Clean Water Act Section 319(h) Nonpoint Source Pollution Control Program Project

Development of the Plum Creek Watershed Protection Plan

Quality Assurance Project Plan (Project # 04-17)

Texas State Soil and Water Conservation Board

Revision 2

prepared by

Texas Water Resources Institute

Texas A&M University Spatial Sciences Laboratory

Effective Period: November 2006 to August 2009

Questions concerning this quality assurance project plan should be directed to:

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Section A1 Approval Sheet

Quality Assurance Project Plan for *Development of the Plum Creek Watershed Protection Plan.*

United States Environmental Protection Agency (USEPA), Region VI

Name: Donna Miller
Title: USEPA Chief; State/Tribal Programs Section

Signature:___________________________________Date:______________

Name: Randall Rush
Title: USEPA Texas Nonpoint Source Project Manager

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Texas State Soil and Water Conservation Board (TSSWCB)

Name: Pamela Casebolt
Title: TSSWCB Project Manager

Signature:___________________________________Date:_____________

Name: Donna Long
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Signature:___________________________________Date:_____________

Texas Water Resources Institute (TWRI)

Name: Kevin Wagner
Title: TWRI Quality Assurance Officer (QAO)

Signature:___________________________________Date:_____________

Texas A&M University (TAMU)—Spatial Sciences Lab (SSL)

Name: Raghavan Srinivasan
Title: Spatial Sciences Lab Director; Project Manager

Signature:___________________________________Date:______________

Name: R. Karthikeyan
Title: Assistant Professor, Co-investigator

Signature:___________________________________Date:______________

Texas Cooperative Extension (TCE)—Soil and Crop Sciences (SCSC)

Name: Mark McFarland
Title: Extension Specialist; Project Manager

Signature:___________________________________Date:______________

Section A2: Table of Contents

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List of Acronyms and Abbreviations

CAR	corrective action report
CBMS	computer based mapping system
CWA	Clean Water Act
DEM	digital elevation model
DQO	data quality objectives
GBRA	Guadalupe Blanco River Authority
GIS	geographic information system
HUMUS	hydrologic modeling of the United States project
NEXRAD	next generation weather radar
NLCD	national land cover data set
NPS	nonpoint source
QA	quality assurance
QAPP	quality assurance project plan
SAS	Statistical Analysis System
SCSC	Soil and Crop Sciences
SOP	standard operating procedures
SSL	Spatial Sciences Laboratory
SSURGO	soil survey geographic
SWAT	surface water assessment tool
TAES	Texas Agricultural Experiment Station
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
SELECT	Spatially Explicit Load Enrichment Calculation Tool
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USDA-NRCS	United States Department of Agriculture-Natural Resources Conservation Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Section A3: Distribution List

Organizations, and individuals within, which will receive copies of the approved QAPP and any subsequent revisions include:

- United States Environmental Protection Agency, Region VI

  Name: Donna Miller
  Title: USEPA Chief; State/Tribal Programs Section

  Name: Randall Rush
  Title: USEPA Texas Nonpoint Source Project Manager

- Texas State Soil and Water Conservation Board (TSSWCB)

  Name: Pamela Casebolt
  Title: TSSWCB Project Manager

  Name: Donna Long
  Title: TSSWCB Quality Assurance Officer

- Texas Water Resources Institute (TWRI)

  Name: Kevin Wagner
  Title: TWRI Quality Assurance Officer

- Texas A&M University—Spatial Sciences Lab (SSL)

  Name: Raghavan Srinivasan
  Title: Spatial Sciences Lab Director

  Name: R. Karthikeyan
  Title: Assistant Professor

- Soil and Crop Sciences – Texas Cooperative Extension

  Name: Mark McFarland
  Title: Project Manager

Section A4: Project/Task Organization

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

USEPA – United States Environmental Protection Agency (USEPA), Region VI, Dallas, Texas. Provides project overview at the Federal level.

Randall Rush, USEPA Texas Nonpoint Source Project Manager

Responsible for overall performance and direction of the project at the Federal level. Ensures that the project assists in achieving the goals of the federal Clean Water Act (CWA). Reviews and approves the quality assurance project plan (QAPP), project progress, and deliverables.

TSSWCB –Texas State Soil and Water Conservation Board, Temple, Texas. Provides project overview at the State level.

Pamela Casebolt, TSSWCB Project Manager

Responsible for ensuring that the project delivers data of known quality, quantity, and type on schedule to achieve project objectives. Tracks and reviews deliverables to ensure that tasks in the work plan are completed as specified. Reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to TSSWCB and USEPA participants.

Donna Long; TSSWCB Quality Assurance Officer

Reviews and approves QAPP and any amendments or revisions. Responsible for verifying that the QAPP is followed by project participants. Monitors implementation of corrective actions. Coordinates or conducts audits of field and laboratory systems and procedures. Determines that the project meets the requirements for planning, quality assessment (QA), quality control (QC), and reporting under the CWA Section 319(h) NPS Grant Program.

TWRI - Texas Water Resources Institute (TWRI), College Station, Texas. Responsible for development of data quality objectives (DQOs) and a quality assurance project plan (QAPP).

Kevin Wagner, Quality Assurance Officer

Responsible for determining that the Quality Assurance Project Plan (QAPP) meets the requirements for planning, quality control, and quality assessment. Conducts audits of field and laboratory systems and procedures. Responsible for maintaining the official, approved QAPP, as well as conducting Quality Assurance audits in conjunction with TSSWCB and EPA personnel.

SSL - Spatial Sciences Lab (SSL), Texas A&M University, College Station, Texas. Responsible for modeling activities associated with SWAT and Statistical Modeling.

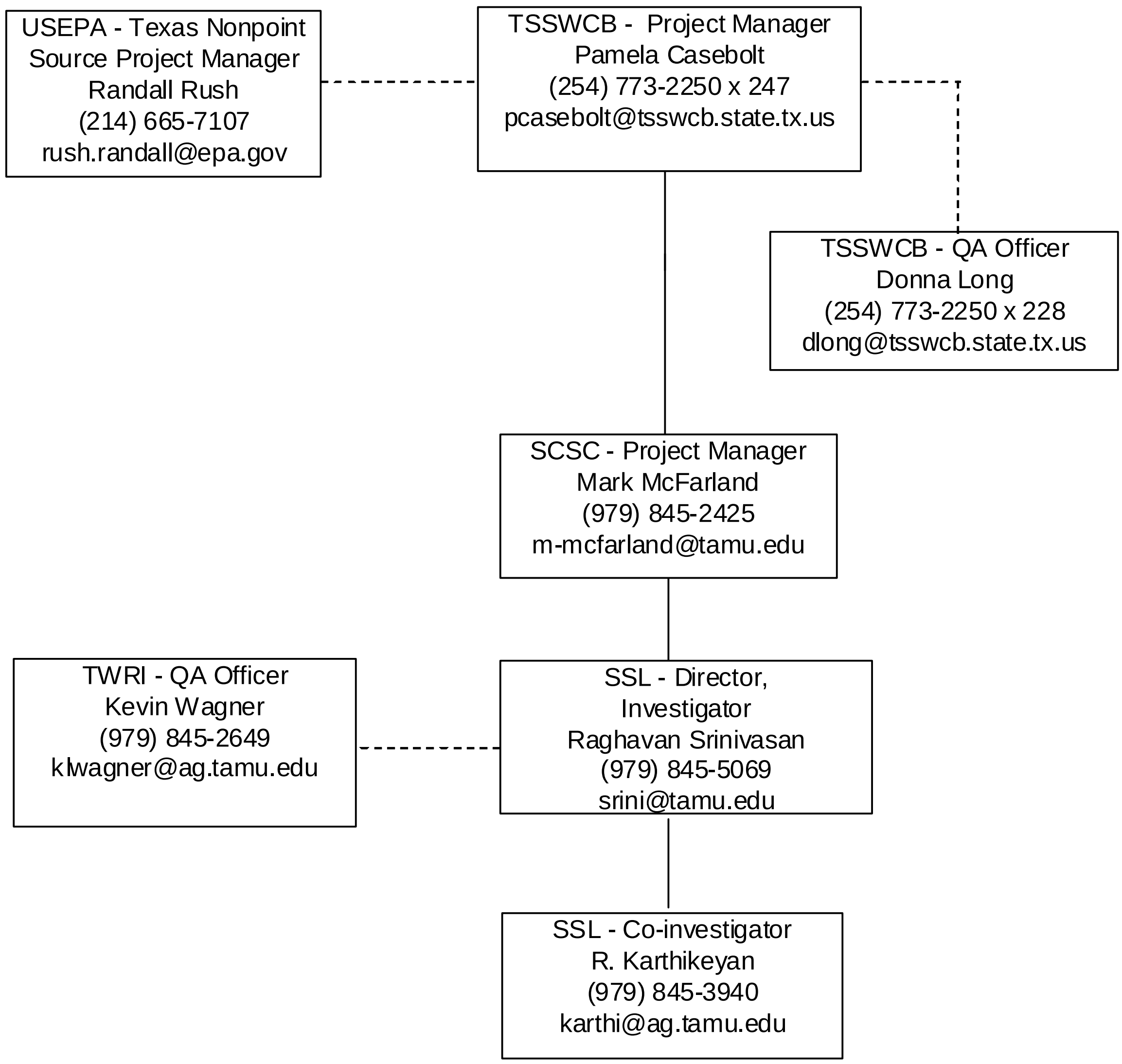
Raghavan Srinivasan, Spatial Sciences Laboratory Director; Project Manager
Responsible for overall operations of the environmental modeling program at TAMU. Responsible for oversight of all laboratory operations and ensuring that all quality assurance/quality control requirements are met. Enforces corrective action, as required.

R. Karthikeyan, Assistant Professor, Biological and Agricultural Engineering
Responsible for supporting water quality modeling using Statistical Models.

SCSC – Soil and Crop Sciences Department (SCSC) – Texas Cooperative Extension, College Station, Texas.

Mark McFarland, Project Manager
Responsible for coordination of quarterly reports and the final project report.

Figure A4-1. Project Organization Chart
Dashed lines indicate communication only



Section A5: Problem Definition/Background

State and federal water resource management agencies have embraced the watershed approach for managing water quality. The watershed approach involves assessing sources and causes of impairment and utilizing this information to develop and implement watershed management plans. To date, most watershed plans have been developed in conjunction with a TMDL. In addition, most plans have involved substantial resource investment and required multiple years. Few plans have been developed in the U.S., and none in Texas, which fully satisfy EPA's nine element guidance.

Given the more than 400 watersheds in Texas that are in immediate need of planning efforts due to known impairments, strategies for more cost effective and time efficient watershed plan development are needed. Limited modeling approaches may be valuable and should be compared to other, more aggressive methods to establish value thresholds. Successfully implemented plans may be able to prevent or resolve potential and existing water quality problems and preclude the need for future development of a TMDL.

As a part of TSSWCB CWA §319(h) Project 04-19, *Regional Watershed Coordinator*, the TSSWCB Wharton Regional Watershed Coordinator established the Regional Watershed Coordination Steering Committee (WCSC) in January 2005. Over the course of the next twelve months, the WCSC quantified criteria to prioritize watersheds in southeast and south central Texas for Watershed Protection Plan (WPP) development. The first watershed selected for plan development was Plum Creek.

To support Project 04-19, Project 05-05 (*A Community-based Water Quality Curriculum which Enhances Stakeholder Involvement in Watershed Protection Plan Initiatives: A Pilot Project*) was developed and implemented. This project has worked in concert with the TSSWCB Regional Watershed Coordinator to initiate WPP development for Plum Creek. The team participated in multiple meetings with local groups and organizations and conducted a media blitz to introduce the project, gain support, and encourage involvement; organized and conducted 3 major public meetings to develop the watershed steering committee and workgroups; and has since convened 3 meetings of the steering committee and 1 each of the 5 topical workgroups.

However, there is a clear need for additional support to achieve both local and multi-agency goals in Plum Creek. Project 04-19 has regional objectives that are much broader than a single watershed. Likewise, Project 05-05 has targeted responsibilities for curriculum development which will support efforts in Plum Creek, but are not directly focused on plan development and implementation. Thus, this proposal defines a complementary project which will provide critical, dedicated technical support both for development and initial implementation of the Plum Creek Watershed Protection Plan.

The purpose of this project is to work in concert with federal, state and local agency partners to coordinate a stakeholder driven process for development of a Watershed Protection Plan in the Plum Creek Watershed which satisfies EPA's nine element guidance.

This project will be a partnership among the primary federal and state agencies directly involved with or linked to water resource management in Texas. The project will work in cooperation with the Plum Creek Technical Advisory Group (PCTAG) which is composed of representatives from the Texas State Soil and Water Conservation Board (TSSWCB), US Environmental Protection Agency (USEPA), Texas Commission on Environmental Quality (TCEQ), Texas Department of Agriculture (TDA), Texas Parks and Wildlife Department (TPWD), USDA Natural Resources Conservation Service (NRCS), USDA Farm Service Agency (FSA), United States Geological Survey (USGS), Texas Cooperative Extension (TCE) and other state and federal agencies, as appropriate, to achieve project objectives. The TCE in concert with the TSSWCB will provide leadership for synthesis of the Watershed Protection Plan for Plum Creek, and will have primary responsibility to facilitate the watershed steering committee and coordinate efforts of the associated workgroups. Each PCTAG agency will be asked to provide a point of contact which will be used to solicit data and information as necessary and appropriate to address planning needs in response to workgroup, steering committee, and/or partner agency requests.

To address pollutant source assessment needs, a three-phase data analysis and modeling effort will be conducted by the TAMU Spatial Sciences Laboratory. The primary purposes of this effort will be to gather basic information to facilitate and support stakeholder decision-making processes as a part of the Watershed Protection Plan development process, and to provide necessary components for ultimate state and federal approval of the developed plan. At the same time and in the process of plan development, an attempt will be made to determine the level of model-based information necessary to meet the needs of the stakeholders and satisfy EPA's nine elements.

Phase I will involve a data analysis effort to classifying the current land use for the watershed. This will be done through "heads-up digitizing" of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software. Individual land use/cover classes will be identified and delineated in shapefile format on screen and verified through field sampling. The results of this effort will be used in the remaining phases of work.

Phase II of will focus on ranking the sources of bacteria and estimating the fate and transport of *E. coli* and nutrients (NO_3, NH_3, PO_4 and TP), within the watershed using a spatially-explicit Geographic Information System (GIS) methodology. For this approach, the watershed will be divided into sub-watersheds and pollutant loads from various sources, i.e. agriculture, urban, and wildlife, will be identified and quantified for each. From this information, total pollutant loading for the watershed can be calculated and contributing components will be ranked based on percentage and estimated production.

Load Duration Curves were developed to determine the amount of reductions for each pollutant (*E. coli,* NO_3, NH_3, PO_4 and TP) required to meet water quality standards at the three monitoring stations. The findings from this phase of the project will be used as input data for the modeling efforts in phase III.

In the final phase, the Soil and Water Assessment Tool (SWAT) will be used to model hydrologic processes and fate and transport of *E. coli* within the watershed. The SWAT model is a basin-scale, distributed-parameter model operating on a daily time step. It is capable of predicting the impact of management on water, sediment, bacteria, and agricultural chemical yields in large river basins for long periods. It is the continuation of a long-term effort on hydrologic and nonpoint source pollution modeling by the USDA-Agricultural Research Service (ARS). The model is physically based, uses readily available inputs, is computationally efficient to operate on large basins in a reasonable time, and is continuous in time and capable of simulating water quantity and quality for long periods.

The model will be run using the highest quality, readily available data for the watershed. Additional information on discharge from wastewater treatment plants and loadings from nonpoint sources will be collected and used in model setup as well. The model will then be calibrated and validated at two USGS long-term streamflow gauges on Plum Creek. Once the model is calibrated and validated for flow and pathogens will be simulated based on the distribution sources throughout the watershed obtained from phases I and II of this project. Finally, recommended Best Management Practices (BMPs) identified by the steering committee, work groups and/or partner agencies will be evaluated for their relative impact on water quality and quantity.

The third task defined for this project will involve efforts to support implementation of the Plum Creek Watershed Protection Plan. Once the WPP is developed, the TCE Program Specialist will continue to support the PCWP through stakeholder facilitation, resource acquisition and tracking of established milestones to achieve plan goals.

Section A6: Project Goals and Task Description

The purpose of this project is to work in concert with federal, state and local agency partners to coordinate a stakeholder driven process for development of a Watershed Protection Plan in the Plum Creek Watershed in Central Texas (see figure A6-1) which satisfies EPA's nine element guidance. This will enable stakeholders to better manage their water resources.

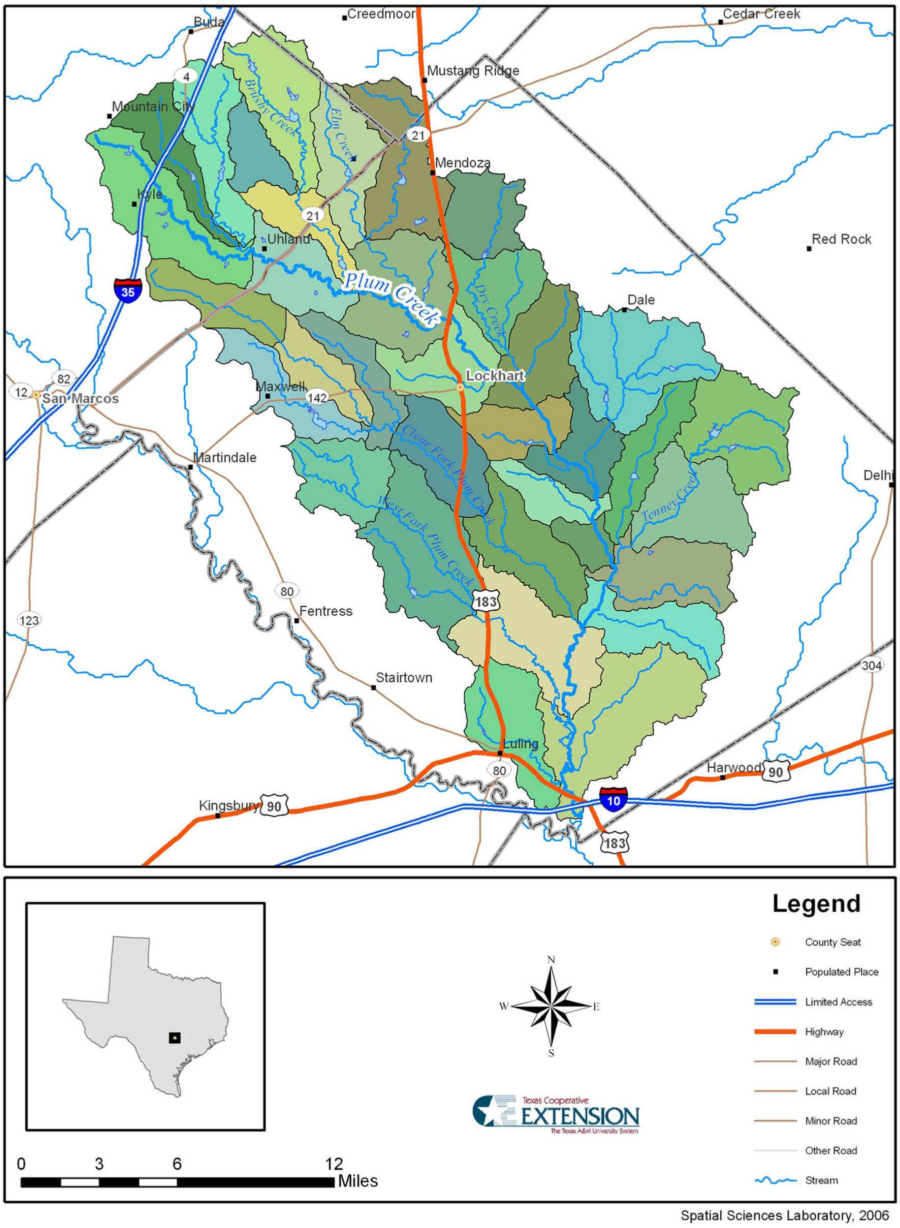


Figure A6-1. Plum Creek Watershed

Task 1: Coordinate the synthesis of the Plum Creek Watershed Protection Plan for the Plum Creek Watershed Partnership Steering Committee and working in concert with federal, state, and local agencies and organizations and other stakeholders.

Objective: Work in concert with stakeholders and partner agencies and organizations to develop a Watershed Protection Plan for Plum Creek.

Subtask 1.1: TCE will hire a Program Specialist to coordinate organization and development of the Plum Creek Watershed Protection Plan. (Start Date: Month 1; Completion Date: Month 3)

Subtask 1.2: In concert with the TSSWCB and the PCTAG, provide leadership for facilitation of the Plum Creek stakeholder Steering Committee and Work Groups for the purpose of plan development and implementation. (Start Date: Month 1; Completion Date: Month 18)

Subtask 1.3: Synthesize the Plum Creek Watershed Protection Plan. (Start Date: Month 1; Completion Date: Month 18)

Deliverables

- Schedules, agendas, attendance lists and minutes from Plum Creek steering committee and work group meetings.
- Quarterly reports documenting progress, status and future activities.
- Draft WPP (Month 12)
- Completed Plum Creek Watershed Protection Plan (Month 18).

Task 2. Conduct data analysis and selective modeling to support development of the Plum Creek Watershed Protection Plan.

Objective: The TAES Spatial Sciences Laboratory in collaboration with faculty in the Department of Biological and Agricultural Engineering at TAMU will conduct a phased modeling effort to development pollutant source and loading information and estimates of load reductions based on proposed BMPs identified by the Plum Creek Steering Committee and Work Groups and by partner agencies and organizations, as appropriate.

Subtask 2.1: Develop a QAPP for Phase I, II and III modeling consistent with *EPA Requirements for Quality Assurance Project Plans (QA/R-5)* and the *TSSWCB Quality Management Plan*. (Start Date: Month 1; Completion Date: Month 2)

Subtask 2.2: Conduct Phase I efforts to classify current land use for the watershed through “heads-up digitizing” of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI’s ArcGIS 9.x software. (Start Date: Month 2; Completion Date: Month 4)

Subtask 2.3: Conduct Phase II analysis efforts to rank sources of bacteria and estimate fate and transport of *E. coli* and nutrients (NO_3, NH_3, PO_4 and TP), within the watershed using a spatially-explicit Geographic Information System (GIS) methodology. Divide the area into sub-watersheds and identify, quantify and rank pollutant loads from various sources, i.e. agriculture, urban, and wildlife. Utilize Load Duration Curves to determine loading and estimate load reductions. (Start Date: Month 2; Completion Date: Month 8)

Subtask 2.4: Phase III modeling will be implemented, to the extent necessary and appropriate, based on the results of Phase II data and information and identified needs of the Plum Creek Steering Committee and Work Groups, and the partner agencies and organizations. Phase III modeling will involve use of the Soil and Water Assessment Tool (SWAT) to model hydrologic processes and fate and transport of *E. coli* within the watershed. (Start Date: Month 3; Completion Date: Month 36)

Deliverables

- Approved QAPP for Phase I, II and III modeling.
- Phase I modeling results.
- Phase II modeling results.
- Phase III modeling results.

Task 3: Support and assist efforts to implement the Plum Creek Watershed Protection Plan through stakeholder facilitation, resource acquisition and tracking of established milestones.

Objective: Work in concert with stakeholders and partner agencies and organizations to implement the Plum Creek Watershed Protection Plan.

Subtask 3.1: Engage and facilitate the steering committee, workgroups, other stakeholders, and/or components of these groups through scheduled meetings on a monthly or as appropriate basis, and work in cooperation with partner agencies to begin implementation of the Plum Creek Watershed Protection Plan. (Start Date: Month 12; Completion Date: Month 36)

Subtask 3.2: Assist stakeholders, including the steering committee, workgroups, local government, etc., in identification and acquisition of resources to enable plan implementation. (Start Date: Month 12; Completion Date: Month 36)

Subtask 3.3: Assist stakeholders, including the steering committee and workgroups, in evaluating progress toward achieving established milestones through continued monitoring of water quality and tracking of implementation efforts. (Start Date: Month 18; Completion Date: Month 36)

Deliverables

- Schedules, agendas, attendance lists and minutes from implementation planning and evaluation meetings.
- Documentation of resource opportunities identified and resources obtained to support plan implementation.
- Quarterly, or more frequent if necessary and appropriate, updates of progress toward plan implementation.

The purpose of this QAPP is to clearly delineate the QA policy, management structure, and procedures, which will be used to implement the QA requirements necessary to model bacteria impairments and their sources under subtasks 2.1 through 2.4

Table A6-1. Project Plan Milestones

TASK	PROJECT MILESTONES	AGENCY	START	END
1.1	TCE will hire a Program Specialist to coordinate organization and development of the Plum Creek Watershed Protection Plan.	TAMU-SCSC	Sept06	Nov06
1.2	In concert with the TSSWCB and the PCTAG, provide leadership for facilitation of the Plum Creek stakeholder Steering Committee and Work Groups for the purpose of plan development and implementation	TAMU-SCSC	Sept06	Feb08
1.3	Synthesize the Plum Creek Watershed Protection Plan	TAMU-SCSC	Sept06	Feb08
2.1	Develop and obtain approval for a QAPP for Phase I, II and III modeling for the Plum Creek Watershed.	TWRI	Sept06	Oct06
2.2	Conduct Phase I efforts to classify current land use for the watershed	TAMU-SSL	Oct06	Dec06
2.3	Conduct Phase II analysis efforts to rank sources of bacteria and estimate fate and transport of *E. coli* and nutrients (NO_3, NH_3, PO_4 and TP) within the watershed	TAMU-SSL	Oct06	Apr07
2.4	Phase III modeling will be implemented, to the extent necessary and appropriate, based on the results of Phase II data	TAMU-SSL	Nov06	Aug09
3.1	Engage and facilitate stakeholders through scheduled meetings, and work in cooperation with partner agencies to begin implementation of the Plum Creek Watershed Protection Plan	TAMU-SCSC	Aug07	Aug09
3.2	Assist stakeholders in identification and acquisition of resources to enable plan implementation	TAMU-SCSC	Aug07	Aug09
3.3	Assist stakeholders in evaluating progress toward achieving established milestones through continued monitoring of water quality and tracking of implementation efforts	TAMU-SCSC	Feb08	Aug09

Model descriptions

Statistical Models

- Spatially Explicit Load Enrichment Calculation Tool (SELECT)
- Load duration curve

Spatially Explicit Load Enrichment Calculation Tool (SELECT)

The Center for TMDL and Watershed Studies at Virginia Tech has been involved in TMDL development for bacteria impairments. The Center personnel developed a systematic process for source characterization that includes the following steps:

- inventorying bacterial sources (including livestock, wildlife, humans, and pets);
- distributing estimated loads to the land as a function of land use and source type; and
- generating bacterial load input parameters for watershed-scale simulation models.

This process provides a consistent approach that is necessary to develop comprehensive bacteria TMDLs. The Center personnel developed a software tool, the Bacteria Source Load Calculator (BSLC), to assist with the bacterial source characterization process and to automate the creation of input files for water quality modeling (Zeckoski, et al., 2005). But BSLC does not spatially reference the sources. A spatially-explicit tool, Spatially Explicit Load Enrichment Calculation Tool (SELECT) is being developed by Spatial Sciences Laboratory and Biological and Agricultural Engineering, TAMU to calculate contaminant-loads resulting from various sources in a watershed. SELECT spatially references the sources, and is being developed under ArcGIS 9 environment. SELECT will calculate and allocate pathogen loading to a stream from various sources in a watershed. All loads will be spatially referenced. In order to allocate the *E. coli* load throughout the watershed, estimations of the source contributions will be made. This in turn allows the sources and locations to be ranked according to their potential contribution. The populations of agricultural animals, wildlife, and domestic pets will be calculated and distributed throughout the watershed according to appropriate land use. Furthermore, point sources such as Waste Water Treatment Plants will be identified and their contribution quantified based on flow and outflow concentration. Septic system contribution will also be estimated based on criteria including distance to a stream, soil type, failure rate, and age of system. Once the watershed profile is developed for each potential source, the information can be aggregated to the sub-watershed level to identify the top contributing areas.

Load duration Curve

This is a simple and an effective first-step methodology to obtain data-based TMDLs (Cleland, 2003; Stiles, 2001). A duration curve is a graph that illustrates the percentage of time during which a given parameter's value is equaled or exceeded. For example, a flow duration curve (FDC) (Figure A6-1) uses the hydrograph of the observed stream flows to calculate and depict the percentage of time the flows are equaled or exceeded.

A load duration curve (LDC) (Figure A6-2), which is related to the FDC, shows the corresponding relationship between the contaminant loadings and stream flow conditions at the monitoring site. In this manner, it assists in determining patterns in pollution loading (point sources, non point sources, erosion, etc.) depending on the streamflow conditions. Based on the observed patterns, specific restoration plans can be implemented that target a particular kind of pollutant source. For example, if the pollutant loads exceed the allowable loads (see Figure A6-2) for low stream flow regimes, then the point sources such as waste water treatment plants and direct deposition sources (wildlife, livestock) should be targeted for the restoration plans. Another main advantage of the LDC method is that it can also be used to evaluate the current impairment as some percent of samples which exceed the standard, and therefore it allows for the rapid development of TMDLs (Stiles, 2001).

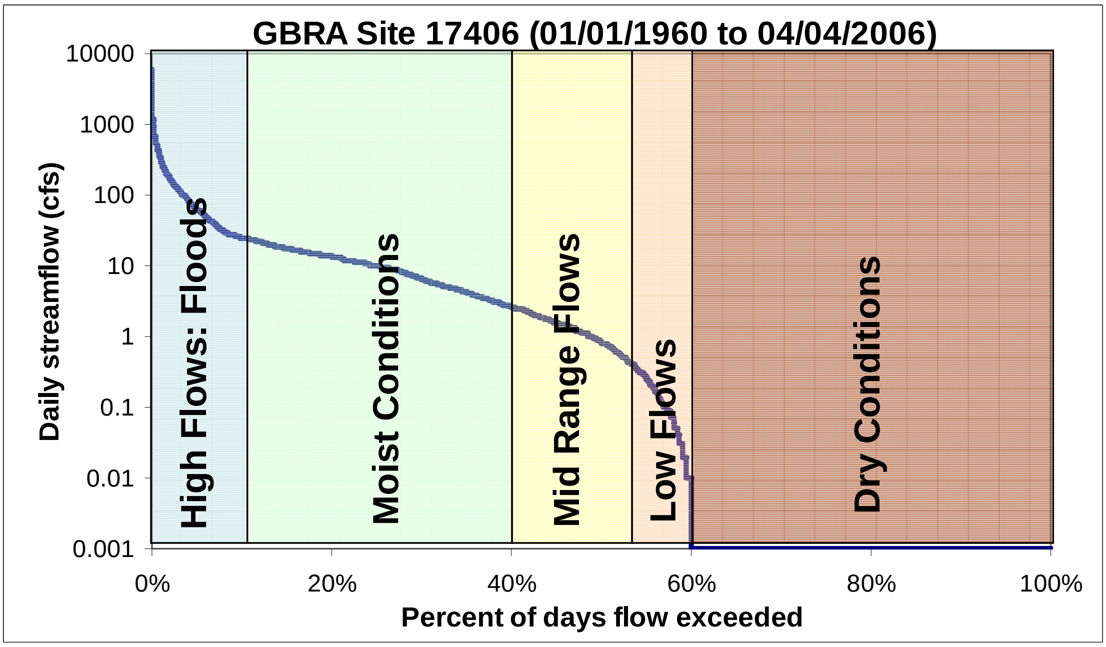


Figure A6-2 Flow Duration Curve (FDC) for streamflow conditions at GBRA monitoring station 17406 on Plum Creek, near Uhland, TX. The flow data at 17406 was obtained from the nearest USGS gage station 8172400, after adjusting for subwatershed aerial contribution during runoff events.

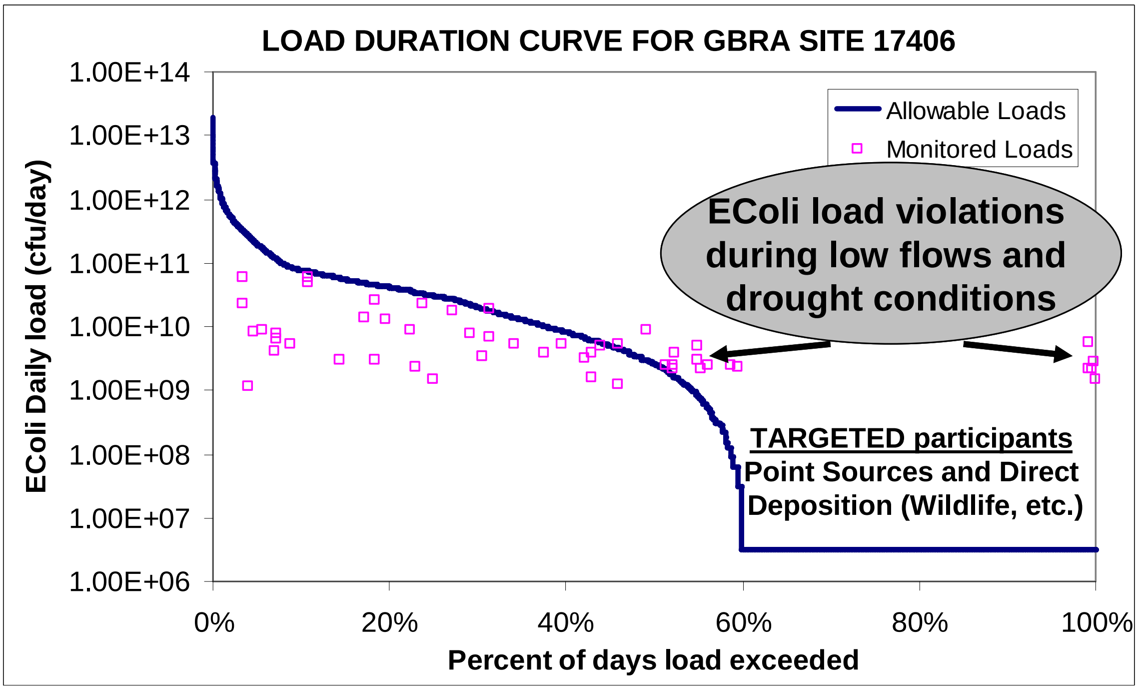


Figure A6-3 Load Duration Curve for *E. coli* at GBRA monitoring station 17406 on Plum Creek, near Uhland, TX. The flow data at 17406 was obtained from the nearest USGS gage station 8172400, after adjusting for subwatershed aerial contribution during runoff events

Deterministic Models

- ***SWAT***

The SWAT watershed model

SWAT is a physically-based watershed and landscape simulation model developed by the USDA-ARS (Arnold et al., 1998). Major components of the model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides and agricultural management. SWAT also has the ability to predict changes in sediment, nutrients (such as organic and inorganic nitrogen and organic and soluble phosphorus), pesticides, dissolved oxygen, bacteria and algae loadings from different management conditions in large ungaged basins. SWAT operates on a daily time step and can be used for long-term simulations. The model output is now available in daily, monthly and annual time scales, although efforts are being made to account for sub-daily time steps. SWAT coding and subroutines are modular, allowing for addition of new subroutines when necessary. SWAT has been successfully applied to model water quality issues including sediments, nutrients and pesticides in watersheds (Arnold et al., 1999). SWAT has been applied to model bacterial water quality issues in watersheds (Parajuli et al. 2006). SWAT has been applied to model phosphorus in TMDL analysis of the Bosque River watershed in Texas (Santhi et al., 2002).

In the Hydrologic Modeling of the United States Project (HUMUS), SWAT was used to analyze water management scenarios (Srinivasan et al., 1998). SWAT is included in EPA's BASINS modeling framework (Di Luzio et al., 2002).

Section A7: Quality Objectives and Criteria for Model Inputs / Outputs

The TAES Spatial Sciences Laboratory in collaboration with faculty in the Department of Biological and Agricultural Engineering at TAMU will conduct a phased modeling effort to develop pollutant source and loading information and estimates of load reductions based on proposed BMPs identified by the Plum Creek Steering Committee and Work Groups and by partner agencies and organizations, as appropriate. The objectives of the water quality modeling for this project are as follows:

1) Develop and obtain approval for a QAPP for Phase I, II and III modeling for the Plum Creek Watershed
2) Conduct Phase I efforts to classify current land use for the watershed through "heads-up digitizing" of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software.
3) Conduct Phase II analysis efforts to spatially characterize and rank sources of bacteria and nutrients (NO_3, NH_3, PO_4 and TP) within the watershed using SELECT, a spatially-explicit Geographic Information System (GIS) methodology. Divide the area into sub-watersheds and identify, quantify and rank pollutant loads from various sources, i.e. agriculture, urban, and wildlife. For each monitoring location in Plum Creek Watershed, obtain Load Duration Curve (LDC) to analyze the temporal trends in the observed water quantity and quality data. Obtain an interpolated model to simulate the trends of the monitored data. Evaluate the violations and the required load-reductions for different flow-rate regimes (low, medium, and high flow) using LDC and interpolated model.
4) Phase III modeling will be implemented, to the extent necessary and appropriate, based on the results of Phase II data and information and identified needs of the Plum Creek Steering Committee and Work Groups, and the partner agencies and organizations. Phase III modeling will involve use of the Soil and Water Assessment Tool (SWAT) to model hydrologic processes and fate and transport of *E. coli* within the watershed.

Phase I

LULC – The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through "heads-up digitizing" of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software. Individual land use/cover classes will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10 m.

NAIP provides two main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 3 meters of reference digital ortho quarter quads (DOQQS) from the National Digital Ortho Program (NDOP) (2004 imagery); and, 2 meter GSD ortho imagery rectified to within +/- 20 meters of reference DOQQs (2005 imagery). The tiling format of NAIP imagery is based on a 3.75' x 3.75' quarter quadrangle with a 360 meter buffer on all four sides. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

As a point of comparison, the USGS National Land Cover Data (NLCD) is created with Landsat Thematic Mapper images. Each image is precision terrain-corrected using 3-arc-second digital terrain elevation data (DTED), and georegistered using ground control points. The resulting root mean square registration error is less than 1 pixel, or 30 meters.

The land use classification scheme to be used in this delineation will include:

- <u>Developed Open Space</u> - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

- <u>Developed Low Intensity</u> - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

- <u>Developed Medium Intensity</u> - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

- <u>Developed High Intensity</u>- Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

- <u>Open Water</u> - All areas of open water, generally with less than 25% cover of vegetation or soil

- <u>Barren Land</u> - (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover and includes transitional areas.

- Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than 50 percent of total vegetation cover.

- Near Riparian Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than 50 percent of total vegetation cover. These areas are found following in near proximity to streams, creeks and/or rivers.

- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent but less than 50 percent of total vegetation cover.

- Rangeland – Areas of unmanaged shrubs, grasses, or shrub-grass mixtures

- Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Phase II

SELECT – this approach is being developed by SSL and Biological and Agricultural Engineering. It is similar to BSCL (Zeckoski, et al. 2005) in TMDL development. High quality spatial data (Landuse data developed in Phase I, SSURGO soils data, NHD, etc) will be processed and utilized in SELECT approach. Distributions for input parameters for SELECT will be created based on literature values and expert knowledge.

LDC – this approach has been utilized in several TMDL projects as an initial screening-tool to evaluate the actual temporal load trends in streams (Cleland, 2003; Stiles, 2001). In cases of violations, it is necessary to determine the required load-reduction in that region near the monitoring station. The load-reductions should be calculated for all flow-regimes of the stream. In order to do this continuous monitoring data will be simulated using the actual monitoring data by regression methods. Uncertainty of the model will be estimated via residual error analysis. The straight line passing through residual error plot should have a slope of zero.

Phase III

The SWAT model will be calibrated for streamflow using the monitoring data available from USGS stream gauges, and historical water quality data collected by GBRA and USGS at various stream segments. Model parameters related to (sub) watershed/landscape processes will be adjusted to match the measured and simulated flow at key locations in each watershed as indicated in the study area. Then the model will be validated without adjusting any parameters.

Model calibration, in this setting, is defined as how well the model is able to reproduce current observed flow rates, as measured from multiple field surveys and stored in the TCEQ monitoring database, GBRA database, and USGS database. Multiple measurements for these parameters are used for verifying the models. Thus, the calibration procedure is able to divide the total variability of the model predictions into two sources:

1. Within-station variability in the input measurements.
2. Variability and uncertainty associated with how well the model fits the data (i.e., lack-of-fit).

Model calibration inputs ands outputs

The following criteria have been established for this project as acceptable model calibration inputs and outputs, respectively:

- Simple and multiple linear regressions with a $r^2 > 0.8$ will be enforced with regard to the SELECT model,
- The straight line passing through residual error plot of the LCD should have a slope of zero,
- Annual flow will be calibrated so that predicted values agree to measured values within 15-20%,
- Flow water balance *(relationship between surface and subsurface flows as defined by base flow filter)* will be calibrated so that predicted values also agree to measured values within 15%,
- Bacteria concentrations will be calibrated so that predicted values agree to measured values within two standard deviations.

If these calibration standards are not obtained, the following actions will be taken:

- Check data for deficiencies and correct any that are found,
- Check model algorithms for deficiencies and correct any that are found, and
- Re-calibrate the model after corrections of deficiencies.

If the standards are obtained, a corrective action report will be submitted to TSSWCB with the following quarterly report. If these steps do not bring predicted values within calibration standards, the Quality Assurance Officer will work with TSSWCB and EPA to arrive at an agreeable compromise.

Section A8: Special Training Requirements/Certification

All personnel involved in model calibration, validation, and development will have the appropriate education and training required to adequately perform their duties. No special certifications are required.

Section A9: Documentation and Records

All records, including modeler's notebooks and electronic files, will be archived by SSL for at least five years. These records will document model testing, calibration, and evaluation and will include documentation of written rationale for selection of models, record of code verification (hand-calculation checks, comparison to other models), source of historical data, and source of new theory, calibration and sensitivity analyses results, and documentation of adjustments to parameter values due to calibration. Electronic data on the UNIX drive and the network server are backed up daily to a tape drive. In the event of a catastrophic systems failure, the tapes can be used to restore the data in less than one day's time. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

TWRI's QAO will produce an annual quality assurance/quality control report, which will be kept on file at TWRI with copies distributed to individuals listed in section A3. Any items or areas identified as potential problems and any variations or supplements to QAPP procedures noted in the quality assurance/quality control report will be made known to pertinent project personnel and included in an update or amendment to the QAPP.

Quarterly progress reports disseminated to the individuals listed in section A3 will note activities conducted in connection with the water quality modeling project, items or areas identified as potential problems, and any variations or supplements to the QAPP. Final reports on Phase 1 LULC, Phase 2 SELECT, LDC and Phase3 SWAT will be generated. Outcomes and stakeholder decisions based on these reports will be documented in project final deliverable, WPP for Plum Creek.

Corrective Action Reports CARs will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at TWRI and will be disseminated to the individuals listed in section A3. CARs resulting in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in updates or amendments to the QAPP.

Section B1: Sampling Process Design (Experimental Design)

Not relevant.

Section B2: Sampling Method Requirements

Not relevant.

Section B3: Sample Handling and Custody Requirements

Not relevant.

Section B4: Analytical Methods

The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through "heads-up digitizing" of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software. Individual land use/cover classes will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10 m.

NAIP provides two main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 3 meters of reference digital ortho quarter quads (DOQQS) from the National Digital Ortho Program (NDOP) (2004 imagery); and, 2 meter GSD ortho imagery rectified to within +/- 20 meters of reference DOQQs (2005 imagery). The tiling format of NAIP imagery is based on a 3.75' x 3.75' quarter quadrangle with a 360 meter buffer on all four sides. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

As a point of comparison, the USGS National Land Cover Data (NLCD) is created with Landsat Thematic Mapper images. Each image is precision terrain-corrected using 3-arc-second digital terrain elevation data (DTED), and georegistered using ground control points. The resulting root mean square registration error is less than 1 pixel, or 30 meters.

The land use classification scheme to be used in this delineation will include:

- Developed Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

- Developed Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

- Developed Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

- Developed High Intensity- Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

- Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil

- Barren Land - (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover and includes transitional areas.

- Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than fifty percent of total vegetation cover.

- Near Riparian Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than fifty percent of total vegetation cover. These areas are found following in near proximity to streams, creeks and/or rivers.

- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent to 50 percent of total vegetation cover.

- Rangeland – Areas of unmanaged shrubs, grasses, or shrub-grass mixtures

- Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Not relevant for Phase 2 and Phase 3 modeling.

Section B5: Quality Control Requirements

The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through "heads-up digitizing" of the 2004-2005 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software. Individual land use/cover classes will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10 m.

Not relevant for Phase 2 and Phase 3 modeling.

Section B6: Equipment Testing, Inspection, & Maintenance Requirements

Not relevant.

Section B7: Instrument Calibration and Frequency

Not Relevant.

Section B8: Inspection/Acceptance Requirements for Supplies and Consumables

Not relevant.

Section B9: Data Acquisition Requirements (Non-direct Measurements)

The GBRA is a partner in the Clean Rivers Program for the state of Texas. As such, they collect data on a regular basis for routine water quality assessment as part of the state's mandate for CWA §305(b) – Water Quality Inventory Report. These data also are used by Texas for consideration of water bodies to be added to their list of impaired water body segments, as described in CWA §303(d). Additional data obtained from the Texas Commission on Environmental Quality are from the TRACS database.

All data used in the modeling procedures for this project are collected in accordance with approved quality assurance measures under the state's Clean Rivers Program, Texas Commission on Environmental Quality, Texas Water Development Board, USDA, National Weather Service, or USGS. Future data collection supported by CWA §319(h) funds through TSSWCB will be incorporated into the modeling process as the data become available. Currently, a proposed monitoring project with GBRA is pending, as data will be collected under a separate QAPP.

GIS data to be used are 2004 and 2005 NAIP (National Agricultural Imagery Program) aerial photos, SSURGO (Soil Survey Geographic) and CBMS (Computer Based Mapping System) soils, USGS NLCD (National Land Cover Dataset) landuse, National Hydrography Dataset (NHD), Census data (2000), Agricultural Census data from USDA-NASS (2002), and the USGS 30-meter resolution digital elevation model (DEM). Measured precipitation and temperature will be collected from National Weather Service climate stations (412585, 414088, 415284, 415285, 415429, 415430, 417983, 419814, and 419815), for input to SWAT. Quality assured stream flow measurements will be collected from USGS stream gage stations (8172400 and 8173000).

Because most historical data is of known and acceptable quality and were collected and analyzed in a manner comparable and consistent with needs for this project, no limitations will be placed on their use, except where known deviations have occurred.

Section B10: Data Management

Systems Design

The SSL uses laptop personal computers, desktop personal computers and UNIX workstations. The computers run Windows operating system and Unix Solaris operating system. Databases include Microsoft® Excel, Microsoft® Access, and a SAS database management system run through a Unix Solaris operating system.

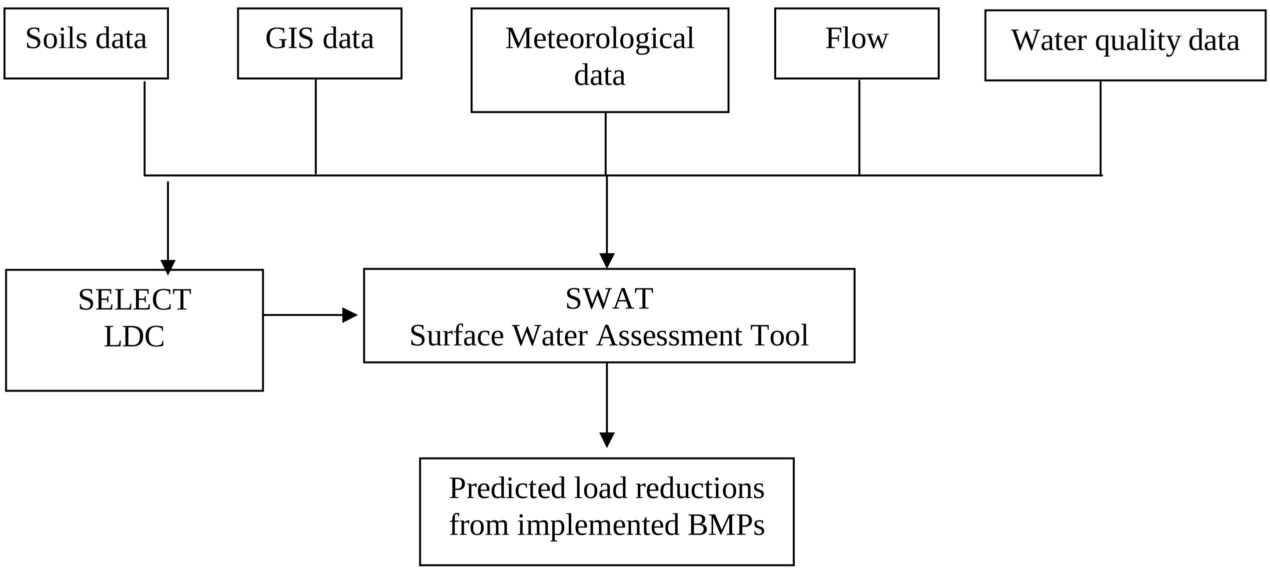
Backup and Disaster Recovery

The UNIX drive and the personal computer drives are backed up on a daily basis to a tape drive and on a monthly basis to an external hard drive for storage in a secure secondary location. In the event of a catastrophic systems failure, the tapes can be used to restore the data in less than one day's time. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

Archives and Data Retention

Original data recorded on paper files are stored for at least five years. Data in electronic format are stored on tape drives in a climate controlled, fire-resistant storage area on either the Texas A&M University campus.

Figure B10-1. Information Dissemination Diagram



Section C1: Assessments and Response Actions

Table C1.1 presents the types of assessments and response actions for activities applicable to the QAPP.

Table C1.1 Assessments and Response Actions

Assessment Activity	Approximate Schedule	Responsible Party(ies)	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	TCE, TWRI	Monitoring of the project status and records to ensure requirements are being fulfilled. Monitoring and review of performance and data quality.	Report to project lead in Quarterly Report
Technical Systems Audit	Minimum of one during the course of this project.	TSSWCB QAO	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Facility review and data management as they relate to the project.	30 days to respond in writing to the TSSWCB QAO to address corrective actions

In addition to those listed above, the following assessment and response actions will be applied to modeling activities. As described in Section B9 (Non-direct Measurements), modeling staff will evaluate data to be used in calibration and as model input according to criteria discussed in Section A7 (Quality Objectives and Criteria for Model Inputs/Outputs Data) and will follow-up with the various data sources on any concerns that may arise.

The model calibration procedure is discussed in Section D2 (Validation and Verification Methods), and criteria for acceptable outcomes are provided in Section A7 (Quality Objectives and Criteria for Model Inputs/Outputs).

Results will be reported to the project QA officer in the format provided in Section A9. If agreement is not achieved between the calibration standards and the predictive values, corrective action will be taken by the Project Manager to assure that the correct files are read appropriately and the test is repeated to document compliance. Corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports (Appendix A) will be filled out to document the problems and the remedial action taken. Copies of Corrective action reports will be included with the TWRI's annual Quality Assurance report. The Quality Assurance report will discuss any problems encountered and solutions made. These QA reports are the responsibility of the Quality Assurance Officer and the Project Manager and will be disseminated to individuals listed in section A3. If the predicted value cannot be brought within calibration standards, the Quality Assurance Officer will work with TSSWCB to arrive at an agreeable compromise.

Software requirements, software design, or code are examined to detect faults, programming errors, violations of development standards, or other problems. All errors found are recorded at the time of inspection, with later verification that all errors found have been successfully corrected. Software used to compute model predictions are tested to assess its performance relative to specific response times, computer processing usage, run time, convergence to solution, stability of the solution algorithms, the absence of terminal failures, and other quantitative aspects of computer operation.

Checks are made to ensure that the computer code for each module is computing module outputs accurately and within any specific time constraints. The full model framework is tested as the ultimate level of integration testing to verify that all project-specific requirements have been implemented as intended. All testing performed on the original version of the module or linked modules is repeated to detect new “bugs” introduced by changes made in the code to correct a model.

Section C2: Reports to Management

Quarterly progress reports developed by the Project Manager will note activities conducted in connection with the water quality modeling project, items or areas identified as potential problems, and any variations or supplements to the QAPP. Corrective action report forms will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at TWRI and disseminated to individuals listed in section A3. CARs that result in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in an update or amendment to the QAPP.

If the procedures and guidelines established in this QAPP are not successful, corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports will be filled out to document the problems and the remedial action taken. Copies of Corrective action reports will be included with the TWRI's annual Quality Assurance report. The Quality Assurance report will discuss any problems encountered and solutions made. These QA reports are the responsibility of the Quality Assurance Officer and the Project Manager and will be disseminated to individuals listed in section A3.

Section D1: Data Review, Validation and Verification

All data obtained will be reviewed, validated, and verified against the data quality objects outlined in Section A7, "Quality Objectives and Criteria for Model Inputs / Outputs." Only those data that are supported by appropriate quality control will be considered acceptable for use.

The procedures for verification and validation are described in Section D2, below. The TAMU Spatial Sciences Laboratory Project Manager is responsible for ensuring that data are properly reviewed, verified, and submitted in the required format for the project database. Finally, the TWRI QAO is responsible for validating that all data collected meet the data quality objectives of the project and are suitable for reporting.

Section D2: Validation Methods

There is no validation and calibration for the SELECT model or LDC as they are data processors. Validation of the SWAT model will be done for a time period of no less than one year - depending on the observed data available. In the validation process, the model is operated with input parameters set during the calibration process without any change and the results are compared to the remaining observed data to evaluate the model prediction. Same evaluation measures will be used for assessing the performance of the model during validation. If the matching of simulated to observed data is not to the standard, the calibration process will be revisited until a best fit between simulated and observed data is obtained.

SWAT is built with state-of-the-art components which simulate the processes physically and realistically. Most of the model inputs are physically based (i.e. based on readily available information). SWAT is not a 'parametric model' with a formal optimization procedure (as part of the calibration process) to fit any data. Instead, a few input variables that are not well defined physically such as runoff curve number and Universal Soil Loss Equation's cover and management factor or C factor may be adjusted to provide a better fit. Moreover, these model parameters are adjusted within literature recommended values so that the results are scientifically valid and defensible. In addition, statistical measures used for evaluating the model's predicted data using the observed data during calibration and validation help to maintain the quality of the model simulation processes and the model results reliable.

Calibration is the process where the model input parameters are adjusted until the simulated data from the model match with observed data. Model parameters related to watershed/landscape processes will be adjusted to match the measured and simulated flow and bacteria at key locations in the watershed. During calibration, all model parameters are adjusted within literature recommended ranges. Calibration is done to represent normal, wet and dry years. Time series plots (between simulated and observed data) and statistical measures such as mean, standard deviation, coefficient of determination and Nash-Suttcliffe simulation efficiency (Nash and Suttcliffe, 1970) will be used to evaluate the prediction (performance) of the model during calibration. Coefficient of determination indicates the strength of relationship between the observed and simulated values. Nash-Suttcliffe simulation efficiency indicates how well the plot of observed versus simulated value fits the 1:1 line. If the values for these two measures are less than or very close to zero, the model prediction is considered 'unacceptable or poor'. If the values are one, then the model prediction is 'perfect'. Calibration is done systematically beginning with flow (Santhi et al., 2001).

Then the model is validated without adjusting any parameters. Depending on the monitoring data available, calibration and validation periods will be chosen. Time series plots and standard statistical measures will be used to evaluate the performance of models during calibration and validation.

Section D3: Reconciliation with User Requirements

The modeling framework developed for this project will be used to evaluate water quality issues in streams within the Plum Creek Watershed. It will provide the Plum Creek Watershed Partnership, through the Steering Committee and Work Groups, with optimum information pertaining to watershed characteristics and to the prediction of possible pollution, the sources of this pollution and will assist in identifying optimum placement of BMPs to prevent pollution loading in area streams. This, in turn, will enable their decision-making efforts as part of a comprehensive Watershed Protection Plan process.

The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. Corrective Action Reports will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the data quality objectives of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final report.

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Corrective Action Report
SOP-QA-001
CAR #:_______________

Date:______________________ Area/Location:______________________

Reported by:______________________ Activity:____________________________

State the nature of the problem, nonconformance or out-of-control situation:
____
____
____
____
____

Possible causes:
____
____
____

Recommended Corrective Actions:
____
____
____

CAR routed to:__________________________________
Received by:____________________________________

Corrective Actions taken:
____
____
____
____

Has problem been corrected?: YES NO

Immediate Supervisor:_________________________________

Program Manager:____________________________________

TWRI Quality Assurance Officer:_______________________________

TSSWCB Quality Assurance Officer:____________________________