



SWAT Modeling Quality Assurance Project Plan

Lake Thunderbird Watershed Analysis and Water Quality Evaluation

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SECTION A: PROJECT MANAGEMENT

A1 TITLE AND SIGNATURE PAGE

Oklahoma Conservation Commission Water Quality Division

Lake Thunderbird Watershed Analysis and Water Quality Evaluation: SWAT Quality Assurance Project Plan

Approving Officers:

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Signature: _____ Date: _____

Name: **Jennifer Wasinger** – Environmental Programs Manager
Oklahoma Office of the Secretary of the Environment

Signature: _____ Date: _____

Name: **Tim Herfel** - Project Officer, Region VI United States
Environmental Protection Agency

Signature: _____ Date: _____

Name: **EPA Approving Official**
Region VI United States Environmental Protection Agency

Signature: _____ Date: _____

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A3 DISTRIBUTION LIST

Finalized, signed, and U.S. EPA Region VI approved copies of the Quality Assurance Project Plan (QAPP) will be distributed to the following persons:

1. Greg Kloxin Oklahoma Conservation Commission, Water Quality Division
2. Baxter Vieux Vieux & Associates, Inc.
3. Jennifer Wasinger Office of the Secretary of the Environment
4. Tim Herfel U.S. EPA Region VI

A4 PROJECT / TASK ORGANIZATION

Personnel of the Oklahoma Conservation Commission (OCC) Water Quality Division will oversee the primary tasks necessary to complete the project. The OCC personnel involved and their responsibilities are listed below. Please see the *Quality Management Plan for the Oklahoma Conservation Commission for Environmental Monitoring and Measurement Activities* for an organization chart (on file at the EPA Region VI Office in Dallas, TX).

Mike Thralls, Executive Director, OCC

Responsible for all operations of OCC including Water Quality Division operations.

Dan Butler, Program Director, OCC Water Quality Division

Responsible for all OCC Water Quality Division programs, the Program Director is the final decision making authority within the Water Quality Division.

Shanon Phillips, Assistant Director, OCC Water Quality Division

Second in OCC WQD command. In addition to specific duties assigned by the director, this position is primarily responsible for the design and implementation of the Commission's nonpoint source programs including water quality, biological and habitat monitoring, implementation of best management practices, and education programs

Jim Leach, Financial Director, OCC Water Quality Division

In addition to administrative duties, responsible for coordinating and expediting management of OCC watershed projects, both within the OCC and with contracted agencies.

Ann Craven, Executive Secretary, OCC Water Quality Division

Division secretary, file manager and invoice/payments manager.

Judith Wilkins, Environmental Projects Coordinator, OCC Water Quality Division
Responsible for the administration and management of WQ projects. Monitors, reviews and coordinates: grant outputs, agreements, and WQ cost-share implementation and demonstration projects. Coordinates and authorizes the purchasing of all water quality monitoring equipment and supplies under the supervision of the WQ Asst. Director and Commission Comptroller. Coordinates with WQ staff on the creation and administration of contracts and agreements with other Agencies, Universities, and non-governmental organizations.

Greg Kloxin, Senior Technical Writer/Water Quality Analyst/Quality Assurance Officer, OCC Water Quality Division
Lead technical writer, data analyst, and field investigator. Responsible for the drafting and review of the technical reports and other information from the Division. Also responsible for all Quality Assurance efforts implemented by the OCC.

Stacey Day, Environmental Programs Manager, OCC Water Quality Division
Technical writer, data analyst, assistant QA officer, and field investigator.

Candace Cunningham, Technical Writer/Water Quality Programs Specialist, OCC Water Quality Division
Technical writer, data analyst, and field investigator.

Stacy Hansen, Technical Writer/Water Quality Programs Specialist, OCC Water Quality Division
Technical writer, data analyst, and field investigator.

For a complete organization chart of the OCC Water Quality Division, please consult the *Quality Management Plan for the Oklahoma Conservation Commission for Environmental Monitoring and Measurement Activities* on file at EPA Region VI.

Vieux & Associates, Inc. will be contracted by the OCC to complete the SWAT modeling and targeting:

Baxter Vieux, Chief Technology Officer/Modeling Leader, Vieux & Associates, Inc.
Responsible for all aspects of the modeling and reporting process. Oversees the modeling, targeting, and reporting and ensures that it is technically sound and scientifically defensible.

A5 PROBLEM DEFINITION/BACKGROUND

The Lake Thunderbird watershed is located in central Oklahoma in Oklahoma and Cleveland counties. Lake Thunderbird is a sensitive water supply lake, serving the City of Norman, Midwest City, and Del City. The municipalities of Moore, Midwest City, Noble, Norman, Oklahoma City, and Slaughterville have land areas within the Lake

Thunderbird watershed. Excessive algal growth in the Lake from runoff of nutrients has led to water quality degradation that includes periodic undesirable taste and odor of the finished drinking water product, as well as potential ecological and recreational impairment. Increased urban growth in the area is expected to exacerbate the problems currently being observed.

The Soil & Water Assessment Tool (SWAT) model is useful in assessing the likelihood of certain areas contributing non-point source pollution in a watershed. Data will be accessed, as described in Section A6.2.1 below, and used to run the SWAT model in order to: 1) evaluate existing land use patterns in the watershed, 2) project the future impact of land use change on non-point source nutrient and sediment load from stormwater runoff to the lake, and 3) target urban management practices to improve water quality in the lake. The results of this modeling effort will be used to devise a Watershed Based Plan for Lake Thunderbird, followed by an implementation project to address non-point source pollution in the watershed.

A6 PROJECT/TASK DESCRIPTION

A6.1 Purpose/Background

Lake Thunderbird was designated as a sensitive water supply (SWS) lake by the State of Oklahoma in 2002. Accelerated eutrophication and annual nutrient load to the Lake has become a concern and has been accompanied by taste and odor complaints by water consumers. Lake Thunderbird is currently not attaining its Fish and Wildlife Propagation (Warm Water Aquatic Community) designated use due to turbidity and low dissolved oxygen or its Aesthetics use due to color. In addition, the chlorophyll-a concentration is approximately three times the water quality standard required for a SWS waterbody.

Understanding the impact of land use changes on non-point source nutrient and sediment load from stormwater runoff to Lake Thunderbird will be accomplished by watershed modeling. The Soil & Water Assessment Tool (SWAT) (Arnold et al. 1998) will be used to model the watershed. The effect of targeted management practices will be assessed by modeling the nutrient and sediment loads to the lake by subbasin. Best management practices that result in improvement of chlorophyll-a concentrations to the level required by the SWS standard will be suggested for implementation in areas that generate the greatest nutrient and sediment loadings.

The study will consist of the following tasks:

- Assess impact of urban development in the Lake Thunderbird watershed using the distributed water quality model SWAT for continuous simulation of surface runoff and nutrient loadings.
- Calculate nutrient and sediment loads released to the Lake under baseline and build-out conditions. Identify areas for application of targeted management practices to control nutrient load to the Lake.

- Develop climatological water balance for the Lake under baseline landuse conditions.
- Evaluate total phosphorus and chlorophyll-a model of lake water quality.
- Evaluate nutrients and sediment concentrations for the Lake under baseline and build-out conditions, with focus on the in-lake relationship between phosphorous and chlorophyll-a.
- Evaluate the effect of the phosphorus-sediment interaction in the Little River Arm of the Lake above Alameda on the main body of the Lake.
- Assess relative improvement of lake water quality through application of targeted management practices.

A6.2 Description of Work to Be Performed

A6.2.1 Watershed Characterization

Landuse in the Lake Thunderbird watershed will be provided by the Association of Central Oklahoma Governments (ACOG) Water Services Division. ACOG has assembled and analyzed landuse trends and future landuse plans provided by the municipalities within the watershed. This geodatabase will provide guidance and digital landuse for the baseline landuse scenario, current as of 2003, and for the build-out scenario, which will be projected to the year 2030. The ACOG landuse maps will provide a consistent landuse classification scheme over the watershed governed by multiple municipalities.

GIS data will be assembled for modeling the watershed with SWAT. Spatial data will be selected based on currency, resolution, industry standards, accuracy, and consistency for use within the SWAT modeling environment. The landuse, soils, and topography data sets to be utilized for analysis in SWAT include:

Landuse & Zoning – Association of Central Oklahoma Governments landuse categories as of July 16, 2003.

Soils – STATSGO – Soils data compiled by the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA).

Topography – National Elevation Dataset (NED) obtained from the United States Geological Survey (USGS) at a resolution of 30 meters.

Streams Network – NHD United States Geologic Survey (USGS) in cooperation with the United States Environmental Protection Agency (EPA), 1999.

Watersheds – Boundaries from NRCS 12-digit Hydrologic Unit Code (HUC 12) Watershed Boundary Dataset (WBD).

Municipalities – Boundaries from University of Oklahoma Center for Spatial Analysis.

Aerial Imagery – National Agricultural Imagery Program (NAIP) 2003 compiled by the USDA, Farm Services Agency, Aerial Photography Field Office.

Information on point discharge and bypass-discharge of untreated waste will be obtained from Oklahoma Department of Environmental Quality (ODEQ) and the Central Oklahoma Master Conservancy District (COMCD) for evaluation.

A6.2.2 Model Development and Calibration

A continuous simulation of the SWAT model using the baseline landuse scenario will be performed for the period 1970-2004. The watershed will be subdivided into subbasins based on the geomorphology of the basin and a stream threshold of four 100-meter cells. Hydrologic response units (HRUs) within the basin will be established with a 5% threshold for soils and landuse (default threshold 20%). Precipitation from the Norman and Oklahoma City gauges will be used for the entire model simulation period. The SWAT database for the Oklahoma City weather station will be used to generate maximum/minimum temperatures, solar radiation, wind speed and relative humidity for the basin. In-stream processes will not be considered in the model analysis.

In-lake water quality modeling will be performed to identify the effects of nutrient load on the water quality of the Lake on an average annual basis. This includes the development of a hydrologic water balance, use of a simple phosphorus mass balance model to predict in-lake total phosphorus concentration, identification of the sediment-to-water phosphorus interaction, and a chlorophyll-a to total phosphorus concentration model to quantify the impacts of various targeted management practices, as well as projected effects of urban development on lake water quality.

A6.2.3 Targeting Critical Source Areas

From the calibrated SWAT model, subbasin estimates by hydrologic response unit (HRU) for annual phosphorus, nitrogen, and sediment loads will be documented. These loads will then be used to target potential critical source areas of nutrients and sediment from upland areas. Graphical basin maps will be produced to show the results of the targeting methodology with the highest phosphorus, nitrogen, and sediment contributing areas shaded by severity using both current landuse data and future, "build-out" landuse data.

A6.2.4 Evaluating BMPs to Meet Water Quality Standards

The SWAT model will also be used to evaluate scenarios to estimate the potential reduction in nutrient and sediment loads resulting from implementing urban Best Management Practices (BMPs) to meet water quality standards in Lake Thunderbird.

A6.2.5 Documentation

The documentation task will consist of compiling all applicable historical and supporting data and developing summary tables for the final report that will be submitted to EPA. The report will also include a summary of model assumptions, model calibration, model projections, targeting results, and assessment of BMP effectiveness under current and build-out scenarios.

A7 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

Targeting critical source areas of pollutants from upland areas is an important component to implementing technical assistance and programs in areas that will potentially provide the greatest improvement in water quality with limited funds. Therefore, the SWAT model should appropriately represent the physical, chemical, and biological processes occurring with the watershed so that the runoff volume, sediment yield, and nutrient loads can be accurately qualified. Model calibration reduces the uncertainty in the model predictions. The process begins by calibrating the SWAT model for flow, then for nutrients. Assessment of calibration performance may be determined using statistical measures (mean, standard deviation, relative error, Nash-Sutcliffe Efficiency, and Coefficient of Determination) as well as graphical techniques (observed vs. predicted and time series graphs). It is important to note that a properly calibrated model will never perfectly match observed data since a hydrologic/water quality model is by definition a simplification of complex real world processes. In addition, there are inherent errors in the observed flow and water quality data. Therefore, rather than trying to match each observed data point, the model attempts to appropriately represent the relevant watershed processes. The ultimate acceptability of the model calibration will be determined based on whether or not the model predictions are believed to accurately represent the watershed processes for this specific targeting application.

A8 SPECIAL TRAINING / CERTIFICATION

Personnel performing modeling for this task will be familiar with the requirements of this QAPP and will have previous experience in applying the SWAT model for targeting purposes. No special training or certifications are necessary for this modeling task.

A9 DOCUMENTATION AND RECORDS

All project activities will be reported in the semi-annual progress reports to EPA. Other reports to be generated as part of the project are outlined in the workplan and include:

- 1) QAPP
- 2) Final Report

As discussed in section A.6.2.5, the report will consist of summary tables for historical and supporting data, as well as summaries for the model assumptions, model calibration, model projections, and targeting results. The report will also include summaries for model input and output and plots of predicted and observed flow, sediment, and nutrient loads (when applicable).

Vieux & Associates, Inc. will be responsible for final electronic and hard copy documentation version control, updates, storage, tracking, and distribution. Because existing software will be used for all phases of this project, there is no need to develop

any new file types or protocols. While the project is ongoing, the GIS/Modeler will backup all electronic documentation and data on local hard drives.

At the end of the project, all documentation, data (GIS, water quality data, etc.), and SWAT model files will be archived on CDs. These CDs will be archived and stored by the OCC, and if requested will be provided to the USEPA Region VI.

SECTION B: DATA MEASUREMENT AND ACQUISITION

B1 DATA SOURCES AND SELECTION

Modeling of the baseline and build-out scenarios will be accomplished with the SWAT 2005 model version with the AVSWAT interface (Arnold et al. 1998). The modeling report will contain all data sources and references. The expected data sources to be used for modeling include:

Landuse & Zoning – Association of Central Oklahoma Governments landuse categories as of July 16, 2003.

Soils – STATSGO – Soils data compiled by the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA).

Topography – National Elevation Dataset (NED) obtained from the United States Geological Survey (USGS) at a resolution of 30 meters.

Streams Network – NHD United States Geologic Survey (USGS) in cooperation with the United States Environmental Protection Agency (EPA), 1999.

Watersheds – Boundaries from NRCS 12-digit Hydrologic Unit Code (HUC 12) Watershed Boundary Dataset (WBD).

Municipalities – Boundaries from University of Oklahoma Center for Spatial Analysis.

Aerial Imagery – National Agricultural Imagery Program (NAIP) 2003 compiled by the USDA, Farm Services Agency, Aerial Photography Field Office.

Information on point source discharge and bypass discharge of untreated waste will be obtained from Oklahoma Department of Environmental Quality (ODEQ) and COMCD. Reservoir data will be obtained from USGS gauges and from the Bureau of Reclamation.

Spatial data will be selected based on currency, resolution, industry standards, accuracy, and consistency for use within the SWAT modeling environment. 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. When accuracy information is not available, the data must be assessed by professional judgment.

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.

B2 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:

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 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.

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.

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 others. Although significant, they may not be able to be simulated with the currently available data.

Hydrologic Response Unit (HRU) Characteristics

Each HRU is assumed to have the uniform characteristics by the SWAT model. An HRU is a unique combination of soil and land cover within a subbasin. Each portion of the HRU has the same characteristics regardless of its location within that HRU. Local factors such as slope are not considered variable within an HRU, even though slope is a important factor in both sediment and nutrient contributions.

B3 MODEL CALIBRATION

In general, at least 10 years of daily flow data is necessary to properly calibrate the SWAT model, assuming that the data reflect a range of wet to dry precipitation years. In order to calibrate the SWAT model, parameters will be adjusted to match cumulative runoff volume with inflow to the Lake. Available records for the Lake will be used to interpret inflow from water level rise, evaporation, precipitation, and discharge from the reservoir.

The watershed will be subdivided into subbasins based on the geomorphology of the basin and a stream threshold of four 100-meter cells, with hydrologic response units (HRUs) established with a 5% threshold for soils and landuse. A consistent rainfall timeseries for all calibration runs will be generated. Calibration is an iterative procedure that progresses from one model component to another and from course to fine parameter modifications, as shown in Figure 1. This block diagram is general, since it is not possible to represent all the specific details or decisions made by a modeler. The blocks actually represent many highly specific decisions based on many aspects of the model predications and observed data comparisons.

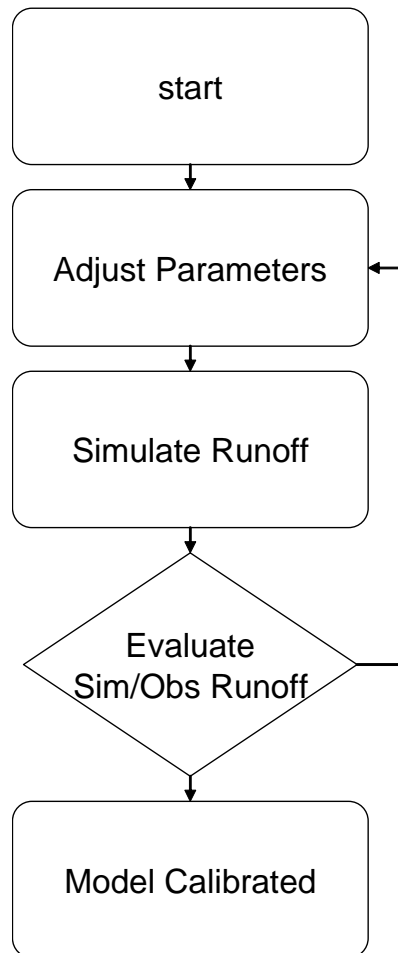


Figure 1. General SWAT model calibration procedure.

The resulting calibrated SWAT model will produce runoff that agrees with the water balance for the Lake in order to determine an improved estimate of the average annual nutrient and sediment load to the Lake.

B4 HARDWARE AND SOFTWARE CONFIGURATION

No special hardware is necessary for the modeling in this task. The software to be used for the modeling is SWAT 2005 running under Microsoft Windows XP, which has been well tested and needs no modification for use in this project.

SECTION C: ASSESSMENT AND OVERSIGHT

C1 ASSESSMENT AND RESPONSE ACTIONS

No external audits will be conducted for the modeling. Internal checking of model results will be performed by the Modeling Leader and through reviews by the Oklahoma Conservation Commission and the US EPA Region VI where necessary. The Modeling Leader will be responsible for the final product before it is submitted to the Oklahoma Conservation Commission and the US EPA Region VI.

C2 REPORTS TO MANAGEMENT

Modeling results and associated documentation will be compiled by the Modeling Leader and submitted to the Oklahoma Conservation Commission and US EPA Region VI as a Final Report.

SECTION D: DATA VALIDATION AND USABILITY

D1 DEPARTURES FROM VALIDATION CRITERIA

Quantitative criteria for acceptance of the calibration were listed in Section B. The model calibration results will be evaluated against these criteria by the Modeling Leader.

D2 VALIDATION METHODS

Validation is the process of verifying the ability of a calibrated model to make predictions outside the calibration period. A portion of the available data is withheld during calibration and later used to validate the model. The SWAT model will not be validated unless sufficient data exist.

D3 RECONCILIATION WITH USER REQUIREMENTS

Modeling will be reviewed by the Modeling Leader to assess the usability of the model results for the intended purpose (e.g., targeting). In general, model results that are generated such that acceptance criteria are met will be deemed usable for the intended purpose. If data quality indicators (performance criteria) do not meet the project's requirements for DQOs as outlined in this QAPP, these data may be discarded.

SECTION E: REFERENCES

Arnold, J.G., R. Srinivasan, R.S. Muttiah and J.R. Williams, 1998. Large Area Hydrologic Modeling and Assessment Part 1: Model Development. *Journal of American Water Resources Association*. 34 (1): 73-89.