Clean Water Act §319(h) Nonpoint Source Grant Program

Development of the Upper Llano River Watershed Protection Plan
TSSWCB Project #11-04

Quality Assurance Project Plan – Modeling
Revision 2

Texas State Soil and Water Conservation Board

prepared by
Texas Water Resources Institute
Texas A&M AgriLife Spatial Sciences Laboratory
Texas Tech University Water Resources Center

Effective Period: March 2012 to August 2015

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Section A1: Title and Approval Sheet

Modeling Quality Assurance Project Plan for *Development of the Upper Llano River Watershed Protection Plan.*

United States Environmental Protection Agency (.EPA), Region VI

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Title: USEPA Chief State/Tribal Programs Section

Signature: ______________________________ Date:___________________

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Title: USEPA Texas Nonpoint Source Project Officer (PO)

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Texas State Soil and Water Conservation Board (TSSWCB)

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Title: TSSWCB Project Manager (PM)

Signature:__________________________________Date:_____________

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Signature:__________________________________Date:_____________

Texas A&M AgriLife, Texas Water Resources Institute (TWRI)

Name: Kevin Wagner, PhD
Title: TWRI Associate Director; Project Lead

Signature:__________________________________Date:_____________

Name: Lucas Gregory
Title: TWRI QAO

Signature:__________________________________Date:_____________

Texas A&M AgriLife, Spatial Sciences Lab (SSL)

Name: Raghavan Srinivasan, PhD
Title: SSL Director; Project Manager

Signature:_________________________________Date:____________

Texas Tech University Water Resources Center (TTU-WRC)

Name: Ken Rainwater, PhD
Title: TTU-WRC, Professor of Civil and Environmental Engineering; Project Manager

Signature:_________________________________Date:____________

KS2 Ecological Field Services LLC (KS2)

Name: Terry McLendon, PhD
Title: Ecological Consultant

Signature:_________________________________Date:____________

Section A2: Table of Contents

List of Tables

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List of Acronyms and Abbreviations

CAFO	Confined Animal Feeding Operation
CAR	Corrective action report
CD	Compact Disc
CWA	Clean Water Act
DEM	Digital Elevation Model
DOQQs	Digital ortho quarter quads
DQO	Data quality objectives
DTED	Digital terrain elevation data
EDYS	Ecological DYnamics Simulation
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
GDG	USDA Geospatial Data Gateway
GIS	Geographic information system
GPS	Global positioning system
GSD	Ground sample distance
LULC	Land use / land cover
MS4	Municipal Separate Stormwater Sewer Systems
NAD	North American Datum
NAIP	National Agriculture Imagery Program
NDOP	National Digital Orthophoto Program
NLCD	USGS national land cover data set
NRCS	USDA Natural Resources Conservation Service
OSSF	Onsite Sewage Facilities
PDOP	Position Dilution of Precision
PM	Project Manager
PO	Project Officer
QA	Quality assurance
QC	Quality control
QAO	Quality Assurance Officer
QAPP	Quality assurance project plan
SLWA	South Llano Watershed Alliance
SSL	Spatial Sciences Laboratory
SSURGO	Soil Survey Geographic Database
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TTU-LRFS	Texas Tech University – Llano River Field Station
TM	Landsat Thematic Mapper
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TTU-WRC	Texas Tech University – Water Resources Center

TWRI	Texas Water Resources Institute
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Section A3: Distribution List

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

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Title: Professor, Project Manager

KS2 Ecological Field Services LLC (KS2)

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Name: Terry McLendon, PhD
Title: Ecological Consultant

Section A4: Project/Task Organization

The following organization chart (fig. A4.1) and list of individuals and organizations participating in the project describes the specific roles and responsibilities of each.

EPA – Provides project oversight and funding at the federal level.

<u>Henry Brewer, USEPA Texas Nonpoint Source PO</u>
Responsible for overall performance and direction of the project at the federal level. Ensures that the project assists in achieving the goals of the clean water act (CWA). Reviews and approves the QAPP, project progress, and deliverables.

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

<u>Jana Lloyd, TSSWCB PM</u>
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 participants.

<u>Mitch Conine, TSSWCB QAO</u>
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 assurance (QA), quality control (QC), and reporting under the CWA §319(h) NPS Grant Program.

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

<u>Kevin Wagner, Project Lead</u>
The TWRI Project Lead is responsible for ensuring that tasks and other requirements in the contract are executed on time and with the quality assurance/quality control requirements in the system as defined by the contract and in the project QAPP; assessing the quality of subcontractor/participant work; and submitting accurate and timely deliverables to the TSSWCB PM.

Lucas Gregory, QAO

Responsible for project reporting and determining that the 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 personnel.

SSL - Texas A&M AgriLife, Spatial Sciences Lab, College Station, Texas. Responsible for developing geographic information system (GIS) inventory and classifying land use and land cover in the Upper Llano River watershed for use in watershed protection plan (WPP) development.

Raghavan Srinivasan, Project Manager

Responsible for coordinating and supervising land use and land cover classification activities. Responsible for ensuring that personnel have adequate training and a thorough knowledge of standard operating procedures specific to the classification of land use and land cover. Responsible for oversight of all Spatial Sciences Laboratory operations and ensuring that all quality assurance/quality control requirements are met. Enforces corrective action, as required.

TTU-WRC - Texas Tech University, Water Resources Center, Lubbock, Texas. Responsible for developing the modeling tasks for the Upper Llano River watershed for use in watershed protection plan (WPP) development.

Ken Rainwater, Project Manager

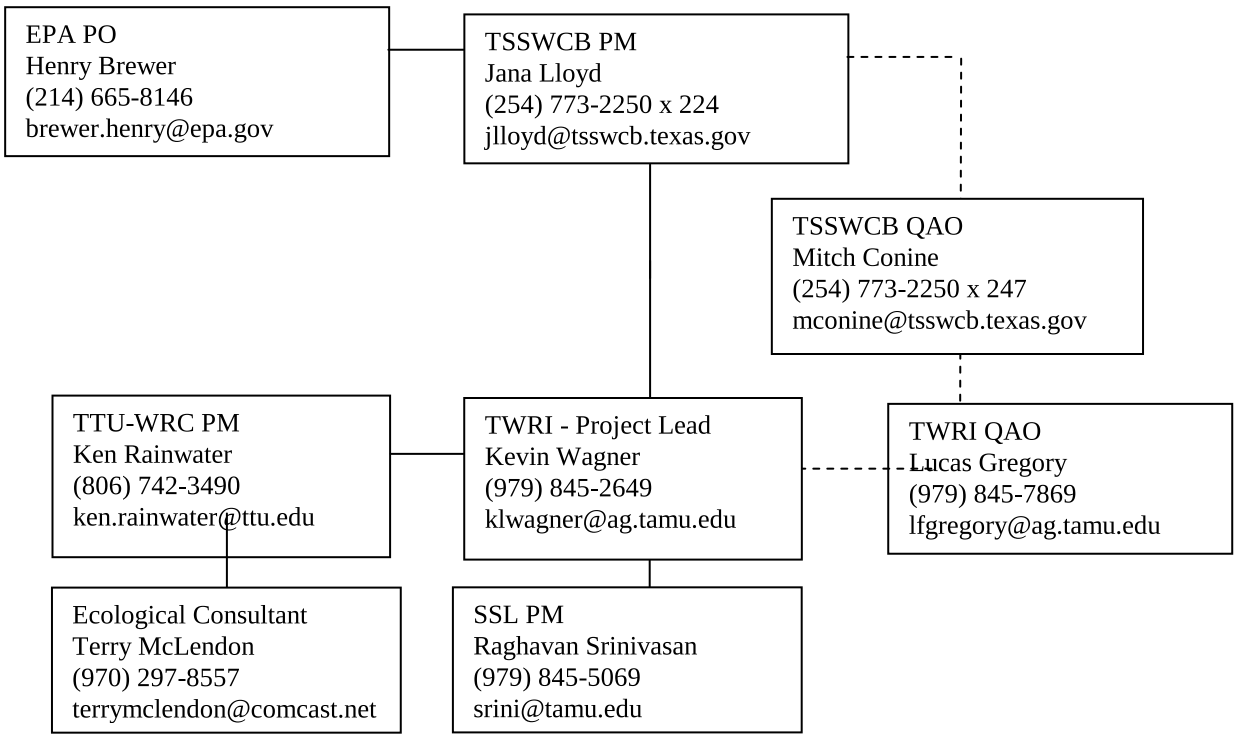
Responsible for coordinating and supervising modeling activities that are carried out by the modeling subcontractor, KS2 Ecological Services. Responsible for ensuring that personnel have adequate training and a thorough knowledge of standard operating procedures specific to watershed modeling. Responsible for oversight of all Water Resources Center operations relative to this project and ensuring that all quality assurance/quality control requirements are met. Enforces corrective action, as required. Oversees the subcontractor team as they develop appropriate input datasets for the cells in the discretized model domain as informed by the GIS results from the SSL and other sources, calibrate the model, and perform the predictive simulations.

KS2 - KS2 Ecological Field Services LLC, Lubbock, Texas. Responsible for modeling the upper Llano watershed using the EDYS model.

Terry McLendon, Ecological Consultant

Responsible for modeling activities. Under the direction of TTU-WRC, develops appropriate input datasets for the cells in the discretized model domain as informed by the GIS results from the SSL and other sources, calibrates the model, and performs the predictive simulations.

Figure A4.1 Project Organization Chart



Section A5: Problem Definition/Background

The South Llano River is a true gem of the Texas Hill Country. Its spring-fed flows are legendary. The South Llano River is important in that during periods of low rainfall and minimal surface runoff, spring flow from the underlying aquifers is paramount in maintaining surface flows. The river and springs that feed it support several unique plant and animal communities, and provide constant critical flows downstream to the Llano and Colorado Rivers and Lake LBJ, especially during times of drought. Stream flow data collected by USGS during the summer of 2006 showed that flow of the spring-fed Llano River accounted for roughly 75% of the water flowing into the Highland Lakes, which support Austin and other downstream Colorado River users. Limited data is available on the water quality, quantity, hydrological or biotic conditions of the North Llano River. Although located in a similar geomorphological and climatological region, it differs from the South Llano River in that much of its flows are derived from surface runoff. Because of these various factors, data collection and analysis of the North and South Llano River Watershed is warranted.

Due to the pristine nature and relatively constant flow of the springs, the South Llano River is currently a healthy ecosystem supporting a variety of aquatic and terrestrial ecosystems, as well as numerous recreational opportunities. It is the only major watershed containing a genetically pure population of Guadalupe Bass, the Texas State Fish. The South Llano River is recognized by the Texas Parks and Wildlife Department as an Ecologically Significant Stream having high water quality, exceptional aquatic life, high aesthetic value, and diverse benthic macroinvertebrate and fish communities (Bayer et al., 1992; Linam et al., 1999). Further, during the early to mid-1980s, the South Llano River was designated by the Texas Commission of Environmental Quality (TCEQ) as a least disturbed ecoregion reference stream for Ecoregion 30. As such, the South Llano River represents a benchmark for which other streams are assessed throughout the ecoregion for water quality standards development and use attainment decisions. The TCEQ Surface Water Quality Monitoring Program (SWQM) is currently conducting a project to further develop and refine the methods and techniques to evaluate the condition of aquatic communities in streams throughout Texas based on these least disturbed streams. TCEQ will be revisiting the South Llano River as part of this effort. Significant and relevant findings from this TCEQ study will be incorporated into the WPP as appropriate.

According to "Land of the Living Waters: A Characterization of the South Llano River, Its Springs, and Its Watershed" prepared by the Environmental Defense Fund, the primary threat to the South Llano River is loss of spring flow. Over the past century, one third of the major spring systems of Texas have ceased flowing largely due to aquifer withdrawals. However, subtle changes due to land fragmentation, loss of riparian habitat, and encroachment of juniper species on upland habitats also have the potential to decrease the water quality and quantity of the river.

Additionally, there is potential for increased biological pollution and reduction in flows should what are now isolated pockets of invasive plants continue to spread. These plants, giant reed (*Arundo donax*) and elephant ears (*Colocasia esculenta*) are emergent hydrophytes and use vast quantities of water relative to native riparian communities. According to the USEPA, more than one third of all the States have waters that are listed for invasive species under §303(d) of the CWA. Physical and biological disruptions of aquatic systems caused by invasive species alter water quantity and water quality. Invasive species have a variety of negative impacts on water resources affecting recreation, irrigation, municipal, and agricultural water supply. These invasive species affect the quantity and timing of runoff, erosion, sedimentation, and other natural physical processes and may affect water availability in general. Comprehensive analyses and evaluations of these processes will provide critical evaluation tools to managers and policy makers on how best to factor invasive species into water management plans. It is far less expensive to address invasive species issues proactively than reactively. To proactively address incipient invasive species issues in the Upper Llano River Watershed, guidance from EPA's Office of Wetlands, Oceans and Watersheds (OWOW) Invasive Species Action Plan to improve effectiveness at countering invasive species that adversely impact the nation's aquatic systems will be used, in particular, monitoring, education and outreach and rapid response elements.

The protection and preservation of the Upper Llano River and its springs is an environmental, economic, and cultural concern. This was recognized by the local community, and in 2009 the South Llano Watershed Alliance (SLWA) was organized as a 501(c)(3) non-governmental organization. The SLWA is an organization of landowners and interested stakeholders whose mission is to preserve and enhance the South Llano River and adjoining watersheds by encouraging land and water stewardship through collaboration, education, and community participation (http://southllano.org/). This group is thought to be the only proactively formed stakeholder group in Texas organized to ensure flows and water quality are maintained for future generations. The group also provides a forum for natural resource management education, discussion, and coordination of efforts to address other identified land and water management issues that may impact the long-term viability of the resource.

Working with SLWA and other local and regional stakeholders, a WPP will be developed to protect and maintain the ecological integrity of this important waterbody from threats arising from land fragmentation, noxious woody vegetation, aquatic invasive species, groundwater availability, and the potential for groundwater exports and aquifer contamination. To the extent possible, the EPA Healthy Watersheds Initiative concepts, assessments, and management approaches outlined in the technical guidance document "Identifying and Protecting Healthy Watersheds" (EPA 2011) will be used to help guide the assessment and planning process.

Section A6: Project/Task Description

Development of a GIS inventory and land use / land cover (LULC) analysis will be conducted by SSL to support watershed modeling and provide needed information for a thorough assessment of the Upper Llano watershed (Figure A6.1). Upon completion of the GIS inventory and LULC analysis, TTU-WRC will analyze this and other watershed data using the EDYS model to assess recommended measures to achieve environmental goals established by stakeholders in the WPP.

Figure A6.1. Watersheds targeted for LULC classification.

SSL will collaborate with project partners, local agencies and stakeholders to develop a comprehensive GIS inventory of the Upper Llano River watershed. This GIS inventory will include the most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, public park lands, municipalities and satellite imagery or aerial photography. Locations of SWQM stations, U.S. Geological Survey (USGS) gages, public access points to the waterbodies, floodwater-retarding structures, wetlands, known OSSFs, TPDES permittees (including WWTFs, CAFOs and MS4s), and subdivisions will also be included. Sites permitted for land application of sewage sludge and septage should be included. Information on distribution and abundance of invasive emergent and aquatic plants from the headwaters (Llano Springs, 700 Springs, South Llano River and North Llano River) to Junction, as well as the distribution, abundance, and severity of cut and eroding banks on the South and North Llano Rivers, as provided by TTU-LRFS will also be included in the GIS inventory. TSSWCB-certified

WQMPs will also be documented. SSL will provide watershed maps for stakeholder meetings as needed.

SSL will perform a combination of satellite based image (2006-2010) classification schemes and where needed "heads-up digitizing" of the 2006-2010 NAIP aerial photos of the watershed using ESRI's ArcGIS 9.x software.

SSL will identify individual LULC classes and delineate them in shapefile or ArcGIS grid format with a minimum mapping unit of 2 acres on screen. Brush type, density, and canopy cover will also be identified and delineated. LULC classes will be comparable to the USGS National Land Cover Dataset (NLCD).

SSL will verify LULC classification through field sampling and ground truthing information 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 meters. According to the National Land Cover Database Zone 32 Land Cover Layer (U.S. Geological Survey, 14 Dec. 2006. http://www.mrlc.gov), 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% 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% 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% 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 80-100% of the total cover.
- <u>Open Water</u> - Areas of open water 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.
- <u>Forested Land</u> – Areas dominated by trees generally greater than 5 meters tall, and greater than 50% of total vegetation cover.
- <u>Near Riparian Forested Land</u> – Areas dominated by trees generally greater than 5 meters tall, and greater than 50% of total vegetation cover. These areas are found following in near proximity (within 30-60 m) to streams, creeks and/or rivers.

- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% but less than 50% 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% of total vegetation.
- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
- Brush Low Density - Areas dominated by woody canopy cover, including ashe juniper, mesquite, live oak and other brush species and comprise less than 30% of total vegetation cover. Where possible, species level analysis will be performed.
- Brush Medium Density - Areas dominated by woody canopy cover, including ashe juniper, mesquite, live oak and other brush species and comprise 30-60% of total vegetation cover. Where possible, species level analysis will be performed.
- Brush High Density - Areas dominated by woody canopy cover, including ashe juniper, mesquite, live oak and other brush species and comprise greater than 60% of total vegetation cover. Where possible, species level analysis will be performed.

TTU-WRC will use the Ecological Dynamics Simulation (EDYS) model to simulate flow and water quality at the watershed and subwatershed scales and identify BMPs and targeted locations to enhance the quality of runoff and recharge. Modeling work will be subcontracted to KS2 Ecological Services, LLC (KS2), the developers of EDYS and the hands-on operators of the model. To support the calibration and validation of this model, TTU-WRC will collect and evaluate relevant hydrologic data for the Upper Llano River watershed, including rainfall, stream flow, and groundwater conditions in addition to the GIS and LULC data collected by SSL. In the EDYS application, GIS datasets are not input directly into the model. The modeled domain is discretized with cells of varying sizes based on the desired scale, and information that has been mapped with GIS is converted by the model user to data values that are employed in the cells.

According to the EDYS 5.1.0 Users Guide provided by KS2, EDYS is a general ecosystem simulation model that is mechanistically-based and spatially-explicit. It has been used for ecological evaluations, watershed management, land management decision making, environmental planning, revegetation and restoration design analysis, and regulatory compliance by federal and state agencies, municipal and water authorities, and corporations. EDYS simulates natural and anthropogenic-induced changes in hydrology, soil, plant, animal, aquatic, and watershed components across landscapes, at spatial scales ranging from 1-meter^2 or less to landscape levels (10^3 kilometer^2 and larger). It is a dynamic model, simulating changes on an hourly (for aquatic) or daily (most terrestrial) basis, over periods ranging from months to centuries. EDYS has been linked with groundwater (MODFLOW) and surface runoff (GSSHA, CASC2D, HSPF) models and is included as part of the US Army Corps of Engineers System-Wide Water Resources Research Program (SWWRP).

The EDYS model developed under this Scope of Work will be fully-functional and will include aquatic, riparian, and upland components and will include the spatial footprint of the North Llano and South Llano Rivers, from their headwaters to their confluence near Junction. Precipitation, topographic, soil, vegetation, animal (livestock and wildlife), aquatic (water quantity and quality, plants, animals), and land management components will be included (described below). The model will include (1) biotic and water chemistry variables and (2) characterization of the spatial footprint (upland, riparian, and river channels) based on existing data sources, primarily aerial/satellite photographs.

The upland, riparian, and river channel components will be fully linked in the model. This will allow for evaluation of potential impacts to the river ecosystem from land management options and natural-occurring events in the uplands as well as directly within the river drainages. For example, brush management or wildfires on the uplands followed by heavy rainfall may increase sediment loads to the river. The sediments might then have an impact on the water quality and, subsequently, the aquatic populations. Conversely, increased grass cover following brush management may decrease sediment loads into the river, with a corresponding positive impact on at least some of the aquatic populations. The model will provide a tool to simulate these hydro-ecological linkages and evaluate the interactions. No additional models are necessary to be linked to EDYS to meet this scope of work.

Several types of spatial datasets were developed by the Spatial Sciences Laboratory to assist in the assembly of input data for the EDYS model of the North and South Llano. These datasets include delineation of the watersheds, topographic information from the National Elevation Dataset, land use and land cover data, flow lines and water bodies from the National Hydrologic Dataset, and soils from the SSURGO dataset. In addition, TWRI provided digital maps with locations of public water supply wells and intakes, wastewater outfalls, roadways, and political boundaries. These datasets will be utilized in the development of the model. The parameters in EDYS are custom-designed for each application. Each module (e.g., precipitation, soil, plant) in the EDYS application for the Upper Llano project will contain parameters specific to the Upper Llano region, as described in the Scope of Work. Precipitation data from area precipitation stations will be used in the precipitation module. Soil data relative to the specific soil series in the area will be used in the soil module. The plant module will contain species ecologically important in that region.

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 develop a high quality GIS inventory, classify the land use/land cover, and model the Upper Llano River watershed. The model outputs from the runs that simulate different combinations of management scenarios will demonstrate impacts on projected streamflows and loss to groundwater, selected water quality variables in relation to regulatory guidance, and selected wildlife species.

Table A6.1. Project Plan Milestones

TASK	PROJECT MILESTONES	AGENCY	START	END
1.1	Provide updates for quarterly progress reports	SSL/TWRI/ TTU-WRC	Nov 11	Aug. 15
1.3	Participate in coordination meetings or conference calls with project partners, at least quarterly	SSL/TWRI/ TTU-WRC	Nov 11	Aug. 15
2.1	Develop QAPP for Task 4 LULC & GIS Inventory	SSL/TWRI	Nov 11	Mar 12
2.2	Provide revisions and necessary amendments to the QAPP	SSL/TWRI/ TTU-WRC	Mar12	Aug. 15
4.1	Develop comprehensive GIS Inventory	SSL	Mar 12	Oct 14
4.2	Classify currently land use & land cover of watershed	SSL	Mar 12	Oct 14
4.3	Transfer GIS Inventory & LULC to TTU-WRC for modeling and TSSWCB for submission to EPA R6	SSL	Mar 12	Oct 14
6.1	Simulate flow and water quality and identify BMPs and targeted locations to enhance the quality of runoff and recharge	TTU-WRC	Jun 13	Aug. 15
6.3	Summarize modeling findings to inform stakeholders of watershed response to implementation scenarios and work with project partners to incorporate this into the WPP	TTU-WRC	Mar 14	Aug. 15

Section A7: Data Quality Objectives and Criteria

The objectives for this project are as follows:

1) Develop and obtain approval for a QAPP and update it annually
2) Classify current land use / land cover for the Upper Llano River watershed for use in the EDYS model, watershed assessment, and WPP development
3) To develop a comprehensive GIS inventory of the watershed using credible, widely used government data (see Section B1 and Table B1.1 for specific data sets and sources used)
4) Collect and evaluate relevant hydrologic data for the Upper Llano River watershed, including rainfall, stream flow, and groundwater conditions
5) Simulate flow and water quality at the watershed and subwatershed scale and identify BMPs and targeted locations to enhance the quality of runoff and recharge

The 2006-2010 National Agriculture Imagery Program (NAIP) aerial photos of the area will be classified by SSL using Definiens Developer 7.0 software. The 2006 NAIP imagery provides four main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 5 meters of reference digital ortho quarter quads (DOQQs) from the National Digital Ortho Program (NDOP); 2 meter GSD ortho imagery rectified to within +/- 10 meters of reference DOQQs; 1 meter GSD ortho imagery rectified to within +/- 6 meters to true ground; and, 2 meter GSD ortho imagery rectified to within +/- 10 meters to true ground. The 2008 and 2010 NAIP imagery provides two main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 5 meters of reference DOQQs from NDOP or from NAIP; 1 meter GSD ortho imagery rectified to within +/- 6 meters to true ground. 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, 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.

To achieve the needed precision and accuracy, the land use / land cover classification scheme to be used in this delineation will include at a minimum the fifteen classifications discussed in A6. Individual LULC classes will be identified and delineated with a minimum mapping unit of 2 acres on screen.

Representativeness will be addressed by collecting ground control points for at least ten locations per land use type per watershed. This GPS survey will utilize the Trimble GeoExplorer 3 Global Positioning System Receiver in the WGS84 (World Geodetic System of 1984) Mode to obtain control point latitude/longitude values within 10 meters of true locations at the 95% confidence level. This level of accuracy is consistent with Tier 3 described in the EPA National Geospatial Data Policy. The Trimble GeoExplorer 3 will be set to capture data provided that at least four satellites are in view and the Position Dilution of Precision (PDOP) value remains at 6 or below. The receiver will be set to provide audible or visual warnings when the quality settings are exceeded. Sample interval and time on station will be consistent with Trimble GeoExplorer 3 Manual recommendations. Post-processing the GPS data will be accomplished using the vendor's software package operating on a local workstation. The higher end software package will perform statistical analyses on the point data downloaded from the GPS receiver. For 10-meter data accuracy, any data points with a standard deviation of 3 meters or more will be a basis to exclude that data point from the collection. Ideally, the standard deviation for 10-meter accuracy data should be 1 meter or less at the 95% confidence level.

Once the ground control points are collected by SSL as outlined in the previous paragraph, the individual LULC classes will be verified by SSL through comparison with the ground control points to ensure an accuracy of 80% or greater. This will be complemented with aerial photographs and other ancillary data that is available (See section B).

Comparability will be addressed by collecting, analyzing, and reporting the GIS and LULC data as described in section B of this document.

A completeness goal of 100% is needed for the GIS and LULC. Valid data is required for each land use / land cover class mapped in order to complete the cover maps for each watershed.

The EDYS model will be used by TTU-WRC and KS2 to simulate flow and water quality at the watershed and subwatershed scale and identify BMPs and targeted locations to enhance the quality of runoff and recharge. The EDYS model is designed to mechanistically simulate complex ecological dynamics across spatial scales ranging from plots (square meters) to landscape and watershed (square kilometers) levels. The EDYS modeler (KS2) develops input datasets for the required variables for each cell in the discretized solution domain. The input datasets include information that has been digitally mapped by the SSL, but the GIS files are not used as direct input files for EDYS and its various mathematical modules. These modules include climatic simulators, hydrology, soil profile, nutrient and contaminant cycles, plant community dynamics, herbivory, animal dynamics, management activities, and natural/anthropogenic disturbances. EDYS has been applied in a wide variety of land and water management scenarios, including: military training, recreational activities, grazing, natural and prescribed fire, impacts of changing weather patterns as a result of climate change, road/trail building and closure, invasive plants inventory and eradication, drought assessment, water quality/quantity, reclamation, restoration, land cover design, and slope stability. Calibration of EDYS is discussed later in this section.

EDYS allows quick evaluation of restoration alternatives that include a combination of several different management actions implemented at different spatial and temporal scales depending on the alternative. The alternatives can also be evaluated based on a range of weather patterns e.g., dry versus average versus wet periods.

Literature information available will be used by TTU-WRC to parameterize the hydrologic and nutrient components, namely flows, and sediment and nutrient loadings. The EDYS model will be calibrated for streamflow, sediment, and nutrients using the monitoring data available from USGS stream gauges, and historical water quality data collected by TCEQ, LCRA, and USGS at various stream segments. Model parameters related to (sub) watershed/landscape processes will be adjusted to match the measured and simulated flow, sediment, and nutrient at key locations in each watershed as indicated in the study area. Then the model will be validated without adjusting any parameters.

The KS2 Ecological Services subcontractor modeling team has all the appropriate education, training, and experience to successfully perform model calibration and validation. Model calibration, in this setting, is defined as how well the model is able to reproduce current observed flow rates, sediments and nutrients (e.g., trends and peak values), as measured from multiple field surveys and stored in the TCEQ monitoring database, LCRA 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).

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

- 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%,
- Sediment (where sedimentation survey or other data is available) will be calibrated so that predicted values also agree to measured values within 20-25%,
- Nutrient concentrations (depending on the length of in-stream data is available) will be calibrated so that the mean of the predicted values falls within two standard deviations of the mean of the measured values.

In the instance that 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 not 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 QAO will work with TSSWCB and EPA to arrive at an agreeable compromise.

The EDYS model will be used to simulate the effectiveness of BMPs in the Upper Llano watershed. Pre-BMP conditions (or without BMPs) representing conditions of the watershed prior to the implementation of BMPs, and post-BMP conditions (or with BMPs) representing the conditions of the watershed after implementation of the practices will be simulated to quantify the impacts of BMPs at different locations within the watershed. Changes in sediment and nutrient loadings between pre-BMP and post-BMP conditions provide information to assess the "long-term impacts" on water quality.

Section A8: Special Training/Certification

Although no special certifications are required, the team in the SSL has obtained GIS and Remote Sensing certificates through Texas A&M University. Each member has also earned a Bachelor of Science in Spatial Sciences and received a Master of Science from Texas A&M University. All personnel involved in classification of land use and land cover has the appropriate education and training required to adequately perform their duties including being trained and field tested in the typical techniques used for land use inventories, having training in the classification scheme employed in the land cover mapping process, and being trained and experienced in using Trimble GeoExplorer 3 GPS Receivers, (ESRI) ARCINFO and ARCVIEW.

The KS2 Ecological Services subcontractor modeling team has all the appropriate education, training, and experience to successfully perform model calibration, validation, and predictive simulations. The TTU-WRC personnel involved in oversight have the appropriate education and training required to adequately perform their duties. No special certifications are required.

Section A9: Documentation and Records

SSL

Digital files of land cover data for each watershed will be produced in shapefile or ArcGIS grid format and stored on CD-ROM disks. Multi-color hard copy maps of land cover can be produced at various geographic scales from these digital files. SSL plans to produce hard copy land cover maps for the Upper Llano River watershed. Other products will be produced as required by the TSSWCB, cooperators and other data users. Metadata documentation will also be developed and will document data sources, processing techniques, accuracy assessment, and other pertinent information.

Appendix B represents the SSL field data collection form used for this project. Other records and documentation to be developed for this project include the following: digital files of spatial data, field data, and scanned photographs. Records of field data, original aerial photos, digital files used for classifying LULC and accuracy assessment, and corrective action reports (CARs) will be maintained and archived by SSL for at least five years.

TTU-WRC

All TTU-WRC records, including modeler's notebooks and electronic files, will be archived by TTU-WRC for at least five years. These records will document model testing, calibration, and evaluation and will include documentation of written rationale for selection of model, 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 are backed up daily to a an external 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. The modeling SOP is appended at the end of this QAPP (Appendix D), and the EDYS user's guide is provided as a separate document. The TTU-WRC is responsible for the adherence to the SOP guidance, and will work with KS2 to insure that the application of the model follows both the user's guide and SOP requirements to meet the scope of work.

All electronic data are backed up on an external hard drive monthly, compact disks weekly, and is simultaneously saved in an external network folder and the computer's hard drive. A blank CAR form is presented in Appendix A.

Progress Reports

Quarterly progress reports disseminated to the individuals listed in section A3 will note activities conducted, items or areas identified as potential problems, and any variations or supplements to the QAPP. CARs will be utilized when necessary. 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. All quarterly progress reports and QAPP revisions will be distributed to personnel listed in Section A3.

Table A9.1 Project Documents and Records

Document/Record	Location	Retention[a]	Form[b]
QAPPs, amendments, and appendices	TWRI	5 years	Paper
QAPP distribution documentation	TWRI	5 years	Paper
Landuse/Landcover	SSL	5 years	Electronic
GIS Inventory	SSL	5 years	Electronic
Modeling SOPs	TTU-WRC	5 years	Paper
Model User's Manual or Guide (including application-specific versions)	TTU-WRC	5 years	Paper
Assessment reports for acquired data	TTU-WRC	5 years	Paper/Electronic
Raw data files	TTU-WRC	5 years	Paper/Electronic
Model input files	TTU-WRC	5 years	Electronic
Model output files	TTU-WRC	5 years	Electronic
Code Verification Reports	TTU-WRC	5 years	Paper
Interim results from iterative calibration runs	TTU-WRC	5 years	Electronic
Model Calibration Report	TTU-WRC	5 years	Paper
Model Assessment Reports	TTU-WRC	5 years	Paper
Progress report/CAR/final report/data	TTU-WRC/ TSSWCB	3 years	Paper/Electronic

[a] After the close of the project
[b] Electronic files should be ASCII (DOS) pipe delimited text files or MS Word/Excel; model input and output files can be archived in the format used by the modeling software, provided the capability of conversion to ASCII (DOS) pipe delimited text files or MS Word/Excel is maintained over the time of retention.

<u>Final Report</u>

Finally, the final report will include:

- GIS maps related to soil, land use, topography, etc.
- Compilation of observed water quality data from various sites from different sources
- Figures showing the time series of water quality data (sediment and nutrients)
- Documentation of the modeling procedures for various BMPs modeled, pre- and post-BMP conditions and model parameters adjusted along with procedures adopted for pre- and post-BMP conditions
- Time series graphs showing the observed and simulated flows, sediment loading and nutrient loading for the calibration and validation periods as observed data is available
- Statistical measures such as means, standard deviation, coefficient of determination (R2), and Nash-Suttcliffe simulation efficiency (Nash and Suttcliffe, 1970) to show the model's prediction with respect to observed data at several locations in the watershed

- Results or the impacts of BMPs on flows and water quality as percentage reductions in average annual sediment, total nitrogen (organic and mineral nitrogen) and total phosphorus (organic and mineral phosphorus) loadings at the watershed level
- A map identifying sediment and nutrient hotspots within the watershed, suggestions for alternative BMPs and the corresponding expected improvement in flows and water quality in terms of percentage reductions in sediment and nutrients

The TSSWCB may elect to take possession of records at the conclusion of the specified retention period. Further, as requested, the model and its inputs and outputs will be delivered to the TSSWCB.

QAPP Revision and Amendments

Until the work described is completed, this QAPP shall be revised as necessary and reissued annually on the anniversary date, or revised and reissued within 120 days of significant changes, whichever is sooner. The last approved versions of QAPPs shall remain in effect until revised versions have been fully approved; the revision must be submitted to the TSSWCB for approval before the last approved version has expired. If the entire QAPP is current, valid, and accurately reflects the project goals and the organization's policy, the annual re-issuance may be done by a certification that the plan is current. This will be accomplished by submitting a cover letter stating the status of the QAPP and a copy of new, signed approval pages for the QAPP.

QAPP amendments may be necessary to reflect changes in project organization, tasks, schedules, objectives and methods; address deficiencies and nonconformances; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Written requests for amendments are directed from the TWRI Project Leader to the TSSWCB PM and are effective immediately upon approval by the TSSWCB PM and QAO or their designees, and the EPA PO. Amendments to the QAPP and the reasons for the changes will be documented and distributed to all individuals on the QAPP distribution list by the TWRI Project Leader or designee. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process.

Field Cod

Section B1: Collection Process/Field Survey Design

The production of a land cover map is an iterative process based on data from NAIP imagery, existing maps and field reconnaissance. Land use / land cover will be assigned to fifteen categories according to the category descriptions provided in Section A6.

Ground reference data must be collected to train the computer software to recognize the spectral reflectance of various land cover categories represented in the NAIP imagery. Since ground reference data generally cannot be collected for the entire project area, representative samples will be used.

SSL staff will collect or acquire at least ten actual ground locations per land use type in the watershed for use in mapping land cover. These locations will be used to conduct supervised classifications of remote sensing data from NAIP imagery. This data will also be used for accuracy assessment as outlined in Section B5.

Field data will be collected according to standard protocols. The SSL PM will review field data and assign appropriate classification prior to digitizing the data for GIS analysis. Descriptions of land use / land cover that cannot be assigned a class corresponding to the scheme used in labeling classes on the land cover map will be rejected.

Types and numbers of samples required: SSL will acquire 10 representative ground locations for each land cover class labeled on the land cover map.

Sampling Locations and frequencies: SSL has a goal of 150 field sites with a minimum of 10 sites for each land use / land cover class. Data are being acquired from the watershed to provide a representative sample (i.e., the GPS points collected represent the landscapes that are found throughout the watershed).

A high quality GIS inventory will be produced by collecting the most recent information from state and federal agencies (Table B1.1). All datasets will be projected using NAD 1983 UTM Zone 14N. United States Department of Agriculture's (USDA) Geospatial Data Gateway (GDG) will be used to acquire information for the GIS inventory. A Digital Elevation Model (DEM) at 10m and 30m resolution will be collected for the watershed. Soil Survey Spatial and Tabular Data (SSURGO) shapefiles will be obtained from the GDG. Texas Natural Resource Information System (TNRIS) will be used to collect data for the GIS inventory as well. The Strategic Mapping Program (StratMap) will be used to obtain rivers, lakes, cities, parks, landmarks, and roads shapefiles. United States Geological Survey (USGS) will be used to gather weather station points in the watershed. TCEQ monitoring and permitted sites (i.e. municipal solid wastes, industrial hazardous wastes, public water supply surface intakes, public water supply wells, surface water quality monitoring sites, and wastewater outfalls) will be collected from the Texas Commission on Environmental Quality (TCEQ). Additional information needed will be collected as needed, and the QAPP will be updated.

Table B1.1 Datasets included in GIS inventory and sources of each.

Data	Source	Website
Northern and Southern Llano Watershed	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
CCN_water	TCEQ	http://www.tceq.texas.gov/gis/sites.html
Municpal solid wastes_sites	TCEQ	http://www.tceq.texas.gov/gis/sites.html
municipalites	TNRIS	http://www.tnris.org/
NLCD 2001	MRLC	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NLCD 2006	MRLC	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NED 10m	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NED 30m	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NHD_flowline	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NHD_waterbodies	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
permitted and industrial hazardous wastes	TCEQ	http://www.tceq.texas.gov/gis/sites.html
Public water supply surface intake	TCEQ	http://www.tceq.texas.gov/gis/sites.html
public water supply wells	TCEQ	http://www.tceq.texas.gov/gis/sites.html
SSURGO	USDA NRCS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
stratmap transportation	TCEQ	http://www.tceq.texas.gov/gis/sites.html
stratmap boundaries	TCEQ	http://www.tceq.texas.gov/gis/sites.html
surface water quality management sites	TCEQ	http://www.tceq.texas.gov/gis/sites.html
wastewater outfalls	TCEQ	http://www.tceq.texas.gov/gis/sites.html
wetlands	USGS	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NAIP 06	USDA-FSA-APFO NAIP	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NAIP 08	USDA-FSA-APFO NAIP	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
NAIP 10	USDA-FSA-APFO NAIP	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
USGS Gauges	USGS	http://waterdata.usgs.gov/tx/nwis/rt
Texas Gazeteer	TNRIS	http://www.tnris.org/
CDL2008	USDA-NASS Cropland Data Layer	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
CDL2009	USDA-NASS Cropland Data Layer	http://datagateway.nrcs.usda.gov/GDGOrder.aspx
CDL2010	USDA-NASS Cropland Data Layer	http://datagateway.nrcs.usda.gov/GDGOrder.aspx

Section B2: Data Collection Methods

Phase 1 Acquisition:

Ancillary data will be used to classify the NAIP images into classes. The SSL is using existing aerial photos, topo maps and field data from the Natural Resource Conservation Service (NRCS) as sources to define LULC polygons. The geographic location of the polygons is known and is matched to the same location on the imagery.

Phase 2 Acquisition:

Field sampling will be used to verify individual LULC classes identified and delineated. Ground control points used in the field sampling will be collected for at least ten locations per land use type for the watershed using GPS units with an accuracy of 1-10 meters. Road maps are created prior to field collection, and routes are designed to cover the extent of the watershed. The ground control points are collected every 5 minutes along accessible roads. Some points will be collected along trails of the South Llano River State Park as well.

LULC categories are identified in the field by an observer who is knowledgeable about LULC identification and classification standards. Observed LULC classifications are recorded on data forms provided by the SSL (Appendix B). No specialized equipment is used to collect the sample data. Since the project classifies land cover, it is preferred to collect samples during a leaf-on season because this time of year makes it easier to identify vegetation types.

Phase 3 Acquisition:

As listed in Table B1.1, GIS inventory will be produced by collaboration with project partners, local agencies, and stakeholders. The most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, public park lands, municipilaties, and satellite imagery or aerial photography. Locations of SWQM stations, USGS gauges, public access points to the waterbodies, floodwater-retarding structures, wetlands, known OSSFs, TPDES permittees (including WWTFs, CAFOs and MS4s), and subdivisions will also be included. Sites permitted for land application of sewage sludge and septage should be included. Existing TSSWCB-certified WQMPs will be documented as well.

The GIS inventory will also include surveys conducted by TTU-LRFS showing the distribution and abundance of invasive, emergent, and aquatic plants in the Upper Llano River Watershed. It will also include TTU-LRFS surveys of distribution, abundance, and severity of cut and eroding banks on the South and North Llano Rivers.

Documentation of Field Sampling Activities

Field sampling activities are conducted according to SSL SOPs (Appendix C) and documented on field survey forms (Appendix B).

Recording Data

All field and SSL personnel follow the basic rules for recording information including: (1) writing legibly in indelible, waterproof ink with no modifications, write-overs or cross-outs; (2) correcting errors with a single line followed by an initial and date; and (3) closing-out incomplete pages with an initialed and dated diagonal line.

Deviations from Sampling Method Requirements or Sample Design, and Corrective Action

Corrective action may be required when deviation from sampling method requirements or sample design as stated in this QAPP occur. It is the responsibility of the TWRI Project Lead and QAO to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the TSSWCB PM both verbally and in writing in the project progress reports and by completion of a corrective action report (CAR).

Corrective Action Reports (CARs) document: root cause(s); programmatic impact(s); specific corrective action(s) to address any deviations; action(s) to prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and the means by which completion of each corrective action will be documented. CARs will be included with project progress reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the TSSWCB immediately both verbally and in writing.

Section B3: Data Handling and Custody

Field data forms provided by SSL are hand delivered or mailed back to the SSL via business reply envelopes. All ancillary data sources are filed by watershed in the SSL. When hardcopy data is digitized or otherwise entered into the computer, backups of the digital files to removable media will be made to ensure no loss of data due to machine failure. All pertinent file backups will take place monthly on an external hard drive and to a server in Centeq Building B Room 213, 1500 Research Parkway, College Station, Texas.

All TTU-WRC records, including modeler's notebooks and electronic files, will be archived by TTU-WRC for at least five years. These records will document model testing, calibration, and evaluation and will include documentation of written rationale for selection of model, 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 are backed up daily to an external 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. All electronic data are backed up on an external hard drive monthly, compact disks weekly, and is simultaneously saved in an external network folder and the computer's hard drive. A blank CAR form is presented in Appendix A.

Section B4: Analytical Methods

Phase 1 Classification:

The SSL is using NAIP images and a combination of image classification schemes to conduct the land cover inventory of the watershed. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

The spectral classes from each scene covering the watersheds are first labeled into the fifteen LULC categories using whatever ground information was available, including aerial photos, topo maps and data from the NRCS. The land use classification scheme to be used is described in Section A6. Individual LULC classes will be identified and delineated in shapefile or ArcGIS grid format with a minimum mapping unit of 2 acres on screen. Ground truth sample polygons are then divided into two randomly selected groups, one for image labeling and the other for classification accuracy testing.

Phase 2 Classification:

ESRI ArcGIS software will be used to classify images in Phase 2. Classification will be done using the geographic extents of one scene. The product of the Phase 1 classification will be used as input to the supervised classification process. One category will be selected as the focus of a classification operation. Appropriate ground samples and ancillary polygons containing LULC data, located and labeled by SSL personnel, will be matched with corresponding areas on the original NAIP images and the image polygons will be classified using on-screen interpretive techniques to an accuracy of 80% or greater. The process will be repeated for each LULC category using field samples and other ancillary data.

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

A detailed account of data processing techniques will be documented in metadata according to the established standards. ESRI ArcCatalog software will be used to record the metadata for this project.

Section B5: Quality Control

Assessing the accuracy of land cover mapping products is an elusive and challenging problem that calls for continuing research and development within GIS and remote sensing technology. The criteria for accuracy assessment reflect the need to balance the requirements for rigor and defensibility with practical limitations of cost and time. The assessment methods must be scientifically sound and economically feasible. Procedures for ensuring quality data are produced are described below and in the SOPs (Appendix C).

The basic unit of the land cover mapping process is a polygon of 2 acres that represents a LULC class with a relatively homogenous composition. An accuracy assessment will be conducted by selecting a sample of locations (e.g., centroids of mapped polygons) from the final version of the land cover map and determining the true land cover classification at these locations. These data are frequently called the reference data set. Properly executing an accuracy assessment involves knowing the nature of the created map, identifying the field methods for obtaining the reference data, designing a sound method for selecting reference data, actually collecting the data, conducting statistical analyses, and reporting the results.

This project has a goal of mapping land cover with 80% accuracy. We will attempt to measure thematic accuracy as a percentage of the land cover map classified correctly overall and by cover type with a standard error no greater than 8%.

Summary of steps and standards used in Accuracy Assessment:

1. Produce a final land cover map, classification, and description of land cover classes that will be assessed.
2. Identify the methods for obtaining reference data.
3. Design a sampling protocol that meets the desired statistical precision.
4. Collect the reference data, test their reliability, and archive the database.
5. Compare the reference data to the map, conduct analyses, and report the results.

Step 1: A final version of a land cover map will be produced as described in section B4. SSL anticipates having at least 15 cover classes that can be delineated on the NAIP imagery. Knowledge of the characteristics of the map to be assessed is important in determining the sampling frame (number, size, and classification of polygons). The methodology used to collect the reference data will match the classification system of the cover map.

Step 2: SSL plans to use field collected data as the primary source of reference data to assess the quality of the final cover map. Ground-truthing involves physically visiting the site in question to determine its true land cover type and will require substantial support and coordination with TTU-LRFS and the South Llano River State Park. The SSL PM and SSL personnel will develop a field sampling plan that will guarantee consistency between reference data and the needs of the assessment project and future remapping, (i. e., the method of collecting the field data will enable the land cover to be identified at the same level of detail as the land cover map). Quality Control will be achieved by assuring that the GPS receiver performance criteria under section A.5 above are met at all times. Statistical checks will be performed on the data during the post-processing phase and the data will be compared to known map coordinates and features using USGS topographic maps and other appropriate map sources of known quality.

The design of the assessment study will be stratified by, and only by, land cover types present in the final land cover map. The protocol for selecting field sampling sites will be based on the final number of land cover classes, the number of polygons within each class, and the number of samples needed to accomplish statistical precision.

With a minimum mapping unit of 2 acres, SSL anticipates that the occurrence of other unmapped cover types (inclusions) within a polygon will cause few problems in collecting field data. Nevertheless, the SSL PM will develop field protocols to ensure that each mapped cover type can be correctly identified in the field. The characteristics of land cover types that may affect these protocols are: polygon sizes (small, medium, large), polygon shapes (linear or non-linear), and heterogeneity of the land cover (degree of patchiness and size of inclusion patches).

An individual measurement will result in a decision as to whether or not the field reference point agrees with the land cover map's label of that polygon. Accuracy is the statistical reduction of many samples into a statement of percent agreement.

Step 3: Sampling units are defined here as all areas within the project area geographically contiguous and of homogenous primary attribute, that is, vector polygons or contiguous raster clusters of the same primary land cover type code. Land cover maps are based on algorithmic clustering of TM pixels with the resultant categories being spectrally similar. Therefore, pixels are probably not independent of each other. Although polygon boundaries are not precise, they are believed to represent real patterns on the the ground and the polygon is the defined feature that should be assessed. Therefore, the sampling unit is defined as a mapped polygon. The sample frame is the list of all polygons that comprise the final land cover map.

The sampling protocol for accuracy assessment will be designed to meet the statistical precision needed to accomplish the stated objectives for accuracy and standard error. Field sites will be selected through a stratified, two-stage probability sample. Accuracy assessment field data will be recorded on forms and returned to the SSL for analysis (see Appendix B). Probability sampling, as opposed to purposive selection of "representative" elements or haphazard selection of convenient elements, is now a standard scientific tool since it guards against selection biases and it leads to objective statistical inferences. Stratification will ensure good geographic spread of the sample across the state and will provide a representative sample of alliances.

Two stages of sampling will be employed. In the first stage, large tracts of land (e.g. counties, Landsat scenes, or some other convenient unit) will be selected in a stratified sample. In the second stage, sampling points within the large tracts will be selected. The reason for sampling in two stages, as opposed to sampling sites directly, is that direct sampling of sites would lead to a widely-scattered sample with high logistical costs.

Because cost of collecting field data could be limiting, consideration will be given to stratifying according to the relative cost or effort required to measure the sampling site.

Step 4. GIS methods will be used to select sampling units from the sampling frame which consists of all the polygons in a vector map.

Field survey forms and standard operating procedures will be used to collect data for classification purposes (Appendix B and C). This reference data will be collected by 2-3 well-trained field observers who have no knowledge of the primary attribute given by the land cover map for the sampling unit. This will involve providing each observer with coordinates and a map showing the polygon to be sampled but without the associated land cover type label. As described previously, road maps are created prior to field collection, and routes are designed to cover the extent of the watershed. The ground control points are collected every 5 minutes along accessible roads. Some points are collected along trails of the South Llano River State Park. The field maps will typically have base information such as roads, streams, and locational grids such as UTM coordinates.

Observers will be trained and field tested in the typical techniques used for land use inventories. They will also be given training in the classification scheme employed in the land cover mapping process. They will be provided written guidelines and other materials to assure that consistent, repeatable results are obtained (Appendix B and C).

The field data for each sampling unit will be assigned a pointer that identifies its location on the land cover map. Reference data will be compiled as a GIS coverage containing both the locations of samples and their attributes. Metadata will include a description of the method used by the analyst to determine agreement between the map and reference data and a measure of observer reliability in order to replicate the published analysis. Field forms will be archived and GIS data managed in accordance with procedures outlined in this document.

Step 5. Measurements from field sampling units will be compared with labeled polygons on the land cover map. As a first step in statistical analysis, agreements, or lack thereof, will be tabulated in a matrix whose rows represent mapped categories and columns represent observed cover types. The resulting error matrix is a contingency table which represents the probabilities of every possible correct or incorrect classification.

Statistical analyses of the measurements from the assessment sample need to recognize that the data arise from a complex sample. It is not valid to analyze these data as if they are independent and identically distributed. Analyzing data from a stratified two-stage sample as if they were independent and identically distributed will typically lead to confidence intervals which are unrealistically narrow and hypothesis tests which reject too easily. That is, the precision of the analysis is overstated. Proper methods for dealing with data from stratified two-stage samples will be employed in this study.

Limitations and Constraints: In planning accuracy assessments, three general constraints (technology, logistics, and cost) must be considered because of the limitations they place on our ability to obtain ideal data sets.

Technological constraints: This category of constraints includes measurement errors relating to aquiring field observations. Error in determining the true location of the sampling unit in the field should not be a major problem in Texas because the terrain is moderate and bisected by an elaborate system of roads and highways. Sampling units will be outlined in advance on topographic maps, county road maps, and aerial photos (if available) and provided to field observers. Also, field observers will usually be able to survey entire sampling units, thereby reducing error caused by inadequate integration of all attributes of a unit.

Logistical constraints: Most sampling units will be located in close proximity of a road and can be visited without great expense. Few locations will be inaccessible due to dangerous terrain. If sampling measurements cannot be made at a site due to inaccessibility, then these sites will be dropped from the sampling scheme and replaced with more accessible ones.

Financial constraints: We will conduct an accuracy assessment that is a reasonable balance between available funding and scientific soundness.

The GIS inventory data will be collected from state and federal agencies that use their own quality control protocol. These agencies provide metadata for all the data collected. Besides the LULC being created, all data is collected from a public domain from federal and state sources.

Failures in Quality Control and Corrective Action

All incidents requiring corrective action will be documented through use of CARs (Appendix A). Corrective action will involve identification of the possible cause (where possible) of the QC failure. Any QC failure that has potential to compromise data validity will invalidate the data. The resolution of QC failures will be reported to the TSSWCB in the quarterly progress report. CARs will be maintained by the Project Leader and the TSSWCB PM.

Section B6: Instrument/Equipment Testing, Inspection, and Maintenance

Equipment testing will be accomplished by the GPS Operator prior to, during and after field use. Built-in equipment diagnostics and functionality checks will be utilized in accordance with the operation manuals. Results will be reported in pre-survey, field and post-processing logs. Relevant procedures for digitizing equipment and other equipment used in this project can be found in Appendix C. Issues will be documented with the SSL PM.

Section B7: Calibration

Instrument/Equipment Calibration and Frequency

GPS receivers cannot be calibrated. However, a number of settings can be changed (maximum PDOP, signal-to-noise ratio, filter coefficient, etc.) which will affect operation of the unit. In general, manufacturer default settings will be employed for optimum data accuracy.

Model Calibration

The EDYS model was developed with an attempt to simulate the processes physically and realistically. Most of the model inputs are physically based (that is, based on readily available information). It is important to understand that EDYS 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 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. The statistical analyses will be straightforward comparison of means and standard deviations, with paired t-tests for 1-1 comparisons, with associated calculations of confidence intervals when appropriate.

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, sediment, and nutrients at key locations in the watershed. During the calibration process, all model parameters will be adjusted within literature recommended ranges. Calibration will be 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, first for flow, then for sediment and followed by organic and mineral nutrients (Santhi et al., 2001).

Literature information and observed water quality as available for the North and South Llano Rivers will be used to validate the EDYS model. Stream flow and monitoring data on sediment and nutrients along different locations of the watershed will be collected to calibrate and validate the model.

Model parameters related to subwatersheds and landscape processes will be adjusted to match measured and simulated flow and water quality trends at key locations in the watershed. All model parameters will be adjusted within ranges recommended in published literature. Then the model will be 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 B8: Inspection/Acceptance for Supplies and Consumables

The primary consumables for GPS operations are batteries. During the equipment testing, inspection and maintenance periods, batteries will be examined by the GPS Operator for functionality, charge and compatibility with manufacturer's specifications. Fully charged, backup batteries will be taken to the field for use when recharging is not an option.

Supplies used in the SSL will be inspected upon receipt by the SSL PM for visible signs of damage. All data will be backed up on removable storage media so that failure of primary storage media will not result in data loss. Supplies will be purchased from reputable vendors to ensure quality.

Section B9: Non-direct Measurements/Secondary Data Use

This GIS inventory will include the most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, public park lands, municipalities and satellite imagery or aerial photography. Locations of SWQM stations, USGS gauges, public access points to the waterbodies, floodwater-retarding structures, wetlands, known OSSFs, TPDES permittees (including WWTFs, CAFOs and MS4s), and subdivisions will also be included. Sites permitted for land application of sewage sludge and septage will be included. Information on distribution and abundance of invasive emergent and aquatic plants from the headwaters (Llano Springs, 700 Springs, South Llano River and North Llano River) to Junction and the distribution, abundance, and severity of cut and eroding banks on the South and North Llano Rivers as provided by TTU-LRFS will also be included in the GIS inventory. TSSWCB-certified WQMPs will also be documented. The primary datasets and data sources used are listed in Table B1.1.

The display of GPS ground points will be accomplished by overlaying the collected points on map features of comparable quality. This provides a road network, topographic features and other map elements that can place the collected points in the context of real-world features. This is an additional quality check, since large deviations from expected locations would cause the data and processing methods to be rechecked. Standard map products of known quality will be used.

NAIP imagery from 2006-2010 will be the primary data source for constructing base maps of LULC. Ancillary information will be drawn from other imagery where applicable.

2006-2010 NAIP aerial photos of the area will be classified using Definiens Developer 7.0 software. 2006 NAIP imagery provides four main products: 1 meter GSD ortho imagery rectified to a horizontal accuracy of within +/- 5 meters of reference DOQQs from the NDOP; 2 meter GSD ortho imagery rectified to within +/- 10 meters of reference DOQQs; 1 meter GSD ortho imagery rectified to within +/- 6 meters to true ground; and, 2 meter GSD ortho imagery rectified to within +/- 10 meters to true ground. 2008 and 2010 NAIP imagery provides two main products: 1 meter GSD ortho imagery rectified to a horizontal accuracy of within +/- 5 meters of reference DOQQs from the NDOP or from the NAIP; 1 meter GSD ortho imagery rectified to within +/- 6 meters to true ground. 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.

All water quality and flow data used in the EDYS model are collected in accordance with approved quality assurance measures under the state’s Clean Rivers Program, the TSSWCB NPS Program, Texas Commission on Environmental Quality, Texas Water Development Board, USDA, National Weather Service, or USGS.

Surface topography is developed in EDYS based on differences in elevations among adjacent cells. Average elevation is entered for each cell. These average elevations are taken from USGS DEMs. The soil data are taken from NRCS soil survey data or from more specific data if such data are available (e.g., published research articles, agency project reports). Precipitation data are taken from area precipitation recording stations (e.g., Sonora, Rocksprings, Junction). Data on vegetation type are taken from NRCS soil survey maps (ecological site descriptions linked to specific soil mapping units) and then modified based on field survey, published data from the region, and extensive personal professional knowledge.

Parameter data are taken from the EDYS data base. The EDYS data base is an extensive collection of species-specific parameter data compiled from published scientific literature. For example, one plant parameter is "maximum potential rooting depth". The EDYS data base contains values for maximum potential rooting depth for 540 species and root distribution by soil depth for 134 species (McLendon et al., submitted manuscript). The data base is continually updated, along with the sources of the data (literature citation). If new species are included in an application for which no appropriate data are available in the EDYS data base, a literature search is conducted to obtain the most appropriate data to use for that species.

Elevation data (USGS), soil data (NRCS), and precipitation data (NOAA) are assumed to be reasonably accurate. However, these data are reviewed to determine if obvious errors occur. For example, precipitation data supplied by NOAA often has missing values for some dates. This is not always noted in monthly and annual totals. Each date is checked to determine if missing data occurred. If missing data did occur, estimated values are calculated for those dates based on amounts received at other area stations.

Quality of parameter data entered into the EDYS data base is based on 1) the quality of the journal or report it was taken from and 2) the comparison of a particular value compared to other values for the same or similar species. These parameter data have been tested on a number of validation studies (e.g., McLendon et al. 2001; McLendon and Coldren 2005; Mata-Gonzalez et al. 2008) and have resulted in close fits with field data over periods up to four years of observation.

The EDYS application will include up to eight runs to simulate selected management scenarios witin the solution domain, as agreed in the scope of work. The manangement scenarios will be selected based on interaction with the TTU-WRC, TTU-LRFS, and the WPP stakeholder group. One management scenario would be a complete set of options for the entire footprint, for example, ranch #1 rootplowed 500 acres, ranch #2 burned 1000 acres, ranch #3 reseeded 100 acres, and ranch # 4 reduced its stocking rate by 50 animal units. An EDYS run will then be made for this particular management scenario, so the management scenario (combination of management options) becomes one run.

CITATIONS

Mata-Gonzalez, R., R.G. Hunter, C.L. Coldren, T. McLendon, and M.W. Paschke. 2008. A comparison of modeled and measured impacts of resource manipulations for control of *Bromus tectorum* in sagebrush steppe. Journal of Arid Environments 72:836-846.

McLendon, Terry and Cade L. Coldren. 2005. Validation of the EDYS ecological model using gauged data from the Honey Creek Research Watershed, Texas. Report prepared for the US Army Engineer Research and Development Center, Vicksburg, MS. MWH Inc. Fort Collins, Colorado. 21 p.

McLendon, Terry, W. Michael Childress, Cade Coldren, and David L. Price. 2001. EDYS experimental and validation results for grassland communities. US Army Corps of Engineers Technical Report ERDC/CERL TR-01-54. 88 p.

McLendon, Terry, David L. Price, Cindy R. Pappas, and Jean A. Swinehart. Root architecture variations among lifeforms, moisture regimes, and successional status: a meta-analysis. Manuscript submitted for publication in Rangeland Ecology and Management. January 2013.

Section B10: Data Management

Field Collection

Field staff will visit each watershed to collect ground control points for at least ten locations per land use type using Trimble GeoExplorer 3 GPS Receivers with an accuracy of 10 meters. Field data will be recorded on field survey forms (Appendix B).

All field observations will be manually entered into an electronic spreadsheet. The electronic spreadsheet will be created in Microsoft Excel software on an IBM-compatible microcomputer with a Windows XP Operating System. The project spreadsheet will be maintained on the computer's hard drive, which is also simultaneously saved in a network folder. All pertinent data files will be backed up monthly on an external hard drive. Current data files will be backed up on r/w CD's weekly and stored in separate area away from the computer.

Original data recorded on paper files will be stored for at least five years. Electronic data files will be archived to CD after approximately one year, and then stored with the paper files for the remaining 4 years.

Spatial Sciences Laboratory Data

NAIP imagery is downloaded and copied to the hard drive of a work station. Field survey forms with field information arrive via hand-delivery or the US mail and are stored in raw form in the lab. Data from the forms are digitized and stored on the hard drive of a computer in the lab as described in Appendix C. Backup copies of all digital data are made to removable media. All field survey forms are checked prior to digitizing for accuracy and then after digitizing to assure correspondence to the original form. All necessary data from ancillary sources are digitized or copied to the hard drive of a computer in the SSL and then backup copies are made of the digital data. Where ancillary data have been digitized, the SSL PM checks that the original data correspond correctly to the digitized data.

A combination of IBM compatible microcomputers with a Windows XP Operating System and workstations using the UNIX operating system will be used to process the data. An effort was made to purchase machines with the most memory, largest hard drives and fastest processing speeds that were available at the time. Additional hard drive space and random access memory will be purchased as project needs require. A suite of software will be used to process the data. All software packages are industry standard and represent the best application available for each processing function.

All GIS and LULC data will be backed up on r/w CD's weekly and stored in separate area away from the computer. Backups are stored on a server in Centeq Building B Room 213, 1500 Research Parkway, College Station, Texas and an external hardrive. The files are easy to retrieve for people with authorization to the files.

At least 10% of all data manually entered in the database will be reviewed for accuracy by the SSL PM to ensure that there are no transcription errors. Hard copies of data will be printed and housed in the Spatial Sciences Laboratory for a period of five years.

LULC Data Validation

Following LULC classification and delineation, LULC data will be validated and verified with field sampling ground control points to an accuracy of 80% or greater. Any LULC that does not meet this will be re-classified until an accuracy of 80% is achieved. No LULC that does not achieve 80% accuracy will be submitted to the TSSWCB.

LULC Metadata Preparation

Metadata will be prepared by the GPS Operator upon conclusion of the data processing phase using the EPA, *Geospatial Metadata Technical Specification v. 1.0*, November 2007.

LULC Data Dissemination

As classification of each watershed is completed, the TWRI Project Lead will provide a copy of the shapefile or ArcGIS grid format of the LULC via recordable CD media to the TSSWCB PM.

TTU-WRC Modeling Data

Figure B10.1 provides a flow chart that connects the input data to the EDYS model, its output, and the final report. As noted previously, the modeling team must converst all of the input data into data values assigned to each cell, individually or in groups of adjacent similar cells, in the solution domain. Model outputs are also generated by cell and or aggregated into composite or total values for groups of cells and are output as tables or mapped by the graphical user interface. All data, software, and simulations will be stored in the computer system used by KS2 housed at the Geospatial Technologies Laboratory (GTL) in the Department of Natural Resources Management at Texas Tech University.

The GTL computer system includes eight 64-bit Dell Precision T7500 computer units with dual 240 GHz processor and dual monitors, as well as one PE 1900 server that connects to four internal and one external hard drive. Eight 1-terabyte external drives are also used to provide additional backup memory space. Computer drives are backed up regularly to external hard drives.

TTU-WRC Archives and Data Retention

Original data recorded on paper files are stored for at least five years. Data in electronic format are stored on external drives and CDs in the Center for Geospatial Technology.

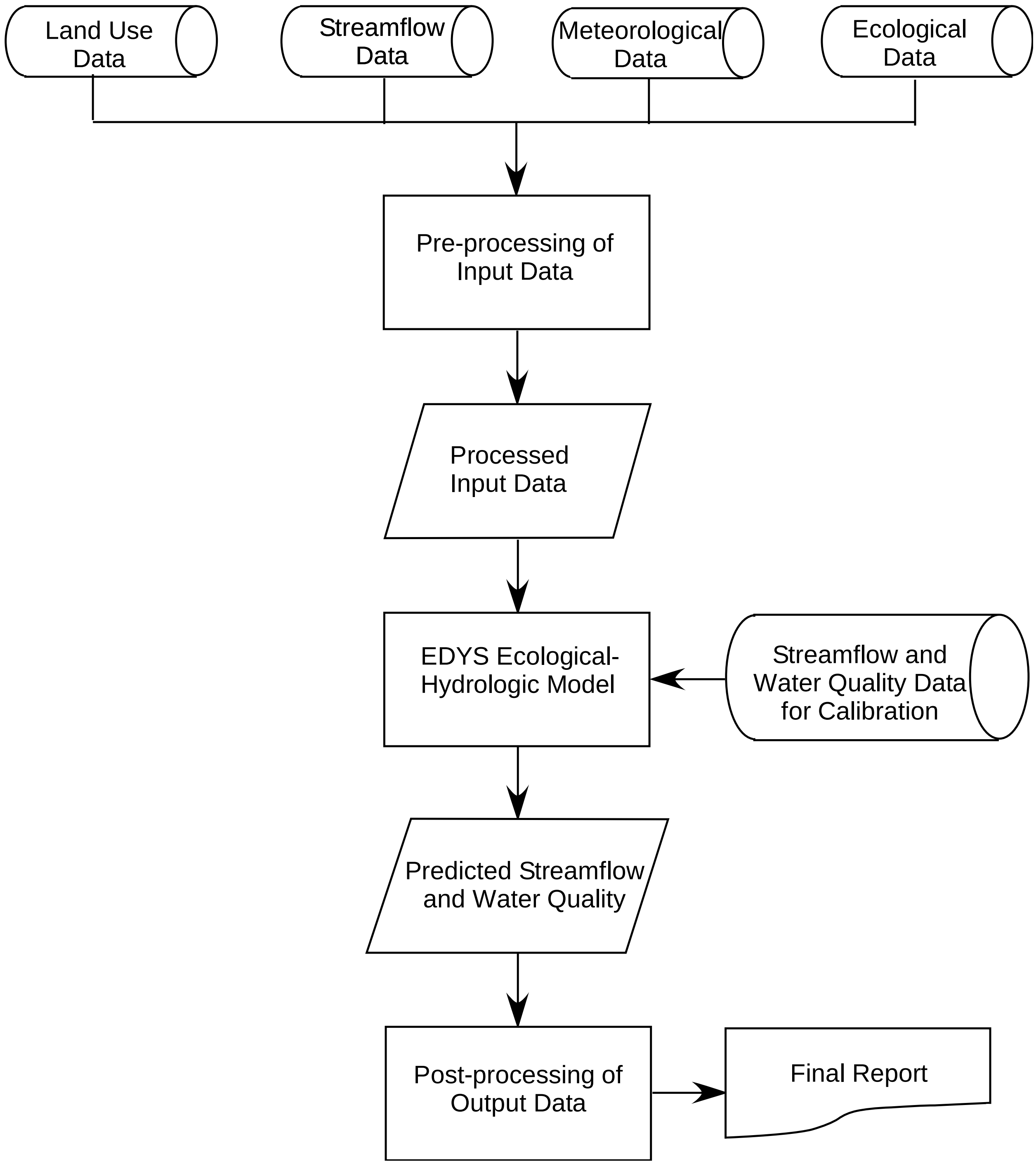


Figure B10.1 Model Data Flow Chart

Section C1: Assessments and Response Actions

The following table presents types of assessments and response actions for data collection 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	Continuous	SSL, TWRI, TTU-WRC	1. Monitor project status & records to ensure requirements are being fulfilled. 2. Monitor and review performance & data quality.	Report to TSSWCB Project Manager in Quarterly Report
Equipment Testing	As needed	GPS Operator	1. Pass / Fail Equipment Testing	Repair or Replace
Data Completeness	As needed	SSL PM	1. Assess Stations Sampled vs. Planned Sampling	Revisit Site or Amend Project Objectives
Data Quality Objectives	As needed	GPS Operator	1. Evaluate if Data Meets / Does Not Meet DQO	Exclude Questionable Data Points
Performance Criteria	As needed	GPS Operator	1. Evaluate if Data Met / Did Not Meet Performance Criteria	Exclude Questionable Data Points
Statistical Quality Checks	As needed	GPS Operator	1. Evaluate if Data Met / Did Not Meet Standard Deviation	Exclude Questionable Data Points
Map Overlay Against Known Locations	As needed	GPS Operator	1. Assess if Data Points are Good / Poor Fit Against Known Locations	Recheck Acquisition and Processing Steps
Technical Systems Audit	As needed	TSSWCB QAO	1. Assess compliance with the QAPP. 2. Review facility & data management as they relate to the project.	30 days to respond in writing to TSSWCB QAO to address corrective actions
Model Tasks Assessment	Continuous	TTU-WRC, KS2	1. Assess calibration and validation efforts. 2. Assess predictive model run results.	Generate effective model and projections

The SSL PM will conduct in-house audits of data quality and staff performance to assure that work is being performed according to standards. Audits will be documented in a written laboratory journal and initialed by the SSL PM. If audits show that the work is not being performed according to standards, immediate corrective action will be implemented and documented in the laboratory journal.

Data generated as part of the modeling results will be evaluated by the TTU-WRC and the KS2 modeling team during the validation and model output interpretation processes. Modeling performance assessments will be made routinely by TTU-WRC and KS2 as described in the validation and calibration processes, and by evaluation of tasks listed in Table D2.1. During the calibration and validation work, statistical comparisons will be made for the model outputs and observed values for streamflow and water quality values using means, standard deviations, and pair t-tests for one-to-one comparisons. The eight predictive runs will be evaluated relative to the appropriateness of the modeled output caused by input changes, such as the expected increase in streamflow that should accompany removal of significant amounts of invasive vegetation in hydrologically advantageous locations.

Modeling data and project deliverables will be quality controlled by the TSSWCB PM in-house review. The TSSWCB PM will maintain overall responsibility for examining TTU-WRC work to ensure methodologies and processes are consistent with the procedures outlined in this QAPP.

The TSSWCB QAO (or designee) may conduct an audit of the field or technical systems activities for this project as needed. The SSL PM and TTU-WRC PM will have the responsibility for initiating and implementing response actions associated with findings identified during the on-site audit. Once the response actions have been implemented, the TSSWCB QAO (or designee) may perform a follow-up audit to verify and document that the response actions were implemented effectively. Records of audit findings and corrective actions are maintained by the TSSWCB PM and TWRI QAO. Corrective action documentation will be submitted to the TSSWCB PM with the progress report. If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

Section C2: Reports to Management

Quarterly progress reports will be generated by TWRI personnel and will note activities conducted in connection with the EDYS modeling efforts, LULC classification, items or areas identified as potential problems, and any variation or supplement to the QAPP.

Preliminary versions of land cover maps will be made available for inspection by the TSSWCB PM as they become available. Other maps of the watershed will be produced as needed.

Once the LULC map for a watershed is complete, the SSL PM will submit the GIS land cover map, metadata, and a report of accuracy assessment activities as outlined in section B to the TSSWCB.

CAR forms will be utilized when necessary (Appendix A) and will be maintained in an accessible location for reference at TWRI. The CARs that result in changes or variations from the QAPP will be made known to pertinent project personnel, documented in an update or amendment to the QAPP and distributed to personnel listed in Section A3. Following any audit performed, a report of findings, recommendations and responses are sent to the TSSWCB PM in the quarterly progress report.

Brief modeling updates will be provided in the project quarterly progress reports. The modeling efforts will generate two reports for this project. The results of the model assembly and calibration will comprise the first report, and the second report will provide the results and discussion of the eight management scenario combination runs.

Section D1: Data Review, Verification and Validation

LULC Validation

In summary, this project will use 2006-2010 NAIP imagery to conduct a general land cover inventory for each watershed. Ancillary data consisting of field surveys, available photography and existing vegetation maps will be used to classify vegetation and label distinct spectrally clustered polygons on the imagery. LULC classification will follow the methods and quality control standards outlined in this QAPP (Section A7). The project has a goal of achieving 80 percent accuracy in the overall classification of LULC. The coverage will include the Upper Llano River watershed in Texas with a minimum mapping unit of two acres. An independent set of ground reconnaissance data will be obtained to conduct the accuracy assessment analysis. Ground reconnaissance data will be reviewed and validated as outlined in Table D1.1.

Table D1.1. Ground Control Point Data Review, Validation, and Verification Criteria

Data Element	Reviewed By	Validation Criteria
Coordinate Data	SSL PM	Consistent with Sampling Process Design
Coordinate Data	GPS Operator	GPS Mode Matches Field Log & GPS Internal Data
Coordinate Data	GPS Operator	Default Settings Match GPS Internal Data
Coordinate Data	GPS Operator	Standard Deviation below 3 Meters for Acceptance
Coordinate Data	GPS Operator	Good Fit when Data Plotted against Known Locations
Coordinate Data	GPS Operator	Meets National Map Accuracy Standards
Metadata	SSL PM	Meets EPA Guidelines for Metadata Documentation

Because of inherent technological, logistical, and financial constraints (Section B6), it is possible that the accuracy goal may not be achieved for all LULC classes. However, accuracy assessment will be essential for validating the final LULC map and providing the user with a measure of reliability. 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 SSL PM is responsible for ensuring that data are properly reviewed, verified, and submitted in the required format for the project. 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.

Model Validation

Validation is an extension of the calibration process that reduces uncertainty. The rates and settings developed during calibration are checked for adequacy using data set(s) that represent the modeled waterbody under different conditions than were observed during the calibration data set.

The rates then, if necessary, are adjusted further so that they work adequately well for all data sets. Validation is the comparison of the modeled results with independently derived numerical observations from the simulated environment. Model validation is, in reality, an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses the range of variables and conditions that are expected within the simulation.

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 TTU-WRC PM 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: Verification and Validation Methods

LULC Verification and Validation

All field and laboratory data will be reviewed, verified and validated to ensure they conform to project specifications and meet the conditions of end use as described in Section A7. The SSL PM is responsible for the integrity, validation and verification of the data each task generates or handles throughout each process. The field and laboratory tasks ensure the verification of all raw data and electronically generated data. The field data will be verified and validated as described in Table D2.1.

Table D2.1. Field Data Verification and Validation Methods

Data Element	Validation Method
Coordinate Data	Compare Sampling Process vs. Field Log and Internal GPS Log
Coordinate Data	Compare GPS Planned Mode vs. Field Log and Internal GPS Log
Coordinate Data	Compare Manufacturer Default Settings vs. Internal GPS Log
Coordinate Data	95% of Coordinate Points fall within National Map Accuracy Standards when overlaid on known quality map features of similar accuracy

Verification, validation and integrity review of LULC data will be performed using self-assessments and peer review by project partners, as appropriate to the project task, followed by technical review by the SSL PM. The LULC data generated are evaluated against ground control points and project specifications and are checked for errors. Potential outliers are identified by examination for unreasonable data. If a question arises or an error or potential outlier is identified, then issues will be resolved through mutual consultation between the SSL PM, TWRI QAO, and TSSWCB PM. Issues which can be corrected are corrected and documented electronically or by initialing and dating the associated paperwork. If an issue cannot be corrected, the SSL PM consults with the TWRI Project Lead to establish the appropriate course of action.

The final versions of the land cover maps and the accuracy assessment report will be peer reviewed by project partners prior to its release to the TSSWCB and the public. Prior to release, the SSL PM has responsibility for reviewing all data and verifying that final products achieved QAPP-defined goals for accuracy, completeness and acceptance criteria. The final version of each land cover map will be conveyed to users as digital GIS files in ARC/INFO format on CD-ROM disks. Hard copy maps will also be provided free to the TSSWCB as needed.

The final element of the validation process is consideration of any findings identified during assessments or audits conducted by the TWRI or TSSWCB QAO. Any issues requiring corrective action must be addressed, and the potential impact of these issues on previously collected data will be assessed. Finally, the SSL PM in coordination with the TWRI QAO validates that the data meet the data quality objectives of the project and are suitable for reporting to the TSSWCB.

Model Verification and Validation

Validation of the EDYS 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. In case, the matching between simulated and observed data is not to the standard, the calibration process will be revisited until a best fit between simulated and observed data is obtained.

The EDYS application will include up to eight runs to simulate selected management scenarios witin the solution domain, as agreed in the scope of work. The manangement scenarios will be selected based on interaction with the TTU-WRC, TTU-LRFS, and the WPP stakeholder group. One management scenario would be a complete set of options for the entire footprint, for example, ranch #1 rootplowed 500 acres, ranch #2 burned 1000 acres, ranch #3 reseeded 100 acres, and ranch # 4 reduced its stocking rate by 50 animal units. An EDYS run will then be made for this particular management scenario, so the management scenario (combination of management options) becomes one run.

Section D3: Reconciliation with User Requirements

The GPS Reconnaissance Survey results and products will be evaluated against the Data Quality Objectives established and user requirements to determine if any reconciliation is needed. Reconciliation concerning the quality, quantity or usability of the data will be reconciled with the user during the data acceptance process. Types of reconciliation may include reduction in the scope of the project in terms quality or quantity of data produced in meeting partial user requirements.

Once the final version of each Land Use / Land Cover Map is produced, the TSSWCB PM will review the product and the accuracy assessment report to determine if they fall within the acceptance limits as defined in this QAPP. Completeness will also be evaluated to determine if the completeness goal for this project has been met. If data quality indicators do not meet the project's requirements as outlined in this QAPP the data may be returned for revisions.

These data, and data collected by other organizations, will subsequently be analyzed and used for watershed assessment, watershed plan development, and EDYS modeling activities. Thus, data that does not meet requirements will not be submitted to the TSSWCB nor will be considered appropriate for any of the uses noted above.

Modeling data generated by this project will be used primarily for planning purposes. By following the guidelines described in this QAPP, and through careful project design, the modeling data generated by this project will be representative of the actual conditions and comparable to similar applications.

The final modeling 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.

The data and modeling framework developed by this project will be used to (1) evaluate the effectiveness of BMPs and (2) provide supporting planning information for implementation of BMPs. It will be incorporated to provide the TSSWCB, NRCS, SWCDs and local stakeholder groups with information pertaining to watershed characteristics and to the effectiveness of BMPs. This, in turn, will enhance their decision-making efforts as part of a comprehensive watershed management strategy.

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:________________________________

Project Manager:___________________________________

TWRI Quality Assurance Officer:______________________________

TSSWCB Quality Assurance Officer:____________________________

FIELD SURVEY FORM

Date: _______________

Name: ________________________________

Agency: _______________________________

Watershed: ___________________________

Site Name: ____________________________

Point No.: _______

UTM Coordinates: _____________________________

OR

Latitude/Longitude: ____________________________

Land Use / Land Cover: Use description in Section A5 to determine LULC for this point:

Developed Open Space_____
Developed Low Intensity_____
Developed Medium Intensity_____
Developed High Intensity_____
Open Water_____
Barren Land_____
Forested Land_____
Near Riparian Forested Land_____
Mixed Forest_____
Rangeland_____
Pasture/Hay_____
Cultivated Crops_____
Brush Low Density_____
Brush Medium Density_____
Brush High Density_____

How confident are you of your assessment?
_____ High confidence _____ Medium confidence _____ Low confidence

Comments:

Spatial Sciences Laboratory
Standard Operating Procedures for Landuse/Land Cover Surveys

SOP for Field Collection

The field staff will prepare for the field by ensuring the equipment is functioning properly. A road map containing all major and minor roads within the watershed will be created using ArcGIS 9.3. Field operators will create routes that will cover the extent of the watershed. These routes are tentative and can be altered during field work based on the field staff's judgment. Permission to enter private property or roads should be obtained prior to field work. SSL will develop a field sampling plan that will guarantee consistency between reference data and the needs of the assessment project and future remapping, (i. e., the method of collecting the field data will enable the land cover to be identified at the same level of detail as the land cover map).

Ground-truthing involves physically visiting the site in question to determine its true land cover type and will require substantial cooperator support and coordination. Field staff will visit each watershed to collect ground control points for at least ten locations per land use type using Trimble GeoExplorer 3 GPS Receivers with an accuracy of 10 meters. Field data will be recorded on field survey forms (Appendix B).

All field observations will be manually entered into an electronic spreadsheet. The electronic spreadsheet will be created in Microsoft Excel software on an IBM-compatible microcomputer with a Windows XP Operating System. The project spreadsheet will be maintained on the computer's hard drive, which is also simultaneously saved in a network folder. All pertinent data files will be backed up monthly on an external hard drive. Current data files will be backed up on r/w CD's weekly and stored in separate area away from the computer.

Original data recorded on paper files will be stored for at least five years. Electronic data files will be archived to CD after approximately one year, and then stored with the paper files for the remaining 4 years.

SSL plans to use field collected data as the primary source of reference data to assess the quality of the final cover map. Quality Control will be achieved by assuring that the GPS receiver performance criteria under section A.5 above are met at all times. Statistical checks will be performed on the data during the post-processing phase and the data will be compared to known map coordinates and features using USGS topographic maps and other appropriate map sources of known quality.

Equipment Calibration, Operation, and Maintenance SOP

Equipment testing will be accomplished by the GPS Operator prior to, during and after field use. The primary consumables for GPS operations are batteries. During the equipment testing, inspection and maintenance periods, batteries will be examined by the GPS Operator for functionality, charge and compatibility with manufacturer's specifications. Fully charged, backup batteries will be taken to the field for use when recharging is not an option.

Supplies used in the SSL will be inspected upon receipt by the SSL PM for visible signs of damage. All data will be backed up on removable storage media so that failure of primary storage media will not result in data loss. Supplies will be purchased from reputable vendors to ensure quality. Built-in equipment diagnostics and functionality checks will be utilized in accordance with the operation manuals. Results will be reported in pre-survey, field and post-processing logs. Issues will be documented with the SSL PM.

GPS receivers cannot be calibrated. However, a number of settings can be changed (maximum PDOP, signal-to-noise ratio, filter coefficient, etc.) which will affect operation of the unit. In general, manufacturer default settings will be employed for optimum data accuracy.

Digitizing SOP

All data from the forms will be manually entered into an electronic spreadsheet. The electronic spreadsheet will be created in Microsoft Excel software on an IBM-compatible microcomputer with a Windows XP Operating System. The spreadsheet will be used to digitize the sample points and create an attribute table in ArcGIS 9.3. The project spreadsheet will be maintained on the computer's hard drive, which is also simultaneously saved in a network folder. All pertinent data files will be backed up monthly on an external hard drive.

Field Survey SOP

All correct information should be written in the blanks. The Point No.: should always correspond with the GPS point number. The UTM Coordinates or the Latitude/Longitude can be documented. Mark the blank next to the Land Use/Land Cover type that the point represents and then mark the blank next to the amount of confidence the operator has on the representation of the point. Any comment of the point should be written if the operator feels it will help remove any confusion when processing the data.

Water Resources Center
Standard Operating Procedure for Model Selection and Application for Ecological and Hydrologic Simulation

Purpose: The purpose this operating procedure is to guide the selection, application, and assessment of the modeling efforts connected to the ecological and hydrologic simulations of selected conditions in the North and South Llano rivers to assure compliance with the EPA's Guidance for Quality Assurance Project Plans for Modeling (EPA QA/G-5M). More specific details are provided in the associated QAPP.

Review: This OP will be reviewed every two years.

1. Problem Definition

The first step in this procedure is clarification of the problem statement. The modeling efforts described in the scope of work are carefully planned to clearly identify their positions relative to the overall project requirements and the required capabilities to achieve the desired results.

2. Conceptual Model

Closely related to the problem definition is the description of the conceptual model of the ecosystem and watershed combination. The step includes consideration of the discretization of the model domain into subwatersheds and smaller grids, representation of the interaction between surface and subsurface water, identification of the appropriate hydrologic input variables, and selection of the ecosystem variables to be simulated.

3. Selection of Modeling Tool and Team

The results of the two previous steps allow selection of a modeling tool that has the appropriate capabilities. This project does not require development and coding of a new model, as existing models such as EDYS and SWAT are readily available and have been used in similar applications. This step also includes identification of the modeling team that has the required expertise and experience to apply the selected model. The teams could include all TTU employees or align with an appropriate subcontractor. The team specifies which modules of the modeling system are to be employed in the application.

4. Input Data Requirements

After the modeling tool is identified, the formats and types of input data that are required can be clearly described and collected. The data include precipitation and streamflow records, watershed characteristics from GIS and other spatial sources, as well as water quality and ecological data developed as part of the overall project.

5. Calibration and Tuning of the Model

The existing historical data are used to the greatest extent possible to calibrate the appropriate modules of the modeling system. Observed rainfall and streamflow data form the basis for calibration of the hydrologic portion of the model. Water quality variations over time can also be calibrated if sufficient data are available. If the time period of the historical records is long enough, part of the data record can be used for calibration, with the rest used to validate the calibrated model.

6. Model Application

After successful model set up and calibration, the modeling system can simulate other future conditions, including changes in precipitation and associated streamflow, or land use changes caused by vegetation management strategies. The modeling team identifies a finite number of simulations to be done to meet the project requirements, and also reviews and critiques the results to ensure the work has been done properly with reasonable results. The evaluation may include statistical comparison of simulated results to past observed behaviors within the simulated site, or to observed behaviors in similar locations previously studied or modeled.

7. Final Report

A final report presents the problem statement, approach, model application, and results in an appropriate format as set by the project sponsor. The modeling team contributes to the production of the report, with the principal investigator providing oversight and final approval of the report.