Adapting the Hickory Creek Watershed Protection Plan for Use in Other Areas of the Lewisville Lake Watershed: the Doe Branch and Stewart Creek Sub-Watersheds

PREPARED FOR: City of Denton
Upper Trinity Regional Water District
North Texas Municipal Water District

PREPARED BY: CH2M HILL

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1 Introduction

1.1 Objectives

This technical memorandum (TM) provides the results of Task 5, *Technology Transfer from Hickory Creek Watershed to Lewisville Lake Watershed*, for the study *Implementing the Hickory Creek Watershed Protection Plan and Adapting the Plan for Use in Other Areas of the Lewisville Lake Watershed*. The objectives of Task 5, as stated in the project's Scope of Work, are:

> *To leverage the analysis and recommendations of the Hickory Creek* [Watershed Protection Plan] *into a larger geographic area of the Lake Lewisville watershed for the purpose of evaluating and developing implementation frameworks for optimizing* [best management practice; BMP] *selection and installation and introducing incentive-based mechanisms to support pollutant reduction targets in selected sub-watersheds for the benefit of the entire watershed. The result will be an identification of the ways in which the cost-effectiveness of meeting overall pollutant control and reduction goals could be improved with greater reliance on BMPs than currently forecasted.*

1.2 Previous Efforts Performed

Prior to the current study, the project team conducted other study efforts that were used as the basis of the study detailed herein. The most recent study, *Control of Nonpoint Source Loads in the Hickory Creek Sub-basin of the Lake Lewisville Watershed as a Component of a Watershed-Based Water Quality Trading Program*, was completed in December of 2008. One of the overarching tasks of the 2008 study was the development of a Watershed Protection Plan (WPP) for the Hickory Creek arm of Lewisville Lake. As part of the Hickory Creek WPP, a series of BMP optimization analyses illustrated various approaches to and benefits of a systematic approach to BMP site identification and BMP type selection at three planning levels: watershed-wide (124,470 acres), on 282 "parcels" of 80 to 125 acres each, and for three Master Planned Communities (one relatively small site of approximately 265 acres and two larger sites of approximately 3,200 acres each). The key results of these analyses include:

- Tailoring BMP "portfolios" to land uses with consideration of relative loadings increases the cost-effectiveness of controlling pollutant loadings at all planning levels.
- Meaningful reductions (for example, 5 percent to 10 percent) are possible at relatively low cost (for example, $5 to $10 per acre per year), higher but still moderate reductions are more expensive but should be affordable, and the highest levels of reduction become fairly expensive.
- Prioritizing BMPs for high-loading areas gets the best results with respect to cumulative load reductions and total cost effectiveness.

- Credit banking and trading (via direct transactions or a centralized in lieu fee system) could facilitate cost-effective reductions by providing those responsible for controlling pollutant loading from development and other land use changes with a mechanism to access BMPs that are more cost-effective than BMP opportunities limited to onsite options.

1.3 Summary of Methods and Analyses for This Project

To attempt to apply the same methodology developed during the creation of the Hickory Creek WPP outside of Hickory Creek, the project team had to identify other sub-watersheds of Lewisville Lake for application. Each of the project partners, Upper Trinity Regional Water District (UTRWD) and North Texas Municipal Water District (NTMWD), selected a sub-watershed of interest for the project's technology transfer task: Doe Branch and Stewart Creek (respectively).

The analytical approach was as follows:

- The objective was to replicate portions of the Hickory Creek WPP analyses. This ultimately involved developing BMP scenarios at two levels, watershed-wide and for selected 80- to 125-acre parcels.
- For the watershed-wide analyses, the project team tailored specific BMP scenarios to illustrate implications of forthcoming Texas Commission on Environmental Quality (TCEQ) Municipal Separate Storm Sewer System (MS4) Phase II permit requirements and voluntary program recommendations.
  - Three different scenarios target 40 percent, 60 percent, and 80 percent control of sediment (as total suspended sediment, or TSS) loading from new (and only new) urban development. TSS was selected because it is the one pollutant that all entities addressing stormwater quality challenges must address by regulation. TSS is also an important metric for managing lake water volumes, as sediment deposition can reduce lake storage.
  - The scenarios simulate future growth and development with an increase in urban land use within the Doe Branch sub-watershed, from a current 39 percent urban area to 60 percent and 80 percent, while decreasing other land uses. For the Stewart Creek sub-watershed, the scenarios simulate an increase in urban land use from a current 69 percent urban area to 80 percent (see **Section 4**, **Exhibit 4-1** for more detail).
  - The scenarios simulated implementation of sediment controls intended to reduce projected future loading by 40, 60, and 80 percent in either of two locations: (1) only on newly developed urban areas (onsite options) or (2) anywhere in the watershed, regardless of land use. The former option represents allowing only onsite compliance (that is, addressing an amount of sediment loading from a newly developed site with BMPs located on that newly developed site). The latter option represents allowing developers to use water quality credit trading, offsets, and/or in lieu fees (as mentioned in TCEQ's current draft of the Phase II MS4 permit) to comply with all or some of the simulated sediment control needs.
- The parcel-level prioritization analyses combine the load-based ranking system used for the Hickory Creek WPP with a "reverse protection" ranking system constructed from the Water Quality Corridor Management (WQCM) model scores (see **Section 5** for a description of WQCM).
  - The Hickory Creek WPP parcel ranking system calculates estimated annual mass sediment, phosphorus, and nitrogen loads for each parcel, assigns the pollutant loads weights of 40 percent, 40 percent, and 20 percent, respectively, sums the weighted total, then indexes the raw scores to a 0 to 100 point scale (see **Attachment B** for more detail).
  - The reverse protection ranking component from the WQCM scores follows the rationale that an area highly favored for protection (that is, of good quality) would not benefit from BMP implementation, and vice versa (see **Section 5**, and **Attachment C** for more detail).

1.4 Organization of This Technical Memorandum

The remainder of this TM is organized as follows:

- **Section 2** provides information about the Doe Branch and Stewart Creek sub-watersheds, including land use, estimated pollutant loadings, and the parcels included in the prioritization analyses.
- **Section 3** presents the basic assumptions for the BMP analyses, including types of BMPs, associated land uses, control effectiveness, and planning-level cost estimates.
- **Section 4** presents results of the watershed-wide BMP scenarios for the two watersheds.
- **Section 5** presents a summary of the WQCM model, the parcel ranking system, and results of the parcel prioritization scenarios for the two watersheds.
- **Section 6** presents overall conclusions and recommendations.

Additional detail about management issues and activities in the two watersheds, the BMP optimization tool, and the WQCM model is provided in **Attachments A**, **B**, and **C**, respectively.

2 Description of the Doe Branch and Stewart Creek Sub-watersheds

2.1 Project Partners' Relationships to the Doe Branch and Stewart Creek Sub-watersheds

UTRWD and NTRWD are interested in investigating the Doe Branch and Stewart Creek sub-watersheds as part of this project because these are locations of impending or existing population growth, thus potential or existing increased pollutant loading, in their respective service areas.

UTRWD is promoting watershed protection within its customer cities, which include communities in the Doe Branch sub-watershed. All customers' water and wastewater contracts include some watershed protection requirements. In general, a contract clause asks signatories to agree to implement practices to reduce pollution in the applicable watershed and adopt requirements to limit development in riparian areas. UTRWD also takes a leadership role in education, data collection, and data analysis for watershed management. Examples of UTRWD's efforts include: providing three technical guidance documents to its customer cities for use in the development of local policies, practices, and standards for watershed protection (see **Attachment A**); funding a U.S. Geological Survey (USGS) monitoring station on Doe Branch; and developing the *Lewisville Lake Watershed Protection and Management Strategies* jointly with the University of North Texas (UNT), which includes the WQCM model (see **Section 5** and **Attachment C** for more detail).

The Doe Branch sub-watershed includes what is referred to as the "U.S. Highway 380 corridor." This is an area of impending growth; numerous developments are in the planning stages and would have already been constructed had the recent economic conditions been different. The sub-watershed is mostly agricultural land use in its current state; it is also within the planning boundaries of several municipalities. Further, there is a wastewater treatment plant planned for construction and discharge in this sub-watershed.

NTMWD is a wastewater treatment service provider in the Lewisville Lake watershed dedicated to maintaining and improving the water quality within the Lewisville Lake watershed. The majority of NTMWD watershed management activities to date have been geared to the Lake Lavon watershed, as Lake Lavon is the primary drinking water source for the District. These include activities related to water conservation, lake monitoring, and lake modeling, and working with customer entities to reduce water consumption. With respect to water quality, NTMWD has a 30-year water quality monitoring record for Lake Lavon that has been used to develop a water quality model for the lake. It uses the model to implement wastewater treatment operations that protects the lake.

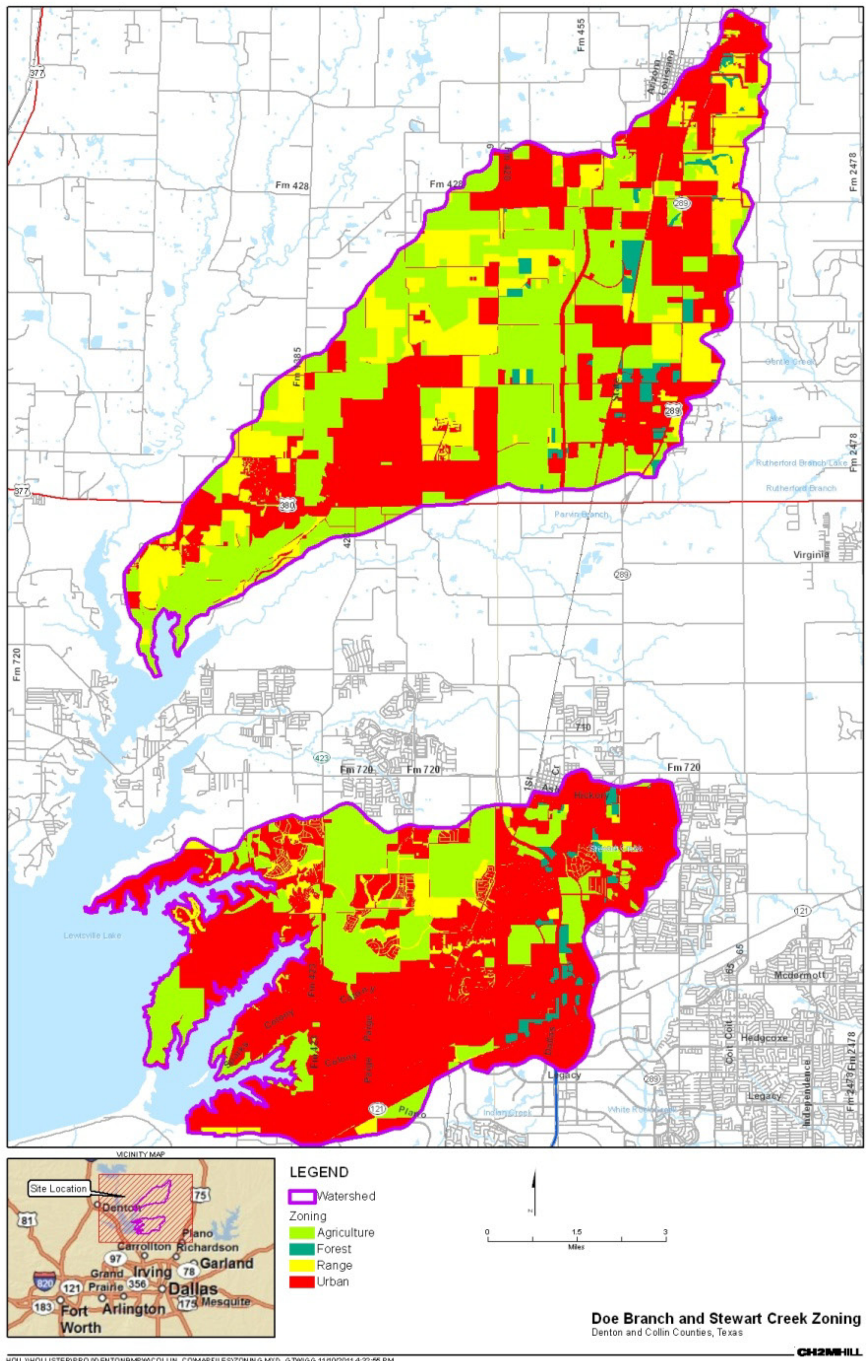
Within the Lewisville Lake watershed, NTMWD owns and operates two wastewater treatment plants, one in the Stewart Creek sub-watershed and one in the Panther Creek sub-watershed, both in the City of Frisco. The City of Frisco has studied the Stewart Creek sub-watershed because it is almost 70 percent urbanized. Conversely, the Panther Creek sub-watershed is an area identified for future growth. Because the objective of this study more aligns with addressing existing urban stormwater challenges, rather than the protection of lands not yet urbanized, the project team selected the Stewart Creek sub-watershed for inclusion. Additionally, NTMWD intends to apply the methods implemented successfully in the Lewisville Lake watershed to the Lake Lavon watershed as applicable.

2.1.1 Watershed Land Use and Summary Data

Land uses in the Doe Branch and Stewart Creek sub-watersheds for the four categories used in this study are shown in **Exhibit 2-1**. Summary data for each watershed are provided below.

- Doe Branch Sub-watershed
  - Size is 29,392 acres.
  - Communities include: Celina, Frisco, Little Elm, and Prosper.
  - Population in 2000 was 3,611.
  - Population in 2010 was 13,340.
  - This represents an annual growth rate of 14 percent over the 10-year period.
  - The watershed is currently 37 percent urban.
- Stewart Creek Sub-watershed
  - Size is 22,555 acres.
  - Communities include: The Colony, Frisco, Lewisville, and Plano.
  - Population in 2000 was 41,203.
  - Population in 2010 was 76,545.
  - This represents an annual growth rate of 6.4 percent over the 10-year period.
  - The watershed is currently 69 percent urban.

EXHIBIT 2-1
Land Uses in the Doe Branch and Stewart Creek Sub-watersheds



With the land use distribution provided, the project team estimated the annual pollutant load for each of the parameters of concern. **Exhibit 2-2** provides the annual constituent load per unit area for each land use and constituent. Pie charts showing the land use distribution and associated pollutant loading for the Doe Branch and Stewart Creek sub-watersheds are provided in **Exhibit 2-3**.

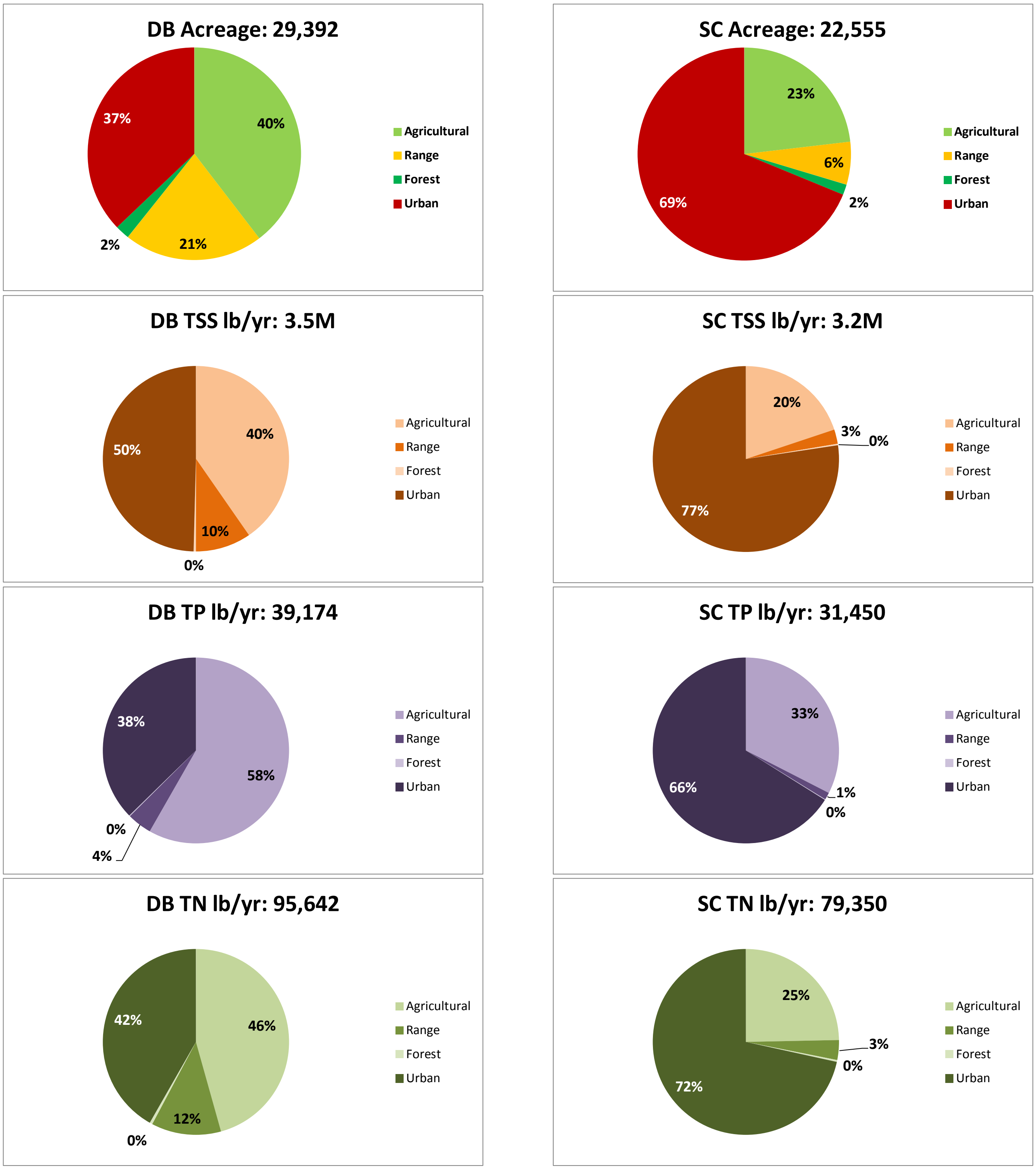
EXHIBIT 2-2
Annual Load Per Unit Area for Each Land Use and Parameter of Concern

Land Use	Annual Load Per Unit Area (lb/acre)		
	TSS	TP	TN
Urban	161.49	1.34	3.66
Agricultural	123.12	1.96	3.75
Rangeland	55.32	0.27	1.87
Forest	21.41	0.09	0.71

EXHIBIT 2-3

Pie Charts for Doe Branch (DB) and Stewart Creek (SC) Sub-watersheds Land Use Distribution and Pollutant Loading

The acreage pie charts show that the Doe Branch sub-watershed is considerably less urbanized than the Stewart Creek sub-watershed, thus the Doe Branch sub-watershed has relatively more agricultural and rangeland. The other three pie charts for each watershed show the amount of the total estimated mass load for three pollutants—total suspended sediment (TSS), total phosphorus (TP), and total nitrogen (TN)—coming from each type of land use. In both watersheds, urban lands deliver TSS loadings in a proportion greater than their land use, agriculture delivers TSS at about the same proportion, and range delivers at a lower proportion (compare acreage percentages to load percentages). The relationship is similar, but to a lesser extent for TN. In contrast, agricultural lands deliver TP loadings in a greater proportion than their land area, while urban lands deliver about the same proportion, and rangelands deliver a lower proportion.



The watershed-wide analyses described in **Section 4** include analyses of the entire acreage of each watershed, with some limitation with respect to parcel size and with some assumptions about future increases in urban land area relative to other land uses, as described in **Section 4**. The parcel prioritization analyses described in **Section 5** identified the 80- to 125-acre sub-drainage areas in the Doe Branch and Stewart Creek sub-watersheds. As in the Hickory Creek project, this size of drainage area was determined to be the best size for this type of analyses; results for drainage areas less than 80 acres might be inaccurate using the Digital Elevation Model, which is what was used to delineate the smaller drainage areas within the Stewart Creek and Doe Branch sub-watersheds, and drainage areas of greater than 125 acres are less practical for BMP implementation on the scale intended for this study (challenges may include numerous land owners, road crossings, and utility crossings, among others).

There are 66 parcels in the Doe Branch sub-watershed and 38 parcels in the Stewart Creek sub-watershed that correspond to this size of drainage area, as shown in **Exhibits 2-4** and **2-5**.

EXHIBIT 2-4
Sub-drainage Parcels in the Doe Branch Sub-watershed

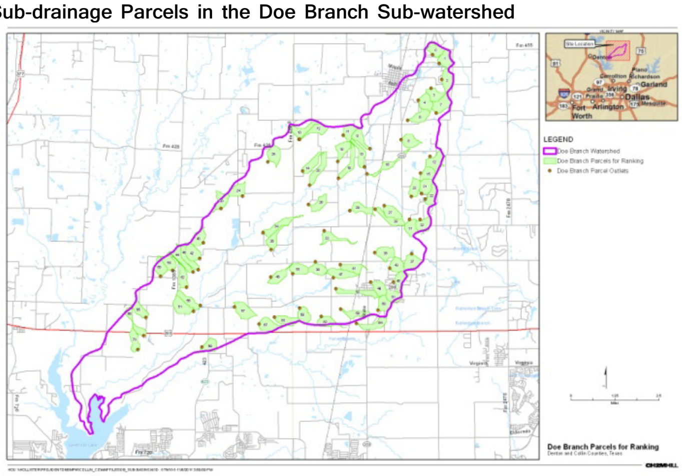
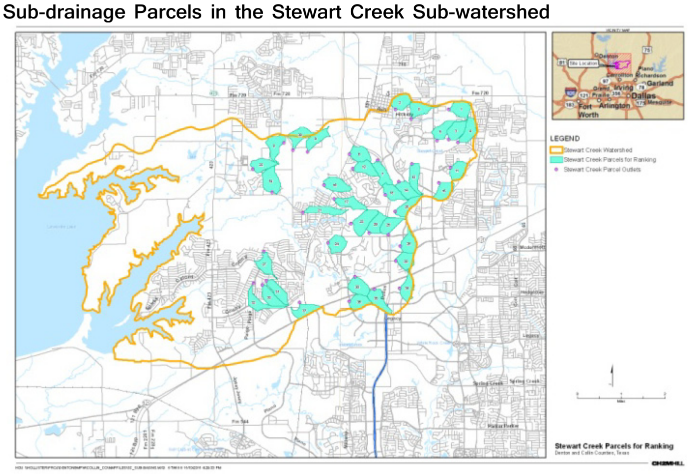


EXHIBIT 2-5
Sub-drainage Parcels in the Stewart Creek Sub-watershed



3 Summary of Inputs and Assumptions for the BMP Scenario Development and Optimization Tool

This section presents a series of screen captures from the Excel-based tool described in **Attachment B** to document in summary fashion some of the key inputs and assumptions that form the basis for the watershed-wide and parcel prioritization analyses described in **Sections 4** and **5**. Captions to the exhibits provide additional detail as to data source and purpose. Please see **Attachment B** for more detailed narrative regarding the tool.

The following exhibits are presented in this section:

- **Exhibit 3-1**: BMPs, removal efficiencies, control area, and useful life
- **Exhibit 3-2**: BMP cost estimates
- **Exhibit 3-3**: BMP unit control costs
- **Exhibit 3-4**: BMP unit control cost relative rankings
- **Exhibit 3-5**: Maximum coverage for BMPs by land use
- **Exhibit 3-6**: Optimization tool scenario development dashboard

EXHIBIT 3-1

BMPs, Removal Efficiencies, Control Area, and Useful Life

The nine BMPs available for the scenarios are presented below. The first three are applicable to agricultural, range, and forest land, while the last six are all urban BMPs. The removal efficiencies are taken from the Integrated Storm Water Management (iSWM) guidance or based on best professional judgment. The "Control" acres indicate how many acres of land are addressed (that is, loading reduced) by an "acre of BMP". The useful life indicates the number of years the BMP is assumed to achieve pollutant removal for the capital and operation and maintenance costs assumed.

Denton BMP Optimization Tool

Assumed BMP removal efficiencies and control ratios for sediment, phosphorus, and nitrogen

	BMP Removal Efficiencies			Control	Useful Life
BMP Name	TSS	TP	TN	Acres	Years
Grass Planting	48%	19%	19%	1	5
Grassed Waterways/Filter Strips	50%	20%	20%	5	10
Grade Stabilization Structures	53%	21%	21%	1	15
Detention Ponds	65%	50%	30%	1	10
Retention (Wet) Ponds	80%	50%	30%	1	20
Treatment Ponds	80%	40%	30%	1	20
Riparian Buffers	50%	20%	20%	20	20
Vegetated Swales/Strips	80%	25%	40%	5	10
Infiltration Basins	80%	60%	60%	1	20

EXHIBIT 3-2

BMP Cost Estimates

Cost estimates for capital and operation and maintenance were developed as part of the Hickory Creek WPP using TxDOT, NRCS, and best professional judgment sources. These were reviewed for this project, deemed appropriate, and escalated into 2011 dollars using the Engineering New Record Indices. The screen capture below shows the base costs per acre implemented, as well total cost and average annual cost in current dollars and net present value (NPV) for a 20 year forecast period.

Denton BMP Optimization Tool

Capital and operating cost estimates, duration, and total costs over the forecast period by BMP

Forecast Yrs = 20

	Cost per Acre Implemented		Total Cost		Avg. Cost per Year	
BMP Name	Capital	Annual O&M	Current $	NPV	Current $	NPV
Grass Planting	$ 585	$ 59	$ 3,521	$ 2,698	$ 176	$ 135
Grassed Waterways/Filter Strips	994	50	2,985	2,287	149	114
Grade Stabilization Structures	11,962	1,197	39,882	30,557	1,994	1,528
Detention Ponds	4,039	404	16,154	12,377	808	619
Retention (Wet) Ponds	7,966	1,594	39,839	30,524	1,992	1,526
Treatment Ponds	7,353	735	22,053	16,897	1,103	845
Riparian Buffers	250	499	10,231	7,839	512	392
Vegetated Swales/Strips	994	198	5,957	4,564	298	228
Infiltration Basins	12,988	2,597	64,938	49,755	3,247	2,488

EXHIBIT 3-3

Annual BMP Unit Control Costs for the Three Pollutants

These costs are calculated by dividing the annualized costs per acre by the annual pound reduction per acre.

Denton BMP Optimization Tool

Current dollar cost per pound estimates for sediment, phosphorus, and nitrogen removal by BMP

	Sediment: Cost per Pound Removed				*Phosphorus: Cost per Pound Removed*				*Nitrogen: Cost per Pound Removed*			
BMP Name	**Agricultural**	**Range**	**Forest**	**Urban**	**Agricultural**	**Range**	**Forest**	**Urban**	**Agricultural**	**Range**	**Forest**	**Urban**
Grass Planting	$ 2.98	$ 6.63	$ 17.13	$ 2.27	$ 473	$ 3,432	$ 10,295	$ 691	$ 247	$ 495	$ 1,305	$ 253
Grassed Waterways/Filter Strips	$ 0.48	$ 1.08	$ 2.79	$ 0.37	$ 76	$ 553	$ 1,659	$ 111	$ 40	$ 80	$ 210	$ 41
Grade Stabilization Structures	$ 30.56	$ 68.01	$ 175.73	$ 23.30	$ 4,845	$ 35,170	$ 105,509	$ 7,086	$ 2,532	$ 5,078	$ 13,374	$ 2,594
Detention Ponds	$ 10.09	$ 22.46	$ 58.04	$ 7.70	$ 824	$ 5,983	$ 17,949	$ 1,206	$ 718	$ 1,440	$ 3,792	$ 736
Retention (Wet) Ponds	$ 20.22	$ 45.01	$ 116.30	$ 15.42	$ 2,033	$ 14,755	$ 44,265	$ 2,973	$ 1,771	$ 3,551	$ 9,352	$ 1,814
Treatment Ponds	$ 11.20	$ 24.92	$ 64.38	$ 8.54	$ 1,406	$ 10,210	$ 30,630	$ 2,057	$ 980	$ 1,966	$ 5,177	$ 1,004
Riparian Buffers	$ 0.42	$ 0.92	$ 2.39	$ 0.32	$ 65	$ 474	$ 1,421	$ 95	$ 34	$ 68	$ 180	$ 35
Vegetated Swales/Strips	$ 0.60	$ 1.35	$ 3.48	$ 0.46	$ 122	$ 883	$ 2,648	$ 178	$ 40	$ 80	$ 210	$ 41
Infiltration Basins	$ 32.96	$ 73.37	$ 189.57	$ 25.13	$ 2,761	$ 20,043	$ 60,128	$ 4,038	$ 1,443	$ 2,894	$ 7,622	$ 1,479

EXHIBIT 3-4

Annual BMP Unit Control Costs for the Three Pollutants

*These rankings are based on the same data presented in **Exhibit 3-3.** A "1" identifies the most cost-effective (least expensive) option on a unit cost basis, and "9" indentifies the least cost-effective (most expensive) option. The color coding helps compare the rankings at a glance: the most cost-effective choices are green, middle choices are yellow-orange, and the least cost-effective choices are red.*

Denton BMP Optimization Tool

Ranking of current dollar cost per pound estimates for sediment, phosphorus, and nitrogen removal by BMP

	Sediment: Cost per Pound Removed				*Phosphorus: Cost per Pound Removed*				*Nitrogen: Cost per Pound Removed*			
BMP Name	**Agricultural**	**Range**	**Forest**	**Urban**	**Agricultural**	**Range**	**Forest**	**Urban**	**Agricultural**	**Range**	**Forest**	**Urban**
Grass Planting	4	4	4	4	4	4	4	4	4	4	4	4
Grassed Waterways/Filter Strips	2	2	2	2	2	2	2	2	3	3	3	3
Grade Stabilization Structures	8	8	8	8	9	9	9	9	9	9	9	9
Detention Ponds	5	5	5	5	5	5	5	5	5	5	5	5
Retention (Wet) Ponds	7	7	7	7	7	7	7	7	8	8	8	8
Treatment Ponds	6	6	6	6	6	6	6	6	6	6	6	6
Riparian Buffers	1	1	1	1	1	1	1	1	1	1	1	1
Vegetated Swales/Strips	3	3	3	3	3	3	3	3	2	2	2	2
Infiltration Basins	9	9	9	9	8	8	8	8	7	7	7	7

EXHIBIT 3-5

Coverage Assumptions for BMPs

To prevent development of scenarios that assume an unreasonable amount of BMPs with respect to cost or relative amount of land use controlled, reasonable maximum coverage limits apply. These were developed as part of the Hickory Creek WPP. In the scenarios, any combination of BMPs can be used subject to the individual BMP and land use category maximums.

Land Use Category **and BMP**	**Max Coverage Percent of Category Acreage**
Agricultural Land	**40**
Grass Planting	5
Grading/Grassed Waterways/Filter Strips	25
Grade Stabilization/Wet Pond	10
Range Land	**50**
Grass Planting	25
Grading/Grassed Waterways/Filter Strips	25
Grade Stabilization/Wet Pond	25
Forest Land	**25**
Grass Planting	20
Grading/Grassed Waterways/Filter Strips	5
Grade Stabilization/Wet Pond	20
Urban Land	**75**
Detention ponds	50
Retention Ponds	50
Riparian Buffers	10
Treatment Ponds (wetlands)	10
Vegetated Swales/Strips	10
Infiltration basins	25

4 Summary of Watershed-Wide BMP Scenarios Tailored to Phase II MS4-Related Implementation

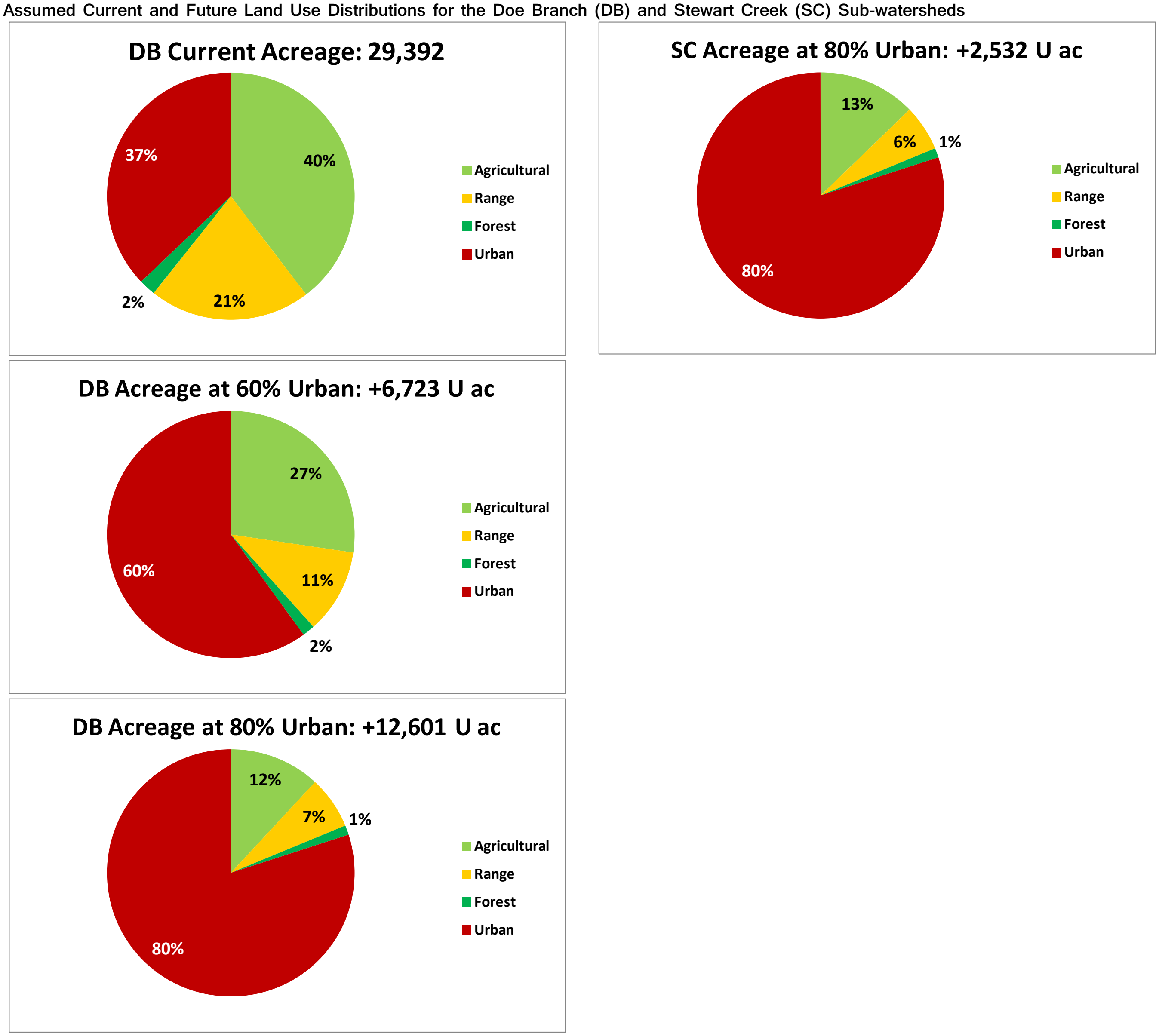
4.1 Overview of Watershed-Wide Scenarios

As described in **Section 1**, the project team developed BMP scenarios for this analysis that would control 80 percent, 60 percent, or 40 percent of TSS loading from newly urbanized areas under two alternative compliance options. In the first option, the requirement can only be satisfied by "placing" BMPs on the new urban areas (onsite); in the second option, the requirement can be satisfied by placing BMPs anywhere in the drainage area of interest. The first option reflects a compliance regime where only onsite controls are allowed; the second reflects a compliance regime where any combination of on- or offsite controls is allowed. This second regime illustrates a situation where water quality credit trading, pollutant offsets, and/or in lieu fees are available to satisfy pollutant control responsibilities. Notably, TCEQ's draft Phase II MS4 permit says the permittee may "utilize an offsite mitigation and payment in lieu components to address this requirement," to achieve the post-construction greenfield and redevelopment Minimum Control Measures requirements (see Part III.B.4.(a).(1)).

This analysis necessarily makes assumptions about future land use changes in each watershed that involve increases in urban land area and decreases in other land use areas. The estimated current and assumed future land use distributions for the Doe Branch and Stewart Creek sub-watersheds used in the analyses are graphically presented in **Exhibit 4-1**.

EXHIBIT 4-1

Assumed Current and Future Land Use Distributions for the Doe Branch (DB) and Stewart Creek (SC) Sub-watersheds



The charts in **Exhibit 4-1** illustrate the current land use distribution for each watershed. For the Doe Branch sub-watershed, the analysis increases amount of urban acreage in two steps: from 37 percent to 60 percent, then to 80 percent, for an incremental addition of 6,723 acres and a total addition of 12,601. Because the Stewart Creek sub-watershed is already heavily urbanized at 69 percent, the analysis increases the amount of urban acreage in one step only, from 69 percent to 80 percent, an increase of 2,532 urban acres. The increases in urban acreage are accomplished by decreasing the amounts of the other types of land use, in amounts and proportions using reasonable assumptions and best professional judgment about how urbanization might occur in these watersheds as agricultural, range, and forest lands are developed into urban areas. These changes are reflected in the charts as smaller percents of the total for these three land uses. For the purposes of this study, no time period was placed on the conversions. In other words, the entire simulated increase in urban land use and decrease in other land uses happens instantaneously.

4.2 Doe Branch Sub-watershed-Wide Results

The BMP scenario results for the Doe Branch sub-watershed are provided in two sets of charts (**Exhibits 4-2** and **4-3**). **Exhibit 4-2** features TSS control cost estimates for the three control levels and two compliance options evaluated. **Exhibit 4-3** illustrates where the BMPs were placed by land use type and the control contribution from each land use type.

In **Exhibit 4-2**, the first three sets of data show results for controlling loads from new urban areas on new urban land only for the three chosen control levels: 80 percent, 60 percent, and 40 percent control of TSS loads. The second three sets of data show results for controlling loads from new urban areas on any type of land—new urban, old urban, and anywhere on the other three types of land use—for the same three chosen control levels.

The large diamonds mark and are labeled with the Annual Cost per Acre Controlled. The two bars mark the annualized Overall Cost per Pound of TSS controlled (in dollars) and the total Annual Cost for the entire BMP package selected for the watershed (in million dollars). The chart illustrates that higher levels of control cost more; this is also intuitive. It is also evident that allowing developers and land owners to satisfy their control requirements on any type of land, urban or otherwise, is less expensive than onsite only options.

EXHIBIT 4-2
Selected Cost Benchmarks for Watershed-Wide BMP Scenario: Doe Branch Sub-watershed at 60 percent Urbanization

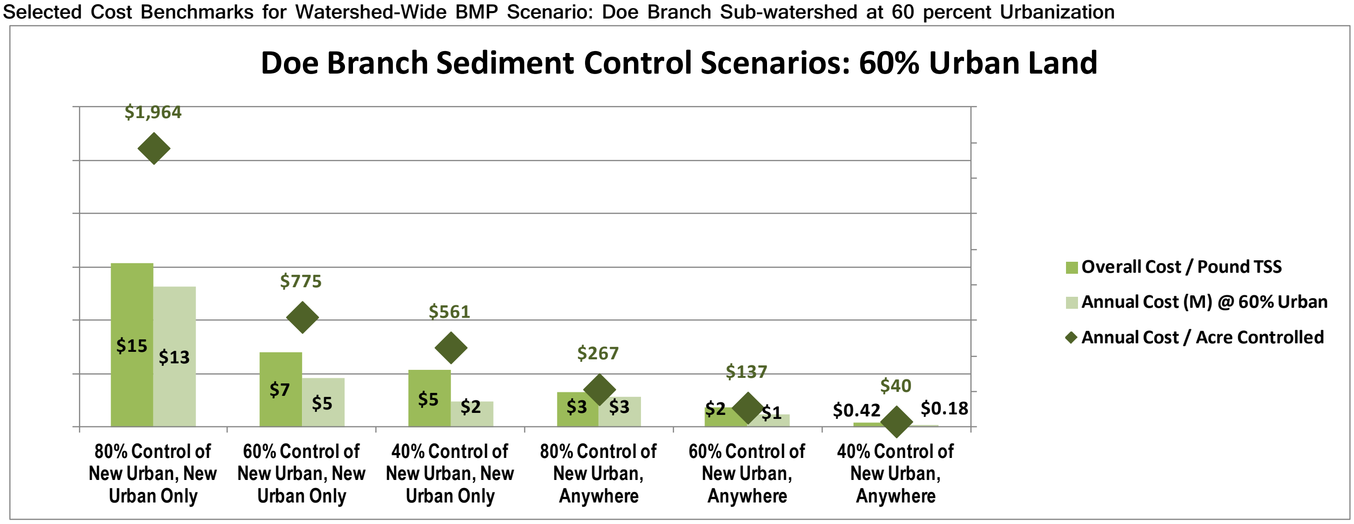
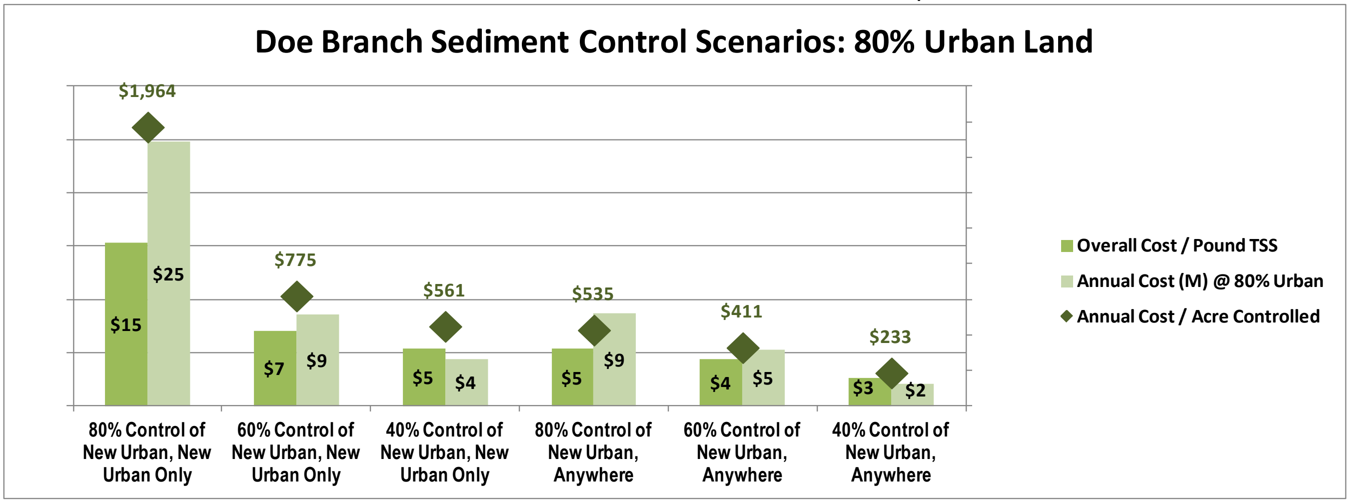


Exhibit 4-3 is presented in the same manner as **Exhibit 4-2**. The results for the new urban-only control scenarios are the same as for the 60 percent level (see values for Annual Cost/Acre Controlled, as well as Overall Cost/Pound TSS); this is because these are unit costs and the same BMP control package was applied for the 60 percent and 80 percent control scenarios, only the amount of acreage controlled differed between the two scenarios.

At an 80 percent urbanization level, it is still less expensive to reduce TSS loads in the amount needed for compliance on any type of land use than to confine compliance to onsite options only.

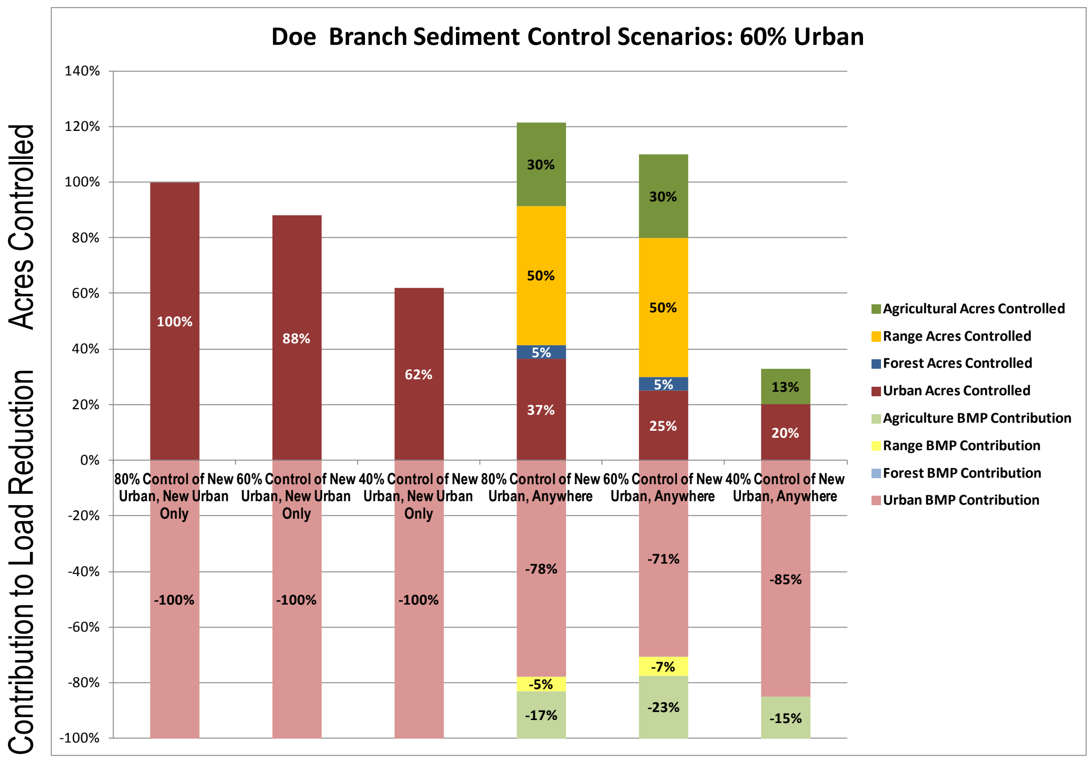
Comparing the three data sets on the right in **Exhibit 4-3** with those in **Exhibit 4-2** also illustrates that, as urban areas increase, compliance options even with offsite options, as represented in the “Anywhere” scenarios, will increase as the “use” of less expensive options on all types of land use are maximized.

EXHIBIT 4-3
Selected Cost Benchmarks for Watershed-Wide BMP Scenario: Doe Branch Sub-watershed at 80 percent Urbanization



Similar to **Exhibits 4-2** and **4-3**, **Exhibit 4-4** presents data for the three onsite only scenarios in the three left bars and for the three "Anywhere" scenarios in the three right bars. In the top, positive percent panel, the percent of each type of land use controlled with BMPs is shown.

EXHIBIT 4-4
Acres Controlled and Contribution to Load Reduction by Land Use Type: Controls on New Urban Only or Anywhere for the Doe Branch Sub-watershed at 60 percent Urban



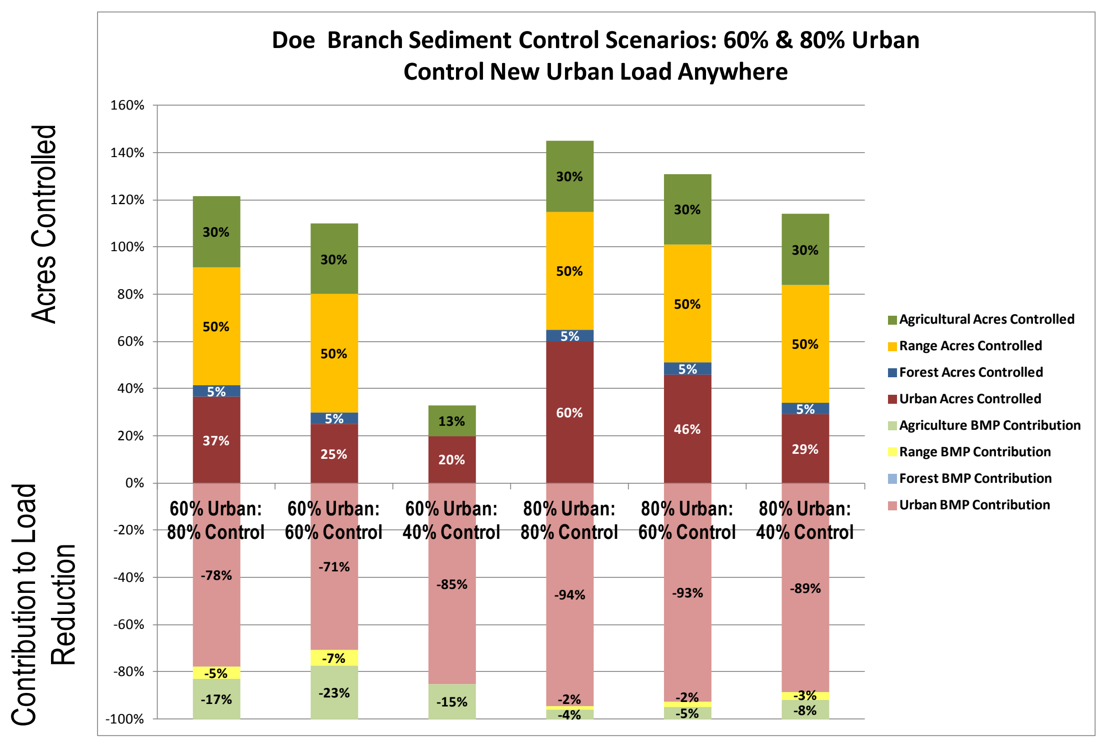
For the three onsite only scenarios, it is necessary to control 100 percent, 88 percent, and 62 percent of the new urban land to achieve TSS control levels of 80 percent, 60 percent, and 40 percent, respectively. No other land use options are available, so these bars are all maroon. In association with these positive left bars, the bars below the x-axis illustrate the percent of TSS reductions gained from BMPs on each type of land use as negative percents. For the onsite-only options, 100 percent (shown as -100 percent) of the reductions are from urban BMPs, as shown in the rose-colored bars.

The top right bars show a very different picture than their counterparts on the left. The addition of green, yellow, and blue sections show that BMPs have been placed on agricultural, range, and forest areas to attain the three control levels in scenarios representing offsite control options. Each bar segment shows the percent of that land use type controlled with BMPs, so these can add up to more than 100 percent. Notably urban BMPs are still important, but the amount of acres controlled decreases as the control level decreases. Additionally, at the 40 percent TSS control level, only the least expensive agricultural and urban BMPs are needed to achieve compliance.

The three bars on the bottom right show the percent of the total load control provided by BMPs on each land use type. The significantly-sized rose-colored sections show that urban BMPs provide the bulk of the load reduction, 71 percent to 85 percent even when offsite options are available. This result occurs in part because there is significantly more urban land in the anywhere scenario on which to apply the least expensive urban BMPs before their coverage limits are reached and more expensive BMPs are needed for compliance.

In **Exhibit 4-5**, the left three bars show the same data as the right three bars in **Exhibit 4-4** for the 60 percent urbanization scenarios with offsite options. The right three bars in **Exhibit 4-5** show the same components but for the 80 percent urbanization offsite scenarios. The onsite only compliance options bars for the 80 percent urbanization scenario are the same as for the 60 percent urbanization scenario. Otherwise, **Exhibit 4-5** is formatted in the same manner as **Exhibit 4-4**. The top positive bar segments illustrate the acres controlled with BMPs as a percent of the total acreage in each unique land use category (thus the sum of those shown may add up to more than 100 percent), while the bottom negative bar segments show the percent of the total load controlled from each type of land use, which will always add to -100 percent. Comparing the results for the 60 percent and 80 percent urbanization levels shows that, while urban BMPs still deliver the preponderance of the load reductions (89 percent to 94 percent), greater coverage levels are needed on both urban and non-urban lands (as seen in the acres controlled values) to achieve compliance at 80 percent urbanization, even with offsite compliance options being available.

EXHIBIT 4-5
Acres Controlled and Contribution to Load Reduction by Land Use Type: Controls Anywhere for the Doe Branch Sub-watershed at 60 percent and 80 percent Urban

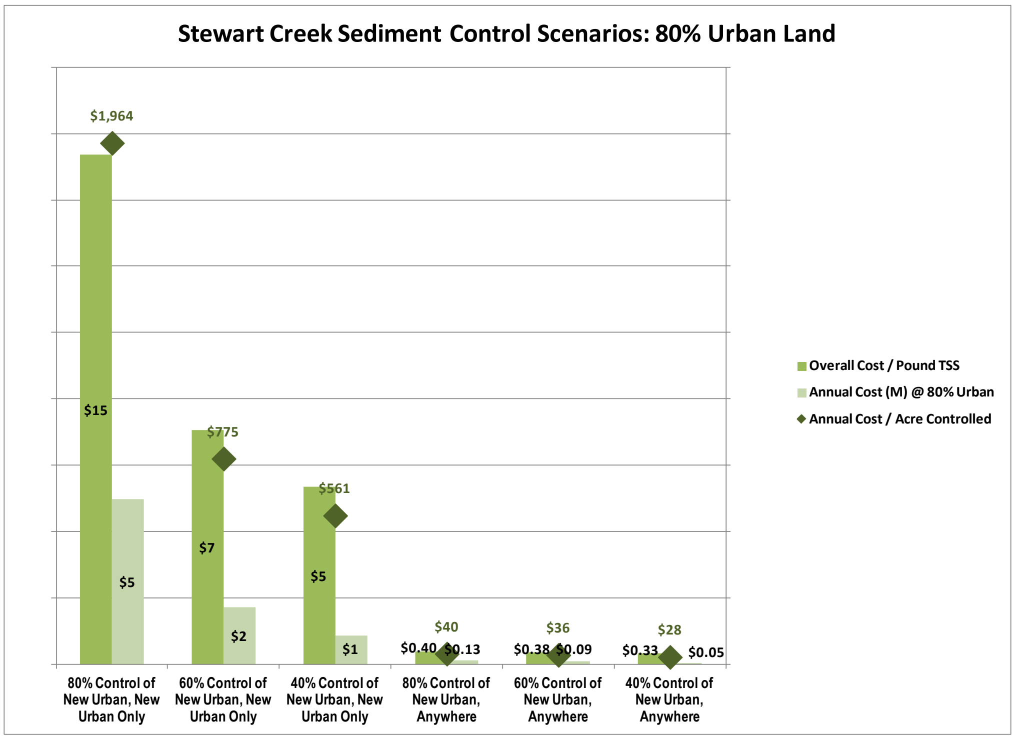


4.3 Stewart Creek Sub-watershed-Wide Results

The BMP scenario results for the Stewart Creek sub-watershed, as they were for the Doe Branch sub-watershed, are provided in two sets of charts presented in **Exhibits 4-6** and **4-7**. The first set features TSS control cost estimates for the three control levels and two compliance options evaluated. The second set illustrates where the BMPs were placed and the control contribution from each land use type.

Exhibit 4-6 is presented the same way as **Exhibits 4-2** and **4-3**, and the unit costs for the first three sets of data are the same in both watersheds. As with the Doe Branch sub-watershed, higher levels of controls cost more, and allowing compliance to be satisfied with BMPs on any type of land use, versus restricting compliance to new urban areas only is much less expensive.

EXHIBIT 4-6
Selected Cost Benchmarks for Watershed-Wide BMP Scenario: Stewart Creek Sub-watershed at 80 percent Urbanization



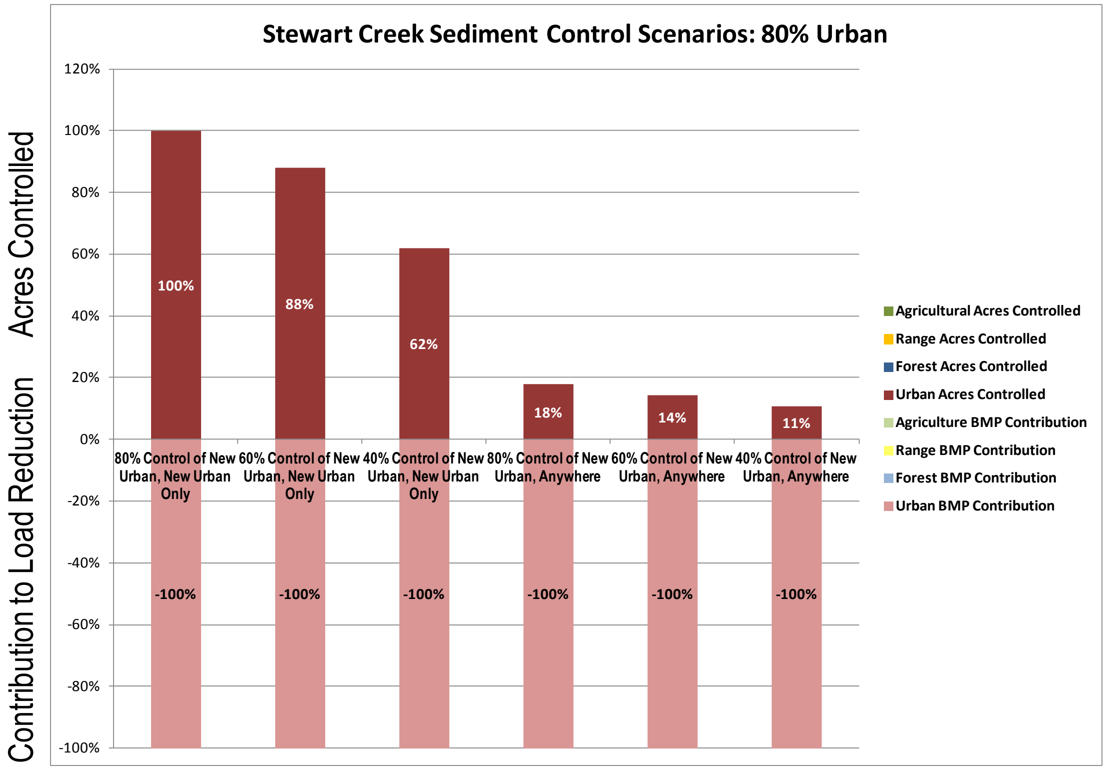
The annual costs per acre controlled to reduce loadings from the 2,532 new urban acres in the Stewart Creek sub-watershed are notably much lower than for the Doe Branch sub-watershed at either the 60 percent or 80 percent urban levels: $28 to $40 per acre compared to $40 to $500. This is because the sediment load to be controlled associated with this 2,532-acre increase in urban area in the Stewart Creek sub-watershed is much less than the sediment load associated with the urbanization in the Doe Branch sub-watershed, with incremental acreage increases on the order of 6,000 and 12,000 acres for the 60 percent and 80 percent urbanization scenarios. While these are planning-level results measured in the aggregate, it still reasonable to expect that any storm water TSS-control program using onsite and offsite compliance options will provide significant opportunities for lowering compliance costs in the aggregate, relative to onsite-only options.

Exhibit 4-7 is set up the same way as **Exhibits 4-4** and **4-5**: the left three bar sets show results for the onsite only compliance scenarios, the right three bar sets show results for the anywhere compliance scenarios, the bar segments above the x-axis show the percent of each land use controlled with BMPs, and the bar segments below the x-axis show the percent of contribution to the total load reduction by the BMPs on each land use. Additionally, due to the way the BMP control packages are constructed, the values in the top and bottom portions of the left three bar sets are the same as for the Doe Branch sub-watershed for these controls on new urban land only scenarios.

The most striking difference in the results between the Stewart Creek and Doe Branch sub-watersheds is that 100 percent of the TSS reduction for the new urban only and anywhere scenarios is achieved by urban BMPs.

EXHIBIT 4-7

Acres Controlled and Contribution to Load Reduction by Land Use Type: Controls on New Urban Only or Anywhere for the Stewart Creek Sub-watershed at 80 percent Urban



This result appears to be caused by two factors. One, much less area is available for control in the Stewart Creek watershed (2,500 versus 6,000 or 12,000 acres in Doe Branch), and, two, the maximum coverage limits on the BMPs. As a result of these factors, the most cost effective scenarios involve applying the least expensive BMPs to between 11 percent and 18 percent of urban land, as the Stewart Creek sub-watershed progresses from 69 percent to 80 percent urban land use. In contrast, the less expensive urban BMPs reach their coverage maximums in some of the Doe Branch sub-watershed scenarios and more expensive BMPs are required on urban and non-urban land to achieve the TSS control targets.

4.4 Summary Findings and Implications of the Watershed-wide Analysis

The watershed-wide analyses described illustrate the following:

- The cost of urban storm water pollution control increases as urbanization increases. It is much more cost effective to initiate control as early as possible.
- Addressing storm water pollutant loading on newly urbanized land only becomes relatively more expensive for increasing levels of control; for TSS control of 40, 60, and 80 percent, planning-level cost estimates are approximately $600, $800, and $2,000 per acre per year, respectively.
- In the aggregate, implementing a combination of onsite urban BMPs and offsite BMPs on urban and other land types is much more cost effective. At a level of 60 percent urbanization, average compliance costs are estimated at $50, $100, and $300 per acre per year for the three control levels evaluated; at a level of 80 percent urbanization, average compliance costs are estimated at $200, $400, and $500 per acre per year.

- This result is made possible by the differentials in the relative control costs between on- and offsite options, as shown in **Exhibit 4-8**.

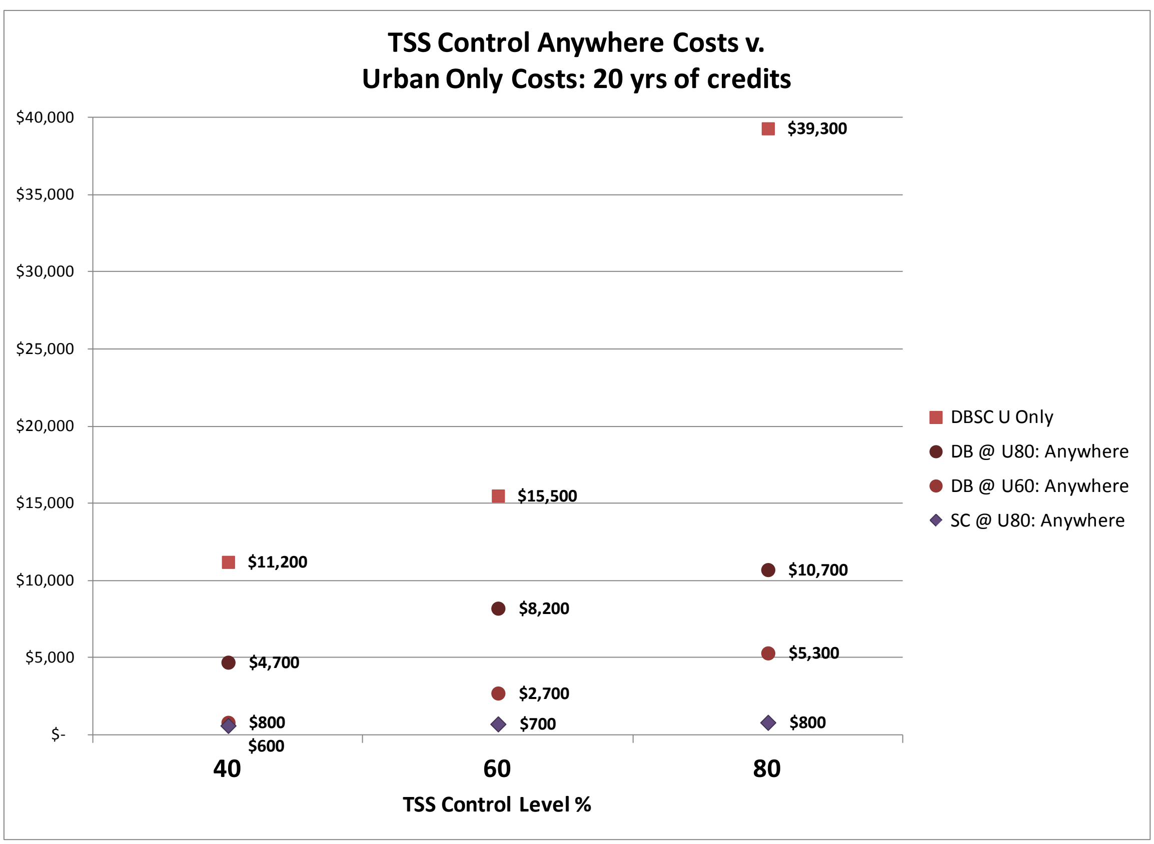
The offsite compliance option could be implemented through an in lieu fee offset program and/or a credit trading and banking system, operated at a watershed and/or regional level.

Exhibit 4-9 presents an example of the practical implications of these results. This chart shows estimated planning-level TSS control costs under the compliance scenarios evaluated. The three red squares show the onsite only costs per acre ranging from $11,200 to $39,200 for control levels of 40 percent to 80 percent for 20 years of control. The two sets of red dots and the purple diamond show that compliance with the simulated requirements are considerably less when BMPs can be implemented anywhere through a trading or in lieu fee program. The 20-year term was selected for this example because it is the compliance period required in several North Carolina urban development offset programs, including those administered through the state's Ecosystem Enhancement Program.

EXHIBIT 4-8
Annual TSS Unit Control Costs
Cost per pound TSS differences among BMP-land use combinations create opportunities for cost-savings with offsets, trading, and banking.

Planning by Land Use and BMP Category	BMP Cost per Pound
Agricultural	
Grass Planting	$ 2.98
Grassed Waterways/Filter Strips	$ 0.48
Grade Stabilization Structures	$ 30.56
Range	
Grass Planting	$ 6.63
Grassed Waterways/Filter Strips	$ 1.08
Grade Stabilization Structures	$ 68.01
Forest	
Grass Planting	$ 17.13
Grassed Waterways/Filter Strips	$ 2.79
Grade Stabilization Structures	$ 175.73
Urban	
Detention Ponds	$ 7.70
Retention (Wet) Ponds	$ 15.42
Treatment Ponds	$ 8.54
Riparian Buffers	$ 0.32
Vegetated Swales/Strips	$ 0.46
Infiltration Basins	$ 25.13

EXHIBIT 4-9
Example TSS Per Acre Control 20 Year Compliance Costs for Onsite Only and Anywhere Compliance Scenarios
Storm water controls can be developed to optimize removal costs for different load reduction objectives when offsite ("anywhere") options are available.



5 Summary of Parcel-Level Prioritization Scenarios Using Load-Based and Reverse WQCM Ranking System

5.1 Overview of Parcel Prioritization Scenarios

As described in **Section 1**, this analysis involved identifying 80- to 125-acre parcels in the Doe Branch and Stewart Creek sub-watersheds and using a prioritization system that combined load-based scores with "reverse protection" scores drawn from the WQCM model. The primary overall objectives of this component of the study are to generally evaluate the ease of using such a combined ranking system and compare the results of the load-only ranking system to the combined load-WQCM system.

5.2 Description of WQCM and the Combined Parcel Scoring System

UTRWD and UNT collaborated to develop the WQCM model, as described in their publication *Lewisville Lake Watershed Protection and Management Strategies*. As stated in the strategy document: "The WQCM model is a geospatial database that utilizes [geographic information systems, GIS] and remote sensing techniques to assess and prioritize stream reaches according to their overall health and sustainability." UTRWD and UNT's 2007 effort assessed Lewisville Lake's sub-watersheds and assigned one of four narrative priority rankings for protection, as shown in **Exhibit 5-1**. The rankings are based on a total numerical score that is the sum of weighted scores for five individual parameters, as shown in **Exhibit 5-2**. The raw scores can vary from 0 to 50 and translate into narrative scores as follows: Low, 0 to 29.76; Moderate, 29.86 to 31.7; High, 31.71 to 33.64; and Very High, 33.73 to 50. According to the developers, field-level assessments correlated well with WQCM results, "highlight[ing] the functionality of the WQCM model in assessing real world conditions."

EXHIBIT 5-1

WQCM Narrative Scores for Lewisville Lake Watersheds

This map taken from the WQCM CD shows the Lewisville Lake subwatersheds, their WQCM ID number (in white or black), and a superimposed narrative score color legend.

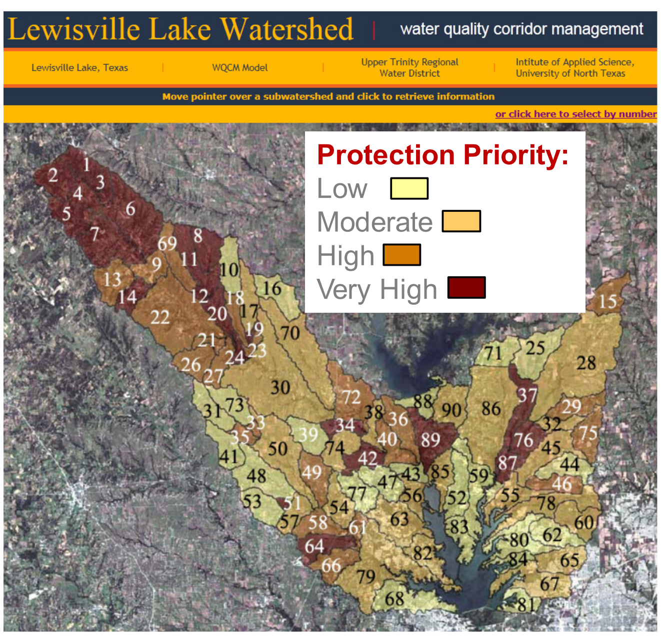
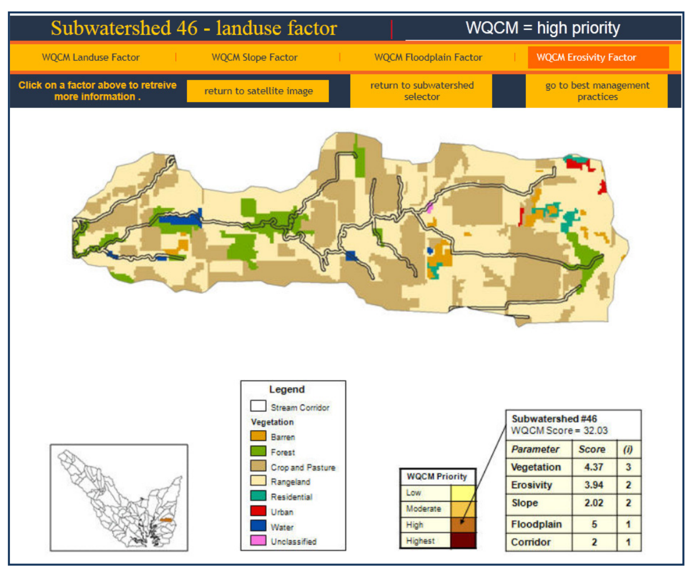


EXHIBIT 5-2

Example of WQCM Numerical and Narrative Scoring

The five WQCM parameters can be seen in the small table in the lower right corner: vegetation, erosivity, slope, floodplain, and corridor. The raw scores out of a possible 0 to 5 are shown, along with the weights in the column marked (i). In this subwatershed (#46) the total score was 32.03, translating into a narrative score of High protection value.



For Hickory Creek WPP, the parcel prioritization analysis used a load-based indexing and ranking system. One study objective was to replicate that approach for this project, as previously described. Another objective was to illustrate if and how load data could be combined with information developed by the project partners in their water quality protection efforts for a richer index and possibly different prioritization results. Toward this end, the project team selected the WQCM system to combine with load data for two pilot watersheds (one selected by each partner) because it was readily available and contains attributes not explicit in load data.

Exhibits 5-3 and **5-4** show the sub-watershed parcels in each watershed overlain with the WQCM watersheds and corresponding narrative scores. The areas delineated with green, blue, and red outline and hash marks show the sub-watersheds used in the WQCM study and corresponding narrative score: Low (L), Moderate (M), and High (H) protective value. The two inset pie charts show the percent of the total sub-watershed acreage and the percent of the total parcel acreage in each land use type.

EXHIBIT 5-3

Doe Branch Sub-watershed Parcels in WQCM Watersheds

The 66 parcels appear in light green under the overlay. The aggregate land use distribution of the parcels is comparable to the sub-watershed.

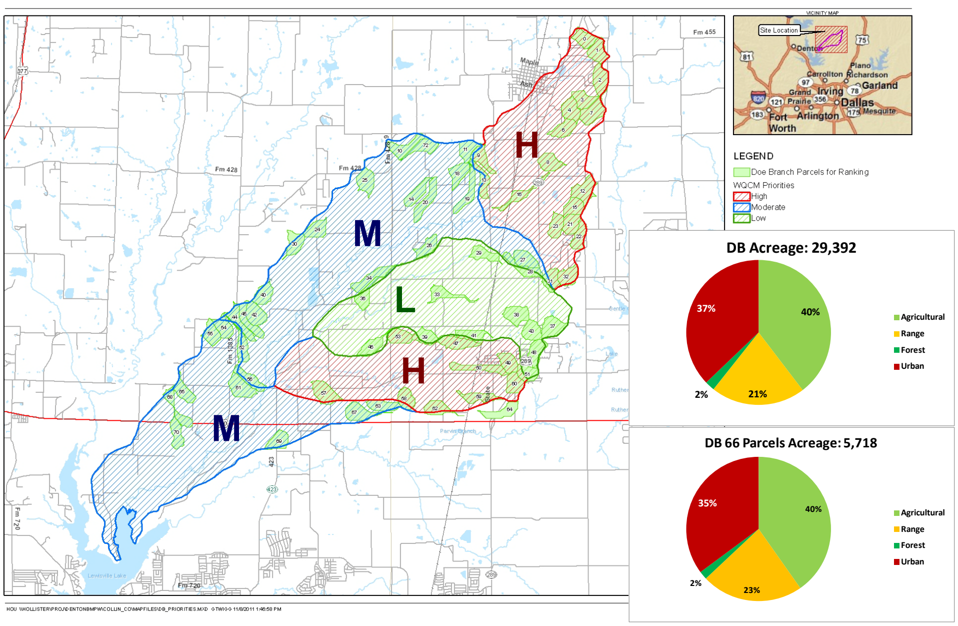
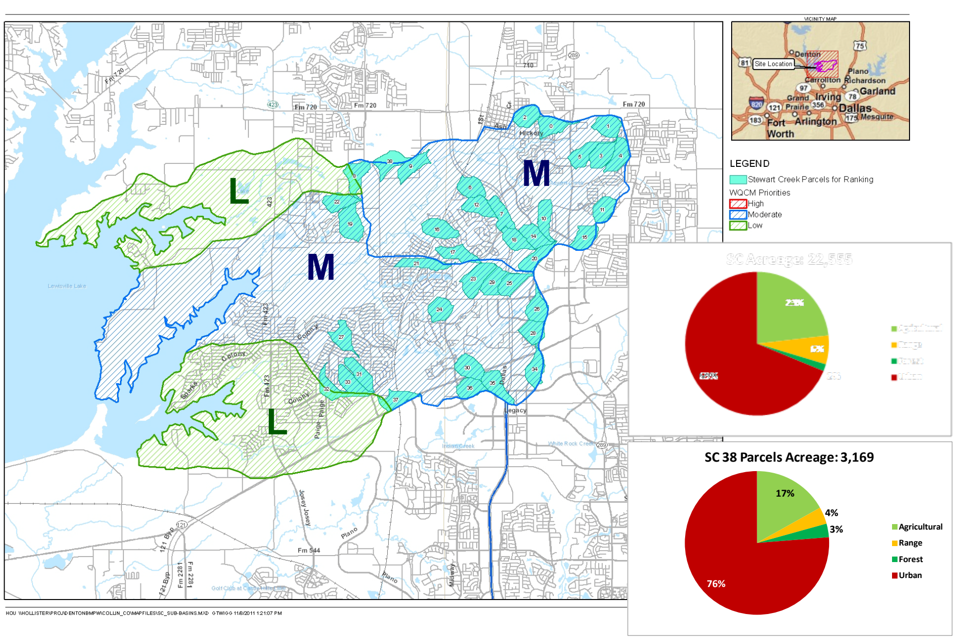


EXHIBIT 5-4

Stewart Creek Sub-watershed Parcels in WQCM Watersheds

The 38 parcels appear in turquoise under the overlay. The aggregate land use distribution of the parcels is more urban than the sub-watershed.



The load-based ranking system relies on a relatively simple approach to create raw loading scores for each pollutant then normalize these to a 0 to 100 point scale (100 representing the highest loads among the parcels) so that the scores for the individual pollutants (TSS, TP, and TN) can be weighted and combined into a single loading score.

The rationale for a "reverse protection" WQCM index component is a hypothesis that the best places for protection would not deliver the highest benefits from BMPs designed for pollutant reduction, and vice versa. The initial thought was to take a similar approach for the "reverse protection" WQCM scoring component and translate the raw scores into a similar 0 to 100 index that could be readily combined with the overall load-based score. However, the raw WQCM scores did not lend themselves to that approach for the Doe Branch and Stewart Creek sub-watersheds because the raw scores were in a very tight range, as shown in **Exhibit 5-5**. Indexing these scores using various methods produced results where the scores were either clustered in the middle range or spread to the lowest and highest values, with no mid-range values.

To generate a set of reverse protection scores compatible with the load-based index scores that could have values between 0 and 100, the simple approach shown in **Exhibit 5-6** was implemented, in which the project team assigned scores of 100, 66, 33, and 0 to the WQCM narrative ratings of Low, Moderate, High, and Very High protective value. This approach produced the desired objective of being compatible with the load-based index and also providing some distinction among the parcels. Where a parcel had acreage in WQCM watersheds with different scores, the individual scores were weighted in proportion to the acreage in each scoring area.

EXHIBIT 5-5
Descriptive Statistics for Raw WQCM Scores

Raw Scores Statistic	*Doe Branch*	*Stewart Creek*
Max	32.03	29.90
Min	28.81	28.32
Mean	31.10	29.83
Median	31.58	29.89
Standard Deviation	0.99	0.26

EXHIBIT 5-6
Reverse Protection WQCM Scoring System for this Project

WQCM Narrative Score	Reverse-Protection Score
Low	100.0
Moderate	66.6
High	33.3
Highest	0.0

To combine the load-based and reverse WQCM index scores, the project team elected to use a 50:50 weighting. This seemed a reasonable way to have each component provide meaningful influence on the overall score without reflecting any preference for one or the other component.

Exhibit 5-7 presents partial results for the Doe Branch sub-watershed. The parcel number (#) identifies each parcel. Under the "Combined Score" banner, the individual "Load" and "Protect[ion]" scores are visible, as is the "Overall" Score at a 50:50 weighting. Under the "Comparison" banner, the relative rankings using the load-based system only (Load Rank), as well as the relative ranking for the combined scoring system (Comb. Rank), are shown. The difference is shown in the column labeled "Difference", which subtracts the Load Rank from the Comb. Rank. Instances where the Comb. Rank that is greater than the Load Rank are highlighted green, and instances where it is less are highlighted orange or red.

EXHIBIT 5-7
Excerpt of Combined Scoring Results

Denton BMP Optimization Tool
Priority ranking of selected parcels within the Doe Branch watershed

Doe Branch Watershed

	Combined Score			*Comparison*		
Parcel #	**Load**	**Protect**	**Overall**	**Load Rank**	**Comb. Rank**	**Difference**
	50%	50%	100%			
MAX	85	100	92	66	66	29
MIN	-	-	-	1	1	-36
0	81	33	57	24	46	22
1	81	33	57	22	45	23
2	41	33	37	52	58	6
3	1	33	17	65	66	1
4	37	33	35	54	59	5
6	36	33	35	56	60	4
7	19	33	26	61	65	4
8	62	33	48	39	54	15
9	57	38	48	44	53	9
11	49	66	58	49	43	-6
12	30	33	32	57	63	6
13	77	41	59	31	37	6
14	77	67	72	30	22	-8
15	24	33	29	60	64	4
16	83	33	58	19	41	22
18	57	67	62	45	31	-14
19	81	67	74	21	16	-5
20	78	67	72	29	20	-9

5.3 Doe Branch Sub-Watershed Parcel Prioritization Results

The prioritization results for the Doe Branch sub-watershed are presented in **Exhibits 5-8**, **5-9**, and **5-10**, a series of three charts that focus on cost metrics, BMP locations, and loading reductions, respectively. In each chart, the combined load-reverse WQCM results are in the left three data sets, and the load-only results are in the right three data sets. For the Doe Branch sub-watershed, three parcel groupings are evaluated, as labeled on the x-axis: the top 10 ranked, the top 20 ranked, and the top 30 ranked.

Exhibit 5-8 is set up similarly to **Exhibits 4-2** and **4-3**. The right three blue diamonds show the annual cost per acre for TSS reductions increasing as mid- and lower-ranked parcels are included in the group. The cost per pound and total costs (in millions of dollars) show the same relationship.

In contrast, the Combo Ranks show increasing per acre costs followed by decreasing costs as the group includes the top 10, then top 20, then top 30. Notably, despite some differences, the cost-per-acre values are all in a relatively small range: $199 to $383.

The distribution of land use types among the land uses and contribution to loading reductions by land use are presented in **Exhibit 5-9**, which is formatted similarly to **Exhibits 4-4** and **4-5**. Looking at the top portions of the bars above the x-axis, it is clear that the Comb Rank selects a different mix of land uses, in particular more range and less agricultural land overall. This results in slightly different results regarding where pollutant loading reductions come from with respect to land use type. See for example the bottom portion of the bars for the top 10 for the Combo Rank and Load Only and the relative sizes of the urban and agricultural segments. This different mix of land use types is evident on the top portion of the bars and associated differences in BMPs implemented, and this drives the similarities and differences between the two indexing methods observed in **Exhibit 5-9**.

These effects do not appear to transfer to the load reductions delivered by each ranking system and set of parcels shown in **Exhibit 5-10**. While there are some differences in the specific level of reductions, in general the levels are within a similar range for each pollutant. For example, the Combo Rank prioritization system delivers between 25 percent and 29 percent TSS reduction, while the load-only prioritization system delivers between 20 percent and 30 percent.

EXHIBIT 5-8
Doe Branch Sub-watershed Parcel Prioritization: Selected Cost Metrics

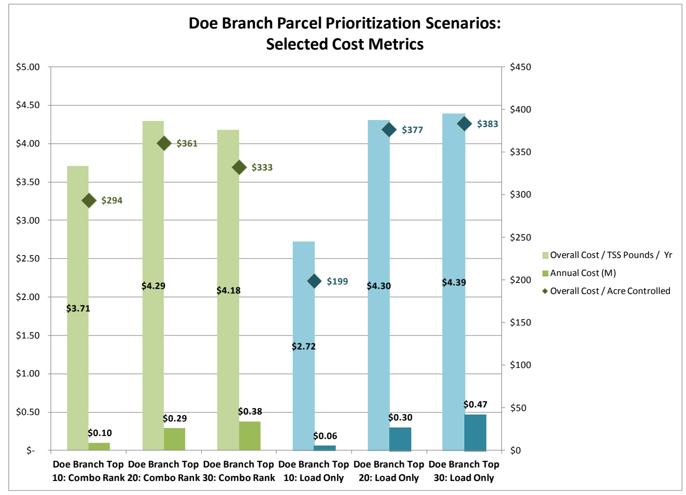


EXHIBIT 5-9
Doe Branch Sub-watershed Parcel Prioritization: BMP Acreage Distribution and Load Reduction Contribution

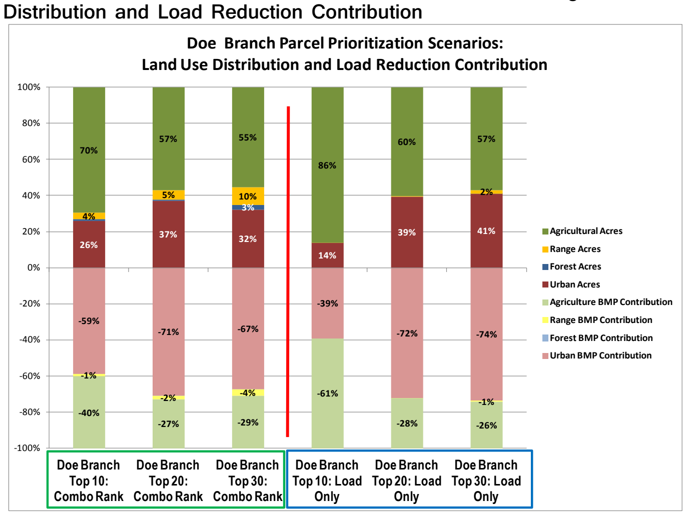
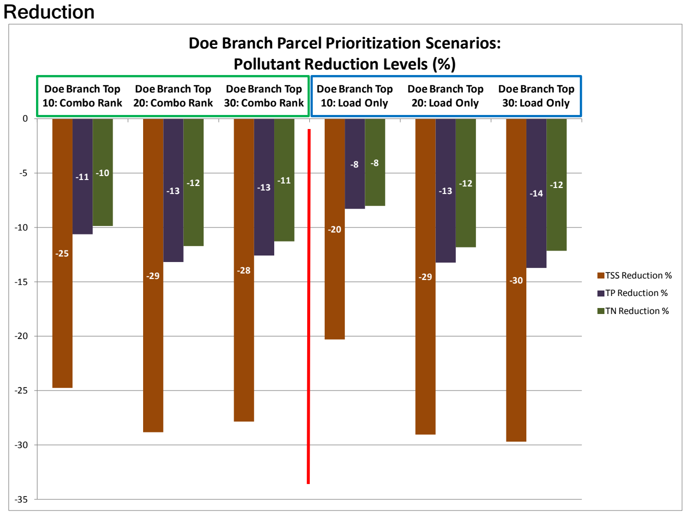


EXHIBIT 5-10
Doe Branch Sub-watershed Parcel Prioritization: Pollutant Load Reduction



5.4 Stewart Creek Sub-watershed Parcel Prioritization Results

The prioritization results for the Stewart Creek sub-watershed are presented in a series of three charts (**Exhibits 5-11**, **5-12**, and **5-13**) that focus on cost metrics, BMP locations, and loading reductions, respectively. In each chart, the combined load-reverse WQCM results are in the left three data sets, and the load-only results are in the right three data sets. For the Stewart Creek sub-watershed, three parcel groupings are evaluated, as labeled on the x-axis: the top 11 ranked, the top 19 ranked, and the top 29 ranked. Due to the fact that some parcels' scores were identical, it was not possible to select groups of 10, as done for the Doe Branch sub-watershed.

Exhibit 5-11 shows a different pattern than **Exhibit 5-8** in that the annual cost per acre controlled decreases as lower ranked parcels are added. This appears to be due to the specific mix of land use types present in each grouping, as illustrated in the top bars of **Exhibit 5-8**. However, as with the Doe Branch sub-watershed results, the cost metrics are all in a relatively small range and are identical for some metrics. This is due to the fact that both indices pulled very high proportions of urban land; see the white values in the maroon portions of the top bars.

Recall from Exhibit 5-4 that the Stewart Creek sub-watershed parcels are 76 percent urban, which will significantly limit the differences between the results of using the two ranking methods, compared to the Doe Branch sub-watershed, where the parcels in the aggregate are less urban (35 percent) and consequently more diverse (see Exhibit 5-3), and there are more differences between results from the two ranking methods.

Not surprisingly then, the pollutant reductions delivered by using either prioritization system—Combo Rank, or Load Only— are essentially identical when the results are rounded, as they are in **Exhibit 5-13**.

Comparing the reductions from the two sub-watersheds shows higher percent reductions from the Stewart Creek sub-watershed groupings. This results from the much higher proportion of urban land in the groupings and the fact that many of the urban BMPs included in the implementation package have higher removal efficiencies than BMPs applied to agricultural or rangeland.

EXHIBIT 5-11

Stewart Creek Sub-watershed Parcel Prioritization: Selected Cost Metrics

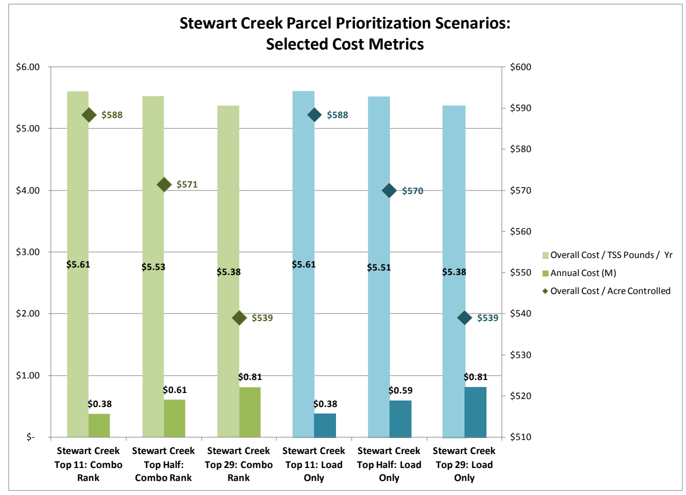


EXHIBIT 5-12

Stewart Creek Sub-watershed Parcel Prioritization: BMP Acreage Distribution and Load Reduction Contribution

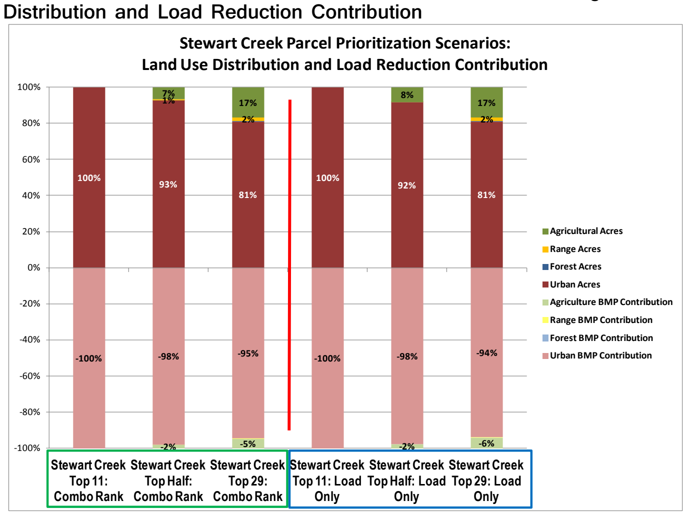
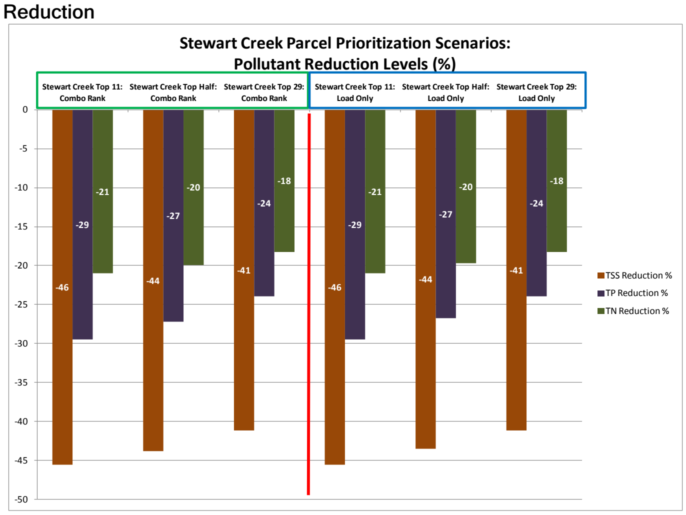


EXHIBIT 5-13

Stewart Creek Sub-watershed Parcel Prioritization: Pollutant Load Reduction



5.5 Summary Findings and Implications of the Parcel Prioritization

The parcel prioritization analyses led to the following conclusions:

- It is relatively easy to use a combined-load WQCM index. The process involves a fairly simple calculation of raw scores and selecting and implementing weights for the load-based scores that results in the overall score. The indexing itself is a relatively simple formula that converts a range of values into a similarly distributed set of values between 0 and 100.
- At a 50:50 weighting, the influence of WQCM is strong enough to change results of load-only approach rankings. For example, in the Doe Branch sub-watershed, the combined index produces rankings that range from being 29 points greater to 36 points less. In contrast, because the Stewart Creek sub-watershed parcel non-indexed scores are more similar, the combined index produces rankings that vary from being 2 points greater to 12 points less.
- Diminishing average cost-effectiveness is not evident as lower-ranked parcels are included, which is the case using the load-only ranking system. The absence of these patterns is due in part to the specific land use mix included in each index grouping and to the fact that the groupings are cumulative: the first group includes the top 10 and the second group includes the entire top 20, not just the top 11 through 20. Incremental groupings are expected to show more differences.
- The combined index produces a different acreage mix as it incorporates the non-load factors in the WQCM score. This is an interesting effect and cannot be judged as either beneficial or detrimental within the context of this project. As stated in the overview for this section, the primary goal was to implement a combined index that was relevant to the sub-watersheds and readily available. The different land use mixes are evident in Exhibits 5-9 and 5-12 and result from the fact that 50 percent of the total parcel score comes from metrics that are not completely load-based, including consideration of vegetation, erosivity, slope, floodplain, and corridor attributes (see Exhibit 5-2). In fact, comparative regression analysis on the load-base ranking method, the WQCM reverse-protection scores used for this project (100, 66, 33, and 0 for Low, Moderate, High, and Very High), and the original raw WQCM numerical scores show that, while the load-based method favors agricultural and urban land, the WQCM reverse-protection scores are more neutral with respect to land use preference, as seen in **Exhibit 5-14**.

EXHIBIT 5-14

Regression Coefficients for Land Use Types by Scoring Method

The values in the shaded cells are the regression coefficients: higher values indicate more weight is given to that land use type relative to others in the scoring system. The load-based method for the Doe Branch (DB) and Stewart Creek (SC) sub-watersheds both favor agricultural and urban land, as reflected in the high positive values for those land uses and negative values for the other two. In contrast, the WQCM methods are more neutral, as reflected in the much tighter range that encompasses the coefficients (with the exception of the high values for forest in the WQCM simple method, which may be a result of the fact that there is little forested land). The adjusted R-squared values (Adj R2) are all high relative to 1, indicating results are statistically significant.

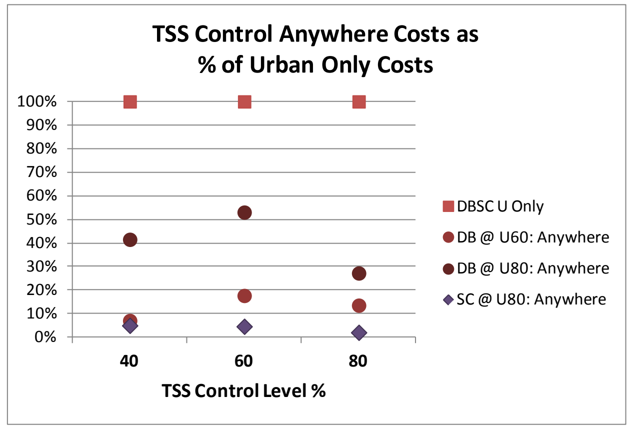
	DB: Load-Based	DB: Simple WQCM	DB: Raw WQCM	SC: Load-Based	SC: Simple WQCM	SC: Raw WQCM
Adj R2	0.98	0.86	0.98	0.97	0.86	0.97
Coefficients						
Intercept	0.0	0.0	0.0	0.0	0.0	0.0
Ag	84.9	60.9	31.3	69.6	75.3	29.9
Range	-4.8	60.6	30.8	-89.6	45.7	29.5
Forest	-35.6	137.4	26.1	-146.8	159.0	30.1
Urban	83.7	50.2	31.3	74.7	39.8	29.8

6 Conclusions and Recommendations

6.1 Recap of Overall Results

- In the aggregate, compliance costs for TSS load reduction from urban development is substantially less with a combination of on- and offsite BMP options than with onsite BMPs alone, as illustrated in **Exhibit 6-1**. There may be some individual sites and situations where onsite BMPs are less costly than other options. As stated previously, the offsite options could be made available through a water quality credit trading, pollutant offset, and/or in lieu fee program. Also, as the analysis shows, onsite BMPs will likely be an important, and situationally cost-effective, part of the overall compliance package, even with alternative options.
- Loading data and other GIS information can be used easily and relatively cheaply to prioritize candidate BMP sites for implementation, as illustrated in **Exhibit 6-1**. Not counting GIS licensing fees and BMP optimization tool development costs, defining parcels for prioritization, developing the indexing systems, and processing the scenarios can cost approximately $25,000.

EXHIBIT 6-1
Cost Savings with BMPs Anywhere Compared to New Urban Only
The top three red squares represent 100 percent onsite compliance costs for TSS control at 40, 60, and 80 percent. The other markers show the costs of using BMPs anywhere as a percent of the onsite only option. In the Doe Branch Sub-watershed (DB), the offsite options cost range from as high as 50 percent to as low as 10 percent of onsite only costs. In the Stewart Creek Sub-watershed (SC), including offsite compliance options brings costs down to less than 10 percent of the onsite only option.



6.2 Recommendations Specific to the New Phase II MS4 Texas General Permit

The draft TCEQ Phase II MS4 storm water permit (as of December 2011) contains language allowing permittees to use offsite mitigation and/or payment in lieu programs to implement their storm water management plans and comply with post construction new and redevelopment Minimum Control Measures (see at Part III.B.4.(a).(1)). Prospective permittees and other stakeholders in the Lewisville Lake watershed could take the actions provided in the following bulleted list to afford themselves the opportunities and mechanisms to implement the types of offsite options discussed in this analysis and achieve the identified potential cost-savings for themselves and their constituents. In fact, general templates for local ordinances, compliance evaluation tools, crediting frameworks and the use of a regional credit bank could help communities in the Lewisville Lake watershed implement storm water pollution control programs more cost-effectively than without such mechanisms.

- Develop a model local storm water ordinance and development plan approval language.
- Develop a standardized compliance evaluation tool for developers and planners (for example, see **Exhibit 6-2**).
- Develop model offset and crediting framework, procedures, and protocols.
- Develop a standard offset/credit calculation and costing /pricing methods.
- Evaluate the need for and benefits of a regional credit bank that could centralize administrative functions and services for multiple jurisdictions in the Lewisville Lake watershed.

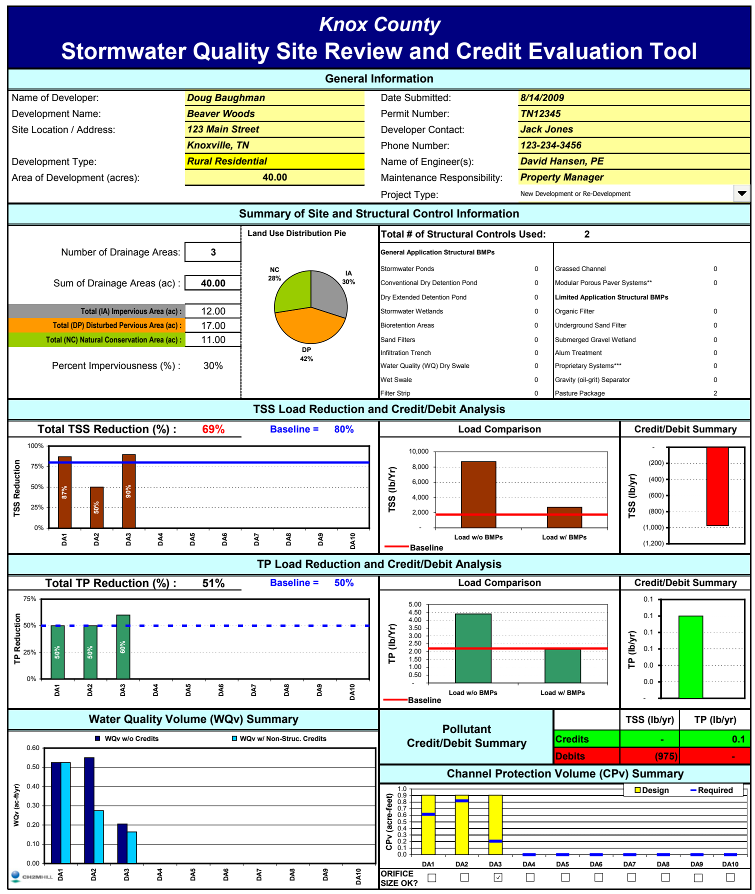
6.3 Recommendations Specific to BMP Site Prioritization Methods and Tools

The load-based approach to prioritizing sites for BMP implementation, as featured in the Hickory Creek WPP, directly optimizes for cost-effectiveness, but other factors may be important for prioritizing BMPs by location and type. The combined load-based and reverse-protection scoring approach featured in this study shows one way other factors can be quantitatively considered. In conjunction with, or separate from, storm water management planning and MS4

Phase II permit implementation, Lewisville Lake MS4 Phase II permittees and stakeholders could take the following actions to identify and use data that could enhance BMP site and type selection programs:

- Further explore if incorporating a reverse-protection index is a valuable addition in developing a priority ranking system for BMP sites, and, if so, which of the underlying components of the overall WQCM score could be used alone or together for this application.
- Further evaluate what general GIS-based methods could be used alone, or in combination with a scoring system, to identify and prioritize BMP sites consistent with the technical and scientific attributes of sites and BMPs.
- For any system, consider the benefits of using a smaller geographic scoring scale to provide greater resolution. In this analysis, the fact that there were only five WQCM watersheds overlaying the Doe Branch sub-watershed and only four WQCM watersheds overlaying the Stewart Creek sub-watershed resulted in many parcels in each watershed having very similar scores.
- For any system, consider using raw score ranges and weights that will provide a greater differentiation among the scored watersheds on key metrics and overall score. In this analysis, the raw scores for WQCM watersheds overlaying the Doe Branch and Stewart Creek sub-watersheds did not represent a very wide range.

EXHIBIT 6-2
Summary Page from One Storm Water Compliance Evaluation Tool
This Stormwater Quality Site Review and Credit Evaluation Tool was developed for Knox County, Tennessee by CH2M HILL. It is an enhanced version of a similar tool that is mandatory for use by developers and local planners in several communities in Georgia. The Knox County tool allows users to: input their site development plan and proposed BMPs; determine compliance with the local ordinance; and calculate their credits and debits for TSS, TP, and Channel Protection Volume (CPv) relative to ordinance requirements. The graphic below is a screen capture from the tool's main summary page. The blue and red horizontal lines show the baseline requirements, the brown and green vertical bars show pollutant loadings by drainage area and for the overall project, and the lime green and red vertical bars in the middle-right portion of the sheet show whether the proposal has credits or debits, respectively, for the specific requirements.



- Develop and pilot test one or more alternative BMP parcel priority ranking systems on a jurisdictional scale and/or a scale consistent with the regional credit bank concept suggested.

6.4 Achievement of Goals for this Project

The analyses described herein demonstrate that the BMP optimization and prioritization approach used for the Hickory Creek WPP can successfully be transferred and adapted to other watersheds to demonstrate how cost-effectiveness metrics can be used in designing and implementing a nonpoint source pollution management program. The watershed-wide analyses show that the use of both onsite and offsite BMPs can reduce the cost of implementing post-construction storm water controls as outlined in the new TCEQ draft MS4 Phase II permit. The parcel prioritization analyses show that BMPs can be implemented in a capital improvement program to provide the greatest return on investment as measured by least cost and highest load reduction. Collectively these results are consistent with the results from the Hickory Creek WPP and suggest that a cost-based BMP prioritization program could be developed for the entire Lewisville Lake watershed and these cost advantages could be realized for large areas by water quality credit trading and an in-lieu payment offset program.

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Attachment A
Data Gathering/Analysis and Selection of the Technology Transfer Sub-Watersheds

ATTACHMENT A

Data Gathering/Analysis and Selection of the Technology Transfer Sub-Watersheds

A1 Introduction

This attachment is provided as a companion to the associated technical memorandum (TM) that describes the methods, analysis, and results conducted for Task 5, *Adapting the Hickory Creek Watershed Protection Plan for Use in Other Areas of the Lewisville Lake Watershed: the Doe Branch and Stewart Creek Sub-watersheds*, of the larger study *Implementing the Hickory Creek Watershed Protection Plan and Adapting the Plan for Use in Other Areas of the Lewisville Lake Watershed*. This attachment documents the work conducted under subtasks 5.1 and 5.2 that led to the selection of the two technology transfer sub-watersheds, Doe Branch and Stewart Creek, and the work under subtasks 5.3, 5.4, and 5.5 that is reported in the TM.

The objectives for subtasks 5.1 and 5.2 as stated in the project's Scope of Work are presented below.

- **Task 5.1, Data Gathering and Analysis:** *Concurrent with the Hickory Creek-focused efforts, the Project Team and Project Partners (North Texas Municipal Water District [NTMWD] and Upper Trinity Regional Water District [UTRWD]) will gather and evaluate pertinent information from the research conducted by the Project Partners and will integrate this information with the information available through the Hickory Creek [Watershed Protection Plan, WPP] and related efforts. The Project Team will evaluate these sources of information in conjunction with the existing implementation strategies outlined in the Hickory Creek WPP to determine the products needed to facilitate an optimized [best management practice, BMP] implementation strategy for areas under the jurisdiction of the Project Partners and the City of Denton.*
- **Task 5.2, Identification of Technology Transfer Opportunities:** *Upon review of existing information (Task 5.1), the Project Team will determine how this information can be used to leverage the analyses, methods, and results of the Hickory Creek WPP into a set of transferable implementation methodologies. To support this evaluation, the Project Team will conduct a Strengths, Weaknesses, Opportunities, and Barriers (SWOB) analysis of the current programs relating to BMP implementation in other areas of the Lake Lewisville watershed to enhance current approaches for more cost-effective pollutant reductions. A key focus will be on identifying how leveraging the Hickory Creek WPP can help capture opportunities and eliminate or mitigate barriers through implementation tools, market-based incentives programs, technical support for BMP optimization, and similar approaches (Tasks 5.3-5.5).*

During the first project partner meeting on June 2, 2010, the attendees decided the key criteria for developing the technology transfer work products were:

- Cost-effectiveness
- Ease of implementation
- Ease of incorporation (into surrounding areas)
- Scalability for different sized communities

With these criteria in mind, the information described in **Section A2** that follows provided a foundation with which to combine the City of Denton's previous and ongoing water quality protection efforts with those of the project partners. Thus, the focus of Task 5, as described in **Section A3**, became an effort to combine protection with pollution reduction, include BMPs specific to the broader watershed, and illustrate how BMP optimization approaches could be included in storm water management plans beyond Hickory Creek.

A2 Data Gathering and Analysis

The objective of the data gathering and analysis effort was to collect and evaluate pertinent information from the research conducted by the project partners and integrate this information with that available through the Hickory Creek WPP and related activities. The results of the review then helped identify the products needed to facilitate an optimized BMP implementation strategy for the two technology transfer sub-watersheds (see Sections 4 and 5 of the TM) and inform the evaluation of regional approaches for the larger Lewisville Lake watershed (see Section 6 of the TM).

Data gathering efforts included in-person project partner meetings, as well as the project team's review of existing studies and data sets.[1] The results of this evaluation are reported in subsequent sections and within the following major sub-headings:

- Upper Trinity Regional Water District
- North Texas Municipal Water District
- City of Denton
- Updated Surface Water Quality Standards

A2.1 Upper Trinity Regional Water District

A2.1.1 UTRWD's Watershed-Related Outreach Efforts

UTRWD is promoting watershed protection within its customer cities. All water and wastewater contracts with customer cities include some watershed protection requirements. In general, the contract clause asks the member entities to agree to implement practices to reduce pollution in the watershed and adopt requirements to limit development in riparian areas. Example language from the Town of Prosper's contract is provided in **Exhibit A-1**.

EXHIBIT A-1
Example Watershed Protection Requirements: Town of Prosper[2]

23. Watershed Protection. To help protect the quality of the District's water supply in Lewisville Lake;

a) Prosper agrees to participate in and support the District's efforts to implement activities for a regional watershed protection program. Elements of a program may include methods to reduce the amount of pollutants from entering the watershed, ways to limit the amount of sediment being transported to local water supply sources, and public education. As part of the public education element, Prosper agrees to assist the District in installing the District's watershed signs along roadways near creeks and streams within the Town's service area.

b) Specifically, as part of the watershed protection program identified above, Prosper agrees to adopt reasonable requirements for local developers within its service area to set aside natural riparian lands to be used as greenbelts in those developments. Pursuant to such "reasonable requirements" adopted by Prosper, Prosper will require or seek dedication of said greenbelts in perpetuity, which greenbelts shall be under the control of and administered by the Town or a local homeowners association. Such greenbelts shall be left largely in their natural state, but may be used for multiple purposes such as buffer zones, hiking or jogging trails, wetlands, storm water retention or playgrounds.

UTRWD representatives have been making presentations to its member cities, asking that the cities adopt resolutions of support for watershed protection programs, which are based on public education. Thirteen of 25 member cities have adopted these resolutions of support and initiated watershed protection programs. Once entities adopt the resolution, the District provides guidance documents to support a city in developing its own watershed protection program.

[1] This evaluation took place roughly between April and October 2010.

[2] Upper Trinity Regional Water District. 2007. Northeast Regional Water Reclamation System – Town of Prosper Participating Member Contract.

With respect to public education and advocacy, UTRWD provides three technical guidance documents to its customer cities. These documents can be used for the development of local policies, practices, and standards for watershed protection:

- *Guidelines for Preserving Floodplains, Creeks, and Riparian Buffer Zones in the Watershed of Lewisville Lake* provides specific recommendations for protective development standards.
- *Examples of Development Standards Used to Protect Floodplains, Creeks, and Riparian Buffer Zones in the Lewisville Lake Watershed* is a comparative table that describes the floodplain and riparian zone protection requirements for several communities in the Lewisville Lake watershed.
- *Strategies and Key Elements of the Lewisville and Grapevine Lakes Watershed Protection Program* outlines goals related to and practices used to achieve watershed protection.

Taken together, the documents provide a framework that communities can use to develop the governing municipal code and environmental conservation practices for watershed protection and preservation programs.

A2.1.2 UTRWD's Lewisville Lake Watershed Protection and Management Strategies

The *Lewisville Lake Watershed Protection and Management Strategies* Technical Memorandum documents the study performed jointly by UTRWD and the University of North Texas (UNT). The Water Quality Corridor Management (WQCM) model used in the study incorporates "…GIS and remote sensing techniques to assess and prioritize stream reaches according to their overall health and sustainability." For the purpose of the study, the focus of the modeling effort was protection, rather than restoration, as the investigators believe protection prior to impairment is less expensive than reversing the impairment once it has occurred.

The model is based on five parameters: vegetation type, erosion potential, surface slope, percent of the stream defined by the Federal Emergency Management Agency 100-year floodplain, and amount of the stream corridor contained within the sub-watershed (the piece of the demonstration study area that was in the Lewisville Lake watershed made up 90 of the 130 sub-watersheds in the demonstration study). Each sub-watershed was ranked in each of these categories as low, moderate, high, and very high priority for protection. Importance weights were given; with vegetation/land use type weighted the heaviest. Section 5 of the TM provides more information on the WQCM model.

The investigators then attempted to "ground truth" the model with field monitoring of 40 sites selected for ease of accessibility. They selected the Stream Visual Assessment Protocol[3] with which to compare the results, and the comparison was favorable and statistically significant.

Because the effort was based on protection, the majority of the sub-watersheds assigned to the highest priority quartile as part of this effort were mainly in less urbanized areas. The parameters most likely to influence the scores, based on statistical analysis, are consistent with the weighting strategy assigned. The study suggests that BMPs should be coupled with those highly ranked sub-watersheds and that the implementation "…is dependent on teaching through public outreach."

The study concludes that the ideal situation would be to have the model address a restoration approach as well, and that the model could use further field verification and differing information based on geographic regions.

A2.1.3 Other, Related Efforts

UTRWD has funded a U.S. Geological Survey (USGS) monitoring station on Doe Branch (near Paloma Creek); the City of Dallas has funded one on Elm Creek. Also, UTRWD has a signage program throughout the Lewisville Lake, North Sulfur River, Lake Ray Roberts, and Grapevine Lake watersheds. North Central Texas Council of Governments (NCTCOG) has contacted UTRWD for use of its logos and signs throughout the North Texas region.

[3] NRCS, 1998.

As a follow on to the WQCM modeling study performed with UNT, UTRWD has developed a non-profit organization that may compliment the efforts conducted as part of this project. The Upper Trinity Conservation Trust was formed to purchase conservation easements throughout the service area. The Trust is new and has only recently been incorporated. The Trust is a legal entity that will hold perpetual conservation easements for land that is donated to the Trust. UTRWD may use some of the watershed protection fees from drinking water customers (two cents per 1,000 gallons) to purchase easements, and the District will encourage other watershed protection advocates to purchase easements as well. The WQCM model will be used to identify the priority areas for the purchase of conservation easements.

Denton County is beginning to take a bigger role in watershed protection via cooperation with UTRWD. The County is now participating in a hazardous waste collection program. UTRWD has agreed to develop a watershed protection brochure directed at land developers for Denton County because residential and commercial development in the floodplains of unincorporated freshwater districts and utility districts is not constrained by municipal code requirements. The content of the brochure was not specified by the County; UTRWD intends to make the brochures broadly applicable to all its member cities.

There are “fresh water supply districts”, which are large, master planned developments that occur within the UTRWD service area. These developments are in unincorporated areas and UTRWD staff members have concerns about their impact on the watershed. UTRWD is currently determining the best way to address this challenge.

A2.2 North Texas Municipal Water District

NTMWD is participating in this project in connection with its role as a wastewater treatment service provider in the Lewisville Lake watershed. The vast majority of NTMWD’s watershed management activities to date have been geared to the Lake Lavon watershed, as Lake Lavon is the primary drinking water source for the District. Within the Lake Lavon watershed, NTMWD is conducting activities related to water conservation, lake monitoring, and lake modeling. NTMWD has a well-established program for working with its customer entities to reduce water consumption.

NTMWD has a 30-year water quality monitoring record for Lake Lavon that has been used to develop a water quality model for the lake. The model is used to implement wastewater treatment operations that protect the lake. NTMWD has focused its past water quality work on developing an understanding of the assimilative capacity of Lake Lavon related to constituents that may be a challenge for wastewater dischargers.

Within the Lewisville Lake watershed, NTMWD owns and operates two wastewater treatment plants, one in the Stewart Creek sub-watershed and one in the Panther Creek sub-watershed, both in the City of Frisco. Wastewater treatment plant operators are held accountable for water quality within the water bodies in which they discharge, thus NTMWD is dedicated to maintaining and/or improving the water quality within the Lewisville Lake watershed. The goal is to protect Lewisville Lake’s water quality in the most cost-effective manner possible, and NTMWD believes the components of this study could produce a broader-vision for watershed protection than increasingly stringent effluent limits on wastewater discharge. Additionally, NTMWD intends to apply the methods applied successfully in the Lewisville Lake watershed to the Lake Lavon watershed as applicable.

A2.3 City of Denton

The City of Denton provides a range of resources including water quality data, city ordinances, and case analyses relevant to this effort. For example, in cooperation with UNT, the City of Denton has posted all City-collected watershed data on the UNT website, to include information collected from seven rainfall gages. Denton’s Environmentally Sensitive Area (ESA) ordinance provides a basis for developing storm water management plans in cooperation with landowners and developers. One recent case example involves the Rayzor Ranch property. Both the ESA ordinance and the Rayzor Ranch development were evaluated during the development of the Hickory Creek WPP. A description of each, current as of Summer/Fall 2010, is provided in the subsequent sections.

A2.3.1 Denton's Environmentally Sensitive Areas

The City of Denton Code language includes areas designated as ESAs and mandates associated development of post-construction storm water controls. For ESAs in riparian areas, Denton (in cooperation with UNT) developed algorithms based on distance from centerline of streams. These designations are also assigned to upland habitats based on elevation and soil types, City-delineated floodplains (slightly different than the latest floodplain delineation from the Federal Emergency Management Agency [FEMA]), and other water-related habitat. Bruce Hunter of UNT, who developed WQCM for UTRWD, developed these algorithms. Thus, Denton and UTRWD have both identified natural areas for preservation.

A2.3.2 Rayzor Ranch

The City of Denton has initiated procedures intended to protect water quality throughout the platting of the Rayzor Ranch development. Rayzor Ranch has been designated an overlay zoning district, not a Master Planned Community (MPC). Special Purpose and Overlay districts were originally intended for "protecting and enhancing certain specific lands and structures, which by virtue of their type or location have characteristics which are distinct from lands and structures outside of such districts." The City of Denton developed design standards specific to these types of districts; MPCs were later added to this group. The distinctions between MPCs and their predecessors are procedural and scale-related. MPC ordinances allow staff approval of site plan-type applications that otherwise would require City Council approval. There are also minimum acreage requirements for MPCs depending on the geographical location of the district. The creation of the Rayzor Ranch overlay district allowed for the incorporation of mitigation of three concerns: ESAs located onsite, anticipated increased quantity of stormwater runoff, and anticipated decreased water quality of the North Lakes detention pond.

Typically, ESAs are addressed during the platting stages. Denton aligned its processes for developing storm water quality controls (that is, BMPs) with the three phases of platting: general, preliminary, and final. Denton did not dictate credentials for the BMP designers but rather a performance standard for the BMP. Maintenance and replacement schedules for each BMP were incorporated into the platting documents and the City developed a property owners' association for this purpose (so future maintenance would not be subject to changes in ownership). The BMPs have not been constructed at this time; the City has installed a storm weather monitoring site at the development's storm water outlet.

The City described the general concept for Rayzor Ranch and associated experiences in a staff-authored paper: *Application of Integrated Storm Water Techniques to Master Planned Communities*[4]. The paper discusses how Denton staff were concerned about the potential for water quality decline as a result of implementation of the community, especially since the area would discharge into a detention pond in North Lakes Park, which is a "…major recreation area for the City of Denton…" The City employed Integrated Storm Water Management (iSWM)[5] techniques in the planning process, but, notably, there are currently no actual requirements for ESA mitigation ("…approvals are granted based on city council discretion.") listed in the City's Municipal Code.

The paper describes some challenges incorporating iSWM: "A successful implementation of iSWM depends on effective negotiation skills, good planning, excellent project management, and careful policy writing. All these requirements translate in manpower and expertise." Essentially, the City needed quite a bit more resources from numerous departments and more time than was originally anticipated.

Other key lessons learned include the following:

- The entity requiring the construction of BMPs (in this case, the City) must incorporate flexibility for political decision-making and changes in the economy in the BMP development process.

[4] Hunter and Viera, 2009.

[5] iSWM is a tool developed by the North Central Texas Council of Governments to assist cities and counties with achieving their goals of water quality protection, streambank protection, and flood mitigation, while also helping them meet their construction and post-construction obligations under state storm water permits. See http://iswm.nctcog.org/index.asp for more information.

- The code requiring BMPs must be in place before development begins, including requirements for BMP maintenance and upkeep. Including life cycle costs in the BMP planning and design is recommended to emphasize the value of maintenance and ensure the long-term performance of the BMP.

A2.4 Updated Surface Water Quality Standards

In July 2010, the Texas Commission on Environmental Quality (TCEQ) promulgated rules that created numeric nutrient standards for 75 reservoirs within the state, to include Lewisville Lake. Lewisville Lake was assigned a chlorophyll-*a* criterion of 18.45 milligrams per liter (mg/L). The 2010 surface water quality inventory was conducted based on chlorophyll-*a* screening criteria of 26.7 mg/L, and four of the six sub-segments of the lake had samples that exceeded this. Samples from the other two sub-segments did not appear to be analyzed for chlorophyll-*a*.

In addition to updating the surface water quality standards, TCEQ has updated the "Procedures to Implement the Texas Surface Water Quality Standards," which will affect the City's and the partners' Texas Pollutant Discharge Elimination System (TPDES) permits. Screening procedures related to total phosphorus (TP) for reservoirs, as well as streams and rivers, have been added. The City of Denton is currently in the process of updating the Pecan Creek Water Reclamation Plant discharge TPDES permit. At this time, the City has been told the permit will contain a numeric total phosphorus limit (as opposed to previous monitoring-only requirements), but that limit has not yet been defined. For its storm water TPDES permit, the City of Denton is a Phase 2 community; the general permit that provides coverage to Phase 2 communities will expire in August 2012 and may also be subject to TP limits at that time.

A3 Identification of Technology Transfer Opportunities

Based on the evaluation described in **Section A2** and discussions with the project partners (UTRWD and NTMWD), the three opportunities were chosen to focus the cost-effectiveness analysis described in the TM (see Sections 4 and 5 in the TM) to meet the overall goal of the technology transfer task (as stated in **Section A1**). The following three opportunities were identified:

- Evaluate how the UTRWD/UNT preservation/protection-focused WQCM approach and prioritization scheme can be combined with the load-based BMP targeting approach developed for the Hickory Creek WPP to provide an expanded set of attributes for targeting and prioritizing locations for sediment and nutrient BMPs, as well as other, complementary preservation actions.
- In conjunction with combining the WQCM and Hickory Creek WPP prioritization approaches, evaluate the BMPs currently included in the Hickory Creek WPP BMP optimization analysis tool for possible substitution or expansion of the options so as to include some representative BMPs that are consistent with the WQCM approach.
- Demonstrate how a combined WQCM-Hickory Creek WPP BMP optimization approach could be applied by revising the Hickory Creek WPP tool and conducting BMP-preservation optimization scenarios for two new sub-watersheds following a similar process and scaling as done for the Hickory Creek sub-watershed.

Additional discussion for these three elements is provided in the subsequent sections.

A3.1 Combining the Hickory Creek WPP BMP Location-Prioritization Approach with WQCM

By the second project team meeting with the partners on July 9, 2010, the group agreed that this project should evaluate the complementary use of the load-based prioritization method developed by Denton for the Hickory Creek sub-watershed, which was based on and made possible by modeling the hydrologic system using the Soil and Water Assessment Tool (SWAT), with the WQCM approach and results. The SWAT model identifies areas of predicted high nonpoint source loading of nitrogen, phosphorous and sediment. The WQCM model identifies areas that have retained a natural value, thus release limited nitrogen, phosphorous and sediment loads to the Lewisville Lake watershed.

The project team evaluated whether the two approaches are compatible. The areas identified as good candidates for the installation of constructed storm water best management practices are generally closer to the Lake, where urbanization is occurring. The purpose of the BMPs is to provide green space and/or similar post-construction storm water controls that will mitigate the water quality impacts of urbanization. The natural areas identified for preservation by the WQCM model are generally located further from Lewisville Lake in undeveloped areas.

Together, these two approaches to location-based watershed targeting identify areas that could be improved to limit the loading of the pollutants and areas that could be preserved. By combining the two different types of areas that the approaches tend to target, watershed protection capabilities can be enhanced.

This evaluation of a potential combination is consistent with:

- The guidelines and development standards UTRWD is promoting for its customer cities
- The newly formed Upper Trinity Conservation Trust formed to hold conservation easements in UTRWD’s service area
- NTMWD’s interest in protecting the water quality within the Lewisville Lake watershed, as well as the potential for them to apply the methods developed during this project to the Lake Lavon watershed

A3.2 Consideration of Revising the Hickory Creek WPP BMP List: No Revisions

When first developed, the BMPs included in the Hickory Creek WPP optimization tool were chosen for their suitability for various land uses, consistency with the iSWM guidance, and accepted sediment and nutrient removal capabilities. To support this project, the project team evaluated the existing list and possible alternatives and/or additions to best support demonstration of the combined Hickory Creek WPP-WCQM approach.

For example, UTRWD’s watershed protection documents and guidelines promote retention of vegetated zones, as well as installing more native vegetation, such as ground vegetation filter strips. In the existing Hickory Creek WPP tool, the BMP “grading, grassed waterways, filter strips” is an option for agricultural, range, or forest land. However, the BMPs “vegetated swales/strips” and “riparian buffer” are only options for urban sites. Additionally, the existing tool has no purely preservation or protection BMP, such as a conservation easement—all BMPs are capable of controlling runoff and reducing pollutant loading.

Ultimately, the list of BMPs used for the Hickory Creek WPP was deemed sufficient and appropriate for the analyses in Doe Branch and Stewart Creek. However, slots are available in the BMP optimization tool for additional BMPs, so with additional resources preservation-oriented BMPs could be added at a later date, if sufficient cost and pollutant reduction data are available.

A3.3 Demonstrate the Combined HCBMP-WCQM Approach in Two New Sub-watersheds

The Hickory Creek WPP showed how a load-based approach to targeting cost-effective BMPs could reduce pollutant loadings with a reasonable public budget. It also showed how a priority location system for BMPs could leverage and target private investments in watershed protection. The City of Denton used the results of the BMP site analysis described in the WPP to select sites for 6 new BMPs being implemented as part of this study.

In this project, a similar demonstration as was conducted for Hickory Creek was conducted for two new sub-watersheds mutually selected by the project team and the project partners: Doe Branch and Stewart Creek. These demonstrations will benefit from the combined HCBMP-WQCM approach to show the partners and their customers/stakeholders how optimizing BMP installation and preservation actions can reduce pollutant loads and protect important areas from degradation. The results of these analyses performed under subtasks 5.3, 5.4, and 5.5 of this project are reported in the TM.

Attachment B
Additional Detail for the Best Management Practice Cost-Effectiveness Analysis: Methods and Tools

ATTACHMENT B

Additional Detail for the Best Management Practice Cost-Effectiveness Analysis: Methods and Tools

B1 Introduction

This attachment is provided as a companion to the associated technical memorandum (TM) that describes the methods, analysis, and results conducted for Task 5, *Adapting the Hickory Creek Watershed Protection Plan for Use in Other Areas of the Lewisville Lake Watershed: the Doe Branch and Stewart Creek Sub-Watersheds*, of the larger study *Implementing the Hickory Creek Watershed Protection Plan and Adapting the Plan for Use in Other Areas of the Lewisville Lake Watershed*. This attachment provides additional detail about the development of the best management practice (BMP) optimization tool and selection of the parcels within the sub-watersheds to supplement the information provided in the TM.

The BMP cost-effectiveness analysis and watershed optimization scenarios developed for the Doe Branch and Stewart Creek sub-watersheds follow the approach used for the Hickory Creek Watershed Protection Plan (WPP).[1] The approach taken for this study (described in subsequent paragraphs) applies the same basic but updated Excel tool to house the data and assumptions, select the scenarios, and generate tabular and graphic results. This study also employed the same method to identify a set of sub-watersheds to use in a demonstration of the benefits of prioritizing BMPs according to load-based criteria. The analysis and scenarios for the Doe Branch and Stewart Creek sub-watersheds differ from that performed for the Hickory Creek sub-watershed, mainly in that the prioritization rankings in the more recent study combine the load-based index system used for the Hickory Creek sub-watershed with a "reverse-protection" index system developed for this study from the Water Quality Corridor Management (WQCM) model scores.

This attachment describes:

- The pollutant loading assumptions associated with the different land uses
- The methods and tools used for the cost-effectiveness analysis and BMP scenario development
- The method used to identify the parcels used in the prioritization scenarios
- The method used to develop individual rankings under a load-based and reverse-protection system and how those systems are combined for this analysis

Note this attachment is intended to supplement the TM, so please refer to that document for a full summary description of the associated methods, tools, and results.

[1] City of Denton. 2008. *Report for Task 2, Watershed Protection Plan, of the Grant Entitled Control of Nonpoint Source Loads in the Hickory Creek Sub-basin of the Lake Lewisville Watershed as a Component of a Watershed-Based Water Quality Trading Program.* December.

B2 Pollutant Loading Assumptions

This study uses the same pollutant loading values for the four land use categories—agriculture, rangeland, forest, and urban—as were developed by Texas A&M University for the Lewisville Lake watershed during the 2008 study using a combination of the Soil and Water Assessment Tool (SWAT) and QUAL-TX models[1,2], as presented in **Exhibit B-1**.

EXHIBIT B-1
Annual Loads per Unit Area from each Land Use (pounds/acre)

Land Use	Sediment	Phosphorus	Nitrogen
Urban	161.49	1.34	3.66
Agriculture	123.12	1.96	3.75
Rangeland	55.32	0.27	1.87
Forest	21.41	0.09	0.71

These values were established using the Soil and Water Assessment Tool (SWAT) and QUAL-TX model developed to evaluate existing and baseline sediment and nutrient loadings to Hickory Creek. To establish baseline conditions, datasets were developed in ArcGIS™ to delineate sub-watersheds, soil classifications, and land uses in the watershed. Precipitation, flow and water quality measurements were collected at a monitoring site near the downstream end of Hickory Creek over a period of four years, from 2001 to 2005. During this period, thirteen rainfall and runoff events were measured and sampled.[3] **Exhibits B-2** and **B-3** show the constituent concentrations and runoff depth results that led to the values presented in **Exhibit B-1**.

EXHIBIT B-2
Constituent Concentrations (mg/L) for each Land Use Category

Land Use	Rainfall Depth	Sediment	Phosphorus	Nitrogen
Urban	All	65	0.55	1.48
Agriculture	0.79 inches	80	1.29	3.04
	1.57 inches	80	1.29	2.39
	3.15 inches	80	1.29	2.26
Rangeland	All	39	0.19	1.30
Forest	All	29	0.11	0.90

EXHIBIT B-3
Runoff Depths for Various Land Use/Rainfall Depth Combinations

Land Use	Rainfall Depth (inches)			
	28.19"/year	*0.787"/event, 16 events/yr*	*1.575"/event, 5.3 events/yr*	*3.150"/event, 2.3 events/yr*
Urban	11	0.170	0.69	2.0
Agriculture	7	0.060	0.42	1.6
Rangeland	6	0.050	0.39	1.5
Forest	3	0.004	0.17	1.0

As illustrated in **Exhibit B-2**, the model predicted higher runoff concentrations for agricultural land than for other land uses. However, because impervious land uses usually generate more runoff than pervious land, urban areas tend to generate greater loads per unit area than rural land, even though urban areas have lower constituent concentrations per unit runoff volume. On a relative basis, among the four land uses, urban areas generate more sediment load per unit area, urban and agricultural areas generate more nitrogen, and agricultural areas contribute more phosphorus. As illustrated in **Exhibit B-3**, urban areas produce the most runoff from a given storm event.

[2] Note that the modeling effort was performed using metric units; the results provided have been converted to English units, save for those results given in milligrams per liter (mg/L), for the purpose of ease of understanding.

[3] The development and calibration of this combined pollutant loading and water quality model is further described in *Control of Non-Point Source Loads in the Hickory Creek Sub-basin of the Lake Lewisville Watershed: TM No. 1 – Model Development* (CH2M HILL, 2006). Also, a more complete description of the calculations for the loading estimates developed for the model are described in *Control of Non-Point Source Loads in the Hickory Creek Sub-basin of the Lake Lewisville Watershed: TM No.2 – Non-Point Source Loads* (CH2M HILL, 2006). These technical memoranda were completed as part of the development of the Hickory Creek WPP (CH2M HILL, 2008).

B3 The BMP Scenario Development and BMP Optimization Tool

For the purposes of constructing and evaluating alternative BMP scenarios in the demonstration sub-watersheds at a sub-watershed-wide and priority parcel level, the project team rebuilt and updated a Microsoft Excel-based tool developed by CH2M HILL for the Hickory Creek WPP. The tool allows the user to construct a BMP "portfolio" for a defined area and calculates key portfolio metrics, including total cost, load reduction, and unit costs (an indicator of cost effectiveness). The rebuild included migration of the Hickory Creek WPP approach and calculations to an Excel 2007 platform from an Excel 97-2003 platform, removed unused data and functions, streamlined formulas, updated the scenario selector interface, and added capability to house two sub-watersheds for the prioritization analysis. Additionally, standard chart outputs were included, along with a semi-automated summary table export function.

To operate the tool, the user enters assumptions about the number of acres in each of the four land use categories (agricultural, rangeland, forest, and urban) for a defined scenario. The tool automatically calculates pre-BMP pollutant loads by land use category for total suspended solids (TSS), total phosphorus (TP), and total nitrogen (TN) using the associated load per unit area estimated by the SWAT model (see **Exhibit B-1**). The user then selects a suite of BMPs to "apply" to the land area and the tool automatically calculates load reductions, as well as a variety of cost and cost-effectiveness metrics.

Additional discussion about the BMPs included in the tool, as well as the tool's strengths and weaknesses, is provided in subsequent sections. Section 3 of the TM provides information about key assumptions and data inputs for the tool in the form of screen captures from the tool in the exhibits listed below. Consequently, they are not replicated in this attachment.

- Exhibit 3-1: BMPs, removal efficiencies, control area, and useful life
- Exhibit 3-2: BMP cost estimates
- Exhibit 3-3: BMP unit control costs
- Exhibit 3-4: BMP unit control cost relative rankings
- Exhibit 3-5: Maximum coverage for BMPs by land use
- Exhibit 3-6: Optimization tool scenario development dashboard

The indexing approach and functionality associated with the parcel prioritization is described in **Section B4.4** of this attachment and Section 5 of the TM.

B3.1 Available BMPs and Associated Costs

In a "BMP Scenario Planning Dashboard" (see Exhibit 3-6 of the TM), the user can select and "turn on" one or more of the BMPs available for a given land use by entering the percent of the total land area within each land use assumed to be managed by the selected BMP. The BMPs available for selection were chosen as the most common and easiest to implement BMPs used in combination with the relevant land uses. Additionally, based on best professional judgment, acreage limits were established to define the maximum amount of acreage that could be feasibly managed related to both a specific BMP and each land use category (see Exhibit 3-5 of the TM).

Where possible, assumed pollutant removal efficiencies associated with each BMP were taken from the Integrated Storm Water Management (iSWM) Manual, Design Manual for Site Development, developed by the North Central Texas Council of Governments.[4] Exceptions include grass planting and grade stabilization; pollutant removal efficiencies associated with these BMPs were based on best professional judgment. These values are the same as those that were used for the Hickory Creek analysis. See Exhibit 3-1 in the TM for the assumed removal efficiencies.

[4] NTCOG, 2006.

Installation and maintenance costs were updated from those used for the Hickory Creek analysis. These were originally estimated for each BMP using two sources: the Texas Department of Transportation (TxDOT)[5] and the Natural Resources Conservation Service (NRCS, 2007). TxDOT supplied the Denton County's "Average Low Bid Unit Price – Construction." The version used was last updated June 30, 2007, and the 12-month moving average was employed. The NRCS supplied the current (as of July 5, 2007) "EQIP Cost List for Denton, Texas, FY 2007," which provides construction costs for practices subsidized by the Environmental Quality Incentives Program (EQIP). For this study, all 2007 estimates were updated to 2011 dollars using the Engineering News Record Building and Construction Cost index series.[6] The tool automatically calculates annual implementation costs or total present value costs over a defined period as selected by the user, and reports results in 2011 dollars. See Exhibit 3-2 in the TM for the cost assumptions used in this project.

B3.2 Strengths and Weaknesses of the Tool

As constructed, the tool provides a great deal of flexibility in defining the areas to be included in a BMP portfolio analysis, while hard-coding certain key assumptions, such as loading rates, BMP efficiencies, and assumed unit costs, that stay constant across different portfolios.

Providing this level of flexibility in the tool involved some tradeoffs in features and functionality. For example, while the tool can accommodate scenarios ranging from one to 30 years, the land use distribution is static for the entire period. Land use changes must be evaluated manually by constructing different scenarios representing different land use distributions. Additionally, the user can only see results for one pollutant at a time in the portfolio "dashboard," but can simply click the reduction category button to populate the dashboard with data and results for another pollutant. However, the summary table builder function exports results for all three pollutants into a single summary sheet as the user clicks through the three pollutants. Despite these manual necessities, the tool has proven more than sufficient for the screening and planning level analyses presented herein.

Sections 4 and 5 of the TM present the estimated load reductions based on BMP portfolios constructed for the Doe Branch and Stewart Creek sub-watersheds using the tool described. Note, though, that these results are based on the projections of a conceptual model calculated at aggregated levels and that actual results from implementing any portion of these portfolios will be determined by the specific conditions of the BMP sites. Loadings associated with the different land uses, removal efficiencies, and other elements obtained from the literature and applied to this system model provide guidance and planning level estimates. Removal efficiencies obtained in practice will vary and site conditions will provide opportunities for and/or constrain design options.

B4 Selection of Parcels for Prioritization

The Hickory Creek WPP evaluated BMP optimization at three spatial scales: watershed-wide, defined Master Planned Communities (MPCs), and a sub-set of 282 sub-watersheds, or "parcels." The purpose of the parcel-level analysis was to show how prioritizing BMP implementation using a load-based ranking system (parcels associated with higher pollutant loads are ranked higher) would optimize site selection and maximize the cost-effectiveness of the chosen BMP portfolio. As this type of analysis was replicated for the Doe Branch and Stewart Creek sub-watersheds, it was necessary to select a set of parcels in each watershed for the prioritization analysis. An approach similar to the one taken for the Hickory Creek analysis was applied for this study, as described in the paragraphs that follow.

During the Hickory Creek study, the project team determined that drainage areas of a size of 80 to 125 acres are optimal for this analysis. Results for drainage areas less than 80 acres might be inaccurate using the Digital Elevation Model (DEM, see description that follows), and drainage areas of greater than 125 acres become less practical for implementing the types of BMPs applied in this study based on professional judgment and experience.

[5] TxDOT, 2007.

[6] Engineering News Record, 2011.

The 10-meter National Elevation Dataset DEM developed by the USGS[7] was used to determine flow directions for defined areas called "cells" and to identify stream reaches, drainage divides, and contributing areas for each cell. That is, for each 0.22-acre cell, a single downstream cell was determined based on the direction of the steepest descent, which was then used to identify the drainage area of each cell. Exhibit 2-2 in the TM presents the annual constituent load per unit area for each land use and constituent. This load per unit area multiplied by the cell area (that is, 0.22 acre) represents the contribution of each cell to the downstream cells. Thus, the load from a given cell will be the sum of the contributions of the cells in its drainage area. Note land use data were provided by multiple municipalities in the two sub-watersheds.

The resulting drainage area polygons were used to clip the land use polygons and determine the areas of each land use draining to each potential BMP location. In some cases, mostly in the Doe Branch sub-watershed, the sum of the land use areas was greater than the drainage area. This problem was caused by overlapping polygons in the land use data; that is, some areas were assigned more than one land use and were counted more than once when estimating areas. The project team evaluated the overlaps in each watershed and determined that small overlaps were acceptable (that is, those less than 5 percent), while larger ones were not. As a result, 1 parcel with excessive overlap was eliminated from the Doe Branch sub-watershed and 0 were eliminated from the Stewart Creek sub-watershed.

Exhibits 2-4 and 2-5 in the TM show the 66 and 38 parcels selected for the Doe Branch and Stewart Creek sub-watersheds, respectively.

B5 Load-Based and Reverse-Protection Parcel Scoring Method

The original Hickory Creek analysis established a method to rank the 282 parcels based on pollutant loading – sites associated with higher pollutant loading rank higher - using the rationale that BMPs on sites with higher pollutant loading will provide more "bang for the buck" in terms of pollutant reductions than on sites associated with smaller loading rates. This analysis for the Doe Branch and Stewart Creek sub-watersheds replicates that method and integrates the WQCM results by adding a reverse-protection ranking component. Each component is described in the subsequent paragraphs, followed by a discussion of how they are combined into a single ranking system and used to develop BMP scenarios.

B5.1.1 Load-Based Indexing and Ranking

Ranking the parcels based on pollutant loading allows prioritizing the parcels for BMP application using this metric. Prioritization may involve choosing the top ten, the top quartile, or the top-most ranked number for which a specified BMP implementation budget is available, for example.

The tool calculates each parcel's annual load per acre for the three pollutants of concern (TSS, TP, and TN) using the acreage in each land use and the acre-based loading values (**Exhibit B-1**). Load per acre is used so that the rankings do not favor large parcels over smaller ones. Because these loading values vary across the three pollutants, it is necessary to translate these raw loading values into a normalized scale so that they can be combined into a weighted score that retains the relative relationships of the parcels among the individual pollutants.

The indexing system used for this analysis converted the raw load per acre values into a score between 0 and 100. Once converted to this common scale, the pollutant scores can be weighted according to importance and combined into a single pollutant loading score that retains the 0 to 100 scale properties. The 40 percent-40 percent-20 percent weights given to TSS, TP, and TN, respectively, for this analysis are the same used in the Hickory Creek analysis.

B5.1.2 Indexing Reverse-Protection Scores

Using a scale of 0 to 50, the WQCM model gives higher scores to watersheds in good and excellent condition as they relate to five weighted parameters: vegetation type, erosion potential, surface slope, percent of the stream defined by the Federal Emergency Management Agency 100-year floodplain, and amount of the stream corridor contained

[7] TNRIS, 2011.

within the sub-watershed. The rationale for this is that the higher quality areas will benefit from protection, which is a less expensive management approach than restoration for areas already impaired.

By the same rationale, if identifying places to cost-effectively implement BMPs, one would prioritize the more degraded sites with higher associated pollutant loading that would have higher potential for pollutant reduction than the less degraded sites targeted for protection. Following this logic, as the project team considered how to integrate the WQCM system with the load-based system used for Hickory Creek, it determined that reversing the WQCM scores would be a reasonable way to develop a WQCM-based BMP opportunity score. In this reverse-protection scoring, the highest WQCM scores become the lowest BMP opportunity score and the lowest WQCM scores become the highest BMP opportunity scores.

Having defined this approach, the next step was to develop an indexing system for the reverse-protection scores so they could be translated into a scale of 0 to 100 and combined with the load-based scores. To accomplish this, each of the Doe Branch and Stewart Creek sub-watershed parcels were mapped to the WQCM watersheds and assigned corresponding raw and narrative (Low, Moderate, High, and Very High) protection scores. If a parcel was mapped to two or more WQCM watersheds, a weighted numerical score was developed using the acres in each WQCM watershed. Exhibit 5-2 in the TM shows the scores for each WQCM watershed overlaying the Doe Branch and Stewart Creek sub-watersheds. Exhibits 5-3 and 5-4 in the TM show the Doe Branch and Stewart Creek sub-watershed parcels mapped to the WQCM watersheds, respectively.

The original intent was to develop a reverse-protection index from the WQCM numerical scores. A variety of methods were implemented and evaluated, but none provided the desired spread for both the Doe Branch and Stewart Creek sub-watersheds, due predominantly to the clustering of the scores within a relatively tight range, as shown in Exhibit 5-5 of the TM. Depending on the method, the index scores either ended up being also clustered in the middle of the range or wildly spread out with clustering at the low end and the high end; both of these situations are undesirable.

The final reverse-protection index system relies on assigning a numerical score to the narrative WQCM scores consistent with giving lower quality areas not targeted for protection higher scores for BMP implementation, as presented in Exhibit 5-6 of the TM. Using a scale of 0 to 100 is compatible with the load-based scoring method and the chosen scores provide the desired spread among parcels. As stated previously, parcels in more than one WQCM watershed were given acreage-based weighted scores.

B5.1.3 The Combined Load-Based and Reverse-Protection Index

With the load-based and reverse-protection scores for each parcel both on a scale from 0 to 100, combining the scores into a single index becomes a matter of choosing relative weights for each set of scores and calculating the total. The objective was to select a weighting that made including the reverse-protection scores meaningful but that still retained the significant influence of the load-based scores that are so closely related to cost-effectiveness. After evaluating several options, a 50:50 weighting was selected. Meeting the stated objective, this weighting produced substantively, but not dramatically, different rankings of the parcels using the combined score, as compared to the load-based score alone, as illustrated in **Exhibits B-4** and **B-5**.

EXHIBIT B-4
Ranking Results With and Without Reverse-Protection Index DB

Denton BMP Optimization Tool
Priority ranking of selected parcels within the Doe Branch watershed

Doe Branch Watershed

	Combined Score			*Comparison*		
Parcel #	**Load**	**Protect**	**Overall**	**Load Rank**	**Comb. Rank**	**Difference**
	50%	50%	100%			
MAX	85	100	92	66	66	29
MIN	-	-	-	1	1	-36
0	81	33	57	24	46	22
1	81	33	57	22	45	23
2	41	33	37	52	58	6
3	1	33	17	65	66	1
4	37	33	35	54	59	5
6	36	33	35	56	60	4
7	19	33	26	61	65	4
8	62	33	48	39	54	15
9	57	38	48	44	53	9
11	49	66	58	49	43	-6
12	30	33	32	57	63	6
13	77	41	59	31	37	6
14	77	67	72	30	22	-8
15	24	33	29	60	64	4
16	83	33	58	19	41	22
18	57	67	62	45	31	-14
19	81	67	74	21	16	-5
20	78	67	72	29	20	-9
21	58	33	46	43	56	13
22	84	33	59	15	40	25
23	84	33	59	11	38	27
24	85	67	76	3	6	3
25	84	67	75	17	13	-4
26	66	68	67	35	25	-10
27	80	67	73	25	18	-7
28	38	82	60	53	35	-18
29	64	100	82	36	4	-32
30	60	67	63	42	29	-13
31	16	53	34	62	61	-1
32	61	33	47	40	55	15
33	85	100	92	7	1	-6
34	29	67	48	59	52	-7
36	7	91	49	64	51	-13
37	50	100	75	47	11	-36
38	29	100	65	58	28	-30
39	85	84	85	2	3	1
40	84	67	75	10	10	0
41	83	86	85	18	2	-16
42	81	67	74	23	17	-6
43	62	100	81	38	5	-33
44	55	67	61	46	32	-14
45	85	67	76	5	8	3
46	36	98	67	55	26	-29
47	85	35	60	6	34	28
48	44	100	72	51	21	-30
49	74	33	54	32	49	17
50	84	33	59	12	39	27
51	60	75	68	41	24	-17
52	83	67	75	20	15	-5
53	85	36	60	8	33	25
54	-	67	33	66	62	-4
55	63	67	65	37	27	-10
56	84	67	76	9	9	0
57	84	36	60	16	36	20
58	85	40	62	1	30	29
59	79	33	56	26	47	21
60	68	33	51	34	50	16
61	74	67	70	33	23	-10
62	78	33	56	28	48	20
63	84	66	75	13	14	1
65	14	67	40	63	57	-6
67	84	67	75	14	12	-2
68	50	67	58	48	42	-6
69	85	67	76	4	7	3
70	48	67	57	50	44	-6
72	78	67	73	27	19	-8
LastDB	-	-	-			

EXHIBIT B-5
Ranking Results With and Without Reverse-Protection Index SC

Denton BMP Optimization Tool
Priority ranking of selected parcels within the Stewart Creek watershed

Stewart Creek Watershed

	Combined Score			*Comparison*		
Parcel #	**Load**	**Protect**	**Overall**	**Load Rank**	**Comb. Rank**	**Difference**
	50%	50%	100%			
MAX	75	85	80	38	38	2
MIN	-	-	-	1	1	-12
0	41	67	54	34	34	0
1	72	67	69	18	19	1
2	75	67	71	4	6	2
3	75	67	71	1	3	2
4	75	67	71	1	3	2
5	73	67	70	16	17	1
6	73	67	70	14	15	1
7	44	67	55	33	33	0
8	61	80	70	25	13	-12
9	57	67	62	27	27	0
10	61	67	64	26	26	0
11	73	67	70	15	16	1
12	75	67	71	1	3	2
14	72	67	70	17	18	1
15	74	67	70	12	12	0
16	32	67	50	35	35	0
17	74	67	70	13	14	1
18	68	67	67	22	24	2
19	23	67	45	36	36	0
20	71	67	69	19	20	1
21	63	67	65	24	25	1
22	48	67	58	32	32	0
23	70	67	68	21	23	2
24	55	67	61	28	28	0
25	9	67	38	37	37	0
26	50	67	59	31	31	0
27	75	67	71	4	6	2
28	53	67	60	29	29	0
29	71	67	69	20	21	1
30	2	67	34	38	38	0
31	75	67	71	4	6	2
32	75	85	80	4	1	-3
33	75	67	71	4	2	-2
34	75	67	71	4	6	2
35	75	67	71	4	6	2
36	75	67	71	4	6	2
37	65	73	69	23	22	-1
38	50	67	59	30	30	0
LastDB	-	-	-			

Attachment C
WQCM Model

ATTACHMENT C

Water Quality Corridor Management Model Detail for the Doe Branch and Stewart Creek Sub-Watersheds

C1 Introduction

This attachment is provided as a companion to the associated technical memorandum (TM) that describes the methods, analysis, and results conducted for Task 5, *Adapting the Hickory Creek Watershed Protection Plan for Use in Other Areas of the Lewisville Lake Watershed: the Doe Branch and Stewart Creek Sub-Watersheds*, of the larger study *Implementing the Hickory Creek Watershed Protection Plan and Adapting the Plan for Use in Other Areas of the Lewisville Lake Watershed*.

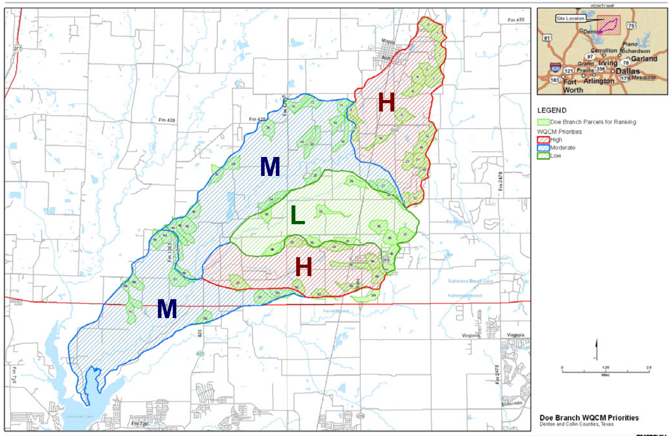
This attachment provides additional detail for the two technology transfer sub-watersheds using the Water Quality Corridor Management (WQCM) model, including detailed land use maps and WQCM component and overall scoring results for those watersheds. **Exhibit C-1** provides WQCM Detail for the Doe Branch parcels and sub-watersheds and **Exhibit C-2** provides WQCM Detail for the Stewart Creek parcels and sub-watersheds.

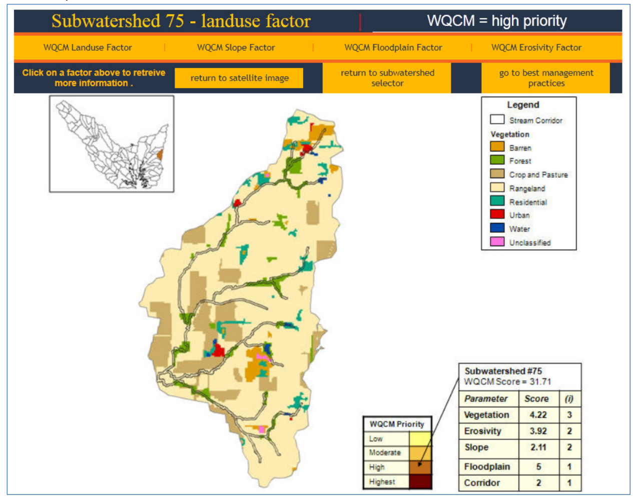
C2 WQCM Detail for Doe Branch Sub-watersheds

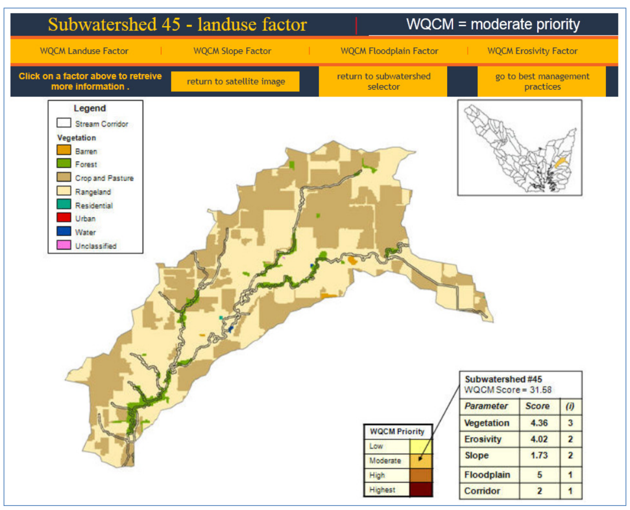
EXHIBIT C-1

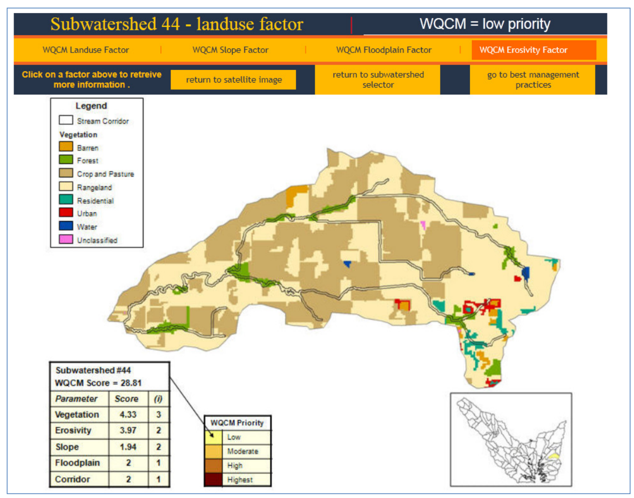
WQCM Detail for Doe Branch Parcels and Sub-watersheds

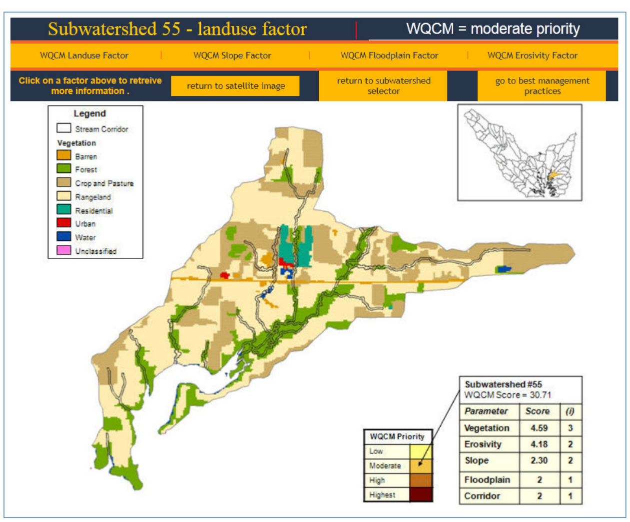
The map in the upper left hand panel shows the 66 Doe Branch parcels in pale green below the outline of the five WQCM sub-watersheds. The five maps pulled from the WQCM model show the land use detail and sub-watershed WQCM scores for each.

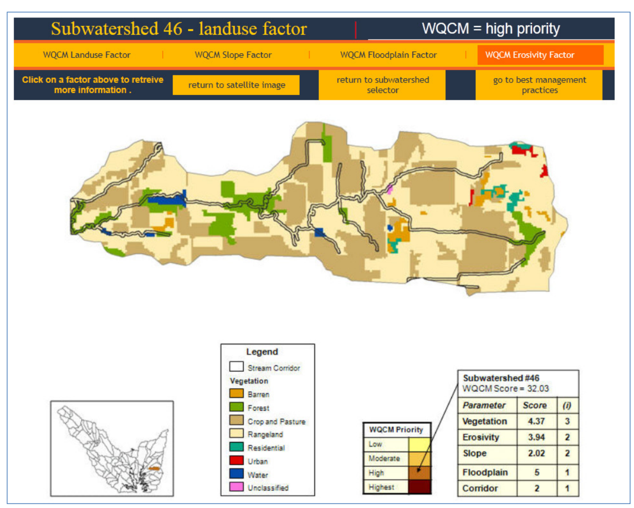












C3 WQCM Detail for Stewart Creek Sub-watersheds

EXHIBIT C.2

WQCM Detail for Stewart Creek Parcels and Sub-watersheds

The map in the top panel shows the 38 Stewart Creek parcels in turquoise blue below the outline of the four WQCM sub-watersheds. The four maps pulled from the WQCM model show the land use detail and sub-watershed WQCM scores for each.