform residents of over-fertilizing and its impacts on Lake Thunderbird. The City of Norman currently has a fertilizer ordinance that is discussed in Section 7.3.

The WTM watershed model was used to estimate the potential reductions of nutrients if the ordinance is followed. Rural residents were included in the WTM. A percent of housing units was used to determine reductions in nutrients as a result of the residential lawn care education program. We assumed that 20% of the population would be informed of the residential lawn care education program and would reduce fertilizer use to recommended levels and switch to non-phosphorus fertilizer.

8.1.2 Pet Waste Education

Surveys indicate that 40% of households own one or more pets and 60% of those owners claim to pick up after their pet some or all of the time (Swann, 1999). Pet waste has potential to enter the Lake Thunderbird Watershed with a storm water runoff event. The City of Norman Parks and Recreation Department has installed pet waste collection stations in local parks to help reduce potential for nutrients entering waterways. Additional pet waste education programs would help inform pet owners of their impact. To be conservative we assumed that 25% of the population will be made aware of the program, and that of those pet owners, 25% of them will pick up after their pets (approximately 6 pet owners per 100). We also assumed that 25% of the housing units had a pet. The percent of pet owners informed is the basis for the reduction of nutrients and TSS inputs in the sub-watersheds.

8.1.3 Street Sweeping

City streets accumulate dirt and other pollutants between storm events and then mobilize these pollutants when a storm runoff event occurs. Sweeping the streets decreases the amount of pollutants that have potential to enter Lake Thunderbird. The City of Norman currently uses street sweeping, however, more frequent sweeping will likely reduce TSS and nutrient loads. The WTM considers existing street sweeping of the roads within each sub-watershed. For existing street sweeping we assumed for each of the sub-watersheds near the suburban/urban portion of Norman, roads are getting swept twice per year. In the WTM, impervious surface area is divided into three road types: residential, city roads, and parking lots. For the modeling we evaluated quarterly street sweeping for the city roads to decrease runoff of TSS and nutrients. For sub-watersheds containing substantial suburban/urban land use, road types were summed to determine the TSS and nutrient reductions produced as a result of bi-annual and quarterly street sweeping. Street sweeping as a BMP was not included for rural sub-watersheds.

8.1.4 Storm Drain Inlet Cleanouts

Storm water from impervious surfaces drains most often to a storm drain. Sediments, vehicle emissions, and litter will enter a storm drain during a storm runoff event. Most storm water conveyance systems drain to storm drain inlets of some type. Once storm water and the pollutants from the impervious surface area drain to an inlet, pollutants can settle out before storm water is released from the inlet. Removing or cleaning pollutants out of the storm drain inlet affects the water quality of water released (similar to catch basin cleanouts). It also prevents drain clogging which could reduce flooding (Novotney and Winer, 2008).

Currently the City of Norman's storm sewer drains and inlets are getting cleaned out on an as needed basis to maintain adequate drainage. The number of times that a inlet is cleaned out each year is unknown. For the modeling we assumed for sub-watersheds near the City of Norman that inlets are not cleaned out annually. In the future, bi-annual cleanouts will be implemented and will decrease amounts of TSS and nutrients being released from the storm drains and into the sub-watershed. In addition to bi-annual cleanouts, older conveyance systems will be upgraded (where possible) and new construction will be designed to include catch basins. Upgrading and replacing catch basins was not an option in the WTM, therefore, its affect was implicitly included in the routine cleanout reductions. In the WTM, impervious surface area is divided into three road types: residential, city roads, and parking lots. For watersheds in the suburban/urban areas, city roads and residential roads were summed to determine the TSS and nutrient reductions as a result of semi-annual inlets cleanouts. Rural portions of the watershed, outside the City storm sewer boundary, would not be affected by this BMP.

8.1.5 Septic System Education Program

A major source of nutrients and TSS in a watershed can be from failing on-site disposal systems or septic systems (Swann, 2001). A two step septic system program was evaluated by the WTM model to include education and system repair/maintenance. The education step involves informing septic system homeowners of potential failures that are associated with their systems if not maintained. The repair step is the rate at which those homeowners informed will repair their systems. When the education program is advertised, we assumed 30% of the population will be reached and 25% of those reached will be willing to implement measures to improve the performance of their systems. For the repair portion, those 25% willing to improve their systems will have their systems inspected and at least 30% of those people will be willing to make suggested repairs. The WTM considers both the education and repair steps together as one with respect to the nutrient and TSS reduction results.

In each sub-watershed that includes some of the urbanized portions of Norman it was assumed that 20% of the population utilized septic systems. For watersheds that are more rural, we assumed 100% of the housing units used a septic system. The percent of housing units with a septic system was used to determine TSS and nutrient reduction potential as a result of the implementation of septic system education programs in each sub-watershed.

8.1.6 Sanitary Sewer Overflow Repair

Properly maintained sanitary sewer systems are designed to transport all of the sewage to a treatment facility. Unintentional discharges of raw sewage from municipal sewer systems occur in every system. When the discharge occurs it is called a sanitary sewer overflow (SSO). Maintenance, inspections and repairs of the sewer lines need to be completed to prevent SSOs from occurring (USEPA, 2004). The City of Norman has a continuous program to replace aging and failing sewer lines and prevent SSOs. Their current efforts have been effective at reducing overflows that once exceeded 200/year to less than 50/year.

In order to evaluate potential pollutant reductions from continued good SSO repair programs, the miles of sewer lines in each sub-watershed within the City was used to determine TSS and nutrient reductions as a result of SSO repair. We assumed for each sub-watershed, with a portion of its area in the City, that most of sanitary sewer overflows since 2009 (TMDL data collection timeframe) would be reduced and majority of those reduced would have repairs completed. SSO repair was not an applied BMP in rural watersheds as these areas do not have sanitary sewersType equation here..

8.1.7 Watershed Education Initiatives

Education of the community on general watershed topics and the importance of protecting the Lake Thunderbird Watershed can be fundamental to success of the NPS reduction effort. It is important that citizens understand what they do on the land where they live, work and play ultimately gets into the streams and lakes. A general watershed education campaign should be implemented which includes a Lake Thunderbird Watershed brochure, workshops, watershed booths at local events, social media, newspaper posts, and presentations in local schools.

Load reductions from this type of education effort are difficult to quantify, but can be assumed to improve overall watershed health.

Table 33. TSS Reductions (lbs/year) if Non-Structural BMPs are Applied.

Best Management Practice	WTM Model TSS Reductions (lb/year)						
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue	Total
Residential Lawn Care[1]	0	0	0	0	0	0	0
Pet Waste Education[1]	0	0	0	0	0	0	0
Street Sweeping[2]	--	--	--	367.1	211.7	212.0	790.8
Storm Drain Cleanouts[2]	--	--	--	52,199	30,103	30,087	112,389
Septic System Education Programs	2,874	2,721	16,563	944.0	790.5	1,496	25,389
Sanitary Sewer Overflow Repair	--	--	--	221.5	442.9	36.8	701.2
Total	2,874	2,721	16,563	53,731	31,548	31,832	139,269

[1]Lawn care and pet waste BMPs do not reduce sediments.
[2]These BMPs are not applicable in rural areas.

Table 34. Nitrogen Reductions (lb/year) if Non-Structural BMPs are Applied.

Best Management Practice	WTM Nitrogen Reductions (lb/year)						
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue	Total
Residential Lawn Care	0.6	0.6	2.8	37.3	8.2	6.9	56.4
Pet Waste Education	33.2	31.4	191.6	54.6	45.7	86.5	443.0
Street Sweeping[1]	--	--	--	12.6	7.3	7.3	27.2
Storm Drain Cleanouts[1]	--	--	--	551.4	318.0	317.8	1187
Septic System Education Programs	431.1	408.1	2,484	141.6	118.6	224.5	3808
Sanitary Sewer Overflow Repair[1]	--	--	--	66.4	15.2	5.5	87.1
Total	464.9	440.1	2,679	863.9	513.0	648.5	5609

[1]These BMPs are not applicable in rural areas.

Table 35. Phosphorus Reductions (lb/year) if Non-Structural BMPs are Applied.

Best Management Practice	WTM Model Phosphorus Reductions (lb/year)						
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue	Total
Residential Lawn Care	0.5	0.6	2.5	33.1	7.3	6.1	50.1
Pet Waste Education	4.3	4.1	25.0	7.1	6.0	11.3	57.8
Street Sweeping[1]	--	--	--	1.9	1.1	1.1	4.1
Storm Drain Cleanouts[1]	--	--	--	59.9	34.6	34.5	129.0
Septic System Education Programs	71.9	68.0	414.1	23.6	19.8	37.4	634.8
Sanitary Sewer Overflow Repair[1]	--	--	--	11.1	2.5	0.9	14.5
Total	76.7	72.7	441.6	136.7	71.3	91.3	890.3

[1]These BMPs are not applicable in rural areas.

In addition to the specific measures described above and with quantified pollutant removals provided in Tables 33-35, the following general measures should be implemented by the City and strongly encouraged in the watershed.

- Encourage good housekeeping practices at all City facilities and local industries. Keep outside storage areas covered, immediately clean up spills of liquid or dry materials, etc.
- Encourage green area enlargement and enhancement and reduce impervious surfaces on new and existing developments.
- Encourage (through incentives) or require use of low impact development techniques (LID) in new developments in critical areas (near WQPZ❜s) or on steep slopes.
- Encourage land conservation. Where possible attain land or establish easements in areas critical to the stream (i.e. riparian buffer zones, wetlands, etc.) and maintain these as green areas. Riparian buffers should be a minimum of 50 feet on each side of the stream where possible.
- Encourage good neighbor practices. Keep yard free of junk and garbage, proper disposal of pet waste, proper disposal of household chemicals, etc.
- Encourage watershed stewardship through education.

These general measures are difficult to quantify but are essential to success of storm water pollution reduction efforts.

8.2 Structural BMPs

The following are a list of BMPs recommended to protect water quality and/or the hydrologic regime of Lake Thunderbird. Practices are recommended according to land-use type. The listings are not comprehensive but provide those typically applied successfully to such land-uses as those found in the Lake Thunderbird Watershed. Reduction estimates are based on

HSPF modeling, and a survey of current literature values on pollutant removal efficiencies, which is provided in Appendix B. A brief explanation of each BMP is described below. Table 36 presents the possible load reductions that can be achieved by implementing these BMPs. Most of the recommended structural BMPs in this section can be applied to new construction or as retrofits in the existing urban/suburban environment. In addition to pollutant removal potential, most of the recommended BMPs will also help mitigate excess runoff that increases peak flow in streams. Reducing these peak flows is critical to preventing stream bank and streambed erosion.

Detention Group

- Wet ponds ï storm water ponds that remain nearly full year round and allow pollutants to settle out during the time they are retained in the pond, prior to discharge.
- Wetlands ï constructed wetlands that function similar to wet ponds but utilize aquatic vegetation to sequester nutrients and slow water flow through to allow time for sediments to deposit and pollutants to be removed.
- Dry extended detention ï basins designed to capture and detain water for a specified volume of rain event and to release the water over a certain time period following the rain event. Detention basins help control peak flow hydrographs and allow sediments and other pollutants to settle out preventing downstream transport.
- Bioretention ï a filtration basin where the substrate has been engineered to promote infiltration and filtration of pollutants. They are typically used on smaller sites where higher levels of pollutants may be present.

Bioswale Group

- Bioswales ï swales (shallow wide channel) designed to slow storm water and promote infiltration while filtering out pollutants. The substrate of a bioswale is engineered to enhance these characteristics.
- Vegetated open channels ï swales that are kept heavily vegetated (mostly grasses) to slow storm water and improve infiltration, which also allows for pollutant removal.
- Wet swales ï the same as a vegetated open channel except they remain wet for most of the year as to sustain wetland flora, which will help sequester nutrients and other pollutants.

Rain Garden/Barrel Group

- Rain gardens ï miniature bioretention cells that are sized to filter pollutants from impervious surfaces (drive ways, roof tops, parking lots, etc.) at residences or small commercial areas.
- Rooftop disconnection ï system which directs storm water from impervious surfaces into pervious areas (rain gardens, vegetated areas, etc.) for infiltration or into collection systems (rain barrels or cisterns) where the water can be released to pervious areas slowly over a longer period of time or put to other uses (garden watering, livestock watering, etc.)

- Cisterns
- Rain barrels

Detention Facility and other BMP Maintenance

In addition to construction of new detention facilities (or other structural BMPs) it is equally important to maintain the existing facilities. Over time detention facilities can fill with sediment and become ineffective. Therefore, it may be possible to achieve as much future pollutant reduction potential from detention facility maintenance or upgrades as from construction of new facilities.

As urbanization and growth continue in Norman so will the number of storm water basins. Maintenance of these controls is important to their effectiveness and safety. While the maintenance of these controls remains with the development, the City has a vested interest to ensure that proper service is performed. It is recommended that the City develop inspection and reporting procedures and detailed guidelines for the maintenance of storm water basins to ensure they function as designed. It is also recommended that basin characteristics (such as age, design, watershed size, outfall structure) be cataloged as these factors may help determine the required schedule for maintenance. This may be particularly important for wet ponds, where capacity cannot be visually determined.

Maintenance and inspection of detention basins should include at a minimum the following items:

- Ensure access way requirements are being cleared and maintained.
- Inspection of embankments for erosion, settling, sloughing, or other problems.
- Inspection of inlet and outfall structure(s) for structural deficiencies, flow impedance, or other visual indicators of improper operation.
- Remove accumulated sediment/debris/trash from basin and screen/outlet.
- Remove vegetation which could interfere with proper operation without using chemicals, etc.
- Mowing/clearing activities should promote healthy grasses.

It may be necessary (to maximize pollutant reduction) to upgrade some of the existing facilities with forebays or with a better outlet design. Water quality outlets (See Appendix C) are designed to control both the flow hydrograph and to remove pollutants and were not typically utilized in older basins.

Similar to Detention facility maintenance, maintenance of all structural BMPs is critical to their function. It is possible that some older BMPs have become ineffective. A BMP maintenance program similar to that for detention basins (described above) should be implemented.

8.2.1 Developed - Commercial and Industrial Land-Uses

In all sub-watersheds and particularly in Little River, Upper Rock Creek, and Upper Dave Blue Creek it is recommended that industrial facilities and commercial establishments adopt industry specific BMPs, and implement the following structural BMPs:

- Detention Group ï on 25% of these land uses
  - Wetlands
  - Wet ponds
  - Dry extended detention
  - Bioretention

- Bioswale Group ï on 25% of these land uses
  - Bioswales
  - Wet swales
  - Vegetated open channels
- Rain garden/barrel group ï on 15% of these land uses
  - Rain gardens
  - Rooftop disconnection
    - Cisterns
    - Rain barrels

8.2.2 Developed - Residential Land-Uses

In the overall watershed and particularly in sub-watersheds Little River, Upper Rock Creek and Upper Dave Blue Creek it is recommended that implementation of best management practices by residents be encouraged.

For residential developments the following Structural BMPs should be implemented:

- Detention Group ï on 25% of these land uses
  - Wetlands
  - Wet ponds
  - Dry extended detention
  - Bioretention
- Bioswale Group ï on 25% of these land uses
  - Bioswales
  - Wet swales
  - Vegetated open channels
- Rain garden/barrel group ï Not applied at this time
  - Rain gardens
  - Rooftop disconnection
    - Cisterns
    - Rain barrels

Table 36. Possible Annual Load Reductions (lb/yr) through Implementation of Urban/Suburban Structural BMPs.

Urban/suburban (pollutant)	Rock Creek (lb/yr)	Little River (Norman Portion) (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Sediment	91,764.0	334,065.0	117,153.0	22,909.0	29,812.0	101,477.0	697,180.0
Nitrogen	2,216.0	7,918.0	1,901.0	178.0	232.0	797.0	13,242.0
Phosphorus	2,542.0	9,356.0	2,008.0	150.0	196.0	673.0	14,925.0

8.3 Rural Land-Use

In each sub-watershed, and particularly in sub-watersheds Jim Blue Creek, Dave Blue Creek and Rock Creek where pasture is the most prevalent, it is recommended that landowners be encouraged to participate in a voluntary program to consider implementation of pasture management practices. This encouragement typically works well as some form of educational materials mail out or forum. Assistance with these types of efforts is available through the National Resource Conservation Service, the Oklahoma Conservation Commission, the Cooperative Extension Service and others. Table 37 presents the possible load reductions that can be achieved by implementing these rural BMPs.

8.3.1 Pasture and Hay

For pasture with on-going grazing operations the following BMPs should be implemented in all sub-watersheds:

- Alternative water sources (away from stream) for cattle use. These can be stock ponds constructed in upland areas or cattle troughs distributed around the pasture, away from the stream channel. This helps keep the cattle out of the stream and away from the banks where they contribute to erosion.
- Fencing cattle out of stream can be used to direct cattle to alternative water sources.
- Rotational grazing. Move cattle into different pastures at different times of the year. This helps avoid over grazing, prevents grasses from becoming too thin or trampled and allows the grasses to help buffer the stream. It also helps prevent soil compaction.
- Control stocking rate, which is the number of head per acre of pasture. This can provide a similar benefit to that of rotational grazing if cattle numbers are kept low.
- Riparian buffers along stream corridors. Minimum of 50 feet of forest. This protects the stream banks from erosion and provides filtration of sediment and associated pollutants in the runoff. This BMP is discussed in detail in Section 8.6.1.

The reduction estimates provided in Table 37 are based on applying grazing BMPs on 25% of pasture/hay land uses.

8.3.2 Row Crops

For rural land being used for farming (row crops) in all sub-watersheds, the following BMPs should be considered:

- Control fertilizer applications (magnitude, timing and method) according to soil tests and USDA or NRCS recommendations to maximize productivity yet protect water quality.
- Use of cover crops (planting of a special annual or perennial crop that will grow well and cover the ground surface) during the off season would prevent top soil erosion and utilizes remaining nutrients.
- Riparian buffers along stream corridors (see detail in Section 8.6.1).

The reduction estimates provided in Table 37 are based on applying cover crops BMP to 25% of row crop land use.

8.3.3 Rangeland (Grassland)

For Rangeland in all sub-watersheds the following BMPs should be considered:

- If applying fertilizer, control fertilizer applications (magnitude, timing and method) according to soil tests and USDA or NRCS recommendations to maximize productivity yet protect water quality.
- Use of cover crops. The rangeland should be managed to maximize grass coverage and minimize bare soil. If planting of a secondary crop/grass is necessary to achieve complete coverage perennially then it should be implemented.
- Riparian buffers along stream corridors (see detail in Section 8.6.1).

The load reductions estimated in Table 37 are based on cover crop BMP implementation on 25% of rangeland.

Table 37. Possible Annual Load Reductions[1] (lb/yr) through Implementation of Rural BMPs.

Rural (Pollutant)	Rock Creek (lb/yr)	Little River (Norman Portion) (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Sediment	26,125.0	26,825.0	53,377.0	12,986.0	12,952.0	39,437.0	171,702.0
Nitrogen	1,791.0	1,577.0	3,381.0	835.0	911.0	2,717.0	11,212.0
Phosphorus	1,099.0	978.0	2,076.0	507.0	562.0	1,678.0	6,900.0

[1]Reduction estimates based on application of rural BMPs in 25% of appropriate land uses.

8.4 Construction Storm Water

Storm water runoff from construction activity can significantly impact water quality in receiving streams. ODEQ regulates discharges of storm water runoff from construction related activity through General Permit OKR10. Additionally, through City ordinances, the City of Norman imposes regulations to reduce the impacts of construction activity within areas of its jurisdiction. As growth and development continue in the Lake Thunderbird Watershed, adherence and expansion of BMPs will play a vital role in protecting water quality. The following actions should be taken to reduce pollutants associated with construction sites:

- **Immediate stabilization after land clearing.** OKR10 requires that areas where construction activity has temporarily or permanently ceased must be stabilized as soon as practicable, but not later than 14 days. If enforced, this requirement could serve to significantly reduce water quality impacts from construction. It may also serve to discourage land clearing before it is necessary. When cleared, erosion control on unstabilized land left idle is reliant upon structural controls which require maintenance and are subject to failure or neglect. Furthermore, the USEPA NPDES Menu of BMPs shows a pollutant removal efficiency of silt fence, the most commonly used BMP for construction sites, at 70%. This suggests that even if proper controls are in place, sediment and nutrient loss is substantial until stabilization is fully achieved.
- **Inspection and Enforcement.** Efforts to reduce impacts from construction storm water could be directed towards enforcement of existing regulations and education for developers, construction site managers, and utility contractors. Inspection of active construction sites and the ability to issue ñCease Workò orders can improve the quality of the storm water controls being used on sites in the Norman MS4.
- **Review SWPPPs.** According to Appendix E of the TMDL (Dynamic Solutions, 2013) construction projects 5 acres or larger are now required to submit Storm Water Pollution Prevention Plans (SWPPP) to ODEQ for review. In addition, the City of Norman should thoroughly review plans within its jurisdiction to ensure adequate controls are designed and implemented.
- **Site monitoring –** Evaluate local construction and industrial sites for possible monitoring.

Table 38 provides a summary of load reductions possible if all construction sites one acre or larger were better controlled. It is assumed that all sites currently have some level of control (silt fence along perimeters, etc.) and are achieving an approximate 50% reduction efficiency.

Table 38. Possible Annual Load Reductions[1] (lb/yr) through Implementation of Construction Storm Water BMPs.

Construction SW (Pollutant)	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Sediment	88,573	400,221	97,322	40,460	22,964	28,431	677,970
Nitrogen	27.1	123	29.8	12.4	7.0	8.7	208
Phosphorus	14.3	64.5	15.7	6.5	3.7	4.6	109

[1]Load reductions are based on 20% additional sediment removal from sites already controlled with silt fence along the perimeter.

8.5 Unpaved Roads Management

Several BMPs are available to decrease sediment transport from unpaved roads. The following BMPs are believed to be appropriate to the unpaved roads in the Lake Thunderbird Watershed:

- Aggregates replacement
- Water bars in steep sections
- Roadside ditch maintenance and check dams
- Proper road surface stabilization/road grading/maintenance
- Turnouts

Potential reductions of pollutants through implementation of some of these BMPs on 50% of the unpaved roads in the MS4 watershed areas is provided in Table 39.

Table 39. Possible Annual Load Reductions (lb/yr) through Implementation of Unpaved Road BMPs.

Unpaved Roads (pollutant)	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Sediment	17,447.0	755.0	11,654.0	5,906.0	8,901.0	31,496.0	76,159.0
Nitrogen	5.3	0.2	3.6	1.8	2.7	9.6	23.2
Phosphorus	2.8	0.1	1.9	1.0	1.4	5.1	12.3

8.6 Stream Corridor Restoration/Enhancement

8.6.1 Riparian Buffers

Riparian vegetated buffers are lacking or limited in several reaches of Lake Thunderbird Watershed. Riparian buffers are critical to the health of a stream system and serve to reduce pollutant loads transported to stream systems from adjacent land uses and they reduce or prevent stream bank erosion. Riparian areas throughout the Lake Thunderbird Watershed should be restored or enhanced. Rural areas most in need of riparian area restoration are Dave Blue Creek, Lake Laterals and Jim Blue Creek. Urbanized areas most in need of riparian restoration are Rock Creek, Little River and Upper Dave Blue Creek. Possible load reductions from restoration of riparian buffers (50 ft each side) in 40% of the main streams in each sub-watershed is summarized in Table 40.

Buffer widths should be planted as wide as possible on each side of the stream. A width of at least 50 ft on each side of the stream should be targeted as a minimum. When riparian buffers are considered, more is always better. Buffers should be composed of native vegetation including trees, shrubs, herbaceous plants, and grasses. Figure 11 presents a representation of how buffers are designed.

Table 40. Possible Annual Load Reductions (lb/yr) through Riparian Buffer Restoration[1].

Riparian Restoration (Pollutant)	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Sediment	316	180	707	616	502	671	2992
Nitrogen	0.10	0.06	0.22	0.19	0.15	0.21	0.92
Phosphorus	0.05	0.03	0.11	0.10	0.08	0.11	0.48
Acres Restored	1.6	0.9	3.6	3.1	2.6	3.4	15.2

[1]Reductions do not include additional load reductions attributed to storm water filtration occurring in riparian areas.

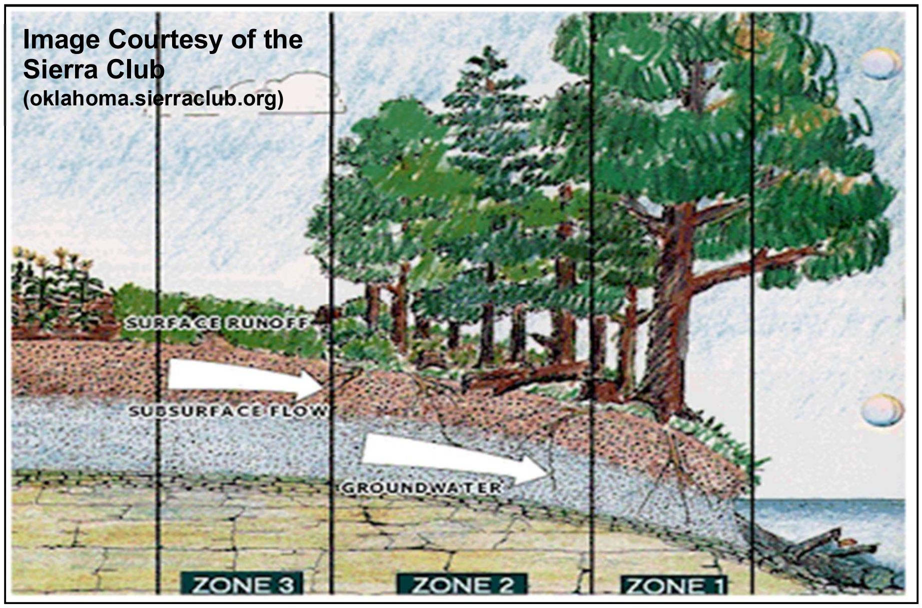

Figure 12. Generic Representation of Riparian Buffer Zone.

8.6.2 Stream Bank and Channel Stabilization

Several of the streams in the Lake Thunderbird Watershed are exhibiting significant stream bank erosion at several locations. It is recommended that efforts be implemented to reduce and prevent stream bank and bed erosion within City of Norman controlled areas of the Lake Thunderbird Watershed. These efforts include measures designed to reduce erosive peak storm flows as discussed in other sections of this report as well as stream bank stabilization and/or remediation efforts where practicable. Where stabilization and/or remediation efforts are implemented, prioritization of efforts should be based on a cost-benefit approach. Factors to consider when selecting stream segments for remediation should include access, land use and ownership, land loss or safety concerns, stream hazard index ranking, and bank/stream size relative to base and peak flows. Other factors may include public relations such as visibility, recreation, etc. Due to the size of the watershed, stabilization/remediation efforts may need to be focused on areas currently undergoing development or urbanization, particularly in the headwater areas of the Little River and Rock Creek Watersheds. Figure 12 provides stream segments which should be evaluated for stabilization/restoration opportunities to meet the sediment and nutrient reduction goals defined in this study. Potential load reductions from bank stabilization alone can exceed 200 lbs sediment, 0.07 lbs nitrogen and 0.04 lbs of phosphorus on an annual basis per foot of eroded bank restored. In addition to bank stabilization, root causes of stream bank instability should be evaluated in each reach and necessary channel restoration also be completed (i.e. installation of grade control, flow training and key habitat features, etc.).

For this compliance plan, stream bank stabilization is the last reduction effort to be counted towards the TMDL reduction goal. After all the other BMP reductions were tallied the load reductions remaining to meet the TMDL goal for Norman were allotted to stream bank stabilization. This was done for three reasons:

1. Stream bank erosion yields more sediment load than nutrient load
2. Stream bank stabilization can be costly, particularly in urban/suburban areas where space may be limited.
3. Until upstream hydrology issues are corrected (better control of storm hydrographs) it may be a waste of time and money to repair stream sections that might destabilize over time, if the root problem is not corrected.

A summary of reductions from stream bank stabilization is provided in Table 41. It is possible to achieve much more reduction of sediment and nutrients from stream bank stabilization than is accounted for in Table 41.

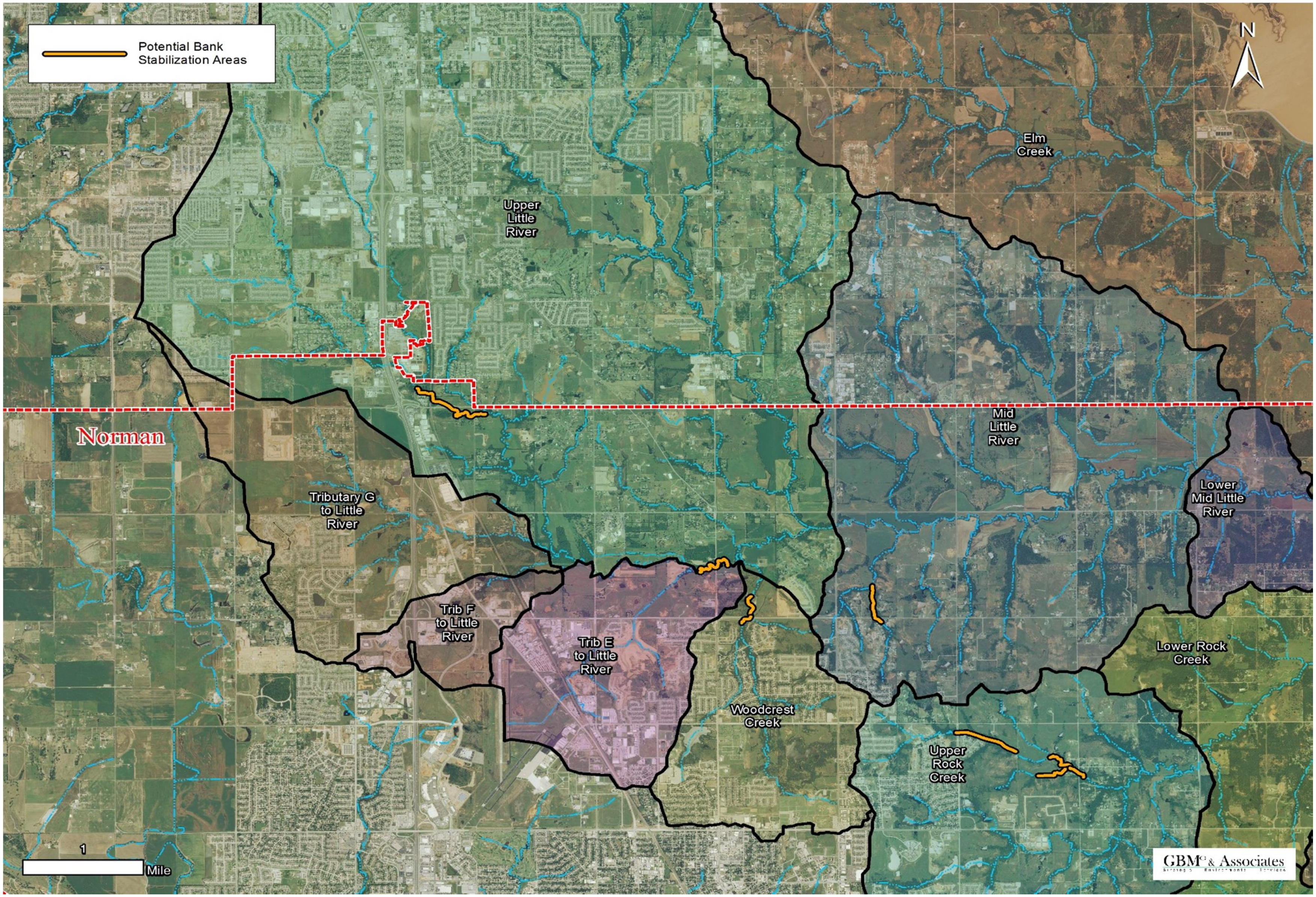

Figure 13. Stream Segments which should be Evaluated for Stabilization/Restoration Opportunities.

Table 41. Annual Load Reductions through Stream Bank Stabilization.

Stream bank stabilization (Pollutant)	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total (lb/yr)
Sediment	469,703	563,644	469,703	140,91 1	140,911	93,941	1,878,812
Nitrogen	1,397	1,676	1,397	419	419	279	5,587
Phosphorus[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Approx. feet bank stabilized[2]	3,100	1,860	2,050	625	625	415	---

[1]No additional phosphorus reduction needed to meet reduction goals.
[2]Length stream stabilized based on height and estimated erosion rates in each sub-watershed.

8.7 Critical Area Conservation

Land conservation should become a priority. Where possible, attainment of land and/or establishment of conservation easements should be considered in areas critical to the stream (i.e. buffer zones, wetlands, etc.). These lands should then be maintained as green areas. The City of Norman WQPZ ordinance should be enforced and where possible the maximum zone widths should be adhered to. Land adjacent to the lake that is not already protected should be placed under conservation easements to protect the shoreline buffer and the water resource. The City of Normanõs Land use and Transportation Plan (2004) sets priorities for establishment of protected natural resource areas and greenbelts and limits development in key special planning areas.

8.8 Load Reduction Summary

A summary of load reductions in each sub-watershed from each BMP group is provided in Tables 42-44.

Table 42. Summary of Annual Sediment Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/ Practice (lb/yr)
Annual Average Reduction Required for Norman: 3,644,083[1]							
Passive/non structural	31,548	53,731	31,832	2,874.0	2,721.0	16,562.0	139,268
Urban/Suburban	91,764.0	334,065.0	117,153.0	22,909.0	29,812.0	101,477.0	697,180
Rural	26,125.0	26,825.0	53,377.0	12,986.0	12,952.0	39,437.0	171,702
Unpaved Road Maintenance	17,447.0	755.0	11,654.0	5,906.0	8,901.0	31,496.0	76,159
Construction SW	88,573.5	400,221.0	97,321.5	40,459.5	22,963.5	28,431.0	677,970
Riparian Restoration	316.0	180.0	707.0	616.0	502.0	671.0	2,992
Stream Restoration	469,703	563,644	469,703	140,911	140,911	93,941	1,878,812
Totals	725,477	1,379,421	781,748	226,661	218,762	312,015	**3,644,083**

[1]Annual average reduction can be converted to MDL using the procedure described below.

Table 43. Summary of Annual Nitrogen Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Annual Average Reduction Required for Norman: 35,881[1]							
Passive/non structural	513.0	863.9	648.5	465.0	440.0	2,678.0	5,608.4
Urban/Suburban	2,216.0	7,918.0	1,901.0	178.0	232.0	797.0	13,242.0
Rural	1,791.0	1,577.0	3,381.0	835.0	911.0	2,717.0	11,212.0
Unpaved Road Maintenance	5.3	0.2	3.6	1.8	2.7	9.6	23.2
Construction SW	27.1	122.5	29.8	12.4	7.0	8.7	207.5
Riparian Restoration	0.1	0.1	0.2	0.2	0.2	0.2	0.9
Stream Restoration	1,396.8	1,676.1	1,396.8	419.0	419.0	279.4	5587.0
Totals	5,949	12,158	7,361	1,911	2,012	6,490	**35,881**

[1]Annual average reduction can be converted to MDL using the procedure described below.

Table 44. Summary of Annual Phosphorus Reductions from Implementation of the TMDL Compliance Plan.

BMP Group	Rock Creek (lb/yr)	Norman tribs to Little River (lb/yr)	Dave Blue Creek (lb/yr)	Jim Blue (lb/yr)	Clear Creek (lb/yr)	Lake Direct and Laterals (lb/yr)	Total/Practice (lb/yr)
Annual Average Reduction Required for Norman: 6,765[1]							
Passive/non structural	71.3	136.7	91.3	77.0	73.0	442.0	891.3
Urban/Suburban	2,542.0	9,356.0	2,008.0	150.0	196.0	673.0	14,925.0
Rural	1,099.0	978.0	2,076.0	507.0	562.0	1,678.0	6,900.0
Unpaved Road Maintenance	2.8	0.1	1.9	1.0	1.4	5.1	12.3
Construction SW	14.3	64.5	15.7	6.5	3.7	4.6	109.3
Riparian Restoration	0.1	0.0	0.1	0.1	0.1	0.1	0.5
Stream Restoration							
Totals	3,729	10,535	4,193	742	836	2,803	**22,838[2]**

[1]Annual average reduction can be converted to MDL using the procedure described below.
[2]To achieve TSS and phosphorus reduction requirements, reductions for nitrogen were in excess of that required.

The TMDL report expresses the WLA as a daily value. This daily value (an MDL) is calculated from the long term average using the following equations and the coefficient provided in Table 5.2 of the TMDL.

MDL = LTA * exp (Zů ï 0.5ů^2)
ů^2 = ln(1 + CV^2)

Where:

MDL= Maximum daily load limit (as kg/day)
LTA = Long-term average load
Z = Z-score statistic
CV = Coefficient of Variation
▯ = Standard Deviation
▯$^▯$ = Variance

This same calculation method can be used to convert annual average reduction values to daily maximum values.

Load reductions for sediment are primarily gained from stream bank stabilization, urban area BMPs and construction storm water improvement (Figure 14). However, load reductions for nutrients (nitrogen and phosphorus) are primarily gained from urban BMPs and rural BMPs (Figure 15 and 16).

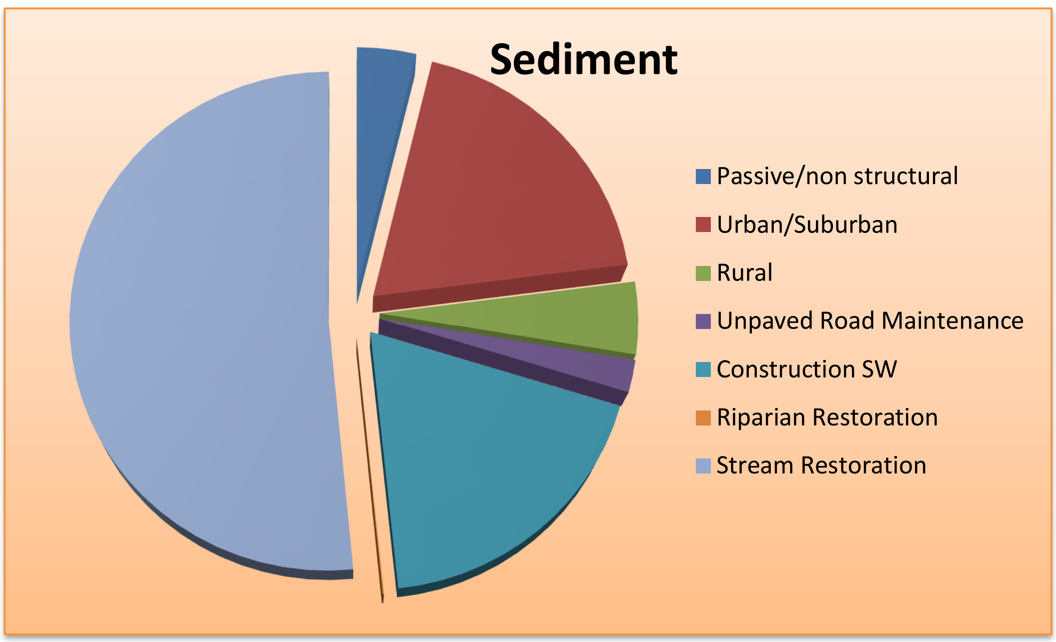

Figure 14. Sediment Reductions from Various Implementation Efforts.

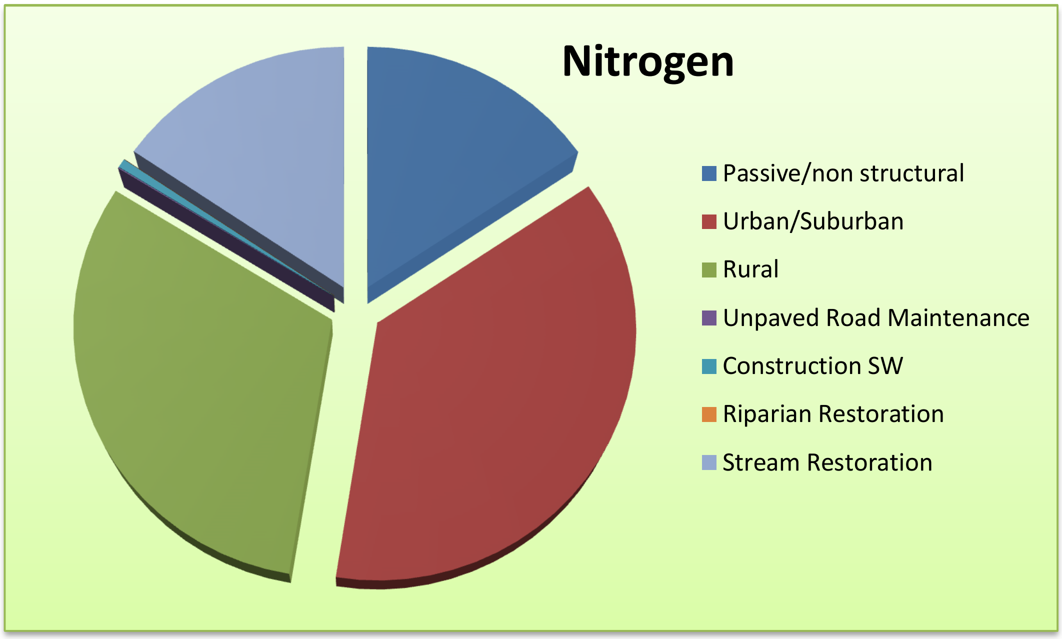

Figure 15. Nitrogen Reductions from Various Implementation Efforts.

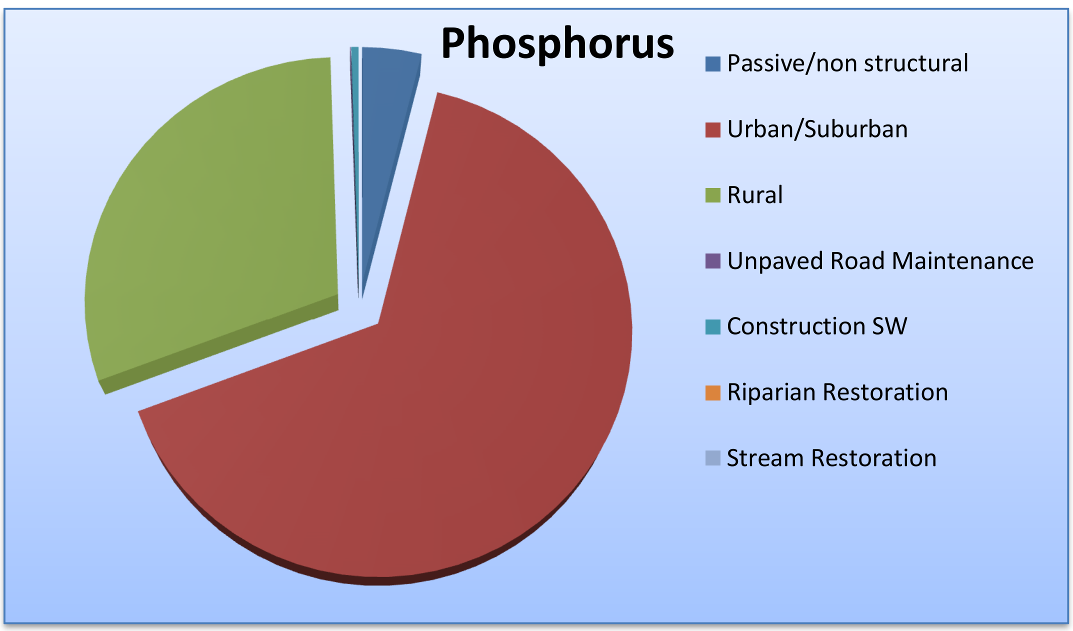

Figure 16. Phosphorus Reductions from Various Implementation Efforts.

9.0 Implementation Schedule and Adaptive Management

9.1 Schedule

The schedule portion of this TMDL Compliance Plan is designed to direct watershed management activities, including: BMP implementation to achieve load reductions, monitoring water quality to track goal attainment, continuing education efforts, etc. The Compliance Plan should be reviewed and updated at least every 5 years to ensure it is still relevant to the current conditions of the watershed and is in line with the data that has been collected over the past 5 years of monitoring. In order to help ensure success of the plan it is necessary to have a schedule prioritizing implementation and listing the tasks that need to be accomplished. The schedule provides 15 years for actions to be accomplished that will result in attainment of the pollutant load reductions assigned to the City of Norman MS4. The basic strategy to attain these goals is to begin monitoring immediately, address education and other non-structural BMPs in the first five years, reassess the loading status and the Compliance Plan applicability, phase in implementation of agricultural and structural BMPs over the next five years and be in attainment of the TMDL by the end of 2031.

Table 45. Implementation Schedule[1].

Action Item	Target Date for completion[1]
Begin Compliance Plan implementation	January 1, 2016[2]
Begin monitoring according to the Monitoring strategy	March 1, 2016[2]
Develop strategy to implement non-structural BMPs	June 30, 2016
Implement education based BMPs	December 31, 2016
Develop Strategy to Address Construction Storm Water	December 31, 2016
Implement Construction Storm Water Plan	June 30, 2017
Implement other non-structural BMPs	October 30, 2017
Review past three years of monitoring data, set baseline and adapt Compliance Plan as needed	June 30, 2019
Develop Strategy to implement rural BMPs	December 31, 2019
Develop Strategy to implement urban/suburban structural BMPs	June 30, 2020
Work with landowners and implement Riparian Buffer Restorations	December 31, 2020
Review past five years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2021
Implement first phase of rural BMPs in priority sub-watersheds	December 31, 2022
Implement first phase of urban/suburban BMPs in priority sub-watersheds	December 31, 2023
Implement second phase of rural BMPs in priority sub-watersheds	December 31, 2024
Review past ten years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2026
Implement second phase of urban/suburban BMPs in priority sub-watersheds	December 31, 2026
Restore/stabilize stream banks in priority sub-watersheds	December 31, 2028
Implement third phase of urban/suburban BMPs	December 31, 2029
Restore/stabilize remaining stream banks	December 31, 2030
Review past 15 years of monitoring data, assess compliance status and adapt Compliance Plan as needed.	June 30, 2031
Implementation complete and TMDL met	July 1, 2031[3]

[1] Participation by landowners and funding are an unknown and could have a significant effect on the schedule and implementation success.
[2] Following approval by ODEQ
[3] Success based on results of final review of data and measurable milestone achievement.

Due to the significant limitations of the HSPF modeling completed for the TMDL, and the lack of data that went into developing the model, it is likely that within the first five years of monitoring and program implementation that significant variation (discrepancy) will be found between the monitoring data collected for compliance and the TMDL findings. In such a case the ODEQ will be appealed to and revision of the TMDL recommended prior to any continuance of BMP implementation efforts.

Each year an annual report from the Norman MS4 is required for submission to the ODEQ. The annual report should include:

1. TMDL implementation report
    a. Status of implementation
    b. Actions taken
    c. Milestones achieved

See Appendix E of the TMDL for further details on reporting requirements

9.2 BMP Success Tracking and Interim Milestones

In order to monitor progress it is necessary to have measurable milestones that can be easily interpreted. The milestones that will be used for gauging progress on this WMP are provided in Table 46.

Table 46. Interim Measurable Milestones.

Milestone	Measurement method
Produce written strategy to implement non-structural BMPs	Strategy document produced
Implementation of educational BMPs	Watershed and other BMP brochures completed and distributed. Education campaign launched.
Produce written strategy to address construction storm water	Strategy document produced
Construction storm water program enhancements	Increased inspections, more BMPs utilized.
First year of monitoring completed	Data from monitoring analyzed and summarized with tables and charts
Non-structural BMP implementation	City ordinances and storm water programs enforced through adjustment of enforcement policies and inspection frequency. Number of citations increases.
First three years of monitoring complete	Data from monitoring analyzed and summarized with tables and charts
Produce written strategy to implement rural BMPs	Strategy document produced
Produce written strategy to implement urban/suburban structural BMPs	Strategy document produced
First five years of monitoring complete	Data from monitoring analyzed and summarized with tables and charts.
Compliance Plan reviewed and updated as needed.	Plan revised if required
Installation of urban/suburban structural BMP	Count of each completed installation, retrofit or significant maintenance occurrence. Acres treated with

Milestone	Measurement method
	BMP.
Rural BMP implementation	Count of each rural land owner that agrees to implement the required BMP and completes implementation. Acres treated with BMP.
Load reductions for sediment, TN or TP.	Monitoring data shows reductions of any pollutant are occurring
Riparian restoration	Acres of riparian area restored
Stream bank stabilization	Feet of stream bank restored
First ten years of monitoring complete	Data from monitoring analyzed and summarized with tables and charts.
TMDL met	Monitoring data and/or watershed modeling indicate the required load reductions have been achieved.

Success will be achieved if all of the above tasks are completed according to schedule. Future success will be measured by number of implementation projects that are completed. In addition, the Norman MS4 will continue their watershed monitoring program and continue to evaluate sediment and nutrient loading to Lake Thunderbird Reservoir. At the time when either the monitoring data or a watershed model (HSPF or similar) show that either the WLA for Norman (as provided in Table 5.5 of the TMDL Report) or the reduction goals have been achieved, the TMDL will be met.

9.3 Adaptive Management

As with any undertaking of this magnitude, obstacles will arise, and plans change. Therefore, every effort will be made to make this TMDL Compliance Plan dynamic, so that it can be easily adapted and adjusted to the needs of the watershed and the TMDL.

Every five years the plan will be reviewed to evaluate effectiveness of:

1. BMPs/Management practices,
2. Monitoring of loading,
3. Interim milestone completion, and
4. Education Outreach

Should any one of these components be found to be ineffective or insufficient then the plan will be revised accordingly to improve that component. After every 10 years the Compliance Plan will be updated. The update will include goals, revisions to key components that have changed over time as well as revisions needed to improve accomplishment of its goals.

9.4 Monitoring

A detailed Monitoring Plan is provided separately. A synopsis of the Monitoring Plan (included elsewhere in this package) is provided here. Norman will monitor water quality through sample collection, physio-chemical measurement and flow gauging at key sub-watershed locations representing upper watershed areas where urbanization is greatest and lower watershed areas that are more rural. Monitoring will occur at each key sub-watershed station on a monthly basis, with a minimum of four samples focused on high flow events. New stream gauges (water level loggers) will be installed in key sub-watersheds and rating curves developed to calculate loading in those sub-watersheds. The Norman MS4 will use loading data (TSS, TN (as NO3-NO2-N and TKN), TP) collected in the future to compare to the loading data collected historically in their program and data collected during TMDL development. Annual loading from the Norman MS4 will be calculated from monitoring data and compared to their WLA or reduction goals to determine compliance. Load reductions or increases will be determined using the loading data, control charts and trend analysis. Norman may use control charts and trend analysis to gauge if the watershed loading is responding positively or negatively to load reduction efforts.

BMP effectiveness will be monitored in at least two of three ways:

1. Implementation of BMPs on the ground, and
2. Modeling of reductions from BMPs implemented, or
3. Monitoring of sub-watershed loads.

In addition, a rotating storm water outfall sampling program will be implemented such that 40% of large outfalls (36 inch or greater) will be sampled at least once annually. Monitoring parameters will be the same for these outfalls as for the sub-watershed monitoring locations.

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Appendix A

Data and Modeling

Soil Sample Location	Nitrogen (mg/kg)	Phosphorus (mg/Kg)	Nitrogen (mg/lbs)	Phosphorus (mg/lbs)	Nitrogen (lb/lbs)	Phosphorus (lb/lbs)
DB-1	170	210	77.11079	95.25451098	0.00017	0.00021
LR-3	370	220	167.8294	99.79044008	0.00037	0.00022
WEC	450	130	204.1168	58.96707823	0.00045	0.00013
Little River @ Franklin	330	190	149.6857	86.18265279	0.00033	0.00019
Rock Creek @ 60th	210	56	95.25451	25.40120293	0.00021	0.000056
Average	306	161.2	138.7994	73.119177	0.000306	0.0001612

Unpaved road Calculations Estimated Sediment Loss: 485 lb/mi from 1 inch rain event

Lake Thunderbird WS

Sub-Watershed	Length of Unpaved Roads (ft)	Length of Unpaved Roads (mi)	Sediment loss from 1 inch rain event (lbs)*	Annual Sediment loss (6 events)	Sediment: Annual Reduction from Maintenance measures on half of roads (lbs)**	Nitrogen: Annual Load Reduction	Phosphorus: Annual Load Reduction
Rock Creek	126628	24.0	11631.5	69789.3	17447.3	5.3	2.8
Little River (Norman portion)	5479	1.0	503.3	3019.7	754.9	0.2	0.1
Dave Blue Creek	84581	16.0	7769.3	46615.7	11653.9	3.6	1.9
Jim Blue Creek	42862	8.1	3937.1	23622.8	5905.7	1.8	1.0
Clear Creek	64605	12.2	5934.4	35606.2	8901.5	2.7	1.4
Lake direct and Laterals	228593	43.3	20997.7	125985.9	31496.5	9.6	5.1
Total		104.7	50773.3	304639.5	76159.9	23.3	12.3

* Sediment loss from gravel roads ranges from over 1300 lb/mile to as little as 140 lb/mile (for well consturcted and maintained roads). Roads in the watershed were assumed to be in fairly good condition with a rate of 485 lb/mi. Data form Center for Dirt and Gravel Road studies (Penn State).

**Implmentation of maintenance measures can reduce sediment run-off by more than 75%. Reduction of 50% is assummed for this study

Riparian Restoration Load Reduced per acre 0.098 tons

Sub-Watershed	Length Impacted (ft)	40% Length Restored (ft)	Acres Restored	Load Recuction (tons)	Sediment Load Reduced (lbs)	Nitrogen Load Reduced (lbs)	Phosphorus Load Reduced (lbs)
Rock Creek	1757	702.8	1.61	0.16	316.23	0.10	0.05
Little River (Norman portion)	1000	400	0.92	0.09	179.98	0.06	0.03
Dave Blue Creek	3926	1570.4	3.61	0.35	706.61	0.22	0.11
Jim blue Creek	3422	1368.8	3.14	0.31	615.90	0.19	0.10
Clear Creek	2789	1115.6	2.56	0.25	501.97	0.15	0.08
Lake Direct and Laterals	3728	1491.2	3.42	0.34	670.97	0.21	0.11
Totals					**2991.65**	**0.92**	**0.48**

Overall Bank Erosion Estimates

Stream	Stream Length (ft)	Stream Length (miles)	% stream affected	Stream Length Affected (ft)	Bank Height (ft)	% Gravel/Cobble	Erosion Rate (ft/year)	Bank Volume Lost (ft3)	lbs bank lost	lbs soil/sediment lost	tons sediment	tons/mi of overal stream	lbs sed/ft eroded bank
Clear Creek	23082.95	4.37	0.17	3927.4	10.42	0.00	0.25	10,227.6	939,203.5	939,203.5	469.6	107.4	239.14
Dave Blue Creek	40328.73	7.64	0.17	6861.7	10.42	0.00	0.25	17,868.9	1,640,903.2	1,640,903.2	820.5	107.4	239.14
Little River (middle)	68270.40	12.93	0.44	30263.6	16.80	0.00	0.25	127,107.0	11,672,232.8	11,672,232.8	5,836.1	451.4	385.69
Elm Creek	8342.22	1.58	0.19	1609.6	22.9	0.0	0.25	9,221.6	846,818.9	846,818.9	423.4	268.0	526.11
Hog Creek	63588.46	12.04	0.08	5116.8	4.21	0.00	0.25	5,383.3	494,353.0	494,353.0	247.2	20.5	96.61
Jim Blue Creek	22014.15	4.17	0.17	3745.6	10.42	0.00	0.25	9,754.1	895,716.1	895,716.1	447.9	107.4	239.14
Little River (upper)	57446.40	10.88	0.39	22404.1	10.63	0.00	0.25	59,557.6	5,469,170.3	5,469,170.3	2,734.6	251.3	244.11
North Fork Little River	52656.83	9.97	0.38	19815.2	14.65	0.00	0.25	72,573.0	6,664,378.2	6,664,378.2	3,332.2	334.1	336.33
Rock Creek	42144.37	7.98	0.52	21888.9	10.22	0.00	0.25	55,908.0	5,134,032.1	5,134,032.1	2,567.0	321.6	234.55
West Branch Hog Creek	35162.64	6.66	0.08	2829.5	4.21	0.00	0.25	2,976.8	273,363.4	273,363.4	136.7	20.5	96.61
West Elm Creek	47032.21	8.91	0.19	9074.6	22.92	0.00	0.25	51,990.0	4,774,240.7	4,774,240.7	2,387.1	268.0	526.11
Willow Branch	17669.20	3.35	No Reaches										

Jim Blue Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	0.6	0.5	0.0	0.0	0.0
Pet Waste Education	33.2	4.3	0.0	289.4	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	0.0	0.0	0.0	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	0.0	0.0	0.0	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
OSDS Programs - Surface	431.1	71.9	2,874.3	4,628.8	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**465**	**77**	**2,874**	**4,918**	**0**
Storm Load Reduction	**34**	**5**	**0**	**289**	**0**
Non-Storm Load Reduction	**431**	**72**	**2,874**	**4,629**	**0**
Reductions to Groundwater Loads					
Urban Land	5	0	0	0	0
OSDSs	-532	-12	0	0	0
Total Groundwater Load Reduction	**-527**	**-12**	**0**	**0**	**0**

Clear Creek Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	0.6	0.6	0.0	0.0	0.0
Pet Waste Education	31.4	4.1	0.0	273.3	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	0.0	0.0	0.0	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	0.0	0.0	0.0	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
OSDS Programs - Surface	408.1	68.0	2,721.0	4,382.0	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**440**	**73**	**2,721**	**4,655**	**0**
Storm Load Reduction	**32**	**5**	**0**	**273**	**0**
Non-Storm Load Reduction	**408**	**68**	**2,721**	**4,382**	**0**
Reductions to Groundwater Loads					
Urban Land	6	0	0	0	0
OSDSs	-504	-11	0	0	0
Total Groundwater Load Reduction	**-498**	**-11**	**0**	**0**	**0**

Lake Thunderbird Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	2.8	2.5	0.0	0.0	0.0
Pet Waste Education	191.6	25.0	0.0	1,665.8	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	0.0	0.0	0.0	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	0.0	0.0	0.0	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
OSDS Programs - Surface	2,484.4	414.1	16,562.9	26,673.4	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**2,679**	**442**	**16,563**	**28,339**	**0**
Storm Load Reduction	**194**	**28**	**0**	**1,666**	**0**
Non-Storm Load Reduction	**2,484**	**414**	**16,563**	**26,673**	**0**
Reductions to Groundwater Loads					
Urban Land	25	1	0	0	0
OSDSs	-3,066	-68	0	0	0
Total Groundwater Load Reduction	**-3,041**	**-67**	**0**	**0**	**0**

Little River Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	37.3	33.1	0.0	0.0	0.0
Pet Waste Education	54.6	7.1	0.0	474.4	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	12.6	1.9	367.1	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	551.4	59.9	52,198.8	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	66.4	11.1	221.5	50,273.3	0.0
OSDS Programs - Surface	141.6	23.6	944.2	1,520.5	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**864**	**137**	**53,953**	**52,268**	**0**
Storm Load Reduction	**689**	**108**	**52,787**	**25,611**	**0**
Non-Storm Load Reduction	**175**	**29**	**1,166**	**26,657**	**0**
Reductions to Groundwater Loads					
Urban Land	334	10	0	0	0
OSDSs	-175	-4	0	0	0
Total Groundwater Load Reduction	**159**	**6**	**0**	**0**	**0**

Rock Creek Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	8.2	7.3	0.0	0.0	0.0
Pet Waste Education	45.7	6.0	0.0	397.5	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	7.3	1.1	211.7	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	318.0	34.6	30,103.3	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	15.2	2.5	442.9	11,465.3	0.0
OSDS Programs - Surface	118.6	19.8	790.5	1,273.1	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**542**	**76**	**31,207**	**13,136**	**0**
Storm Load Reduction	**416**	**55**	**30,365**	**6,130**	**0**
Non-Storm Load Reduction	**126**	**21**	**841**	**7,006**	**0**
Reductions to Groundwater Loads					
Urban Land	612	3	0	0	0
OSDSs	-146	-3	0	0	0
Total Groundwater Load Reduction	**465**	**0**	**0**	**0**	**0**

Dave Blue Future Practices

This table summarizes the ***Net pollutant load and runoff reductions*** achieved by practices included in the **"Future Practices"** tab. The reductions presented in this table include only the benefits beyond the practices already in place in the Existing Conditions. So, for example, an improvement to an existing education program would include only the ***additional load reduction*** achieved by improving the program.The purple cells summarize the total load reduction from all practices, while the grey cells report the benefits of individual practices. Note that, while the summary table presents only the Total Surface Water loads, this table also breaks out the reductions from loads during storm events (i.e., the Storm Load) and the loads occuring during dry weather conditions (i.e., the Non-Stormwater Load). In some cases, a *negative load reduction* may be reported. This represents an *increase* in load, which would occur if a program or practice was made *less* effective in the future condition.

Net Benefit (Load Reductions) of Future Practices

	TN (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Bacteria (billion/year)	Runoff Reduction (acre-ft/yr)
Reductions to Surface Water Loads					
Lawn Care Education Surface	6.9	6.1	0.0	0.0	0.0
Pet Waste Education	86.5	11.3	0.0	752.5	0.0
Erosion and Sediment Control	0.0	0.0	0.0	0.0	0.0
Street Sweeping	7.3	1.1	212.0	0.0	0.0
Street Sweeping - Sanding	0.0	0.0	0.0	0.0	0.0
Structural Stormwater Management Practices	0.0	0.0	0.0	0.0	0.0
Riparian Buffers	0.0	0.0	0.0	0.0	0.0
Catch Basin Cleanouts	317.8	34.5	30,086.8	0.0	0.0
Marina Pumpouts	0.0	0.0	0.0	0.0	0.0
Urban Downsizing	0.0	0.0	0.0	0.0	0.0
Redevelopment With Improvements	0.0	0.0	0.0	0.0	0.0
Stormwater Retrofits	0.0	0.0	0.0	0.0	0.0
Illicit Connection Removal	0.0	0.0	0.0	0.0	0.0
CSO Repair/ Abatement	0.0	0.0	0.0	0.0	0.0
SSO Repair/ Abatement	5.5	0.9	36.8	4,173.3	0.0
OSDS Programs - Surface	224.5	37.4	1,496.4	2,409.8	0.0
Channel Protection	0.0	0.0	0.0	0.0	0.0
Point Source Reduction	0.0	0.0	0.0	0.0	0.0
Total Surface Water Reduction	**648**	**91**	**31,832**	**7,336**	**0**
Storm Load Reduction	**421**	**54**	**30,317**	**2,839**	**0**
Non-Storm Load Reduction	**227**	**38**	**1,515**	**4,496**	**0**
Reductions to Groundwater Loads					
Urban Land	62	2	0	0	0
OSDSs	-277	-6	0	0	0
Total Groundwater Load Reduction	**-215**	**-4**	**0**	**0**	**0**

Appendix B

BMP Reduction Efficiency Summary

BMP Sources:
Center for Watershed Protection
National BMP Database
University of Maryland – Mid Atlantic Water program
USEPA - National Management Measures
Bureau of Watershed Conservation - PA Dept of Env. Protection

Urban / Suburban

Stormwater Retrofits	Total Nitrogen Removal Effeciencies (%) (CWTM)	Total Nitrogen Removal Effeciencies (%) (UoM)	Total Nitrogen Removal Effeciencies (%) (BMP Database)	Average Nitrogen Removal (%)	Total Phosphorus Removal Effeciencies (%) (CWTM)	Total Phosphorus Removal Effeciencies (%) (UoM)	Total Phosphorus Removal Effeciencies (%) (BMP Database)	Average Phosphorus Removal (%)	Total TSS Removal Effeciencies (%) (CWTM)	Total TSS Removal Effeciencies (%) (UoM)	Total TSS Removal Effeciencies (%) (BMP Database)	Average TSS Removal (%)
Wetland	55	20	0	25	75	45	28	49	85	60	62	69
Wet Pond	40	20	26	29	75	45	56	59	85	60	71	72
Infiltration Practices	15	80*	--	15	25	85*	--	25	50	95*	--	50
Bioretention	60	25	21	35	50	45	0	32	50	55	74	60
Dry Extended Detention Pond	10	20	0	10	15	20	22	19	70	60	66	65
Dry Swale (bioswale, WQ swale)	35	70	0	35	40	75	0	38	40	80	22	47
stream bank stabilization	--	--	--	--	--	--	--	--	--	--	--	--
Riparian buffers		25	--	25	--	50	--	50	--	50	--	50
Grass Filter Strips	0	0	16	5	0	0	0	0	0	0	57	19
Sheet Flow to Open Space (excluding riparian buffers)	0	--	--	0	0	--	--	0	0	--	--	0
Grass (open) Channel	20	10	--	15	15	10	--	13	40	50	--	45
Raintanks and Cisterns	0	25	--	13	0	45	--	23	0	55	--	28
Wet Swale	35		23	29	40	--	8	24	40	--	24	32
Media Filter (mostly sand filters)	--	--	15	15	--	--	41	41	--	--	83	83
Porous Pavement	--	--	NA	--	--	--	43	43	--	--	72	72
Rain gardens / Rooftop Disconnection	0	25	--	13	0	45	--	23	0	55	--	28
Wetland/Retention Pond	--	--	16	16	--	--	46	46	--	--	71	71
Composite/treatment	--	--	29	29	--	--	62	62	--	--	79	79

* Data only avaliable for A/B soil types

Agriculture/Rural

Stormwater BMPs	Total Nitrogen Removal Effeciencies (%) (PDEP)	Total Nitrogen Removal Effeciencies (%) (UoM)	Total Nitrogen Removal Effeciencies (%) (BMP Database)	Average Nitrogen Removal (%)	Total Phosphorus Removal Effeciencies (%) (PDEP)	Total Phosphorus Removal Effeciencies (%) (UoM)	Total Phosphorus Removal Effeciencies (%) (BMP Database)	Average Phosphorus Removal (%)	Total TSS Removal Effeciencies (%) (PDEP)	Total TSS Removal Effeciencies (%) (UoM)	Total TSS Removal Effeciencies (%) (BMP Database)	Average TSS Removal (%)
Cover crops*	43	22	--	33	32	11	--	22	15	15	--	15
rotational grazing	--	10	--	--	--	24	--	--	--	30	--	--
alternate water sources	--	33	--	--	--	0	--	--	--	0	--	--
fencing	--	5	--	--	--	8	--	--	--	10	--	--
nutrinet management plans	--	12	--	--	--	10	--	--	--	0	--	--
riparian buffers	--	48	--	--	--	0	--	--	--	0	--	--
stream bank stabilization	--	--	--	--	--	--	--	--	--	--	--	--
Conservation Tilage	50	7	--	29	38	18	--	28	64	31	--	32

* Average of all types of cover crops listed in CAST

Passive

Stormwater BMPs	Total Nitrogen Removal Effeciencies (%) (CWTM)	Total Nitrogen Removal Effeciencies (%) (UoM)	Total Nitrogen Removal Effeciencies (%) (BMP Database)	Average Nitrogen Removal (%)	Total Phosphorus Removal Effeciencies (%) (CWTM)	Total Phosphorus Removal Effeciencies (%) (UoM)	Total Phosphorus Removal Effeciencies (%) (BMP Database)	Average Phosphorus Removal (%)	Total TSS Removal Effeciencies (%) (CWTM)	Total TSS Removal Effeciencies (%) (UoM)	Total TSS Removal Effeciencies (%) (BMP Database)	Average TSS Removal (%)
Detention Ordinance	--	--	--	--	--	--	--	--	--	--	--	--
Enforce WQPZ Ord	70	--	--	--	--	--	--	--	--	--	--	--
Enforce Fertilizer Ord	--	--	--	--	--	--	--	--	--	--	--	--
Pet waste Education	--	--	--	--	--	--	--	--	--	--	--	--
Watershed education	--	--	--	--	--	--	--	--	--	--	--	--
Enforce construction SW	--	--	--	--	--	--	--	--	--	--	--	--

Appendix C

BMP Summary Sheets

Sources:
Center for Watershed Protection
USEPA

ST-1

Stormwater Treatment Options

EXTENDED DETENTION

This option relies on 12 to 24 hour detention of stormwater runoff after each rain event. An under-sized outlet structure restricts stormwater flow so it backs up and is stored within a pond or wetland. The temporary ponding enables particulate pollutants to settle out and reduces the effective shear stress on downstream banks. Extended Detention (ED) differs from stormwater detention, which is used for peak discharge or flood control purposes and often detains flows for just a few minutes or hours. ED is normally combined with other stormwater treatment options such as wet ponds and constructed wetlands to enhance retrofit performance and appearance (Figure 1). The most common design variations for ED retrofits include:

- Micropool Extended Detention (Water Quality)
- Micropool Extended Detention (Channel Protection)
- Wet Extended Detention Pond
- ED Wetlands

Schematics of each ED retrofit design variation are provided in Figure 2. ED is an ideal stormwater treatment option because it is cost-effective, versatile and safe, and is also the preferred stormwater treatment option for providing downstream channel protection.

Typical ED Retrofit Applications

ED is an attractive option to retrofit existing ponds (SR-1), and can also be utilized for other storage retrofits with the possible exception of the conveyance system (SR-4). ED is generally not suited for on-site retrofit applications. Dry ED ponds should seldom be considered as a standalone retrofit strategy, unless downstream channel protection is a priority.

Figure 1: This shallow wetland was designed with extended detention. (Rolling Stone retrofit, Montgomery County, MD)

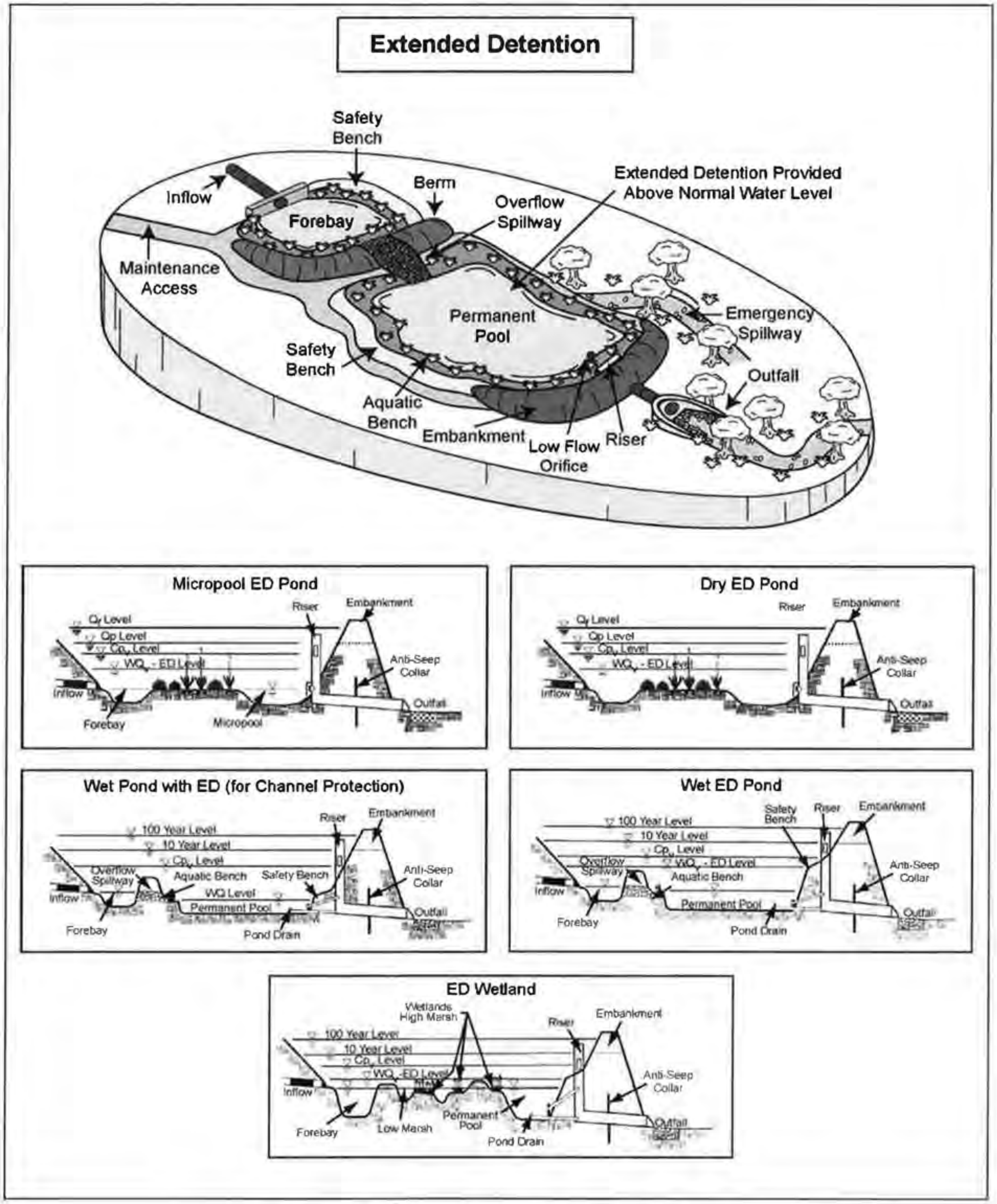

Figure 2: Extended Detention Schematics

ED Pollutant Removal Capability

ED ponds rely on gravitational settling as their primary pollutant removal mechanism. Consequently, they generally provide fair to good removal for particulate pollutants but low or negligible removal for soluble pollutants, such as nitrate and soluble phosphorus (Table 1). ED generally has the lowest overall pollutant removal rate of any stormwater treatment option. As a result, ED is normally combined with wet ponds or constructed wetlands to maximize pollutant removal rates.

Several site-specific factors can have a strong influence on ED pollutant removal rates. Designers should review the design factors in Table 2 to compute the expected pollutant removal rates for the individual retrofit using the design point method.

Table 1: Range of Reported Removal Rates for Dry Extended Detention Ponds			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	50	70	80
Total Phosphorus	15	20	30
Soluble Phosphorus	-10	-10	40
Total Nitrogen	25	25	35
Organic Carbon	15	25	35
Total Zinc	25	30	60
Total Copper	30	30	50
Bacteria	0	40	90
Hydrocarbons	40	70	80
Chloride	0	0	0
Trash/Debris	65	80	85
See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25th and 75th quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for ED Retrofits		
Design Factors	**X**	**Points**
Wet ED or Multiple Cell Design		+ 2
Exceeds target WQv by more than 25%		+ 1
Exceeds target WQv by more than 50%		+ 2
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay		+ 1
Constructed wetland elements included in design		+ 1
On-line design		- 1
Flow path less than 1:1		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max. of 5 points)		

An important factor influencing pollutant removal rates is whether ED is combined with another treatment option, such as a wet pond or stormwater wetland. As a general rule, if more than 50% of the target WQv is provided by a wet pond or constructed wetland, then the higher pollutant removal rate for the treatment option should be applied (see Profile Sheets ST-2 and ST-3).

Other Stormwater Benefits Provided by ED

ED retrofits can provide other stormwater benefits to address other restoration objectives:

Recharge: Dry ED pond retrofits can provide modest groundwater recharge benefits. Strecker *et al.* (2004) reported up to 30% runoff reduction for a large population of monitored dry ED ponds, presumably due to infiltration through the bottom soils of the basin. Recharge benefits will be reduced if the ED pond has impermeable or compacted soils, a liner, or a permanent pool of water.

Channel Protection: ED ponds are the primary means to protect downstream channels if full channel protection storage can be provided at the retrofit site. It should be noted, however, that channel protection normally requires about 20-40% more storage volume than that needed for water quality treatment (see Figure 1.3 in Chapter 1). Consequently, designers may have difficulty finding adequate space to retrofit channel protection storage at tight sites. Guidance on estimating channel protection storage volume for individual retrofit sites can be found in Appendix C.

ST-2	Stormwater Treatment Options	
	WET PONDS	

Wet ponds consist of a permanent pool of standing water that promotes a better environment for gravitational settling, biological uptake and microbial activity (Figure 1). Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate.

Wet pond retrofits can be employed in several different design configurations:

- Wet Pond
- Wet ED Pond
- Wet Pond with ED for Channel Protection
- Pond Wetland System

Figure 2 illustrates each wet pond design variation. Wet ponds are an ideal retrofit treatment option due to their high and reliable pollutant removal performance, community acceptance and amenity value. Wet ponds can also provide channel protection above the permanent pool in some retrofit situations.

Figure 1: Wet ponds can provide additional pollutant removal through settling

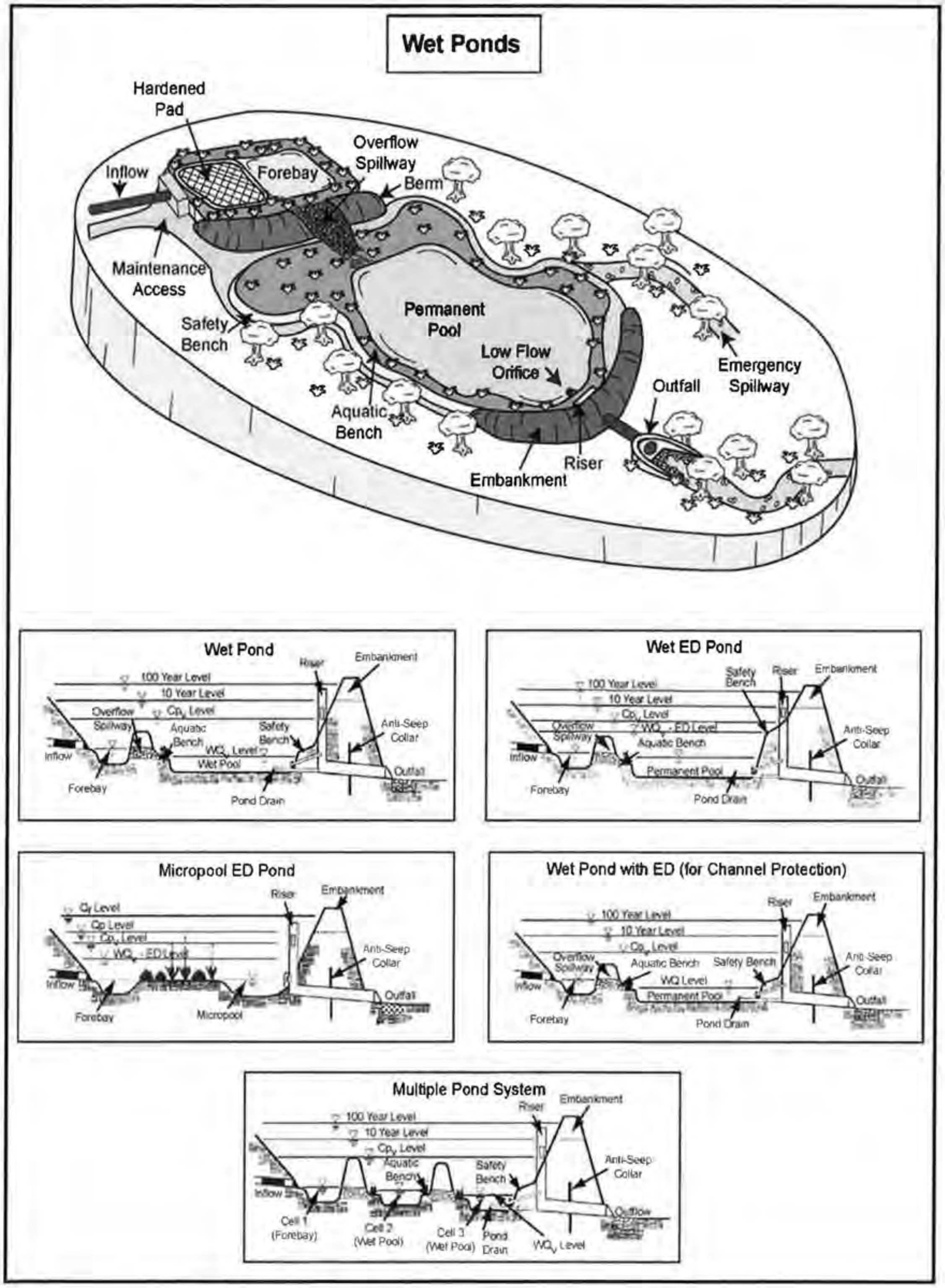

Figure 2: Schematics for various wet pond variations

Typical Retrofit Applications

Wet ponds can be used as either a primary or secondary treatment option in most storage retrofit situations. Wet ponds are not recommended for conveyance retrofits (SR-4) and most on-site retrofit applications.

Wet Pond Pollutant Removal Capability

Many pollutant removal mechanisms operate in the water column and bottom sediments of wet ponds including gravitational settling, algal uptake, adsorption, ultra-violet radiation and microbial processes. Many wet ponds have been intensively monitored in the past three decades and researchers consistently report moderate to high removal rates across the full range of stormwater pollutants (Table 1). Wet ponds generally have higher pollutant removal rates than other stormwater treatment options reviewed in this chapter.

Wet pond research has revealed many site-specific conditions and design factors than can enhance or detract from the median removal rates (Table 2). In general, the walkaway volume of a retrofit is when it cannot provide at least 35% of the target WQv. In addition, if more than 50% of the target water quality volume is provided by ED, the lower removal rates outlined in Profile Sheet ST-1 should be applied. Designers can review the design factors and site conditions in Table 2 to evaluate whether their individual retrofit design will perform better or worse than normal, using the design point method.

Other Stormwater Benefits Provided by Wet Ponds

Wet pond retrofits have limited potential to provide other stormwater benefits:

Groundwater Recharge: Due to their standing water and sealed bottoms, wet ponds do not offer much benefit in terms of groundwater recharge.

According to Strecker *et al.* (2004), wet ponds reduce incoming runoff volumes by less than 5%, most of which is accomplished by evaporation rather than soil infiltration.

Channel Protection: When site topography permits, extended detention can be stacked above the permanent pool to provide downstream channel protection. Designers should note that the CPv storage is typically 20 to 40% greater than the WQv storage so it is often hard to provide full channel protection at tight retrofit sites. Guidance on estimating the channel protection volume needed at individual retrofit sites can be found in Appendix C.

Table 1: Range of Reported Removal Rates for Wet Ponds			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	60	80	90
Total Phosphorus	40	50	75
Soluble Phosphorus	40	65	75
Total Nitrogen	15	30	40
Organic Carbon	25	45	65
Total Zinc	40	65	70
Total Copper	45	60	75
Bacteria	50	70	95
Hydrocarbons	60	80	90
Chloride	0	0	0
Trash/Debris	75	90	95
See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25^{th} and 75^{th} quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for Wet Pond Retrofits		
Design Factors	**X**	**Points**
Wet ED or Multiple Pond Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Exceeds target WQv by more than 25%		+ 1
Off-line design		+ 1
Flow path greater than 1.5 to 1		+ 1
Sediment forebay at major outfalls		+ 1
Wetland elements cover at least 10% of surface area		+ 1
Single cell pond		- 1
Flow path less than 1:1		- 1
On-line design		- 1
Pond SA/CDA ratio less than 2%		- 2
Does not provide full WQv volume		- 2
Pond intersects with groundwater		- 2
NET DESIGN SCORE (max of 5 points)		

ST-3

Stormwater Treatment Options

CONSTRUCTED WETLANDS

How Constructed Wetlands Work

Constructed wetlands are shallow depressions that receive stormwater inputs for treatment. Wetlands are typically less than one foot deep (although they have deeper pools at the forebay and micropool) and possess variable microtopography to promote dense and diverse wetland cover (Figure 1). Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity.

Constructed wetlands can be a stand-alone treatment option, or be combined with other stormwater treatment options in several configurations:

- Shallow Marsh
- ED Wetland
- Pond Wetland
- Wet Swales

Each constructed wetland design variation is illustrated in Figure 2.

Constructed wetlands are ideal because they replicate natural wetland ecosystems, provide efficient and reliable pollutant removal and have low construction costs (if ample space is available at the retrofit site). Well-designed stormwater wetlands enjoy widespread community acceptance, and possess high amenity and habitat value. Depending on site topography, constructed wetlands can also provide downstream channel protection when ED storage is stacked above the normal water level of the wetland.

Figure 1: This wetland was constructed to treat stormwater from a nearby commercial area.

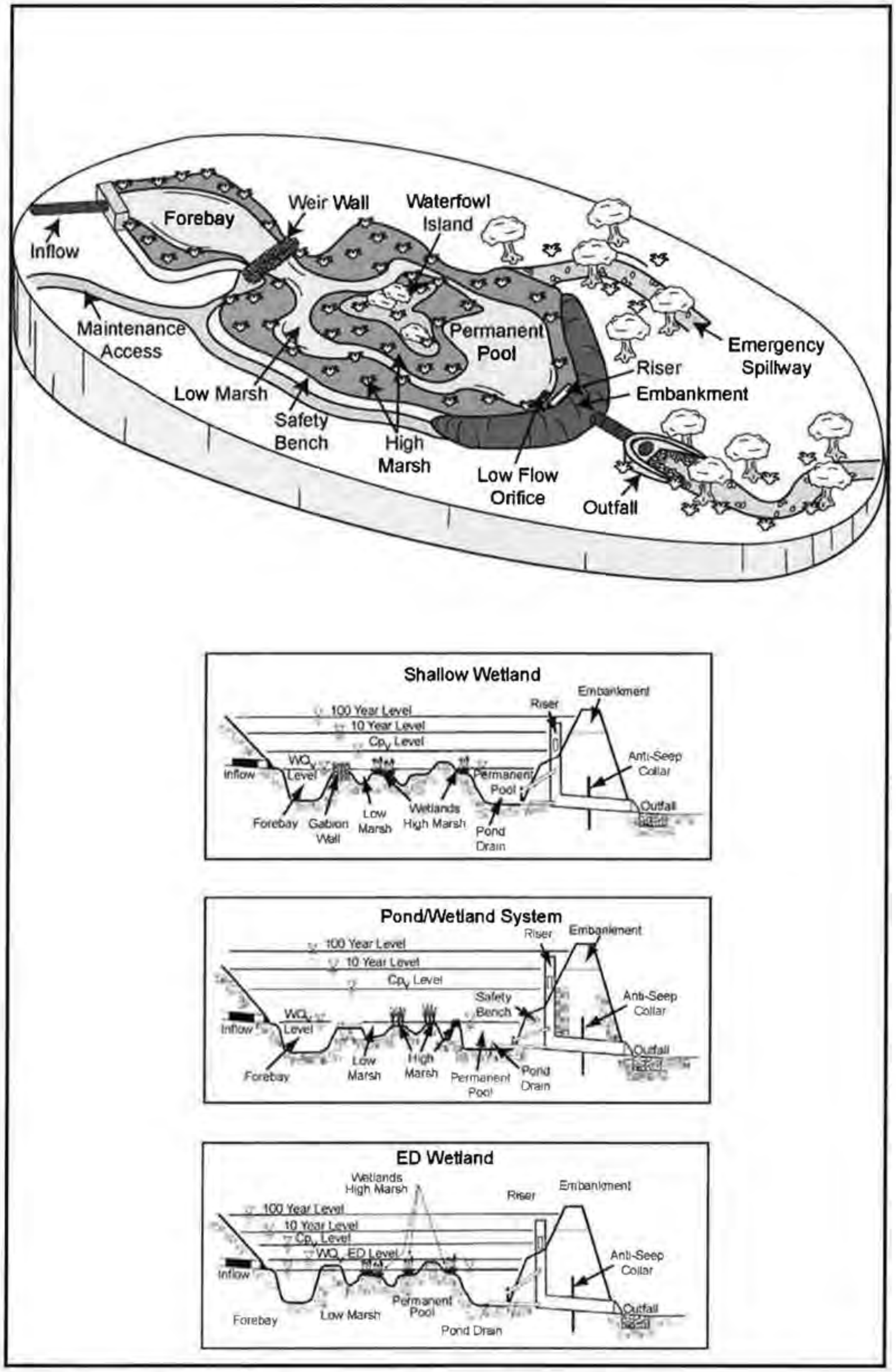

Figure 2: Schematics of three wetland variations

Typical Retrofit Applications for Constructed Wetlands

Constructed wetlands can be the primary or secondary form of stormwater treatment in the following storage retrofit applications:

- **SR-1** Excavate shallow wetland in bottom of pond or add aquatic benches to wet pond
- **SR-2** Create wooded wetlands above road crossings (often with ED)
- **SR-3** Divert runoff from pipe to shallow wetland treatment cells in floodplain
- **SR-4** Install offline shallow wetland cells or in-line wet swales in the conveyance system
- **SR-5** Install wetland cells in highway cloverleaf or create wet swales in highway right of way
- **SR-6** Create wetland treatment cell adjacent to large parking lots

Constructed wetlands are seldom used for on-site retrofit applications, although several may incorporate some wetland elements.

Pollutant Removal Capability of Constructed Wetlands

Constructed wetlands utilize a range of physical, chemical, microbial and biological mechanisms to remove pollutants. Wetland vegetation and sediments provide a growth media for microbes and filter and settle pollutants attached to sediments. Researchers have studied a large population of stormwater wetlands, and have concluded their removal rates are similar to wet ponds, but are somewhat more variable, especially for nutrients and organic carbon (Table 1).

Key design factors and site conditions that increase or decrease pollutant removal rates within constructed wetland retrofits are outlined in Table 2. The recommended walkaway volume for wetland retrofits is when they provide less than 35% of the target WQv. Constructed wetlands that allocate more than 50% of their storage for ED should use the lower removal rates for ED ponds shown in Profile Sheet ST-1. The median pollutant removal rates at individual retrofit sites can be adjusted to account for runoff capture volume and other site factors using the design point method (Table 2).

Other Stormwater Benefits Provided by Constructed Wetlands

Constructed wetlands can offer additional stormwater benefits:

Runoff Reduction: Constructed wetlands are capable of reducing 5 to 10% of the incoming runoff volume through evaporation and seepage losses, according to Strecker *et al* (2004). This minor reduction is not likely to provide a meaningful groundwater recharge benefit.

Channel Protection: Designers can stack ED above constructed wetlands to provide channel protection storage, although the frequent changes in water levels will degrade the quality and density of wetland cover. Designers can avoid the "bounce" problem by limiting the vertical depth of extended detention. Guidance on estimating the channel protection volume needed at an individual retrofit site is provided in Appendix C.

Table 1: Range of Reported Removal Rates for Constructed Wetlands			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	45	70	85
Total Phosphorus	15	50	75
Soluble Phosphorus	5	25	55
Total Nitrogen	0	25	55
Organic Carbon	0	20	45
Total Zinc	30	40	70
Total Copper	20	50	65
Bacteria	40	60	85
Hydrocarbons	50	75	90
Chloride	0	0	0
Trash/Debris	75	90	95
See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25th and 75th quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for Wetland Retrofits		
Design Factors	**X**	***Points***
Pond-Wetland or Multiple Cell Design		+ 2
Pond-Wetland or Multiple Cell Design		+ 2
Exceeds target WQv by more than 50%		+ 2
Complex wetland microtopography		+ 2
Exceeds target WQv by more than 25%		+ 1
Flow path greater than 1.5 to 1		+ 1
Wooded wetland design		+ 1
Off-line design		+ 1
No forebay or pretreatment features		- 1
Wetland intersects with groundwater		- 1
Flow path is less than 1:1		- 1
No wetland planting plan specified		- 2
Wetland SA to CDA ratio is less than 1.5%		- 2
Does not provide full WQv volume		- 2
NET DESIGN SCORE (max of 5 points)		

ST-4

Stormwater Treatment Options

BIORETENTION

Bioretention is a landscaping feature adapted to treat stormwater runoff at retrofit sites (Figure 1). Individual bioretention areas serve drainage areas of one acre or less. Surface runoff is directed into a shallow landscaped depression that incorporates many of the pollutant removal mechanisms that operate in forested ecosystems. The filter is composed of an 18 to 48 inch deep sand/soil bed with a surface mulch layer. During storms, runoff temporarily ponds six to nine inches above the mulch layer and then rapidly filters through the bed. Normally, the filtered runoff is collected in an underdrain and returned to the storm drain system (Figure 2). The underdrain consists of a perforated pipe in a gravel jacket installed along the bottom of the filter bed.

In other cases, bioretention can be designed to infiltrate runoff into native soils. This can occur at sites with highly permeable soils, a low groundwater table, and a low risk of groundwater contamination. This design features the use of a "partial exfiltration" system that promotes greater groundwater recharge. Underdrains are only installed beneath a portion of the filter bed or are eliminated altogether, thereby increasing stormwater infiltration.

Figure 1: Bioretention created in a parking lot turn-around

Bioretention creates an ideal environment for filtration, biological uptake, and microbial activity, and provides moderate to high pollutant removal. Bioretention can become an attractive landscaping feature with high amenity value and community acceptance. In the right landscape setting, bioretention can be a cost effective and flexible retrofit option.

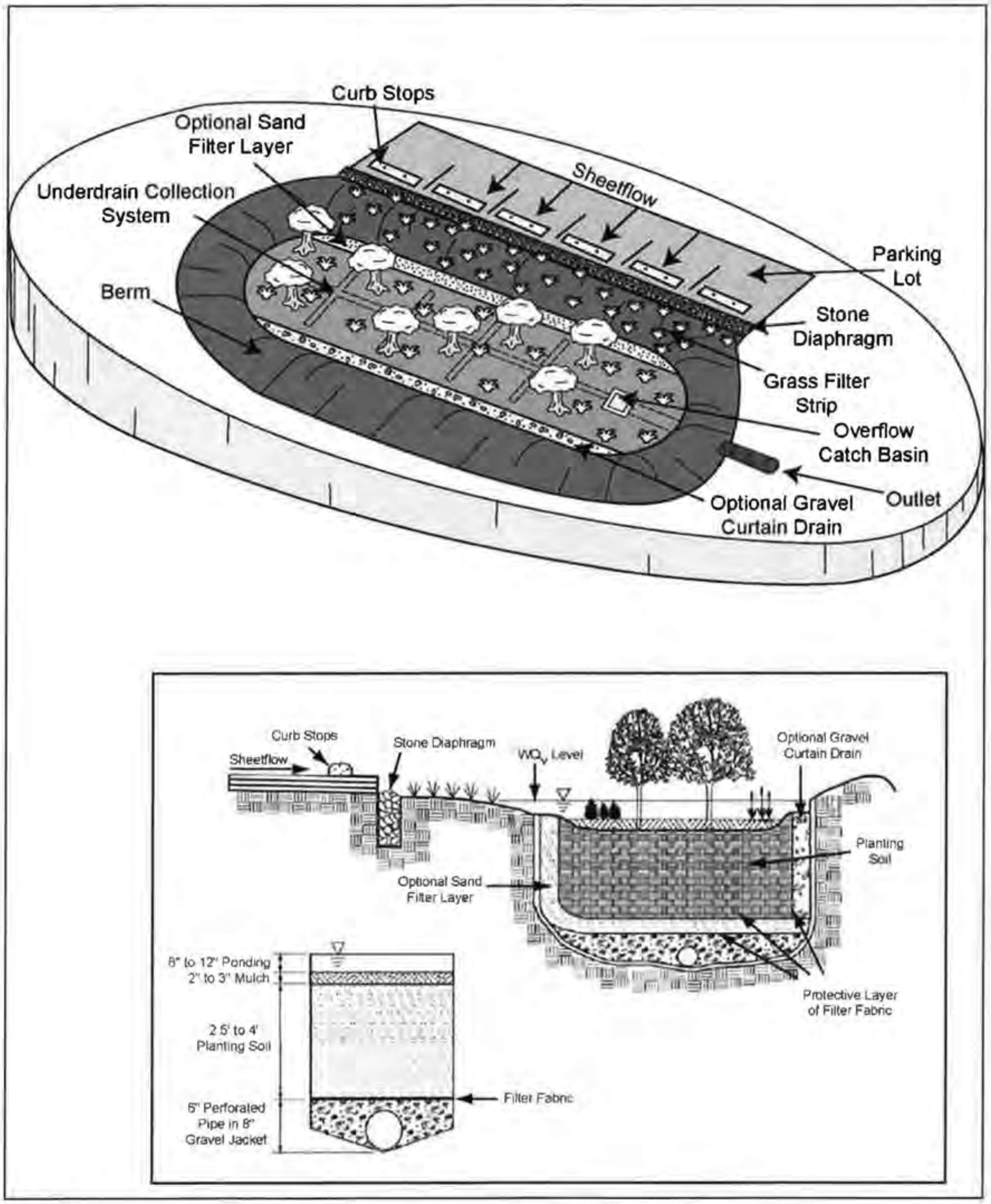

Figure 2: Bioretention schematic with underdrain

Typical Retrofit Applications for Bioretention

Bioretention is an extremely versatile stormwater treatment option for both storage and on-site retrofits that can fit within unused land at a variety of different sites. Common bioretention retrofit opportunities include:

- **SR-1** Install bioretention in bottom of dry pond
- **SR-3** Split flows from smaller pipes to a large bioretention area
- **SR-4** Create series of on-line or off-line bioretention cells
- **SR-5** Install two-cell bioretention area
- **SR-6** Divert flow to two-cell bioretention area
- **OS-7** Install bioretention w/ underdrain to treat hotspot
- **OS-8** Install bioretention within parking lot islands or perimeter
- **OS-9** Incorporate bioretention in streetscapes, tree pits, cul-de-sacs or traffic calming measures
- **OS-10** Install rain-garden to treat residential or commercial rooftop runoff
- **OS-12** Utilize bioretention as a landscape feature

Estimated Pollutant Removal by Bioretention

Until recently, only a handful of monitoring studies had measured the pollutant removal performance of bioretention areas. The most recent studies indicate that bioretention provides effective pollutant removal for many pollutants as a result of sedimentation, filtering, plant uptake, soil adsorption, and microbial processes. Table 1 summarizes bioretention pollutant removal rates for a variety of common stormwater pollutants.

The recommended walkaway volume for bioretention is about 50% of the target water quality volume. Another notable factor is whether the underlying soils have enough permeability to dispense with an underdrain. If an underdrain is not needed, pollutant removal will be enhanced by the greater infiltration of runoff into the soil and may approach the higher pollutant removal rates achieved by infiltration practices (see Profile Sheet ST-6). From the standpoint of nutrient removal, it is strongly recommended that the phosphorus index of topsoil mixed into the bioretention media be tested.

Table 2 can be used to adjust the median removal rates for individual retrofit projects by using the design point method.

Other Stormwater Benefits Provided by Bioretention

Bioretention retrofits can provide important stormwater benefits under certain site conditions.

Recharge: Bioretention has been shown to reduce runoff volume by 35 to 50% through evapotranspiration and infiltration of runoff, according to Hunt *et al.* (2006) and Traver (2006). Runoff reduction exceeding 90% has been reported for deeper filter beds that lack underdrains and are situated on permeable soils (Horner *et al.*, 2003).

Channel Protection: The feasibility of storing the channel protection volume within bioretention areas has not yet been demonstrated, although the impressive runoff reduction rates suggests that widespread use of bioretention could be an effective element of a larger strategy to protect downstream channels from erosion.

Table 1: Range of Reported Removal Rates for Bioretention Areas			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	15*	60*	75*
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	0	50
Total Nitrogen	40	45	55
Total Zinc	40	80	95
Total Copper	40	80	100
Bacteria	20	50	80
Hydrocarbons	80	90	95
Chloride	0	0	0
Trash/Debris	80*	90*	95*
* Adequate pretreatment must be provided to reduce sediment loads to bioretention areas or clogging and practice failure may result See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25th and 75th quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for Bioretention Retrofits		
Design Factors	**X**	**Points**
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested filter media soil P Index less than 30 (phosphorus only)		+ 3
Filter bed deeper than 30 inches		+ 1
Two cell design with pretreatment		+ 1
Permeable soils; no underdrain needed		+ 2
Upflow pipe on underdrain		+1
Impermeable soils; underdrain needed		- 1
Filter bed less than 18 inches deep		- 1
Single cell design		- 1
Bioretention cell is less than 5% of CDA		-1
Does not provide full water quality storage volume		- 2
Filter media not tested for P Index (phosphorus only)		- 3
NET DESIGN SCORE (max of 5 points)		
NET PHOSPHORUS SCORE (max of 5 points)		

ST-6

Stormwater Treatment Options

INFILTRATION

Infiltration practices capture and temporarily store stormwater runoff before infiltrating it into underlying soils where most pollutants are trapped. Infiltration can be an ideal on-site retrofit to treat stormwater runoff as long as minimum geotechnical requirements are met. Infiltration retrofits consists of a rock-filled chamber with no outlet. Stormwater runoff must first pass through some form of pretreatment, such as a swale or sediment basin. Runoff is then stored in the voids between the stones, where it slowly infiltrates into the soil matrix over a few days (Figure 1). Alternatively, proprietary materials such as perforated corrugated metal pipe, plastic arch pipe, or plastic lattice trays can be substituted for stone to increase storage capacity. A schematic of a typical infiltration trench is provided in Figure 2.

Where favorable soil conditions exist, infiltration can improve water quality, increase groundwater recharge and reduce runoff volumes. Infiltration practices are particularly desirable in subwatersheds that seek to reduce runoff volumes to prevent combined sewer overflows.

Figure 1: Infiltration Trench

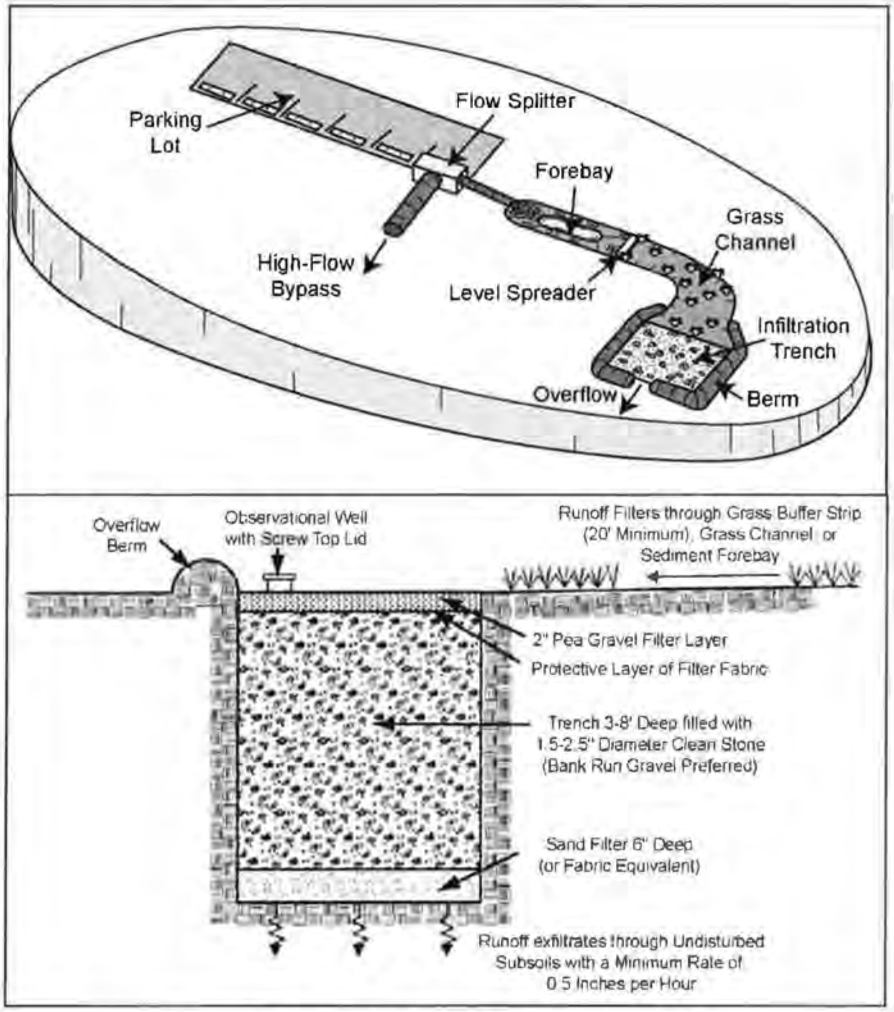

Figure 2: Schematic of an infiltration trench

Other Stormwater Benefits Provided by Stormwater Filters

Stormwater filter retrofits can seldom address other stormwater management objectives beyond water quality treatment. Since they have an impermeable liner and underdrain, they cannot recharge groundwater. They usually lack enough storage capacity to provide meaningful channel protection.

Typical Retrofit Application

Infiltration retrofits can be located on small, unused portions of a site and consume as little as 2-5% of site area. They are effectively used in narrow linear areas along setbacks or property boundaries. Where soils are acceptable, infiltration can treat runoff in the following retrofit locations:

- **OS-8** Infiltration trenches along margins of small parking lot or use of permeable pavers
- **OS-9** Perforated storm drain pipes to infiltrate street runoff
- **OS-10** Simple disconnection of roof leaders over appropriate soils or use of french drains/dry wells to infiltrate rooftop runoff

- **OS-11** Disconnection of small impervious surfaces
- **OS-12** Permeable pavers in urban hardscapes
- **OS-13** Underground infiltration galleries

Infiltration is seldom used for storage retrofits unless underlying soils have exceptional infiltration capability. It is important to confirm that retrofit soils can support adequate infiltration, since past grading, filling, disturbance, and compaction can greatly alter original soil infiltration qualities. The greatest opportunity for infiltration retrofits exists in sensitive or impacted subwatersheds, where some of the original soil structure may still exist. By contrast, most soils in non-supporting subwatersheds are not likely to be suitable for infiltration. Some regions of the country still have excellent soils that allow for widespread implementation of infiltration retrofits (e.g., glacial tills, sand).

Pollutant Removal by Infiltration Retrofits

Infiltration retrofits utilize several pollutant removal mechanisms including filtering, soil adsorption and transfer to groundwater. Theoretically, nearly all the pollutants that enter an infiltration practice should be removed except for soluble pollutants that travel through groundwater and return downstream. It is important to note that infiltration retrofits **are not** intended to treat sites with high sediment or trash/debris loads, as they will cause the practice to clog and fail.

Very few infiltration practices have been monitored, so only limited pollutant removal data has been published. Designers should therefore regard the infiltration pollutant removal rates shown in Table 1 as an initial estimate until more performance monitoring data becomes available.

Several site-specific and design factors can have a strong influence on infiltration pollutant removal rates (Table 2). As always, removal rates for individual retrofit projects should be adjusted to account for site-specific design factors that can enhance or diminish pollutant removal using the design point method. The most important design factor is the size of the individual retrofit in relation to the target WQv treatment. Pollutant removal rates diminish for under-sized infiltration retrofits; the recommended walkaway volume is about 50% of the target WQv.

Other Stormwater Benefits Provided by Infiltration

Infiltration retrofits are desirable because they confer other stormwater benefits:

Groundwater Recharge: Infiltration of stormwater runoff is the preferred means to provide groundwater recharge within a subwatershed. When designed properly, they can infiltrate the entire runoff reduction or WQv to keep stormwater runoff out of combined sewers.

Channel Protection: While infiltration practices are not specifically designed to store the channel protection volume, their ability to reduce runoff volumes should help protect downstream channels from erosion. If suitable soils are present across a subwatershed, infiltration may be an effective channel protection strategy.

Table 1: Range of Reported Removal Rates for Infiltration Practices			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	60*	90*	95*
Total Phosphorus	50	65	95
Soluble Phosphorus	55	85	100
Total Nitrogen	0	40	65
Organic Carbon	80	90	95
Total Zinc	65	65	85
Total Copper	60	85	90
Bacteria	25	90	95
Hydrocarbons	85	90	95
Chloride	0	0	0
Trash/Debris	90*	95*	99*
* Adequate pretreatment must be provided to reduce sediment loads to infiltration practices or clogging and practice failure may result See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25th and 75th quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for Infiltration Retrofits		
Design Factors	**X**	**Points**
Exceeds target WQv by more than 50%		+ 3
Exceeds target WQv by more than 25%		+ 2
Tested infiltration rates between 1.0 and 4.0 in/hr		+ 2
At least two forms of pretreatment prior to infiltration		+ 2
CDA is nearly 100% impervious		+ 1
Off-line design w/ cleanout pipe		+ 1
Underdrain utilized		- 1
Filter fabric used on trench bottom		- 1
CDA more than 1.0 acre		- 1
Soil infiltration rates < 1.0 in/hr or > 4.0 in/hr		- 2
Pervious areas or construction clearing in CDA		- 2
Does not provide full WQv volume		- 3
NET DESIGN SCORE (max of 5 points)		

ST-7	Stormwater Treatment Options	
	SWALES	

Swales utilize the stormwater conveyance system to provide treatment in either storage or on-site retrofit applications. Swales have moderate pollutant removal capability, can reduce runoff volume and increase groundwater recharge. Swales are designed to treat the WQv within an open channel. The three design variants are the dry swale, wet swale, and grass channel.

Dry swales are a linear soil filter system that temporarily stores and then filters the desired WQv (Figure 1). Dry swales are similar to bioretention areas in that they rely on a fabricated soil bed on the bottom of the channel. Existing soils are replaced with a sand/soil mix that meets minimum permeability requirements. Dry swales provide a good environment for filtration, biological uptake, and microbial activity. Stormwater treated by the soil bed flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system is typically created by encasing a perforated pipe within a gravel layer on the bottom of the swale.

Wet swales are linear wetland cells that intercept shallow groundwater to maintain a wetland plant community (Figure 2). Saturated soils support wetland vegetation, which provides an ideal environment for gravitational settling, biological uptake, and microbial activity.

Grass channels are open channels that provide limited water quality treatment using rate-based design criteria. Grass channels reduce flow velocities and increase filtration capacity. Grass channels generally cannot provide the same degree of pollutant removal as dry or wet swales.

All three swale designs provide significantly better water quality treatment than the conventional roadside ditch. Schematics of the dry and wet swale designs are illustrated in Figure 3.

Figure 1: Dry Swale

Figure 2: Wet Swale

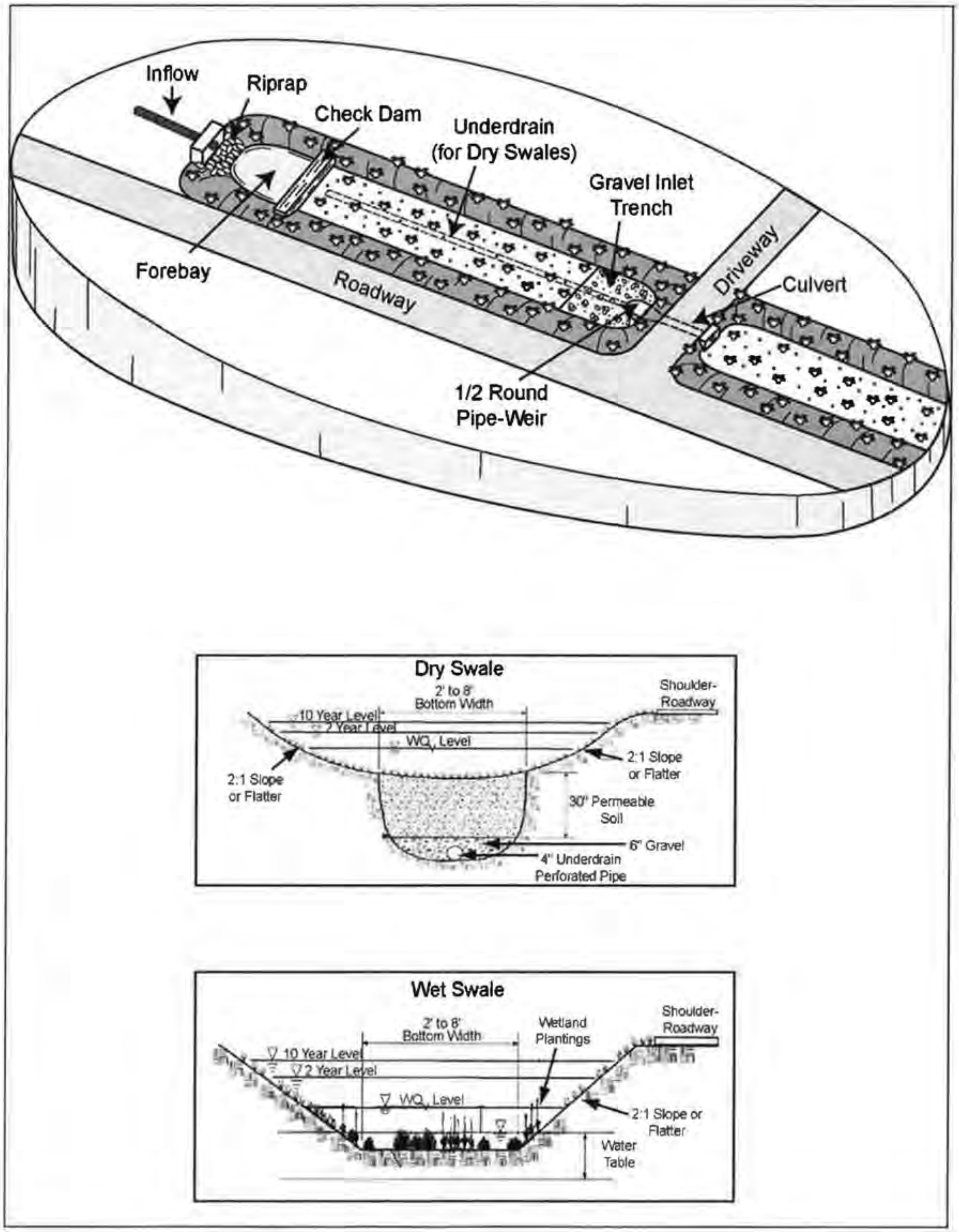

Figure 3: Schematic of a dry and wet swale

Typical Swale Retrofit Application

Most swale retrofits require that an existing open channel be widened, deepened, reduced in gradient, or some combination of all three. Swales are particularly well suited to treat runoff from low and medium density residential streets and small parking lots. Typical retrofit situations where swales can be applied include:

- **SR-4** Install dry swale or grass channel within existing conveyance system
- **OS-8** Install swales along margins of small parking lots
- **OS-9** Install swale retrofit along open section street or convert closed section street into dry swale
- **OS-11** Direct runoff to swale as means to disconnect a small impervious area

Estimating Pollutant Removal Capability of Swale Retrofits

The primary pollutant removal mechanisms operating in swales are settling, filtering infiltration and plant uptake. The reported pollutant removal rates for swales are highly variable. Table 1 shows the range in removal rates for swales that have been specifically designed for stormwater treatment (e.g., dry swales, wet swales and biofilters). Please note that the median removal rates should be cut in half if the proposed retrofit is a grass channel.

Designers may find it difficult to define the expected removal rate for a swale retrofit. Many site conditions and design factors can enhance or diminish their pollutant removal rates (Table 2). A reasonable estimate for each individual swale retrofit can be developed using the design point method. A primary factor influencing swale removal rates is the proportion of the WQv that is actually infiltrated or stored within retrofit treatment cells. A second influential factor is how the retrofit is sized in relation to the target WQv-- the recommended walkaway volume is about 50% of the target WQv.

Table 1: Range of Reported Removal Rates for Swales			
Pollutant	**Low End**	**Median**	**High End**
Total Suspended Solids	70	80	90
Total Phosphorus	-15	25	45
Soluble Phosphorus	-95	-40	25
Total Nitrogen	40	55	75
Organic Carbon	55	70	85
Total Zinc	60	70	80
Total Copper	45	65	80
Bacteria	-65	0	25
Hydrocarbons	70	80	90
Chloride	0	0	0
Trash/Debris	0	0	50
See Appendix D for data sources and assumptions used to derive these removal rates Low End and High End are the 25th and 75th quartiles			

Table 2: Design Point Calculation to Estimate Pollutant Removal for Swale Retrofits		
Design Factors	***X***	***Points***
Exceeds target WQv by more than 50%		+ 3
Dry or wet swale design		+ 2
Exceeds target WQv by more than 25%		+ 2
Longitudinal swale slope between 0.5 to 2.0%		+ 1
Velocity within swale < 1 fps during WQ storm		+ 1
Measured soil infiltration rates exceed 1.0 in/hr		+ 1
Multiple cells with pretreatment		+ 1
Off-line design w/ storm bypass		+ 1
Longitudinal swale slope < 0.5% or > 2%		- 1
Measured soil infiltration rates less than 1.0 in/hr		- 1
Swale sideslopes more than 5:1 h:v		- 1
Swale intersects groundwater (except wet swale)		- 1
No pretreatment to the swale or channel		- 1
Swales conveys stormflows up to 10 year storm		- 2
Does not provide full WQv volume		- 2
Grass channel		- 3
NET DESIGN SCORE (max of 5 points)		

Other Stormwater Benefits Provided by Swales

Swales retrofits can provide other stormwater benefits, including:

Groundwater Recharge: Swales can reduce runoff volumes by an average of 40% through infiltration on the swale bottom and across side-slopes, according to Strecker *et al*. (2004). Some research studies have reported as much as 80 to 90% runoff reduction for dry swales that are heavily landscaped with trees and shrubs to promote greater evapotranspiration (Horner *et al.*, 2003).

Channel Protection: While most swales are not designed to provide channel protection storage, the high degree of runoff reduction suggests that they have some potential to protect downstream channels from erosion. It may be possible to capture and detain the entire channel protection volume at small sites.

ST-8

Stormwater Treatment Options

Other Retrofit Treatment

This stormwater treatment option includes a diverse group of on-site techniques that capture, store and partially treat rooftop runoff in residential areas and highly urban landscapes, including:

Residential Rooftops

- Rainbarrels
- Rain Gardens
- French Drains/Drywells

Non-Residential Settings

- Cisterns
- Green Rooftops
- Permeable Pavers
- Stormwater Planters

Each rooftop technique has a unique ability to reduce runoff, remove pollutants or recharge groundwater and differs greatly in its design, installation cost and maintenance needs. A full description of each treatment option is provided in the series of fact sheets provided in Appendix F.

Typical Retrofit Applications

Many of these practices are primarily used to treat runoff from individual rooftops (OS-10), but stormwater planters and permeable pavers can also be applied to retrofit small parking lots (OS-8) and urban landscapes/hardscapes (OS-12).

Pollutant Removal Capability

These techniques can provide partial or full treatment of the target WQv, depending on site conditions. The pollutant removal rate for each technique varies greatly, so designers should consult the appropriate fact sheet in Appendix F to get an accurate estimate.

Benefits, Constraints, Concerns and Design, Construction and Maintenance Issues

Taken as a group, these stormwater treatment techniques are suitable for use in small, on-site retrofits and have few site constraints. Individually, each technique has numerous siting, design, and maintenance issues which are described in Appendix F.

Installation Costs for Other Stormwater Retrofits

The installation costs for this group of retrofits are compared in Table 1.

Table 1: Installation Costs for Other Stormwater Retrofits (per cubic foot treated)		
Retrofit Type	**Median Cost**	**Cost Range**
Residential Settings		
Rain Barrels	$ 25.00	$ 12.50 to $ 40.00
Rain Gardens:		
Volunteer Installation	$ 4.00	$ 3.00 to $ 5.00
Professional Installation	$ 7.00	$ 5.00 to $ 10.00
Professional Landscaping	$ 12.00	$ 10.00 to $ 15.00
French Drains/Drywells	$ 12.00	$ 10.50 to $ 13.50
Non-Residential Settings		
Cisterns	$ 15.00	$ 6.00 to $ 25.00
Intensive Green Rooftops	$ 360.00	$ 300.00 to $ 420.00
Extensive Green Rooftops	$ 225.00	$ 144.00 to $ 300.00
Permeable Pavers	$ 120.00	$ 96.00 to $ 144.00
Stormwater Planters	$ 27.00	$ 18.00 to $ 36.00
Rain Gardens	$ 12.00	$ 10.00 to $ 15.00
Note: See Appendix E for documentation and cost assumptions		

MO-4

Municipal Operation

STREET SWEEPING

Description

Public streets and roadways can comprise as much as 10 to 20% of total impervious cover in suburban subwatersheds and as much as 20 to 40% in highly urban subwatersheds. Particulate matter or "street dirt" tends to accumulate along the curbs of streets and roadways in between rainfall events. Sources of pollutants include run-on, atmospheric deposition, vehicle emissions and wear and tear, breakup of street surface, littering, leaves and other organic material and sanding. This results in the accumulation of stormwater pollutants such as sediment, nutrients, metals, hydrocarbons, bacteria, pesticides, trash and other toxic chemicals.

In many communities, these pollutants remain on public streets and roadways until they are washed into the storm drain system during a rainfall event. However, some communities use street sweeping (Figure 1) to remove some of these pollutants and prevent them from being conveyed into the storm drain system.

The ability of street sweepers to remove common stormwater pollutants varies depending on sweeper technology, sweeper operation and frequency, street conditions and the chemical and physical characteristics of the pollutants that have accumulated on the pavement. Although newer street sweeping technology can remove more than 90% of street dirt under ideal conditions, street sweeping does not necessarily guarantee water quality improvements (CWP, 2006a). Street sweepers are typically more effective at removing larger-sized particles than fine-grained particles and nutrients, although newer technology such as small-micron surface cleaning technologies may be capable of picking up smaller particles (Sutherland and Jelen, 1997). However, as illustrated in Figure 2, only 27% of Chesapeake Bay communities rely on this modern sweeping technology. The street sweepers most commonly used by Chesapeake Bay communities are mechanical brush and mechanical brush with vacuum assist sweepers (CWP, 2006b), which tend to have lower pollutant removal capabilities than newer air or vacuum assist technologies.

Figure 1. This broom sweeper is assisted by a following vacuum sweeper for increased removal.

Table 1 provides expected pollutant removal rates for street sweeping. These pollutant removal rates are lower than reported "pick-up" efficiencies of street sweepers, due to a number of discount factors that impact the effectiveness of street sweeping (CWP

2006a). In general, street sweeping is usually more effective in arid and semi-arid climates where pollutants can accumulate over longer intervals on street and curb surfaces.

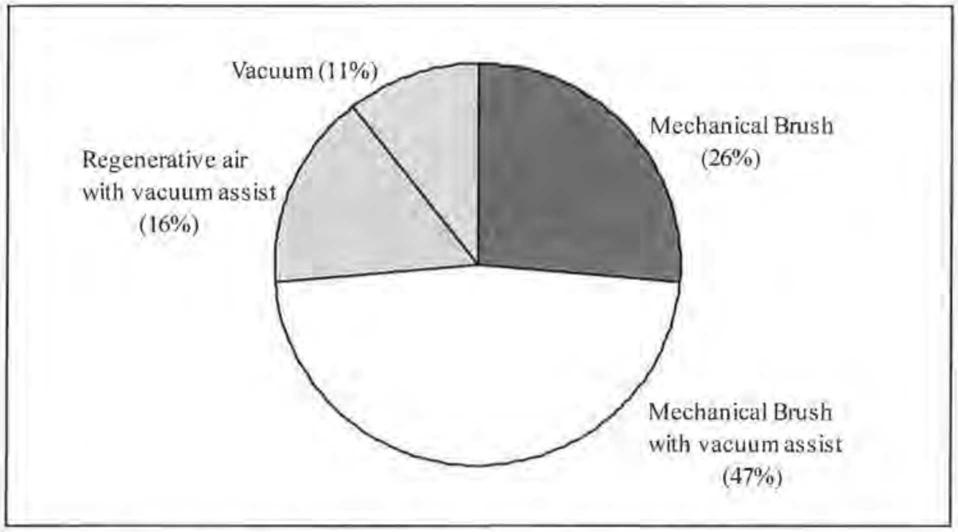

Figure 2. Most common street sweeping technology used by Chesapeake Bay communities

Table 1: Expected Pollutant Removal Rates for Street Sweeping (Law et al., 2008)				
Frequency	**Technology**	**Total Suspended Solids**	**Total Phosphorus**	**Total Nitrogen**
Monthly	Mechanical	9%	3%	3%
	Regenerative Air/Vacuum	22%	4%	4%
Weekly	Mechanical	13%	5%	6%
	Regenerative Air/Vacuum	31%	8%	7%

Investigating and Improving the Operation

Improving or initiating street sweeping activities in your community can reduce the amount of stormwater pollution that is conveyed into local aquatic resources. It requires you to examine your existing street sweeping operations, if they exist, and identify where improvements can be made to reduce the amount of pollution that has accumulated on public streets and roadways. This can be accomplished within the context of the seven-step program planning and development process (Chapter 2), as described below.

Step 1: Identify Existing Municipal Operations

Recall that the first step in the process is to identify the municipal operations that are conducted within your community. In terms of street sweeping, this means determining whether or not your community currently sweeps any public streets and roadways. If it does, the next step in the process is to collect some basic information about how the way those activities are conducted. If not, you should consider developing a street sweeping program or begin investigating the other municipal operations that are conducted within your community.

Step 2: Collect Information About Each Operation

Once you have determined that your community currently conducts street sweeping operations, the next step in the process is to collect some basic information about how those operations are carried out. Basic information to collect about the street sweeping activities conducted in your community includes:

- Narrative description of the street sweeping activities
- Locations of active and planned street sweeping activities
  - Street address
  - Watershed and subwatershed address
  - Geospatial coordinates (e.g. latitude, longitude)
- Map showing locations of active and planned street sweeping activities
- Operation manager name
- Operation manager contact information

This information should be added to the simple database or binder that contains the information about all of the municipal operations conducted in your community.

As you collect some basic information about the street sweeping operations conducted in your community, you should begin communicating with the individual who oversees or manages these activities. This is an ideal time to inform this individual about the community's pollution prevention/good housekeeping efforts and the purpose of the community's municipal pollution prevention/good housekeeping program. It is also a good time to educate them about the influence that street sweeping can have on water quality and how it can be used to reduce the amount of pollution that has accumulated on public streets and roadways.

Step 3: Complete the Municipal Operations Analysis (MOA)

The next step in the process is to use the basic information that you have collected about the street sweeping activities conducted in your community to complete Section 4 of the MOA. This section of the MOA asks a series of questions about the nature, scope and distribution of the street sweeping operations conducted within your community. In some cases, you will be able to answer all of the questions using only the information that you have already collected about the street sweeping activities. In most cases, however, answering the questions will require additional input from the individual who manages or oversees your community's street sweeping operation.

Once you have answered all of the questions presented within Section 4 of the MOA, you should calculate your score to determine how well your community is currently conducting its street sweeping activities. When you have completed the entire MOA, you should also compare the score that you received in Section 4 with the scores you received in each of the other sections of the analysis. This will help you focus your pollution prevention/good housekeeping efforts on the municipal operations that have the greatest influence on water quality in your community.

Step 4: Focus Pollution Prevention/Good Housekeeping Efforts

The next step in the process is to use the results of the MOA, as well as information about local subwatershed restoration goals and objectives, to develop a list of the municipal operations in the order in which they will be further investigated and improved. This list, known as the prioritized municipal operations list, can be used to guide your local pollution prevention/good housekeeping efforts and ensure that you are using your resources on improving the operations that have the greatest influence on water quality in your community. The operations at the top of the prioritized municipal operations list should be those that you will address first, while those at the bottom should be those that you will address over time.

If street sweeping comes out on top of your prioritized municipal operations list, the next step in the process is to further investigate the way that street sweeping activities are conducted in your community and determine the improvements that can be used to reduce the amount of pollution that has accumulated on public streets and roadways. If it does not, you should begin investigating the operation that is located at the top of your list. The other profile sheets presented in this chapter provide additional information about investigating each of the other municipal operations.

Step 5: Investigate Municipal Operations and Select Pollution Prevention/Good Housekeeping Practices

<u>Step 5.1: Collect Additional Information About Street Sweeping Activities</u>
Once you have determined that street sweeping will be the focus of your pollution prevention/good housekeeping efforts, the next step in the process is to collect some additional information about these activities to determine how they can be improve to reduce the amount of stormwater pollution that has accumulated on public streets and roadways. To collect this additional information, you should coordinate with the individual who manages or oversees these activities. This individual will be able to answer questions about the street sweeping activities and help you determine where improvements can be made. It is also a good opportunity for them to learn more about how street sweeping can influence stormwater quality. Table 2 provides a list of example questions that can be used to collect additional information from the individual who manages or oversees the street sweeping activities conducted in your community.

Table 2: Sample Discussion Questions
• Are you familiar with our pollution prevention/good housekeeping efforts and the purpose of our municipal pollution prevention/good housekeeping program?
• What pollutants are most commonly associated with street dirt?
• What areas or streets in the community are dirtier than others (e.g. have higher street particulate matter loadings compared to others)?
• What proportion of streets in the community is swept?
• Do sweepers pick up leaf piles?
• How is sweeping frequency defined?
• Is sweeping coordinated with fall leaf pickup?
• Is tandem sweeping used?
• Are no-parking zones used to increase pick up efficiency?
• What technology is being used and what is the size of the street sweeper fleet?

Table 2: Sample Discussion Questions
• What is the frequency of street sweeping for public streets? • Do you have a training program for street sweeper operators? • How do you dispose of material collected from the street sweepers? • What problems affect the performance of street sweeping (e.g., on-street parking, inadequate budget, untrained operators)

When collecting addition information about the street sweeping activities conducted in your community, you should strive to determine what streets are being swept (if any), how frequently they are swept (e.g. twice a month) and the technology that is used to sweep them. The basic idea is to determine if the street sweeping program is operating at a level where measurable pollutant reductions can be achieved. In particular, you should evaluate:

- *Sweeper frequency* - should be defined based on local rainfall statistics, where the optimal frequency is about twice the interstorm period (runoff producing event) based on national rainfall statistics (i.e., approximately once a week, if the storm frequency is once every two weeks). At a minimum, sweeping should occur during periods of heavy accumulation. For example before the rain or wet season in drier, arid climates or in the fall and early spring in temperate climate. In the fall, sweepers should pick up leaves (and not avoid them) as they can contribute 25% of nutrient loadings in catch basins. If more substantial piles of leaves are found in your community during the fall, street sweeping activities should be coordinated with leaf pickup. Equally important is an early spring sweeping before rains begin to pick up sand, de-icing material and winter debris, to include municipally owned parking lots. More frequent sweeping may reduce the need for catch basin cleaning (see Profile Sheet MO-5). Figure 3 illustrates the percent of Chesapeake Bay communities that sweep more than once per year and the associated street sweeping frequency.

- *Sweeper technology and operations* – the ability of street sweeping to impact water quality is dependent on the sweeper's pick-up efficiency of fine-grained sediment. There are three main types of sweepers: mechanical, regenerative air, and vacuum sweepers. Mechanical sweepers (broom-type) are typically the least expensive and are better suited to pick up large-grained sediment particles. Vacuum and regenerative air sweepers are better at removing fine grained sediment particles and are more effective as part of a NPDES plan (Partland, 2001), but are less effective on wet surfaces and are more expensive. Removal efficiency can be improved through tandem sweeping (two sweepers sweeping the same route, with one following the other to pick up missed material) or if the street sweeper makes multiple passes on a street.

- *Conditions* – access to the curb is paramount to street sweeping efficiency, as the majority of pollutants on streets are closest to the curb. Parked cars can restrict access; a regional survey conducted for Concord, CA revealed that appropriately enforced no-parking zones overwhelming achieved adequate compliance to allow street sweeping (Berryman and Henigar, 2003).

- *Distance to storage and disposal facilities* - street sweepers do not travel very quickly so the distance to the storage and disposal facilities can significantly reduce the number of hours that operators actually spend sweeping streets.

- *Staff training* - street sweepers are a major investment and operators must be specially trained on how to properly drive and maintain them. Training should be held at least once a year for all staff to provide them with a thorough understanding of the proper implementation of sweeping and other pollution prevention/good housekeeping practices, and safety procedures. Also see Profile Sheet MO-10.

> The most common purposes for street sweeping in the Chesapeake Bay area are aesthetics, followed by residential demand. Keeping material out of the storm drains and street safety were also common responses. Public health, safety, permit requirements, and water quality were not among the most frequently cited reasons for street sweeping, but are considered important by a significant proportion of communities (CWP 2006b).

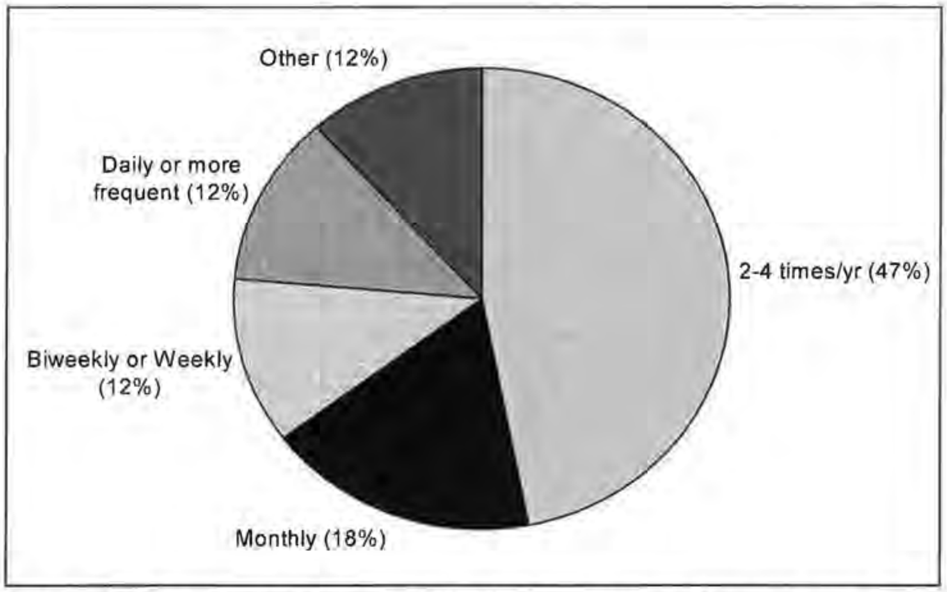

Figure 3. Percentage of communities that sweep more than once per year and the associated sweeping frequency

Step 5.2: Conduct Field Investigations

Once you have collected some additional information about the street sweeping activities conducted in your community, the next task is to conduct some field work to determine where street sweeping can be most effective in improving water quality your community. The Street and Storm Drains (SSD) investigation measures the average pollutant accumulation in the streets, curbs and catch basins of a subwatershed. It is a visual inspection of pollutant accumulation along streets curb and gutters, and storm drain inlets. This information should be used to identify the dirtiest streets and quantify the impact of current maintenance practices on urban streams and identify changes to current street sweeping program. For example, a high accumulation rate may suggest that more regularly scheduled street sweeping is needed. The SSD is time intensive and probably cannot be completed for all streets in a community; however, the stormwater manager should consider conducting the SSD in subwatersheds with impaired waters or sensitive aquatic resources. This information is particularly useful for communities with limited resources who may not be able to increase street sweeping in all areas. For more information on the SSD, see Manual 11.

Step 5.3: Prescribe Pollution Prevention/Good Housekeeping Practices

Once existing operations have been assessed, the next step in the process is to develop a targeted street sweeping program that can help improve water quality by removing and properly disposing of the street dirt that has accumulated on public streets and roadways. In order to observe water quality improvements, most communities will need to invest in better street sweeping technologies and increase sweeping frequency. Depending on the results of Step 1, a variety of improvements can be made to the way that street sweeping operations currently occur (Table 3). If resources are limited, street sweeping should be concentrated on the dirtiest streets in sensitive subwatersheds at the right times of year (fall and early spring).

Table 3: Good Housekeeping Techniques for Street and Parking Lot Sweeping
• Analyze sweeper wastes for hazardous waste content and dispose of properly at the landfill
• Sweep prior to rainstorms so pollutants are not washed into storm drain system
• Sweep as soon as possible following application of deicers or other applied chemicals
• Properly maintain sweepers and operate according to manufacturers directions
• Store swept material in a covered and contained site until it can be disposed of at a landfill
• Implement parking controls to improve street sweeper efficiency by maximizing sweepable street edges where dirt tends to collect
• Routinely inspect street curbs for sediment and debris and schedule dirtiest streets for regular sweeping
• Coordinate seasonal sweeping schedules to coincide with important pollution prevention events during the subwatershed year. These include the end of curbside leaf collection, winter sanding operations, and peak pollen production in the spring
• Select the most effective combination of street sweeper technology that is consistent with municipal budget resources
• Sweep streets at the optimal frequency to remove the greatest pollutant removal, given local rainfall, street density, curb access and traffic safety
• Post permanent signs to notify vehicle owners and residents about forthcoming sweeping operations and associated parking restrictions
• Work with local police department to patrol designated routes to ticket illegally parked cars

Step 5.4: Develop Implementation Plan

Once there is a targeted street sweeping program, a brief implementation plan should be created. The plan should summarize the results of the assessment and the street sweeping effort that will be used to reduce the amount of pollution that has accumulated on public streets and roadways. The plan should also include a schedule that describes when the street sweeping program will be implemented. The implementation plan can be used to guide the implementation of the prescribed street sweeping program.

Step 6: Implement Pollution Prevention/Good Housekeeping Practices

Once an implementation plan has been created, the next step in the process is implementing the prescribed street sweeping program. Although it may be tempting to hand the responsibility for implementation over to the individual who manages or oversees the community's street sweeping activities, it is important to work with this individual during the implementation phase to get the prescribed street sweeping program up and running. Simple techniques that can be used to do this include providing additional education and information about the prescribed street sweeping program and providing assistance in securing funding for the program.

Step 7: Evaluate Progress in Implementation

The last step in the process involves evaluating the progress made in implementing the prescribed pollution prevention/good housekeeping practices. Measurable performance goals and implementation milestones will be needed to evaluate progress in implementation and track success in addressing local water quality issues and subwatershed restoration goals and objectives. Some example measurable goals and implementation milestones are presented in Table 4.

Table 4: Measurable Goals and Implementation Milestones for Improving Municipal Street Sweeping Activities[1]

Example Measurable Goals	Timeframe	Priority
Goals related to program startup		
Identify and collect basic information about municipal street sweeping activities	Complete shortly after program startup; update regularly after that	●
Add the information about street sweeping activities to the simple database or binder that contains basic information about each municipal operation		●
Develop a digital GIS or hard copy map showing the location of all municipal street sweeping activities		⊙
Complete Section 4 of the Municipal Operations Analysis (MOA)	Year 1; repeat every 5 years	●
Prioritize local pollution prevention/good housekeeping efforts based on the results of the MOA and other factors, such as local pollutants of concern		●
Goals related to preventing or reducing stormwater pollution		
Collect additional information about the way that street sweeping activities are conducted within your community	Year 1	●
Prescribe pollution prevention/good housekeeping practices to improve the way that municipal street sweeping activities are conducted within your community		●
Develop implementation plan for prescribed street sweeping program		●
Secure funding and resources to implement prescribed street sweeping program	Begin in Year 1	●
Implement prescribed street sweeping program	Begin in Year 2	●
Goals related to program evaluation		
Develop measurable performance goals and implementation milestones	Complete shortly after program startup; update regularly after that	●
Evaluate progress in meeting measurable goals and implementation milestones		●
Evaluate progress in implementing prescribed pollution prevention/good housekeeping practices	End of Year 1 and each year after that	●

Table 4: Measurable Goals and Implementation Milestones for Improving Municipal Street Sweeping Activities[1]		
Example Measurable Goals	**Timeframe**	**Priority**
Notes 1) Assumes that street sweeping is as the top of your prioritized municipal operations list. *Key* ● = Essential ◉ = Optional but Recommended		

The methods used to evaluate success in meeting these measurable performance goals and implementation milestones can be as simple as a semi-annual or annual inspections used to identify the improvements that have been put in place and the improvements that still need to be made.

Scoping the Required Level of Effort

The level of effort required to develop an effective street sweeping program varies greatly from one community to the next. Basic guidance on scoping the level of effort required to develop a street sweeping program is provided in Table 5. Communities can use this information to estimate the level of effort required to develop their own street sweeping programs.

Table 5: Scoping the Level of Effort Required to Improve Street Sweeping Operations	
Step	**Staff Hours**
Step 1: Identify Existing Municipal Operations	4-8[1]
Step 2: Collect Information About Street Sweeping Activities	4-8
Step 3: Complete Section 4 of the Municipal Operations Analysis (MOA)	10-20
Step 4: Focus Pollution Prevention/Good Housekeeping Efforts	4-8[1]
Step 5: Investigate Municipal Operations and Select Pollution Prevention/Good Housekeeping Practices	80-200
Step 5.1: Collect Additional Information About Street Sweeping Activities	20-40
Step 5.2: Conduct Field Investigations	20-80
Step 5.3: Prescribe Pollution Prevention/Good Housekeeping Practices	20-40
Step 5.4: Develop Implementation Plan	20-40
Step 6: Implement Pollution Prevention/Good Housekeeping Practices	Varies[2]
Step 7: Evaluate Progress in Implementation	20-40/evaluation[1]
Notes 1: Represents total level of effort required to complete step for all municipal operations. 2: Varies according to the extent and type of improvements required.	

Resources

Urban Subwatershed Restoration Manual 11: Unified Subwatershed and Site Reconnaissance: A User's Manual. http://www.cwp.org/PublicationStore/USRM.htm

The Smart Watershed Benchmarking Tool. http://cwp.org.master.com/texis/master/search/+/form/Smart_Watershed.html

City Madison Street Sweeping Study
http://www.ci.madison.wi.us/engineering/stormwater/street_sweeping.htm

Stormwater Effects Handbook: Chapter 5
http://www.epa.gov/ednnrmrl/publications/books/handbook/index.htm

Sutherland, R.C., and Jelen, S.L. (1997). Contrary to Conventional Wisdom: Street Sweeping can be an Effective BMP. In James, W. *Advances in Modeling the Management of Stormwater Impacts* – Vol. 5. Published by CHI, Guelph, Canada. pp 179-190.

US Department of Transportation, Federal Highway Administration's Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Street Sweeping Fact Sheet http://www.fhwa.dot.gov/environment/ultraurb/3fs16.htm

Walker, T. and Wong, T. (1999). Effectiveness of Street Sweeping for Stormwater Pollution Control. Technical Report 99/08. Cooperative Research Centre for Catchment Hydrology, Melbourne, AUS. http://www.catchment.crc.org.au/archive/pubs/1000009.html

Waschbusch, Robert J.; Selbig, W. R.; Bannerman, Roger T.1999. WRI 99-4021. Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994-95. http://wi.water.usgs.gov/pubs/WRIR-99-4021/

World Sweeper Website http://www.worldsweeper.com/Street/Studies/index.html

MO-5	**Municipal Operation**	
	STORM DRAIN MAINTENANCE	

Description

Public streets and roadways can comprise as much as 10 to 20% of total impervious cover in suburban subwatersheds and from 20 to 40% of highly urban subwatersheds. Fine particles and pollutants naturally tend to accumulate along the curbs of roads in between rainfall events. Sources of pollutants include run-on, atmospheric deposition, vehicle emissions, breakup of street surface, littering, and sanding. This results in the accumulation of stormwater pollutants such as sediment, nutrients, metals, hydrocarbons, bacteria, pesticides, trash and other toxic chemicals.

Storm drain maintenance is often the last opportunity to remove pollutants before they enter the storm drain system. The effectiveness of this pollution prevention/good housekeeping practice depends on the basic design of the stormwater conveyance in a subwatershed. Most systems have a catch basin or sump pit located in the storm drain inlet to trap sediment and organic matter and prevent clogging (Figure 1). In some eras, however, conveyance systems were designed to be self-cleansing and thus have no storage. Each catch basin or sump pit tends to be unique in how quickly it fills up, and whether the trapped material is liquid, solid or organic. To this extent, each reflects the conditions and behaviors that occur within the few hundred feet of street it serves.

Storm drain maintenance can be an effective strategy in urban subwatersheds that have few other feasible options to remove pollutants. For many communities, storm drain maintenance is reactive and conducted in response to complaints from residents. Water quality is not a commonly cited reason for a storm drain cleanout program (see Figure 2). When performed properly, regular maintenance can improve water quality and prevent clogging and flooding.

(Source: City of Garrett, IN)

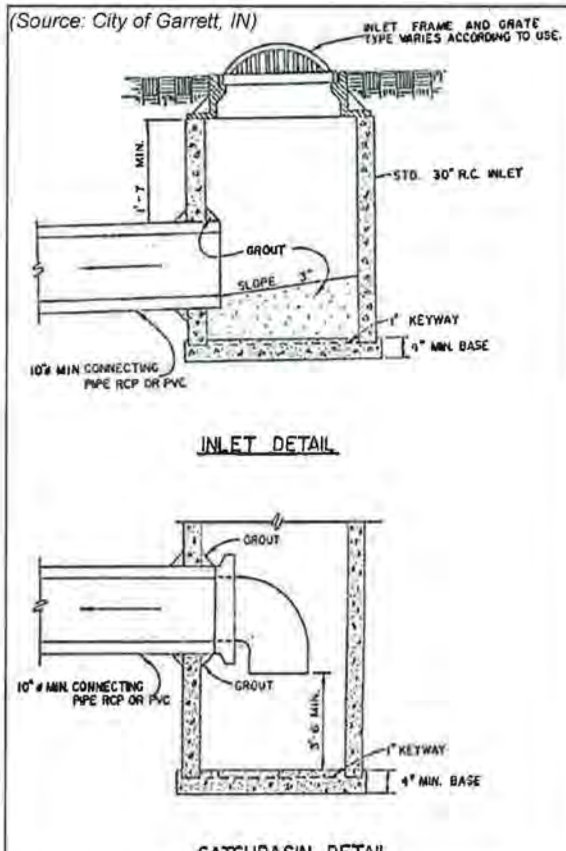

Figure 1. Catch Basin Detail

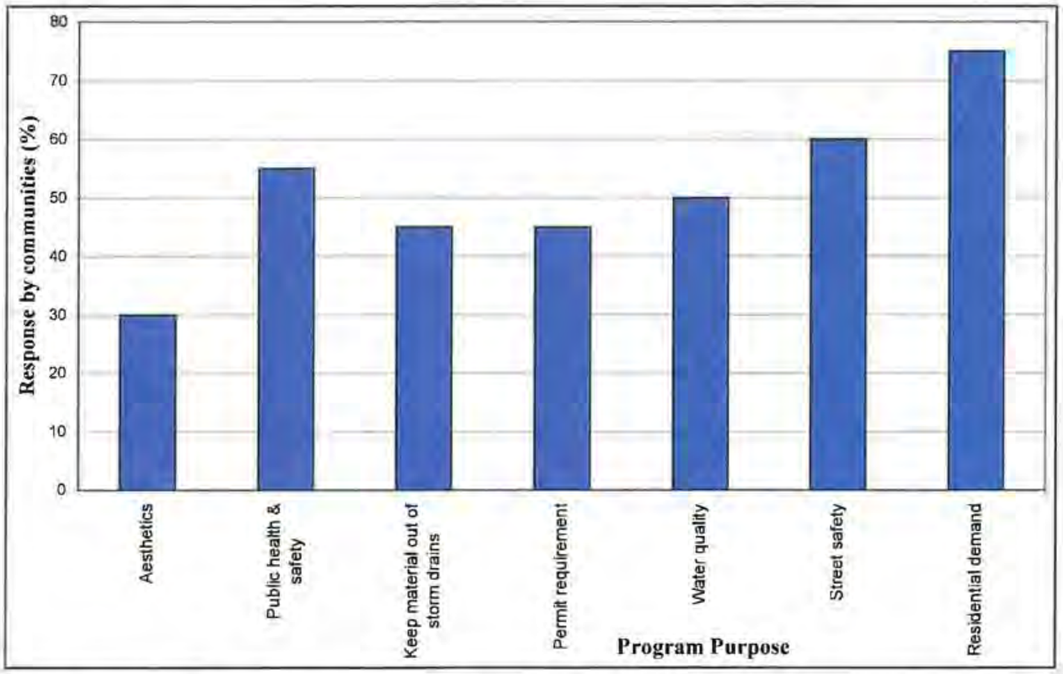

Figure 2: Purpose of storm drain cleanout programs in the Chesapeake Bay watershed

The amount of pollution removed by storm drain maintenance is influenced by the amount of pollution removed by street sweeping (see profile sheet MO-4). The amount of dirt removed by street sweeping influences the quantity of dirt that can be trapped within storm drains, inlets or catch basins. Storm drain cleanout effectiveness is also impacted by both the frequency and method of cleanout. Table 1 provides estimated pollutant removal rates for catch basin cleanouts.

Table 1: Expected Pollutant Removal Rates for Catch Basin Cleanouts (Law et al., 2008)

Frequency	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Annual	18%	< 1%	3%
Semi-Annual	35%	2%	6%

Investigating and Improving the Operation

Improving or initiating storm drain maintenance your community can reduce the amount of stormwater pollution that is conveyed into local aquatic resources. It requires an examination of existing storm drain maintenance operations to identify where improvements can be made to reduce pollutant accumulation in catch basins, inlets and storm drain pipes. This can be accomplished within the context of the seven-step program planning and development process (Chapter 2), as described below.

Step 1: Identify Existing Municipal Operations

In this step, determine whether catch basin, inlet and storm drain cleanouts are currently conducted. If so, the next step in the process is to collect some basic information about how these activities are conducted. If not, you should consider developing a storm drain maintenance plan or investigating the other municipal operations that are conducted within the community.

Step 2: Collect Information About Each Operation

Once you have determined that your community currently conducts storm drain maintenance activities, the next step in the process is to collect some basic information about how those operations are conducted. Basic information to collect about the storm drain maintenance activities conducted in your community includes:

- Narrative description of the storm drain maintenance activities
- Locations of storm drain maintenance activities
    - Street address
    - Watershed and subwatershed address
    - Geospatial coordinates (e.g. latitude, longitude)
- Map showing locations of storm drain maintenance activities
- Operation manager name
- Operation manager contact information

This information should be added to the simple database or binder that contains the information about all of the municipal operations conducted in your community.

After collecting basic information about storm drain maintenance activities, begin communicating with the individual who oversees or manages these activities. This is an ideal time to inform this individual about the community's pollution prevention/good housekeeping efforts and its purpose. It is also a good time to educate them about the influence that storm drain maintenance can have on water quality and how it can be used to reduce the amount of pollution that has accumulated on public streets and roadways.

Step 3: Complete the Municipal Operations Analysis (MOA)

The next step in the process is to use the basic information that you have collected about the storm drain maintenance activities conducted in your community to complete Section 5 of the MOA. This section of the MOA asks a series of questions about the nature, scope and distribution of the storm drain maintenance operations. In some cases, you will be able to answer all of the questions using only the information that you have already collected about the street sweeping activities. In most cases, however, answering the questions will require additional input from the individual who manages or oversees your community's storm drain maintenance activities.

Once you have answered all of the questions presented within Section 5 of the MOA, you should calculate your score to determine how well your community is currently conducting its storm drain maintenance activities. When you have completed the entire MOA, you should also compare the score that you received in Section 5 with the scores you received in each of the other sections of the analysis. This will help you focus your pollution prevention/good housekeeping efforts on the municipal operations that have the greatest influence on water quality in your community.

Step 4: Focus Pollution Prevention/Good Housekeeping Efforts

The next step in the process is to use the results of the MOA, as well as information about local subwatershed restoration goals and objectives, to develop a list of the municipal operations in the order in which they will be further investigated and improved. This list, known as the prioritized municipal operations list, can be used to guide your local pollution prevention/good housekeeping efforts and ensure that you are using your resources on improving the operations that have the greatest influence on water quality in your community. The operations at the top of the prioritized municipal operations list should be those that you will address first, while those at the bottom should be those that you will address over time.

If storm drain maintenance comes out on top of your prioritized municipal operations list, the next step in the process is to further investigate the way that storm drain maintenance activities are conducted in your community and determine the improvements that can be used to reduce the amount of pollution that has accumulated in inlets, catch basins and storm drain pipes. If it does not, you should begin investigating the operation that is located at the top of your list. The other profile sheets presented in this chapter provide additional information about investigating each of the other municipal operations.

Step 5: Investigate Municipal Operations and Select Pollution Prevention/Good Housekeeping Practices

Step 5.1: Collect Additional Information About Storm Drain Maintenance Activities
Once you have determined that storm drain maintenance will be the focus of your pollution prevention/good housekeeping efforts, the next step in the process is to collect some additional information about these activities to determine how they can be improve to reduce the amount of stormwater pollution that has accumulated in inlets, catch basins and storm drain pipes. To collect this additional information, you should coordinate with the individual who manages or oversees these activities. This individual will be able to answer questions about the storm drain maintenance activities and help you determine where improvements can be made. It is also a good opportunity for them to learn more about how street sweeping can influence stormwater quality. Table 2 provides a list of example questions that can be used to collect additional information from the individual who manages or oversees the storm drain maintenance activities conducted in your community.

Table 2: Sample Discussion Questions
• Are you familiar with our pollution prevention/good housekeeping efforts and the purpose of our municipal pollution prevention/good housekeeping program? • Do you understand how storm drain maintenance can impact stormwater quality? • How frequently do you perform catch basin, inlet and storm drain cleanouts? • How do you dispose of materials removed from the storm drain system? • What additional resources would you need to improve the community's existing storm drain maintenance program? • Do you provide regular stormwater pollution prevention training to employees who are involved with storm drain maintenance activities?

When collecting addition information about the storm drain maintenance activities conducted in your community, you should strive to determine how the storm drain system is currently being maintained, how frequently it is maintained and the technology that is used to maintain it. The basic idea is to determine if the storm drain maintenance program is operating at a level where measurable pollutant reductions can be achieved. In particular, you should evaluate:

- *Tracking* – the location and maintenance of storm drains should be tracked using a database and spatial referencing system (e.g., Global Positioning System, Geographic Information System). Additionally, knowing the type and era of the storm drain system may be of use since some inlets/catch basins are designed to be self-cleaning while others have some trapping capacity.

- *Frequency* – should be defined such that blockage of storm sewer outlet is prevented and it is recommended that the sump should not exceed 40 – 50 percent of its capacity. Semiannual cleanouts in residential streets and monthly cleanouts for industrial streets are suggested by Pitt and Bissonnett (1984) and Mineart and Singh (1994). More frequent cleanouts should be scheduled in the fall as leaves can contribute 25% of nutrient loadings in catch basins.

- *Technology* – the four common methods of cleaning catch basins are described in Table 3. Almost 65% of the Chesapeake Bay communities used vacuum-based technology or hydraulic suctions to cleanout storm drains (Figure 3). The remaining communities use more basic technology such as manual removal or bucket loaders.

- *Staff training* - operators need to be properly trained in catch basin maintenance including waste collection and disposal methods. Staff should also be trained to report water quality problems and illicit discharges. See profile sheet MO-10 for more on employee training.

- *Material disposal* - since catch basin waste may contain hazardous material, it should be tested and disposed of accordingly. Maintenance personnel should keep a log of the amount of sediment collected and the removal date at the catch basin.

Table 3: Equipment Used for Catch Basin and Inlet Cleaning (from Lager et al. 1979)	
Equipment	**Description**
Manual cleaning	Bail out sediment-laden water and shovel into street then truck. Or crew enters catch basin and fill buckets with sediment that are then carried to a dump truck. Clean water is used to refill the catch basin.
Eductor cleaning	Eductor truck evacuates the catchment of the sediment-laden water into a settling tank.
Vacuum cleaning	Air blower of the vacuum truck is used to create a vacuum and the air-solid-liquid material is separated in the vacuum truck unit by gravity separation and baffles.
Vacuum combination jet cleaning (e.g. Vaccon)	A vacuum assisted truck that uses a combination of air, water and hydraulic suction. Suction is used to extract material from storm inlets. Water is used to clear material from storm drain pipes that is not removed by the vacuum. The material is stored in the truck holding tank and transported for disposal.

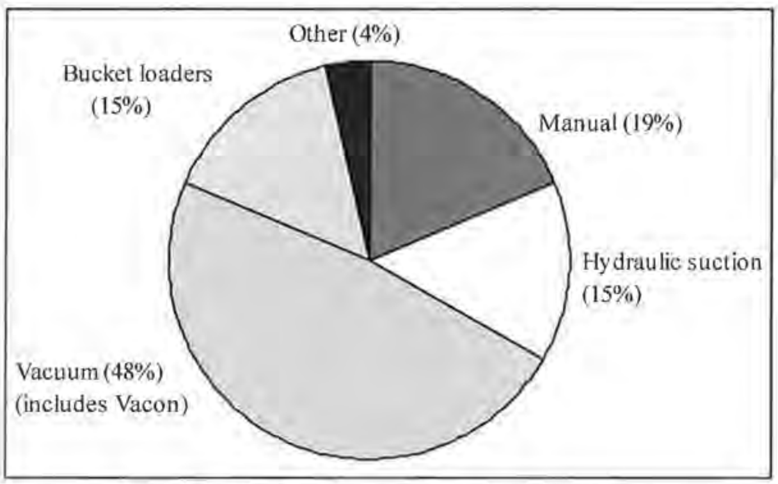

Figure 3. Most common storm drain cleanout technology used in NPDES Phase I and II Chesapeake Bay communities

Step 5.2: Conduct Field Investigations

After collecting some additional information about the storm drain maintenance activities in the community, it is time to conduct some field work to determine where storm drain maintenance can provide the most improvement to water quality (Figure 4). Conducting these field assessments is a key way to transform existing storm drain maintenance activities from reactive (response to resident complaints) to proactive activities. The Street and Storm Drains (SSD) investigation measures the average pollutant accumulation in the streets, curbs and catch basins of a subwatershed. The SSD can be used to characterize the current condition of storm drain infrastructure and the degree of pollutant accumulation in catch basins. This information should be used to quantify the impact of current maintenance practices on urban streams and identify changes to current storm drain maintenance program. For example, a high accumulation rate may suggest that more frequent and regular cleanouts are needed. The SSD is time intensive and probably cannot be completed for all streets, but the stormwater manager should consider conducting the SSD in subwatersheds with impaired waters or sensitive aquatic resources. This information is particularly useful for communities with limited resources who may not be able to increase storm drain maintenance in all areas. For more information on the SSD, see Manual 11.

Figure 4. Conducting the SSD in Watershed 263, Baltimore, MD

Step 5.3: Prescribe Pollution Prevention/Good Housekeeping Practices

Once existing operations have been assessed, the next step in the process is to select and implement the pollution prevention/good housekeeping practices that can help improve water quality through storm drain maintenance procedures and training. In order to observe water quality improvements, most communities will need to track maintenance activities and increase frequency. Depending on the results of Step 1, a variety of improvements can be made to the way that storm drain maintenance currently occurs (Table 4). If resources are limited, storm drain maintenance should be concentrated on the dirtiest streets in sensitive subwatersheds at the right times of year (just before and after rainy season).

Table 4: Good Housekeeping Techniques for Storm Drain Cleanout
• Maintain a log of the amount of sediment collected and the date removed • Analyze waste to determine the nature of disposal method • Any liquids collected during cleanouts should be decanted and disposed of separately, depending on its hazard class • Minimally clean once or twice per year (just before and just after the rainy season) or when the catch basin storage is one-third full, whichever happens first • Plan cleaning to coincide with municipal street sweeping (MO-4) • Locate and map all the catch basins within the community, and use these maps to promote widespread storm drain stenciling • Keep records on accumulation rates within each individual catch basin using GIS or other tracking system • Report all suspicious catch basins to appropriate local authorities for follow-up inspection and enforcement (e.g., inappropriate discharges and illegal dumping)

Step 5.4: Develop Implementation Plan

Once you have developed a targeted storm drain maintenance program, a brief implementation plan should be created. The plan should summarize the results of the assessment and the storm drain maintenance effort that will be used to reduce the amount of pollution that has accumulated in inlets, catch basins and storm drain pipes. The plan should also include a schedule that describes when the storm drain maintenance program will be implemented. The implementation plan can be used to guide the implementation of the prescribed storm drain maintenance program.

Step 6: Implement Pollution Prevention/Good Housekeeping Practices

Once an implementation plan has been created, the next step in the process is implementing the prescribed storm drain maintenance program. Although it may be tempting to hand the responsibility for implementation over to the individual who manages or oversees the community's storm drain maintenance activities, it is important to work with this individual during the implementation phase to get the prescribed storm drain maintenance program up and running. Simple techniques that can be used to do this include providing additional education and information about the prescribed storm drain program and providing assistance in securing funding for the program.

Step 7: Evaluate Progress in Implementation

The last step in the process involves evaluating the progress made in implementing the prescribed pollution prevention/good housekeeping practices. Measurable performance goals and implementation milestones will be needed to evaluate progress in implementation and track success in addressing local water quality issues and subwatershed restoration goals and objectives. Some example measurable goals and implementation milestones are presented in Table 5.

Table 5: Measurable Goals and Implementation Milestones for Improving Municipal Storm Drain Maintenance Operations[1]

Example Measurable Goals	Timeframe	Priority
Goals related to program startup		
Identify and collect basic information about current municipal storm drain maintenance operations	Complete shortly after program startup; update regularly after that	●
Add the information about storm drain maintenance activities to the simple database or binder that contains basic information about each municipal operation		●
Develop a digital (e.g. GIS) or hard copy map showing the location of all storm drain maintenance activities		⦿
Complete Section 5 of the Municipal Operations Analysis (MOA)	Year 1; repeat every 5 years	●
Prioritize local pollution prevention/good housekeeping efforts based on the results of the MOA and other factors, such as local pollutants of concern		●
Goals related to preventing or reducing stormwater pollution		
Collect additional information about the way that storm drain maintenance activities are conducted within your community	Year 1	●
Prescribe pollution prevention/good housekeeping practices to address deficiencies and improve the way that the municipal storm drain system is maintained within your community		●
Develop implementation plan for prescribed pollution prevention/good housekeeping practices		●
Secure funding and resources to implement prescribed pollution prevention/good housekeeping practices	Begin in Year 1	●
Implement prescribed pollution prevention/good housekeeping practices	Begin in Year 2	●

Table 5: Measurable Goals and Implementation Milestones for Improving Municipal Storm Drain Maintenance Operations[1]		
Example Measurable Goals	**Timeframe**	**Priority**
Goals related to program evaluation		
Develop measurable performance goals and implementation milestones	Complete shortly after program startup; update regularly after that	●
Evaluate progress in meeting measurable goals and implementation milestones		●
Evaluate progress in implementing prescribed pollution prevention/good housekeeping practices	End of Year 1 and each year after that	●
Notes 1) Assumes that storm drain maintenance is as the top of your prioritized municipal operations list. *Key* ● = Essential ◉ = Optional but Recommended		

The methods used to evaluate success in meeting these measurable performance goals and implementation milestones can be as simple as a semi-annual or annual inspections used to identify the improvements that have been put in place and the improvements that still need to be made.

Scoping the Required Level of Effort

The level of effort required to develop an effective storm drain maintenance program varies greatly from one community to the next. Basic guidance on scoping the level of effort required to improve storm drain maintenance operations is provided in Table 6. Communities can use this information to estimate the level of effort required to improve their own storm drain maintenance programs.

Table 6: Scoping the Level of Effort Required to Improve Storm Drain Maintenance Operations	
Step	**Staff Hours**
Step 1: Identify Existing Municipal Operations	4-8[1]
Step 2: Collect Information About Street Sweeping Activities	4-8
Step 3: Complete Section 5 of the Municipal Operations Analysis (MOA)	10-20
Step 4: Focus Pollution Prevention/Good Housekeeping Efforts	4-8[1]
Step 5: Investigate Municipal Operations and Select Pollution Prevention/Good Housekeeping Practices	80-200
Step 5.1: Collect Additional Information About Storm Drain Maintenance Activities	20-40
Step 5.2: Conduct Field Investigations	20-8
Step 5.3: Prescribe Pollution Prevention/Good Housekeeping Practices	20-40
Step 5.4: Develop Implementation Plan	20-40
Step 6: Implement Pollution Prevention/Good Housekeeping Practices	Varies[2]
Step 7: Evaluate Progress in Implementation	20-40/evaluation[1]
Notes 1: Represents total level of effort required to complete step for all municipal operations. 2: Varies according to the extent and type of improvements required.	

Resources

Urban Subwatershed Restoration Manual 11: Unified Subwatershed and Site Reconnaissance: A User's Manual. http://www.cwp.org/PublicationStore/USRM.htm

The Smart Watershed Benchmarking Tool. http://cwp.org.master.com/texis/master/search/+/form/Smart_Watershed.html

U.S. EPA, Office of Water. Stormwater O&M Fact Sheet: Catch Basin Cleaning http://www.epa.gov/owm/mtb/catchbas.pdf

Santa Clara Valley Urban Runoff Pollution Prevention Program http://www.scvurppp.org/

N-9	Neighborhood Source Area: Yard **SEPTIC SYSTEM MAINTENANCE**	

Description

While most urban subwatersheds are served by sewers, some still rely on septic systems for sewage disposal, particularly in less developed subwatersheds that may lie outside of the sewer service envelope. The ideal watershed behavior is to regularly inspect and maintain septic systems, make repairs as needed, and prevent disposal of household chemicals through the leach field. The accepted practice is to inspect the tank and leach field once every two years to make sure it is working properly, and to pump out the tank (Ohrel, 1995; Figure 1). The negative watershed behavior is to ignore regular inspections and pumpouts to the point that the septic system becomes a subwatershed pollution source.

How Septic Systems Influence Subwatershed Quality

Failing septic systems can be a major source of bacteria, nitrogen, and phosphorus, depending on the overall density of systems present in a subwatershed (Swann, 2001). Failure results in surface or subsurface movement of nutrients and bacteria into the stream. According to the U.S. EPA (2002), more than half of all existing septic systems are more than 30 years old, which is well past their design life. The same study estimates that about 10% of all septic systems are not functioning properly at any given time, with even higher failure rates in some regions and soil conditions. It is extremely important to understand resident behavior in regard to inspection, pump out and repair, particularly if septic system density in a subwatershed is high.

Figure 1: Septic System Inspection/Cleaning Truck

Percentage of Homeowners Engaging in Septic System Maintenance

Until recently, homeowner awareness about septic system maintenance was poorly understood. Swann (1999) conducted one of the first surveys to examine how frequently homeowners maintain their septic systems. Roughly half of the owners were classified as "septic slackers," since they indicated that they had not inspected or cleaned out their systems in the past three years. A small, but significant, fraction (12%) of septic system owners had no idea where their septic system was located on their property. In addition, only 42% of septic system owners had ever requested advice on how to maintain their septic system, and they relied primarily on the private sector for advice (e.g., pumping service, contractors, and plumbers).

Variation in Septic System Maintenance

Septic system failure rates appear to vary regionally, ranging from five to 40% (Swann, 2001). In most regions, failure rates are tied to current or past design, construction and maintenance regulations, which are set by local or state public health authorities. Failing systems are often clustered together. At the neighborhood level, many factors can influence septic system problems. Key factors linked to failure include small lot size, aging systems, poor soil or water table conditions, and close proximity to streams, lake fronts or ditches. In other cases, failure rates are tied to experimental septic system technologies, and seasonal use of properties.

Difficulty in Improving Septic System Maintenance

Septic systems are a classic case of "out of sight, out of mind." Many owners take their septic systems for granted, until they back up or break out on the surface of their lawn. Subsurface failures, which are the most common, go unnoticed. In addition, inspections, pump outs, and repair can be costly, so many homeowners tend to put off these expenditures until there is a real problem. Lastly, many septic system owners lack basic awareness about the link between septic systems and water quality at the subwatershed level.

Techniques to Increase Septic System Maintenance

Many carrots and sticks have been developed in recent years to improve resident behaviors in regard to septic system maintenance, including:

- Media campaigns to increase awareness about septic system and water quality (e.g., billboards, radio, newspaper)
- Conventional outreach materials on maintenance (e.g., brochures, bill inserts, newsletters)
- Free or mandatory inspections
- Discount coupons for septic system maintenance
- Low interest loans for septic system repairs
- Performance certification upon property transfer
- Creation of septic management districts
- Certification and training of operation/maintenance professionals
- Termination of public services for failing systems

Good Examples

Swann (2001) describes a series of case studies of effective local programs to improve septic system maintenance. Some additional examples are provided below:

Washtenaw County, Michigan Time-Of-Sale Program: The County's septic system regulation requires the inspection of all residential septic systems by private evaluators at the time of sale of a property. Evaluations must be done by a certified inspector who has received a license after training and an exam.
http://www.rougeriver.com/pdfs/illicit/OSS-02.pdf

Yarmouth, Maine Free Pumpouts (Septic Tank Pumping Ordinance) - The town offers free septic system pump-outs to residents once every three years.
http://www.yarmouth.me.us/vertical/Sites/%7B13958773-A779-4444-B6CF-0925DFE46122%7D/uploads/%7B363C4270-0879-43BC-8639-55BFA419AC12%7D.PDF

Cannon Township, MI Septic Inspections and Testing - The township used school children to conduct dye tests to identify failing septic systems. This program doubled as an education campaign to increase awareness of septic system owners.
http://peer.tamu.edu/curriculum_modules/Water_Quality/module_1/Kids%20Dye%20Project.htm

Top Resources

Many excellent resources are available to educate homeowners about septic systems and water quality. Some of the better reference websites are provided below, and many contain additional educational links.

On-site Wastewater Treatment Systems Manual
http://www.epa.gov/ord/NRMRL/Pubs/625R00008/html/625R00008.htm

A Homeowner's Guide to Septic Systems
http://www.epa.gov/npdes/pubs/homeowner_guide_long.pdf

National Small Flows Clearinghouse
http://www.nesc.wvu.edu/nsfc/nsfc_septicnews.htm

On-site Septic Systems: Educating the Homeowner
http://www.nesc.wvu.edu/nsfc/Articles/SFQ/SFQw02_web/SFQw02_Onsite Education.html

University of Minnesota Onsite Sewage Treatment Program
http://septic.coafes.umn.edu/

*North Carolina Coast*A*Syst*
http://www.soil.ncsu.edu/assist/cas/septic/index.htm

N-18

Neighborhood Source Area: Common Areas

PET WASTE PICKUP

Description

The ideal watershed behavior is to pick up and properly dispose of pet waste (Figure 1). The negative watershed behavior is to leave pet waste in common areas and the yard, where it can be washed off in storm water runoff.

How Pet Waste Influences Subwatershed Quality

Pet waste has been found to be a major source of fecal coliform bacteria and pathogens in many urban subwatersheds (Schueler, 1999). A typical dog poop contains more than three billion fecal coliform bacteria and as many as 10% of dogs are also infected with either *giardia* or salmonella, which is not surprising considering they drink urban creek water. Fecal coliform bacteria are frequently detected in urban streams and rivers after storms, with levels as high 5,000 fecal coliform per tablespoon. Thus, it is not uncommon for urban and suburban creeks to frequently violate bacteria standards for swimming and water contact recreation after larger rainstorms.

Percentage of Residents that Pick Up After Pets

Surveys indicate that about 40% of all households own one or more dogs (Swann, 1999). Not all dog owners, however, are dog walkers. Only about half of dogs are walked regularly. About 60% of dog walkers claim to pick up after their dog some or all of the time (Swann, 1999; HGIC, 1998; and Hardwick, 1997). The primary disposal method reported by residents for pet waste is the trash can, with toilets coming in distant second. Dog walkers that do not pick up after their dogs are highly resistant to change; nearly half would not pick up even if confronted with fines or complaints from neighbors (Swann, 1999). Men are also prone to pick up after their dogs less often than women (Swann, 1999).

Figure 1: Pet Waste Pickup Station

Techniques to Promote Pet Waste Pickup

The key technique is to educate residents on sanitary and convenient options for retrieving and disposing of pet waste. Several communities have used both carrots and sticks to get more owners to pick up after their pets, including:

- Mass media campaigns of the water quality impacts of pet waste
- Conventional outreach materials (brochures, flyers, posters)
- Pooper bag stations in parks, greenways and common areas
- Educational signs in same areas
- "Pooper scooper" ordinances and enforcement
- Banning dogs from beaches and waterfront areas
- Providing designated "dog parks"

Good Examples

Water Quality Consortium Nonpoint Source Education Materials
The Water Quality Consortium implemented an ad campaign focused on four themes: a man pushing a fertilizer spreader, a car driving on water leaking oil, a man washing his car, and man walking his dog. Each ad explains how the behavior leads to water pollution and provides specific tips outlining what residents can do to protect water quality.
http://www.psat.wa.gov/Programs/Pie_Ed/Water_Ed_Materials.htm

Pick It Up - It's Your Doodie Campaign (Gwinnett County Parks & Recreation Department) - The county park agency provides plastic grocery bags for pet owners to use to clean up after their pets as part of a pilot program. The baggies are attached to a wooden post at a local park. Underneath a sign explains their purpose. Pet owners are also encouraged to bring replacement bags when they visit the park.
http://www.gwinnettcitizen.com/0203/doodie.html

Top Resources

Public Open Space and Dogs: A Design and Management Guide for Open Space Professionals and Government
http://www.petnet.com.au/openspace/frontis.html

Considerations for the Selection and Use of Pet Waste Collection Systems in Public Areas
http://www.ecy.wa.gov/programs/wq/nonpoint/pet_waste/petwaste_station.pdf

Properly Disposing of Pet Waste
http://www.cleanwatercampaign.com/what_can_i_do/pet_waste_home.html

Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water
U.S. EPA Source Water Protection Practices Bulletin.
http://www.epa.gov/safewater/protect/pdfs/petwaste.pdf

N-1

Neighborhood Source Area: Yard

REDUCED FERTILIZER USE

Description

The ideal behavior is to not apply fertilizer to lawns. The next best thing for homeowners who feel they must fertilize is to practice natural lawn care: using low inputs of organic or slow release fertilizers that are based on actual needs as determined by a soil test. The obvious negative watershed behavior is improper fertilization, whether in terms of the timing, frequency or rate of fertilizer applications, or a combination of all three. The other important variable to define is who is applying fertilizer in the neighborhood. Nationally, about 75% of lawn fertilization is done by homeowners, with the remaining 25% applied by lawn care companies (Figure 1). This split, however, tends to be highly variable within individual neighborhoods, depending on its income and demographics.

How Fertilizer Influences Water Quality

Recent research has demonstrated that lawn over-fertilization produces nutrient runoff with the potential to cause downstream eutrophication in streams, lakes, and estuaries (Barth, 1995a and 1995b). Scientists have also discovered that nitrogen and phosphorus levels in lawn runoff are about two to 10 times higher than any other part of the urban landscape such as streets, rooftops, driveways or parking lots (Bannerman *et al.*, 1993; Steuer *et al.*, 1997; Waschbusch *et al.*, 2000; Garn, 2002).

Figure 1: Lawn Care Company Truck

Percentage of People Engaging in Fertilizer Use

Lawn fertilization is among the most widespread watershed behaviors in which residents engage. A survey of lawn care practices in the Chesapeake Bay indicated that 89% of citizens owned a yard, and of these, 50% applied fertilizer every year (Swann, 1999). The average rate of fertilization in 10 other regional lawn care surveys was even higher (78%), although this may reflect the fact that these surveys were biased towards predominantly suburban neighborhoods and excluded non-lawn owners. Several studies have measured the frequency of lawn fertilization, and have found that lawns are fertilized about twice a year, with spring and fall being the most common season for applications (Swann, 1999).

A significant fraction of homeowners can be classified as "over-fertilizers" who apply fertilizers above recommended rates. Surveys indicate the number of over-fertilizers at 50% to 70% of all fertilizers (Morris and Traxler, 1996; Swann, 1999; Knox *et al.*, 1995). Clearly, many homeowners, in a quest for quick results or a bright green lawn, are applying more nutrients to their lawns than they actually need.

Variation in Fertilization Behavior

Many regional and neighborhood factors influence local fertilization behavior. From a regional standpoint, climate is a very important factor, as it determines the length of the growing season, type of grass, and the irrigation needed to maintain a lawn. A detailed discussion of the role these factors play in fertilization can be found in Barth (1995a). A host of factors also comes into play at the individual neighborhood scale. Some of the more important variables include average income, market value of houses, soil quality, and the age of the development (Law *et al.*, 2004). Higher rates of fertilization appear to be very common in new suburban neighborhoods where residents seek to establish lawns and landscaping. Also, lawn irrigation systems and fertilization are strongly associated.

Difficulty in Changing Behavior

Changing fertilization behaviors can be hard since the desire for green lawns is deeply rooted in our culture (Jenkins, 1994; Teyssott, 1999). For example, the primary fertilizer is a man in the 45 to 54 year age group (BHI, 1997) who feels that "a green attractive lawn is an important asset in a neighborhood" (De Young, 1997). According to surveys, less than 10% of lawn owners take the trouble to take soil tests to determine whether fertilization is even needed (Swann, 1999; Law *et al.*, 2004). Most lawn owners are ignorant of the phosphorus or nitrogen content of the fertilizer they apply (Morris and Traxler, 1996), and are unaware that grass-cycling can sharply reduce fertilizer needs.

Most residents rely on commercial sources of information when making their fertilization decisions. The average consumer relies on product labels, store attendants, and lawn care companies as their primary, and often exclusive, sources of lawn care information. Consumers are also influenced by direct mail and word of mouth when they choose a lawn care company (Swann, 1999 and AMR, 1997).

Two approaches have shown promise in changing fertilization behaviors within a neighborhood, and both involve direct contact with individual homeowners. The first relies on using neighbors to spread the message to other residents, through master gardening programs. Individuals tend to be very receptive to advice from their peers, particularly if it relates to a common interest in healthy lawns. The second approach is similar in that it involves direct assistance to individuals at their homes (e.g., soil tests and lawn advice) or at the point of sale.

Techniques to Change Behavior

Most communities have primarily relied on carrots to change fertilization behaviors, although sticks are occasionally used in phosphorus-sensitive areas. The following are some of the most common techniques for changing fertilization behaviors:

- Seasonal media awareness campaigns
- Distribution of lawn care outreach materials (brochures, newsletters, posters, etc.; Figure 2)
- Direct homeowner assistance and training
- Master gardener program
- Exhibits and demonstration at point-of-sale retail outlets
- Free or reduced cost for soil testing
- Training and/or certification of lawn care professionals
- Lawn and garden shows on radio
- Local restrictions on phosphorus content in fertilizer

Good Examples

King County, Washington- Northwest Natural Yard Days. This month-long program offers discounts on natural yard care products and educational information about natural yard care in local stores throughout King County and Tacoma. Education specialists came to Saturday and Sunday events at some stores and spent time with buyers to help them make good choices and learn about natural yard care, including the use of organic fertilizers that don't wash off into streams and lakes as easily as "quick release" chemical fertilizers. For more details, consult: http://dnr.metrokc.gov/swd/ResRecy/events/naturalyard.shtml

North Carolina Department of Agriculture Free Residential Lawn Soil Testing. Residents can get a free soil test to determine the exact fertilizer and lime needs for their lawn, as well as for the garden, landscape plants and fruit trees. Information sheets and soil boxes are available from various government agencies, or local garden shops and other businesses. For more information, consult: http://www.ncagr.com/agronomi/stfaqs.htm

Minnesota Department of Agriculture Phosphorus Lawn Fertilizer Use Restrictions. Starting in 2004, these restrictions limit the concentration of phosphorus in lawn care products and restrict its application at higher rates to specific situations based on need. http://www.mda.state.mn.us/appd/ace/lawncwaterq.htm

Top Resources

Cornell Cooperative Extension. The Homeowner's Lawn Care Water Quality Almanac. http://www.gardening.cornell.edu/lawn/almanac/index.html

University of Rhode Island Cooperative Extension Home*A*Syst Healthy Landscapes Program http://www.healthylandscapes.org/

University of Maryland Cooperative Extension - Home and Garden Information Center. http://www.agnr.umd.edu/users/hgic/

Turf and Landscape Best Management Practices. South Florida Water Management District and the Broward County Extension Education Division http://www.sfwmd.gov/org/exo/broward/c11bmp/fertmgt.html

Florida Yards and Neighborhoods Handbook: A Guide to Environmentally Friendly Landscaping http://hort.ufl.edu/fyn/hand.htm

University of Minnesota Extension Service Low-Input Lawn Care (LILaC) http://www.extension.umn.edu/distribution/horticulture/DG7552.html

Austin TX, Stillhouse Spring Cleaning http://www.ci.austin.tx.us/growgreen/stillhouse.htm

Figure 2: Educational Brochure on Fertilizer
Source: ***http://www.state.ma.us/dep/brp/wm/files/fertiliz.pdf***

COVER CROP
(acre)
CODE 340

DEFINITION

Grasses, legumes, forbs, or other herbaceous plants established for seasonal cover and conservation purposes.

PURPOSES

- Reduce erosion from wind and water
- Increase soil organic matter
- Manage excess nutrients in the soil profile
- Promote biological nitrogen fixation
- Increase biodiversity
- Weed suppression
- Provide supplemental forage
- Soil moisture management

CONDITIONS WHERE PRACTICE APPLIES

On all lands requiring vegetative cover for natural resource protection

CRITERIA

General Criteria Applicable To All Purposes

Plant species, seedbed preparation, seeding rates, seeding dates, seeding depths, and planting methods will be consistent with approved local criteria and site conditions.

The species selected will be compatible with the nutrient management and pest management provisions of the plan.

Cover crops will be terminated by harvest, frost, mowing, tillage, and/or herbicides in preparation for the following crop.

Herbicides used with cover crops will be compatible with the following crop

Cover crop residue will not be burned

Additional Criteria to Reduce Erosion From Wind and Water

Cover crop establishment, in conjunction with other practices, will be timed so that the soil will be adequately protected during the critical erosion period(s).

Plants selected for cover crops will have the physical characteristics necessary to provide adequate protection.

The amount of surface and/or canopy cover needed from the cover crop shall be determined using current erosion prediction technology.

NUTRIENT MANAGEMENT

(Acre)

CODE 590

DEFINITION

Managing the amount, source, placement, form and timing of the application of nutrients and soil amendments.

PURPOSES

- To budget and supply nutrients for plant production.
- To properly utilize manure or organic by-products as a plant nutrient source.
- To minimize agricultural nonpoint source pollution of surface and ground water resources.
- To maintain or improve the physical, chemical and biological condition of soil.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all lands where plant nutrients and soil amendments are applied.

CRITERIA

General Criteria Applicable to All Purposes

Plans for nutrient management shall comply with all applicable Federal, state, and local laws and regulations.

Plans for nutrient management shall be developed in accordance with policy requirements of the NRCS General Manual Title 450, Part 401.03 (Technical Guides, Policy and Responsibilities) and Title 190, Part 402 (Ecological Sciences, Nutrient Management, Policy); technical requirements of the NRCS Field Office Technical Guide (FOTG); procedures contained in the National Planning Procedures Handbook (NPPH), and the NRCS National Agronomy Manual (NAM) Section 503.

Persons who review or approve plans for nutrient management shall be certified through any certification program acceptable to NRCS within the state.

Plans for nutrient management that are elements of a more comprehensive conservation plan shall recognize other requirements of the conservation plan and be compatible with its other requirements.

A nutrient budget for nitrogen, phosphorus, and potassium shall be developed that considers all potential sources of nutrients including, but not limited to animal manure and organic by-products, waste water, commercial fertilizer, crop residues, legume credits, and irrigation water.

Realistic yield goals shall be established based on soil productivity information, historical yield data, climatic conditions, level of management and/or local research on similar soil, cropping systems, and soil and manure/organic by-products tests. For new crops or varieties, industry yield recommendations may be used until documented yield information is available.

POND
(No.)
CODE 378

DEFINITION

A water impoundment made by constructing a dam or an embankment or by excavating a pit or dugout.
In this standard, ponds constructed by the first method are referred to as embankment ponds, and those constructed by the second method are referred to as excavated ponds. Ponds constructed by both the excavation and the embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at spillway elevation is 3 ft or more.

PURPOSE

To provide water for livestock, fish and wildlife, recreation, fire control, crop and orchard spraying, and other related uses, and to maintain or improve water quality.

SCOPE

This standard establishes the minimum acceptable quality for the design and construction of ponds if:

1. Failure of the dam will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities.
2. The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the emergency spillway. The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point in the cross section taken along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.
3. The effective height of the dam is 35 ft or less, and the dam is hazard class (a).

CONDITIONS WHERE PRACTICE APPLIES

Site conditions. Site conditions shall be such that runoff from the design storm can be safely passed through (1) a natural or constructed emergency spillway, (2) a combination of a principal spillway and an emergency spillway, or (3) a principal spillway.

Drainage area. The drainage area above the pond must be protected against erosion to the extent that expected sedimentation will not shorten the planned effective life of the structure. The drainage area shall be large enough so that surface runoff and groundwater flow will maintain an adequate supply of water in the pond. The quality shall be suitable for the water's intended use.

Reservoir area. The topography and soils of the site shall permit storage of water at a depth and volume that ensure a dependable supply, considering beneficial use, sedimentation, season of use, and evaporation and seepage losses. If surface runoff is the primary source of water for a pond, the soils shall be impervious enough to prevent excessive seepage losses or shall be of a type that sealing is practicable.

PRESCRIBED GRAZING

(Acre)
CODE 528A

DEFINITION

The controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective.

PURPOSES

This practice may be applied as part of a conservation management system to accomplish one or more of the following purposes:

- Improve or maintain the health and vigor of selected plant(s) and to maintain a stable and desired plant community.
- Provide or maintain food, cover and shelter for animals of concern.
- Improve or maintain animal health and productivity.
- Maintain or improve water quality and quantity.
- Reduce accelerated soil erosion and maintain or improve soil condition for sustainability of the resource.

CONDITIONS WHERE PRACTICE APPLIES

This practice may be applied on all lands where grazing and/or browsing animals are managed.

CRITERIA

General Criteria Applicable For All The Purposes Stated Above.

Removal of herbage will be in accordance with production limitations, plant sensitivities and management goals using Sections I & II of the FOTG and other references as guidance.

Frequency of defoliations and season of grazing will be based on the rate and physiological conditions of plant growth.

Duration and intensity of grazing will be based on desired plant health and expected productivity of key forage species to meet management unit objectives.

Maintain enough vegetative cover to prevent accelerated soil erosion due to wind and water.

Application of this practice will manipulate the intensity, frequency, duration, and season of grazing to:

- Insure optimum water infiltration,
- Maintain or improve riparian and upland area vegetation,
- Protect stream banks from erosion,
- Manage for deposition of fecal material away from water bodies, and
- Promote ecological and economical stable plant communities on both upland and bottom land sites which meet landowner objectives.

Additional Criteria For Improved Animal Health And Productivity.