Quality Assurance Project Plan

for

Project 3: SWAT Model Code Modifications to Include Instream Phosphorus Analysis and Update of the SWAT Model for the Tenkiller Ferry Reservoir Watershed

FY08/09 Section 106 Grant (CA# I-006400-08)

Prepared by:

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September 20, 2007

SECTION A
PROJECT MANAGEMENT

A1 APPROVAL PAGE

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Tim Herfel Date

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ACRONYMS AND ABBREVIATIONS

CAFO	Concentrated Animal Feeding Operation
CD-ROM	Compact Disc – Read Only Memory
CGI	Common Gateway Interface
DEM	Digital Elevation Model
DLG	Digital Line Graph
E-coli	Escherichia coli
FC	Fecal coliform
GIS	Geographic Information System
GRS80	Geodetic Reference System of 1980
HRU	Hydrologic Response Unit
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
km	kilometer
NAD83	North American Datum of 1983
NED	National Elevation Data set
NHD	National Hydrography Data set
NLCD	National Land Cover Data set
NRCS	Natural Resource Conservation Service of the USDA
NWIS	National Water Information System
ODAFF	Oklahoma Department of Agriculture, Food, and Forestry
ODEQ	Oklahoma Department of Environmental Quality
ODWC	Oklahoma Department of Wildlife Conservation

OCC	Oklahoma Conservation Commission
OSE	Oklahoma Office of the Secretary of Environment
OWRB	Oklahoma Water Resources Board
PCS	Permit Compliance System
PDES	Pollutant Discharge Elimination System
PM	Project Manager
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
RF3	USEPA stream Reach File 3
STATSGO	USDA State Soil Geographic Database
STF3	Summary Tape File 3 (federal census data)
STORET	USEPA Storage and Retrieval System
TMDL	Total Maximum Daily Load
USACOE	United States Army Corps of Engineers
USBOR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator, a map projection

A3 DISTRIBUTION LIST

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A4 PROJECT/TASK ORGANIZATION

The assessor for this project will be the Project Manager and the management of Water Quality Division. Others are available for technical consulting as requested, including the participants at OSU, the WQD's QA Coordinator, and the Department's QA Officer. Water Quality Division management has the ultimate authority to continue or modify work in a significant fashion, based on the recommendations of the Project Manager or other involved parties. The Project Manager is responsible for modifying conditions to achieve results which he believes are realistic and supportable by actual conditions, and which he thinks would reflect probable results should future sampling be undertaken in attempts to verify modeling results.

The following individuals are involved in implementing this project:

MARK DERICHSWEILER – ODEQ SECTION MANAGER
The section manager is responsible for direct supervision of the project manager and reporting progress on the project to other managers in the water quality division.

BOB BEDNAR – ODEQ PROJECT MANAGER
The ODEQ Project Manager is responsible for planning and oversight of the project for the ODEQ. Responsible for ensuring that the project and its resulting deliverables meet the requirements of the USEPA-approved work plan, and will assist in managing and improving water quality in the State of Oklahoma. Responsible for developing and managing contracts with the Biosystems and Agricultural Engineering Department at Oklahoma State University to achieve work plan objectives. Reviews project deliverables to ensure that tasks in the work plan are completed as specified, and data is of known and sufficient quality, as specified in the QAPP.

KAREN KHALAFIAN – ODEQ QA OFFICER
Reviews and approves QAPP (including any revisions) to ensure project will deliver data of known and sufficient quality to achieve project objectives. Conveys QA problems to appropriate ODEQ management. Monitors implementation of corrective action.

KAREN MILES – ODEQ WQD QA COORDINATOR
Reviews and approves QAPP (including any revisions) to ensure project will deliver data of known and sufficient quality to achieve project objectives. Conveys QA problems to appropriate ODEQ water quality division (WQD) management. Monitors implementation of corrective action.

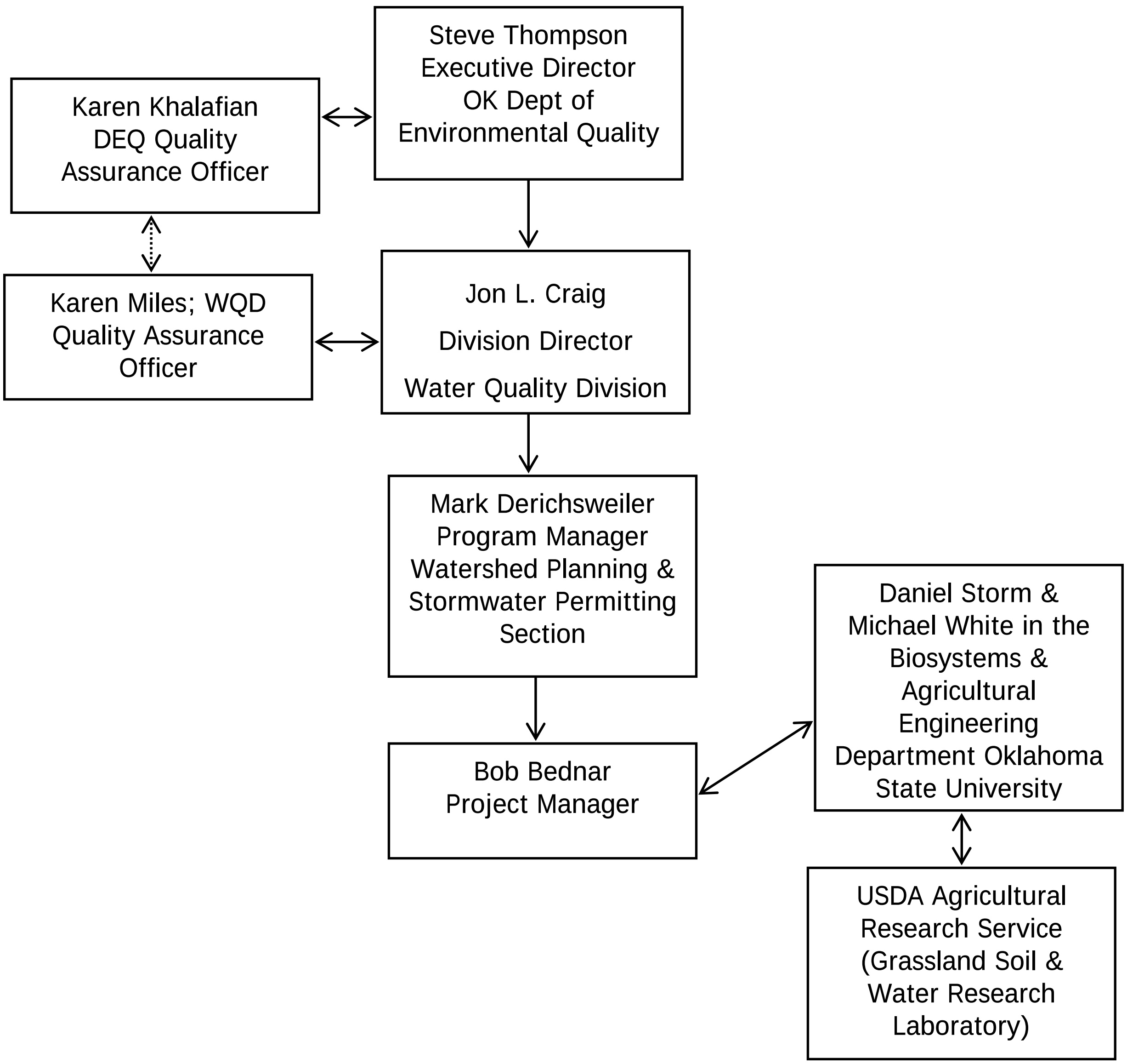
DANIEL STORM – PROFESSOR, OSU

Principal contractor of this project. Oversees the execution of all the technical aspects of the project and ensures the final products meet project objectives. Responsible for meeting project milestones, including those set for USDA, a subcontractor of this project.

MICHAEL WHITE – RESEARCH ENGINEER, OSU

Works with Dr. Storm in developing the project products.

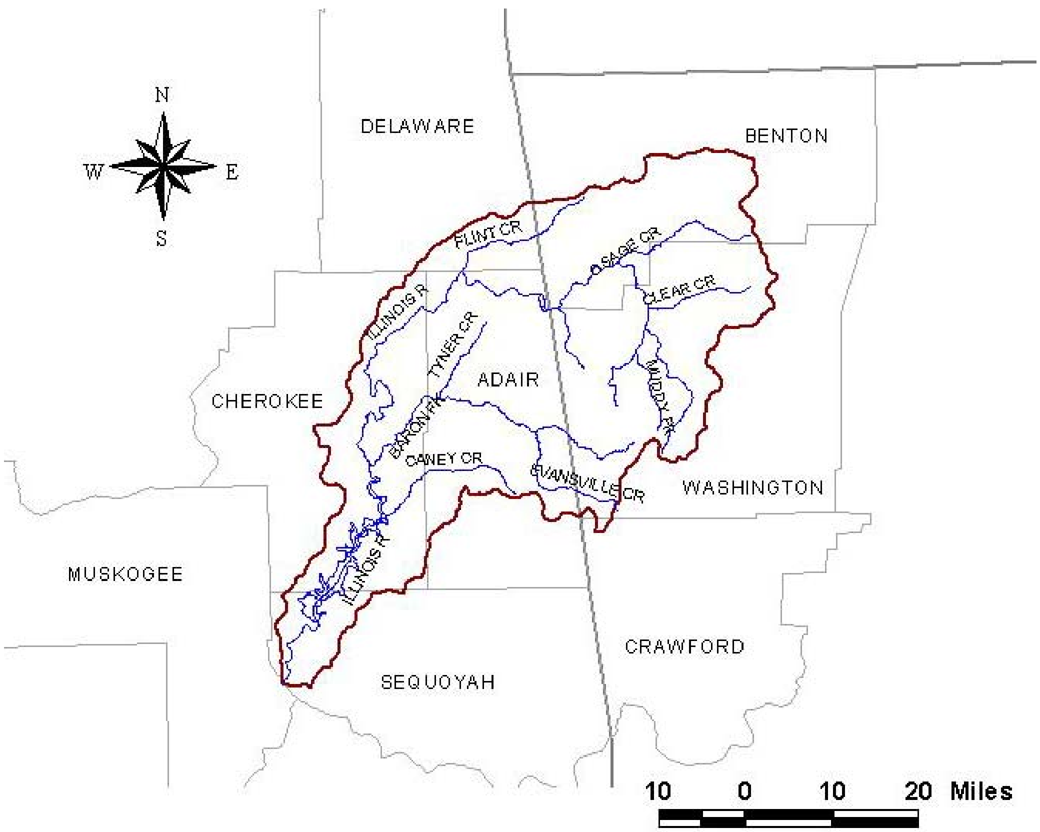
Figure 1: Organizational Chart for SWAT Model Modification



A5 PROBLEM DEFINITION/BACKGROUND

For several years, various state and federal agencies have studied the impacts of nutrient enrichment upon the Illinois River watershed and body of Tenkiller Ferry Reservoir. Tenkiller Ferry Reservoir and all of its major tributaries (Illinois River, Flint Creek, Sager Creek, Peacheater Creek, Ballard Creek, West Brook, Caney Creek, Shell Branch, and Baron Fork River) have been listed in Oklahoma's 303(d) list (Figure2). They are considered "impaired."

Figure 2. The Tenkiller Ferry Lake / Illinois River Watershed



The system has been studied extensively by other agencies, and reports have been issued regarding water quality in the watershed. These data are thought to be reliable, and on the basis of that information and the professional judgment of this and other environmental agencies, the ODEQ will proceed to gather and assimilate historical data needed to perform computer modeling and complete a TMDL. The ultimate goal of projects in this Program is to develop tools to aid in a more refined assessment of lakes and streams from the standpoint of contaminant abatement and the understanding and control of contaminant sources. As a result of these earlier studies, Tenkiller Ferry Reservoir and the Illinois River watershed have been classified as Category I[1] under Oklahoma's Unified Watershed Assessment methodology.

[1] "In need of restoration."

The primary goal in this project is to evaluate whether phosphorus load reductions from Best Management Practices in the Tenkiller Ferry Reservoir Watershed will meet the water quality standard of 0.037 mg/L 30 day geometric mean for total phosphorus set by the State of Oklahoma. To accurately model the total phosphorus concentration in the Illinois River, one must account for the in-stream processes. The current in-stream model in SWAT is a derivation of the Enhanced Stream Water Quality (QUAL2E) model created by Browns and Barnwell (1987). The SWAT version of the in-stream model has not been fully tested (Houser and Hauck, 2002). QUAL2E and the SWAT in-stream model are steady state models which may not be an appropriate application for a daily time step model run, i.e. non-steady state. Other issues with the in-stream model in SWAT are the inability to account for the phosphorus balance/continuity and difficulty in parameterizing the models without the collection of data specific for that purpose.

In previous projects with SWAT, the in-stream model was disabled. Without an in-stream model, streams and rivers are treated basically as pipes and all forms and amount of nutrients are conservative. The need arose to create a simplified and robust in-stream model based on a mass balance approach, which included the stream sediments and the water column.

Before modeling can be implemented, the Project Manager will begin by assimilating and assessing historical analytical data for the Lake Tenkiller Watershed. These data will come from agencies such as the OWRB, Oklahoma Conservation Commission, and US Geological Survey. At this early point in the project, a complete inventory of sampling and analysis results is not available to the Project Manager.

A6 PROJECT/TASK DESCRIPTION AND SCHEDULE

A6.1 PROJECT/TASK DESCRIPTION

Task 1: SWAT Model Code Modification

The objective of this task is to accurately predict daily in-stream phosphorus concentrations in the Lake Tenkiller Watershed in Oklahoma and Arkansas. To meet this goal, an in-stream phosphorus model will be coded into SWAT 2005 and used to predict in-stream phosphorus concentrations. In-stream phosphorus modeling is very complex with several physical, biological, and chemical processes occurring simultaneously which controls phosphorus spiraling in rivers and streams. This complex process will be simplified to three phosphorus storage pools being tracked in each stream reach and only four input parameters for both point source impacted streams and nonpoint source impacted streams. The four parameters values used in each stream reach will use a linear interpolation scheme between two set of parameters (point and nonpoint) based on the fraction of phosphorus originating from point sources in that reach on that day (Storm et al., 2006). The generalized in-stream model is shown in Figure 3.

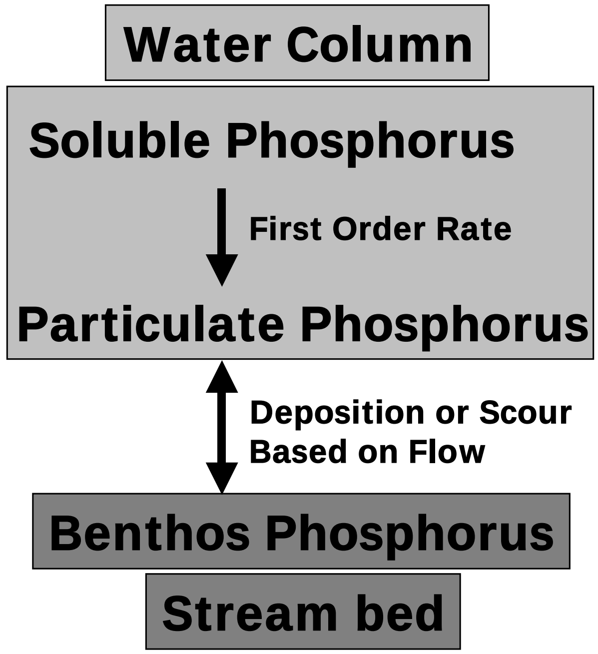


Figure 3. In-stream model applied to SWAT 2000 upland predictions in the Illinois River Basin.

The current SWAT 2005 model will be modified to include code allowing the analysis of instream phosphorus concentrations in addition to the models existing capabilities for evaluating nutrient loads from upland areas. No other changes will be performed to the SWAT model. This work will be done through the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory. The modification(s) will be made to SWAT 2005.

Task 2: Update/Recalibrate the SWAT Model for the Tenkiller Ferry Reservoir Watershed

Because SWAT is a distributed model, data requirements are vast. A variety of available GIS data will be used in SWAT. Below is a list of GIS and other related data that will be utilized in the updated SWAT model.

- Recently available land cover will be evaluated to determine if it is more appropriate then the 2001 land cover used in the previous study (source of these data will be determined based on data availability)
- Updated poultry house locations with active/inactive status (data provided by Oklahoma Attorney General (OAG))
- Litter application by sub-basin (ODA; OSU; Benton County, Arkansas)
- New 10 m USGS DEM
- 1:250,000 NRCS STATSGO soils data
- Tabular weather data from the NOAA COOP (National Oceanic and Atmospheric Administration Cooperative Observer Program) network

- USGS gage data
- Updated point source data (provided by ODEQ)
- Phosphorus contribution from groundwater Inflow, (data provided by OAG)
- Updated livestock numbers (data provided by OAG)
- Cattle grazing (data provided by OAG)
- Slope by land cover correction (OSU)
- Updated soil test phosphorus data (OUS)
- Soil test phosphorus estimates by land use and by sub-basin (OSU)

The Watershed Planning and Stormwater Permitting Section of ODEQ will provide monthly estimates of mineral and organic phosphorus, mineral and organic nitrogen, and flow for the period 1990 to current for all permitted point sources in the basin. In addition, ODEQ will provide flow from these permitted discharges for the period 1980 to 1989.

Nutrient loads will be estimated using the USGS software LOADEST2 for 1990 through the most recent available data.

The SWAT model will be calibrated for flow for the period 1990 to current for the multiple stations, and then calibrated for phosphorus and nitrogen loads for the period 1997 to current. Next, the SWAT model will be validated for flow for the period 1980 to 1989 and then validated for phosphorus and nitrogen loads for the period 1990 to 1996. The calibration and validation will follow standard modeling procedures based on observed data and established statistical criteria.

Task 3: Nutrient Load and Reduction Scenarios

Nutrient loads will be predicted using the calibrated SWAT model for the following:

1) Nutrient contributions from Oklahoma and Arkansas independently for the period 1990 through current.
2) Nutrient contributions from point and nonpoint sources independently for the period 1990 through current.
3) Nutrient contributions from nonpoint sources by category for current conditions
   a. soil test phosphorus (STP)
   b. Poultry litter
   c. Other significant nonpoint sources as applicable
4) Estimate projected total phosphorus load resulting from poultry litter export.

Scenarios for nutrient reductions will be evaluated to determine which scenarios or combination of scenarios will meet the Oklahoma Water Quality Standards of a monthly geometric mean total phosphorus concentration of 0.037 mg/l for Scenic Rivers..

Task 4: Final Reports

All public comments received will be properly addressed and the draft reports revised if necessary. All comments and the response to the comments will be included as part of the final TMDL reports. The updated TMDL report will be submitted to the USEPA for final approval.

A6.2 PROJECT/TASK SCHEDULE

The following is a schedule of activities to be performed

1.	Nutrient loads	October 1, 2007
2.	SWAT Inputs	November 1, 2007
3.	Completed SWAT Calibration and Scenarios	December 30, 2007
4.	SWAT source code, executables and other related computer programs and their documentation	January 31, 2008
5.	Draft Final Report	January 31, 2008
6.	Final Report	February 30, 2008

A7 QUALITY OBJECTIVES & CRITERIA

The in-stream model will be evaluated using water quality data collected in the watershed from 1990 to 2006. Except for some analytical water data, input data have already been compiled, and will be accepted at face value. Analytical reports, which will be several years old, also must be accepted at face value because the ability to match laboratory QC data from past years is beyond the resources of this project. The Project Manager is free to exclude such information based on professional experience and judgment, will scrutinize data that appears obviously out-of-scale.[2]

Model calibration for the in-stream model is defined by how well the model is able to reproduce total phosphorus concentrations at various monitoring stations in the watershed. The in-stream modeling process will be complete and successful when predicted values for total phosphorus fall within two standard deviations of the observed mean values 90% of the time. There is also a great deal of uncertainty in measured water quality data. Harmel et al. (2006) calculated a cumulative probable uncertainty (±) of 4 to 48% for measure water quality data. Coupled with uncertainty in stream flow measurements of 6 to 19%, the errors in calculating the storm loads can range from (±) 8 to 104% for dissolved nutrients and 8 to 110% for total nitrogen and phosphorus under typical conditions.

The SWAT 2005 model must be calibrated so that the output for stream flow matches historical records. Most analytical results will have confidence intervals that range between +/- 15% to +/- 30% of the specific parameter measured. The limitations of the SWAT model in representing true physical and biological processes in a watershed are well-understood in the modeling community and will be highlighted in the final report. The applicability of the model in future watershed management activities will, therefore, be cautioned against these limitations. Users of this SWAT model will be advised of these limitations in the final report. From that point, a worst-case modeling effort to reflect a baseline year should also reflect those confidence intervals.

The "data user" here is the Project Manager, who may recommend that Tenkiller Ferry Reservoir Watershed be de-listed from the 303(d) list for some analytical parameters, and who

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[2] The Project Manager may, at his discretion, assume that analytical data generally fits a Gaussian distribution, calculate means, medians, sample and population standard deviations, and from these estimates, decide whether a given data point is an outlier. The Project Manager may have more sophisticated techniques available, but this is suggested as a starting point. An outlier might, therefore, lie outside of three sample standard deviations from the sample mean.

will use remaining information generated to prepare a TMDL report for the reservoir and its system.

There is no ultimate "decision error" associated with this project. Decision errors related to the use of historical or regional background data can be "lumped" into apparent analytical results by model calibration. Uncertainties in flow, climate, assumptions about land use, permeability, and pollutant fate-and-transport in the modeled system, etc., are all reflected by the error associated with analytical measurements when computer models are calibrated.

The primary success criterion for watershed modeling will be the acceptance of the calibrated model for strategic planning purposes such as allocation of funds. Final acceptance must come from other state agencies, and USEPA. County agencies and municipal elected officials must also be comfortable that the model gives a reasonable representation of local conditions.

A8 SPECIAL TRAINING REQUIREMENTS/CERTIFICATIONS

No special training or certification is required for participants in this project beyond the general training in engineering, modeling, mathematics, or other sciences that they have obtained in order to fulfill job requirements commensurate with their current assignments.

A9 DOCUMENTATION AND RECORDS

Much work has already been done and published information is already available. The Project Manager will clearly indicate material which is used in this project, and will clearly indicate any material which he discards and the reasons for not using material. Notes are adequate for this purpose. A Corrective Action Form, like that found Appendix B, is also adequate for this purpose.

All documents and electronic files will be archived by Oklahoma State University for at least five years. These documents will include the final report, calibration and/or validation data, model testing for the in-stream model, updated source code for the SWAT model and in-stream model, and SWAT 2005 model results.

A9.1 INFORMATION TO BE INCLUDED IN REPORTING PACKAGES

At this time, this project consists solely of data evaluation, data input to two computer models, and data output from those two computer models. Additional steps in the TMDL process will be added to this QAPP in addendum form at a later date.

For the present, then, two general forms of records are needed.

1. An inventory of data input parameters for each model, including those used for calibration and sensitivity analyses.
2. Output from each computer model.

A9.2 DATA REPORTING PACKAGE FORMAT AND DOCUMENTATION CONTROL

The ODEQ Project Manager is responsible for retaining this information and will do so both in electronic and hard-copy form. Electronic files stored on ODEQ computers are automatically backed up daily by the State's data maintenance center. All official records of the agency are stored according to the State's recording keeping policy. He should do so in such a fashion that another person could duplicate his work with a reasonable amount of similar effort. Computer output material can be tabular, graphical, and can be obtained via computer monitor or printer. The Project Manager can best decide the approach to this when he moves into the actual modeling work involved.

A9.3 DATA REPORTING PACKAGE ARCHIVE AND RETRIEVAL

Electronic data packages are the natural result of computer modeling. The Project Manager will retain this material, as he will use it in additional phases of TMDL work. In addition, the Project Manager will retain his work and results in an easily-contained, easily-referenced hardcopy form[3]. A three-ring binder is recommended, but the final form is discretionary.

[3] The Project Manager must arrange for data archival and storage for a time frame sufficient to meet regulatory requirements, and part of his responsibility for this project is to be aware of this requirement, which may differ from the requirements of other state and federal programs.

SECTION B
DATA ACQUISITION

B1 SAMPLING PROCESS DESIGN

No new measurements are to be undertaken as part of this project. Historical information is to be applied to two computer-modeling efforts. The first model is to result in volumetric flow assumptions and fate-and-transport output that can be applied to a second model that predicts impacts upon the already-impaired Tenkiller Ferry Reservoir Watershed.

All data parameters used in these computations are critical, and output for these models, like all computer models, must be examined for reasonableness, checked for sensitivity to various input parameters, and calibrated to match assumptions with actual behavior of the system being modeled. The list of input parameters is extensive, and will not be dealt with in detail in this QAPP. Examples of data input include land use, soil types, rainfall, air and water temperatures, reaction mechanisms, contaminant loadings, flow rates and resistance to flows.

B2 SAMPLING METHODS REQUIREMENTS

This section is not relevant to the project.

B3 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

This section is not relevant to the project.

B4 ANALYTICAL METHODS REQUIREMENTS

This section is not relevant to the project.

B5 QUALITY CONTROL

This section is not relevant to the project.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

This section is not relevant to the project.

B7 MODEL CALIBRATION

Model Calibration is the process by which model parameters are adjusted to make its predictions agree with measured data. Model parameters will only be adjusted within literature recommended ranges. Calibration generally improves the reliability and reduces the uncertainty of the model predictions. If enough data are available, then the models will be validated. Validation is similar to calibration except the model is not modified. Validation tests the model with measured data that are not used in the calibration process.

The in-stream model will be calibrated to agree with measured data from various monitoring stations in the basin. Nash-Sutcliffe Efficiency (NSE) and Coefficient of Determination (R^2) will be used as an indicator of goodness of fit (Nash and Sutcliffe, 1970). There is no range of values for goodness-of-fit statistical parameters which judge the in-stream model performance as acceptable. The in-stream model will predict an average daily concentration which may vary dramatically from the measured data. Measured data are collected at a single point in time. They are not a daily average. These differences in concentrations can have an impact when calibrating total phosphorus during storm events or high flow periods immediately following a storm. Samples could have been collected prior to the storm event which can cause differences between predicted and measured data. As suggested by the Agricultural Research Service (ARS) – Grassland Soil and Water Research Laboratory, the modeling process will be complete and successful when predicted values for total phosphorus fall within two standard deviations of the observed mean values 90% of the time.

The SWAT 2005 model will be calibrated for stream flow at multiple stations within the basin from the January 1, 1990 to December 31, 2006. Similar to the in-stream model, the SWAT 2005 model will use the NSE and R^2, as an indicator of goodness of fit. There are no standards or a range of values for goodness-of-fit statistical parameters that adjudge the model performance as acceptable (Loague and Green, 1991). In the past, other researchers have suggested values of goodness-of-fit statistics for determining the acceptable performance. Ramanarayanan et al. (1997) indicated that values close to zero for the correlation coefficient and/or the Nash-Sutcliffe coefficient indicated the model performance was unacceptable or poor. They judged the model performance as satisfactory or acceptable if the monthly correlation coefficient was greater than 0.5 and the monthly Nash-Sutcliffe coefficient was greater than 0.4. Santhi et al. (2001) assumed a monthly Nash-Sutcliffe coefficient greater than 0.5 and a monthly R^2 greater than 0.6 indicated acceptable model performance when calibrating and validating SWAT. However, acceptable statistical measures are project and model specific. Model performance on a daily basis will be somewhat different than monthly model runs. The SWAT 2005 model must be calibrated so that the output for stream flow matches historical records. Along with the NSE and R^2, SWAT will be calibrated so that predicted values for flow agree with measure values within the range between +/- 15% to +/- 30%.

When calibration standards are not met, Oklahoma State University will check the measured data for deficiencies and correct them (if possible). The same procedure will be applied to both the in-stream and SWAT 2005 model. Algorithms in both models will be thoroughly examined for deficiencies and corrected. The models will be re-calibrated if any deficiencies are found in either the measured data or model algorithms.

B8 INSPECTION/ACCEPTANCE REQUIREMENTS FOR SUPPLIES AND CONSUMABLES

This section is not relevant to the project.

B9 NON-DIRECT MEASUREMENTS

No new measurements are to be undertaken as part of this project. Most of these data used in this project are from sources other than within this project. Table 1 identifies the most important data published (with exceptions noted). Basin scale hydrologic modeling requires a vast amount of data. The modeling report will contain all data sources and references. These data come from a variety of sources:

Table B1: Selected Secondary Data for Basin/Subbasin Modeling

Data set	Applications	Notes	Sources
Soil map unit boundaries and properties	Assignment of soil properties to SWAT HRUs	Polygons digitized from 1:24,000 maps. See USDA/NRCS 1999 for metadata template.	USDA NRCS.
Soil general map unit boundaries and properties	Assignment of soil properties to SWAT HRUs	National STATSGO database.	USDA NRCS
Aerial photographs	Selected area (such as villages) for manual land cover characterization.	Published resolution is 1 image pixel representing 1 meter on the ground. Photography from 1998	ODEQ CD-ROM
Sub-watershed ridge lines	Definitions of subbasins for meteorology data and spatially-distributed simulation	Hand-drawn ridges on USGS 1:24,000 scale Digital Raster Graphic DRG maps.	USGS GIS data repositories
Daily weather: precipitation, temperature	SWAT input: time series meteorology data per subbasin.	Point measurements at 27 stations. Data summarized on a daily basis.	US National Weather Service
Daily streamflow	Calibration. Checking of precipitation data.	Measurements at various USGS gauges. (Figure 3)	USGS Water Resources
Daily phosphorus and sediment loadings in streams	Calibration.		
WWTP effluent flows solids loadings, and phosphorus loadings	Direct input to SWAT as point sources to streams.	Discharge Monitoring Reports(DMR) under NPDES permits; All permittees, period of record	USEPA Permit Compliance System
WWTP effluent P concentrations	Corroboration of DMR data.		

Land cover maps	Area of land of each type in each subwatershed; for definition of HRUs and weighting of simulation results within subbasin.	Interpretations of satellite imagery. Two different spatial resolutions and dates.	
Tax parcel maps and parcel descriptions	Area of land of each type in villages	Manual records kept for tax purposes,.	
Septic system counts by subbasin	Direct input to SWAT as pseudo-point sources to streams.	Derived from tax parcel centroids for selected classes, SSURGO digital soil maps, surface hydrography maps.	

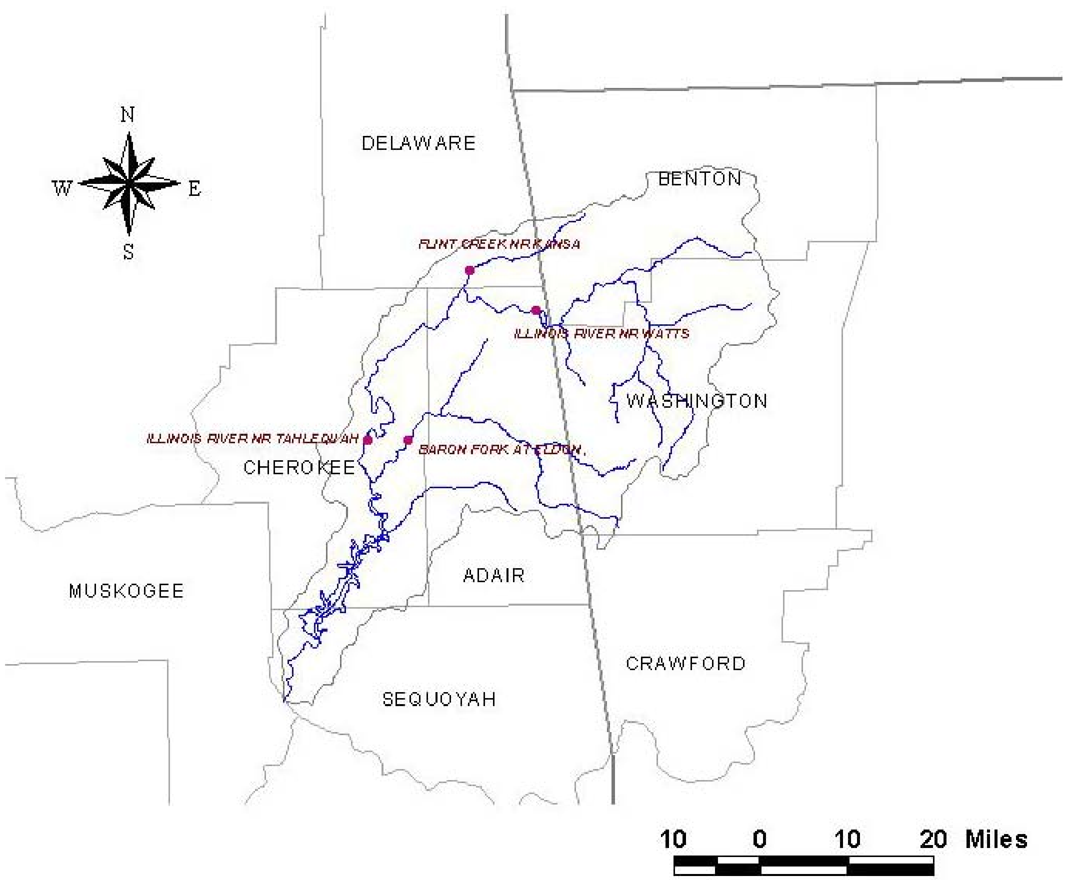

Figure 4. Locations of USGS Gages Used for Model Calibration

Often there are several data sets available from which to choose for a particular modeling task. The sources of secondary data will be identified in all deliverables. These data are evaluated based on the following criteria:

1. GIS Data Detail

GIS data come in a variety of detail levels, which may be expressed as a resolution or map scale. White (2001) found that the detail of input GIS data has a significant impact on SWAT model output.

2. Age of Data

Some data are more time sensitive than others. For example, land cover may change dramatically over the span of a decade, where as soils typically change only over geologic time.

3. Accuracy

When accuracy information is not available, the data must be assessed by professional judgment.

4. Temporal Continuity

Temporal continuity is of great importance when selecting weather, streamflow, or water quality data. Weather and streamflow should ideally be continuous on a daily basis, although it is possible to estimate missing days based on other data. These data are seldom continuous for long periods of time, thus continuity is a common criterion for data selection.

5. Spatial Consistency

Spatial consistency is often sacrificed to use the most current data available. Most data sets cover only a limited area such as a state or county. A basin is typically not limited to those same boundaries, and often cross both state and county lines. This leads to the use of multiple GIS data sets to define a single model input layer and may create a lack of consistency across the basin.

Quality and Limitations of SWAT Model Data

It is not currently possible to comprehensively quantify the error in SWAT model predictions, thus there are no quantitative data quality requirements. It is possible, however, to list model limitations. Model limitations may be the result of data used in the model, inadequacies in the model, or using the model to simulate situations for which it was not designed. Hydrologic models will always have limitations, because the science behind the model is neither perfect nor complete. A model by definition is a simplification of the real world. The following is a list of notable SWAT model limitations:

1. Weather

Weather is the driving force for any hydrologic model. Data collected at a few points are applied to an area of thousands of square miles. Rainfall can be quite variable, especially in the spring when convective (“pop-up”) thunderstorms produce precipitation with a high degree of spatial variability. It may rain heavily at a weather station, but may be dry a short distance away. On an average annual or average monthly basis, these errors may cancel. This limitation among others, cautions us against using daily model output.

2. Radical Parameter Changes

Scenarios involving radical changes to the basin result in greater uncertainty. The SWAT model is calibrated using estimates of what is presently occurring in the basin. Large departures from calibration conditions raise the level of uncertainty in model predictions.

3. Small Land Covers

Land uses that cover very small areas are not represented in the SWAT model. Land uses that occupy limited areas such as unpaved roads, bare areas, construction sites, and some row crops may not be simulated. In addition, most of these features may not be depicted in the available land cover. Some of these small areas may contribute many times more sediment on a per unit area basis than rangeland. Although significant, they may not be able to be simulated with the currently available data.

4. Hydrologic Response Unit Characteristics

Each HRU in a particular subbasin is assumed to have the same characteristics by the SWAT model. For instance, the same slope is used for all rangeland and agricultural HRUs in a single subbasin. Agricultural land is generally located in valleys or other flat areas. Rangeland generally occupies land that is unsuitable for row crop production.

5. Management Uncertainty

There is a great deal of uncertainty associated with pasture and other agricultural land management practices. In reality, management varies significantly from field to field. It is not possible to easily determine what is happening where, or to simulate all these activities in the model. Therefore, categories are created to cover reasonable management choices only.

6. Unidentified Point Sources

There are very few point sources in the basin; these are not expected to be significant. Potential point sources include CAFOs and small municipalities.

B10 DATA MANAGEMENT

Since no sampling or measurements are conducted in this project, no monitoring data will be generated. Published reports from the Oklahoma Water Resources Board and Oklahoma Conservation Commission, and possibly the US Geological Survey and US Bureau of Reclamation will be the primary source of data. This data has already been compiled and will be accepted at face value.

Data processing equipment within Dr. Storm's workgroup will be backed up at least weekly or more frequently during periods of rapid data processing or generation. Data from all computers used in this project will be copied to external hard disks during each backup. Multiple backup hard disks will be rotated such that the data exist on at least 3 separate hard disks at any given time. One copy of the data is kept offsite, to prevent all copies from being lost in any single event. Upon completion of the project, all data will be written to DVDs for long-term storage in Dr. Storm's office. Hard disk copies of the data in its original structure will continue to be maintained.

At DEQ, the data processing equipment are personal computers and network stations using the Windows 2000 operating system. Water quality models (Section A6.1) will be used in the project. Output data from these models will be stored in text format in a network drive and removable media. Backup copies for network drives are created everyday by the State's central data service to prevent any potential data losses. The project officer will be responsible for storing and backing up the data.

SECTION C
ASSESSMENT AND OVERSIGHT

C1 ASSESSMENT AND RESPONSE ACTIONS

As discussed in section B, the acceptability of modeling results will be determined by those most affected by the modeling - county officials other state agencies, the State of Arkansas, and USEPA. The primary response actions if quantitative inadequacies are uncovered are:

- attaching tolerances or ranges to simulation results that realistically represent uncertainty;
- isolating key weaknesses in input data or algorithms, and addressing them via supplemental research, replacement, or new data collection.

Another type of possible inadequacy is not aiming the model at questions considered important by ODEQ. The watershed modeling task is an iterative one in which early results are evaluated to refine subsequent work.

<u>This project breaks down into these general phases:</u>

1. Computer input data gathered and assimilated by ODEQ and OSU. During this event, outliers can be identified and documented, and recommendations made to de-list appropriate contaminants from the 303(d) list for Tenkiller Ferry Reservoir Watershed where appropriate. This phase of the project should require about 30 days.

2. Data input will be performed by either the Project Manager or Oklahoma State University staff/students under the direction and supervision of Professor Storm. Flow modeling and contaminant fate-and-transport modeling for the watershed system are the resulting output. Model calibration and sensitivity studies will be required, so that the final result models a “severe” set of conditions that are also plausible. The Project Manager’s judgment, tempered by the recommendations and experience of OSU staff, will be the guiding force in assessing the success of this phase of the project. Flow and transport output from the second phase of the project will be used to estimate what impact those modeled contaminant loadings have upon the Tenkiller Ferry Reservoir Watershed proper, and that output will be compared to whatever actual available analytical data exists for each contaminant. The process may be iterative between phases 2 and 3, because calibration will be needed, and a “severe” set of input conditions is necessary so that maximum contaminant loadings can be simulated. This phase should also require about 60 days from the close of the first phase.

3. Source code and executables of the SWAT model and related documentation will be organized by OSU and provided to ODEQ as part of the final project outcome. A draft report of the modeling effort will also be provided by OSU to ODEQ. The Project Manager will review the submitted documentation and draft report to determine the deficiency of these products in achieving project goals. Revision will be requested if necessary. This phase should take about 30 days from the close of the second phase.

4. The last phase of the project results in a final SWAT model report that describes the new in-stream code and the updated modeling of the Tenkiller Ferry Reservoir watershed. The model can be used to understand the phosphorus dynamics in the watershed and serve as the basis for watershed management. This phase of the project will require about 30 days following the initial completion of phase 3.

The Project Manager may wish to keep a journal of this project, such that input and output of computer analysis can be tracked and reproduced if necessary. The State Environmental Laboratory uses a "Corrective Action Form" (attached) that can also be used by the Project Manager to track and solve project anomalies.

C2 REPORTS TO MANAGEMENT

Memorandums to Water Quality Division Management, in particular the Division Director, provide the most effective formal means of involving management in the progression of the Tenkiller Ferry Reservoir Watershed project. At a minimum, a progress report in memo form will be provided in this fashion at the completion of each of the four phases of the project. Corrective Action Reports, if used, and specific recommendations for 303(d) listing removals should also be transmitted in this format as they occur and are resolved, and an additional summary should be provided at the conclusion of each phase. The final report should make recommendations regarding how to follow up the project with the next logical step, that of TMDL preparation. This final report should also include a TMDL workplan.

The Project Manager here is the logical and most competent individual to accomplish this task.

SECTION D
DATA VALIDATION AND USABILITY

D1, D2, D3 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS; VALIDATION AND VERIFICATION METHODS; RECONCILIATION WITH DATA QUALITY OBJECTIVES[4]

Published reports will be the primary source of data used for this project, which, again, consists of a computer match of predicted watershed performance against limited historical data. No new water quality sampling will be undertaken as part of this project. Except for some analytical water data, input data has already been compiled, and will be accepted at face value. Analytical reports, which will be several years old, also must be accepted at face value because the ability to match laboratory QC data from past years is beyond the resources of this project. The Project Manager is free to exclude such information based on professional experience and judgment, will scrutinize data that appears obviously out-of-scale.[5]

The in-stream and SWAT 2005 model will be validated (if sufficient data are available). The in-stream model will be validated for phosphorus loads for the period of 1990-1996. The SWAT 2005 model will be validated for flow for the period of 1980 to 1989. Validation is similar to calibration except the model is not modified. Validation tests the model with measured data that are not used in the calibration process. The same evaluation measures will be used for assessing the performance of both the in-stream and SWAT 2005 model. If the validation procedure does not meet the standard, then the calibration process will be reworked until a goodness of fit between predicted and measured data is achieved. The validation process will be conducted by Oklahoma State University.

The limitations of the SWAT model in representing true physical and biological processes in a watershed are well-understood in the modeling community and will be highlighted in the final report. The applicability of the model in future watershed management activities will, therefore, be cautioned against these limitations. Users of this SWAT model will be advised of these limitations in the final report.

The “data user” here is the Project Manager, who may recommend that Tenkiller Ferry Reservoir Watershed be de-listed from the 303(d) list for some analytical parameters, and who will use remaining information generated to prepare a TMDL report for the reservoir and its system.

This scope and scale of this project are such that the primary person responsible for data selection, use, calibration, verification, and reconciliation, is the Project Manager. He may choose to solicit input from others, including the Program Manager, the QA Coordinator, the QA Officer, or others, but the specialized nature of the project makes the Project Manager the true expert in accomplishing the project.

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[4] These sections are combined because of the unique nature of this project, and the interlocking descriptive aspects of this particular section of the QAPP.

[5] The Project Manager may, at his discretion, assume that analytical data generally fits a Gaussian distribution, calculate means, medians, sample and population standard deviations, and from these estimates, decide whether a given data point is an outlier. The Project Manager may have more sophisticated techniques available, but this is suggested as a starting point. An outlier might, therefore, lie outside of three sample standard deviations from the sample mean.

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Appendix A

Corrective Action Form – ODEQ Watershed Planning and Toxics Control Section

DATE:		**CAF Number**

What is the problem? Describe below.
Would you describe this as a Major or Minor problem? **Major** ➢ ☐ **Minor** ➢ ☐

What are the causes of the problem?

Corrective Action Form – ODEQ Watershed Planning and Toxics Control Section

DATE:		**CAF Number**
How do you propose to eliminate the problem?		
What is the justification for your proposed fix?		

Submitted by: **Approved by:**

Date: **Date:**

Corrective Action Form – ODEQ Watershed Planning and Toxics Control Section

Follow-up: Was the problem solved? Describe.

Program Manager Approval: ___________________________ Date:________________

QA Coordinator Review: __________________________________ Date: _______________