Quality Assurance Project Plan
Canandaigua Lake Watershed SWAT Model
April 2020- Updated March 2021

Canandaigua Lake Watershed Council

In partnership with the Cornell University Soil and Water Lab

Prepared by:

Name: **Kevin Olvany and Kim McGarry**
Agency: **Canandaigua Lake Watershed Council**
Address: **205 Saltonstall Street, Canandaigua, NY 14424**
Phone: **(585) 396-3630**
Email: **Kevin.olvany@canandaiguanewyork.gov**

QAPP Update Log

Prepared/Revised By:	Date:	Revision No:	Summary of Changes:
Kevin Olvany	4/1/2020	0	original

This document has been prepared according to the United States Environmental Protection Agency publication EPA Requirements for Quality Assurance Project Plans dated March 2001 (QA/R-5).

ABSTRACT

This document details a quality assurance project plan to guide the successful implementation of the Canandaigua Lake Watershed Soil and Water Assessment Tool (SWAT) Model. The purpose of the model is to assess pollutant loading to Canandaigua Lake and estimate load reductions associated with best management practice implementation. The modeling results will be utilized in an addendum to the 2014 Comprehensive Update to the Canandaigua Lake Watershed Management Plan to meet the EPA's 9 Element Plan criteria.

This QAPP documents the project goals and objectives, project organization, tasks, quality objectives and model testing, calibration and validation.

1.0 PROJECT MANAGEMENT

1.1 Title and Approval Page

Canandaigua Lake Watershed SWAT Model
Quality Assurance Project Plan
April 2020
Canandaigua Lake Watershed Council
205 Saltonstall Street, Canandaigua, NY 14424

Approvals Signature (required prior to project start):

Kevin Olvany sign here 5/13/2021

Project Manager **Date**
Kevin Olvany, Watershed Program Manager
Canandaigua Lake Watershed Council

Todd Walter sign here 5/13/2012

Dr. M. Todd Walter, Professor **Date**
Cornell University

m.sepehr sign here 5/13/2021

Mahnaz Sepehrmanesh, PhD Student **Date**
Cornell University

sign here 05/13/2021

Anthony Prestigiacomo, Research Scientist **Date**
NYS DEC Finger Lakes Watershed Hub

sign here 05-13-2021

Rose Ann Garry **Date**
Quality Assurance Officer (QAO), NYSDEC Division of Water Standards and Analytical Support Section

This QAPP will be approved by NYSDEC Division of Water, Quality Assurance Officer (QAO) before work will begin on this project.

1.2 Table of Contents

ABSTRACT 2
1.0 PROJECT MANAGEMENT 2
1.1 Title and Approval Page 2
1.2 Table of Contents 3
1.3 Distribution List 3
1.4 Project Organization 4
1.5 Problem Definition/Background 7
1.6 Project/Task Description and Schedule 8
1.7 Quality Objectives and Criteria for Measurement Data and Models 14
1.7.1 Objectives and Project Decisions 16
1.7.2 New Data Measurement Performance Criteria/Existing Data Acceptance Criteria 17
1.8 Special Training Requirements/Certification 17
1.9 Documents and Records 17
1.9.1 QA Project Plan Distribution 18
2.0 DATA GENERATION AND ACQUISITION 18
2.1 Data Acquisition Requirements (Non-Direct Measurements) 18
2.2 Data Management 23
3.0 ASSESSMENT AND OVERSIGHT 24
3.1 Assessments/Oversight and Response Actions 24
4.0 MODEL APPLICATION 24
4.1 Model Setup and Initialization 24
4.2 Model Parameterization (Calibration) 25
4.3 Model Corroboration (Validation and Simulation) 26
4.4 Reconciliation with User Requirements 26
4.5 Reports to Management 27
5.0 REPORTS 27
6.0 REFERENCES 28
APPENDIX A - EPA Council for Regulatory and Environmental Modeling (CREM) Guidelines for Model Development 29
APPENDIX B – QAPP Guidelines for Use of Models for Comparative Purposes 30
APPENDIX C - Useful Project Plan Guidelines for Model Evaluation and Documentation 31
Attachment 1. Description of Watershed Model and Initial Setup Considerations 32
Attachment 2. Documentation of Watershed Model Flow and Chemistry Calibration 32
Attachment 3. Documentation of Watershed Model Flow and Chemistry Validation 34

1.3 Distribution List

The following individuals must receive a copy of the approved QAPP in order to complete their role in this project. Copies will be distributed electronically unless otherwise noted. All personnel will keep a hard copy for reference.

Name	**Title (relative to project)**	**Organization**	**Contact Information**	**Document Type**
Rose Ann Garry	QA Officer	NYSDEC	roseann.garry@dec.ny.gov (518) 402 - 8159	Hardcopy and Electronic
Anthony Prestigiacomo	Overall Project Coordinator	NYS DEC Finger Lakes Watershed Hub	anthony.prestigiacomo@dec.ny.gov (315) 426-7452	Hardcopy and Electronic
Kevin Olvany	Project Manager	Canandaigua Lake Watershed Council	Kevin.olvany@canandaiguanewyork.gov (585) 396-3630	Hardcopy and Electronic
Kim McGarry	Technician	Canandaigua Lake Watershed Council	kmcgarry@canandaiguanewyork.gov	Electronic
Todd Walter	Contractor Project Manager / Lead Modeler	Cornell University Soil and Water Lab	Mtw5@cornell.edu (607) 255-2488	Hardcopy and Electronic
Mahnaz Sepehrmanesh	Modeler	Cornell University Soil and Water Lab	ms3549@cornell.edu	Electronic
Lauren Townley	Project Oversight	NYSDEC	lauren.townley@dec.ny.gov	Electronic[1]
Katherine Hogle	Project Oversight	NYSDOS	katherine.hogle@dos.ny.gov	Electronic[1]

1 Project oversight and grant administration.

1.4 Project Organization

The Canandaigua Lake Watershed Council is responsible for the design and execution of this project. Any changes to this planning document or associative components will receive technical and managerial review by the Project Manager, and the Project Quality Assurance Officer. Review is subject to conformity to expectations. The following organizations will actively participate in this project:

- NYSDEC
- Canandaigua Lake Watershed Council
- Cornell University

New York State Department of Environmental Conservation (NYSDEC)

Rose Ann Garry
Title/Affiliation: Quality Assurance Officer, NYSDEC Division of Water Standards and Analytical Support Section
Address: 625 Broadway, Albany, New York 12233-0001
Phone No.: (518) 402 - 8159
E-mail: roseann.garry@dec.ny.gov
Responsibilities:
- oversee Division of Water Quality Assurance activities, and is not subject to the authority of any persons connected to the project, provide expertise regarding analytical and QA/QC Issues
- review the QA project plan to verify that those elements outlined in the EPA Requirements for QA Project Plans (QA/R-5) are successfully discussed
- review and final approval of project quality assurance plan

Anthony Prestigiacomo
Title/Affiliation: Overall Project Coordinator
Research Scientist, Division of Water, Finger Lakes Watershed Hub
Address: 615 Erie Blvd West, Syracuse, NY, 13204
Phone No.: (315) 426-7452
E-mail: Anthony.Prestigiacomo@dec.ny.gov
Responsibilities:
- Project coordination
- Provide technical review of project work plan
- Review summary presentation
- Approve final modeling report

Canandaigua Lake Watershed Council (CLWC)

Kevin Olvany
Title/Affiliation: Project Manager
Watershed Program Manager, Canandaigua Lake Watershed Council
Address: 205 Saltonstall Street, Canandaigua, NY 14424
Phone No.: (585) 396-3630
E-mail: kevin.olvany@canandaiguanewyork.gov
Responsibilities:
- Will develop the workplan and be the responsible official for overseeing the overall projects and budgets, as well as tasking contractors with work required to complete projects. He/she will communicate project needs to the contractor's project manager.
- Determine project and model strategy, including design, model setup and objectives.
- Will be responsible for developing and maintaining the QA Project Plan. He may provide technical input.
- Determine modeling scenarios for future best management practices
- Responsible for communication with other project partners (NYSDEC, Cornell University)
- Provide assistance on final modeling report

Kim McGarry
Title/Affiliation: Technician
Watershed Program Technician, Canandaigua Lake Watershed Council

Address: 205 Saltonstall Street, Canandaigua, NY 14424
Phone No.: (585) 396-3630
E-mail: kmcgarry@canandaiguanewyork.gov
Responsibilities:

- Will provide assistance on the overall projects and budgets, including workplan review, communication with contractor's project manager and providing technical input on model development and report writing assistance

Cornell University Soil and Water Lab

Dr. M. Todd Walter
Title/Affiliation: Contractor Project Manager/Lead Modeler
Professor, Cornell University, Department of Biological and Environmental Engineering, Soil and Water Laboratory
Address: Cornell University, 232 Riley Robb, Ithaca, NY 14853-5701
Phone No.: (607) 255-2488
E-mail: mtw5@cornell.edu
Responsibilities:

- Will have overall responsibility for assigning appropriate personnel to complete the tasks included in this plan. He will ensure that the project budget is adhered to. He will communicate with the Project Manager on work accomplished in this plan and any problems or deviations that need to be resolved.
- Will oversee all students and staff of the Cornell University Soil and Water Lab that will work on the model.
- Will provide technical input on model calibration/validation procedures
- Will ensure the modeling adheres to this QAPP and will meet the criteria for use in an EPA 9 Element Plan.
- Review and edit final modeling report

Mahnaz Sepehrmanesh
Title/Affiliation: Modeler
PhD Student, Cornell University, Department of Biological and Environmental Engineering, Soil and Water Laboratory
Address: Cornell University, Riley Robb, Ithaca, NY 14853-5701
Phone No.:
E-mail: ms3549@cornell.edu
Responsibilities:

- Complete model while adhering to this QAPP, including set up, calibration and validation
- Data analysis for model coefficient development and conduct model calibration and validation
- Conduct model simulations under the guidance of the Lead Modeler and Project Manager
- Complete draft modeling report

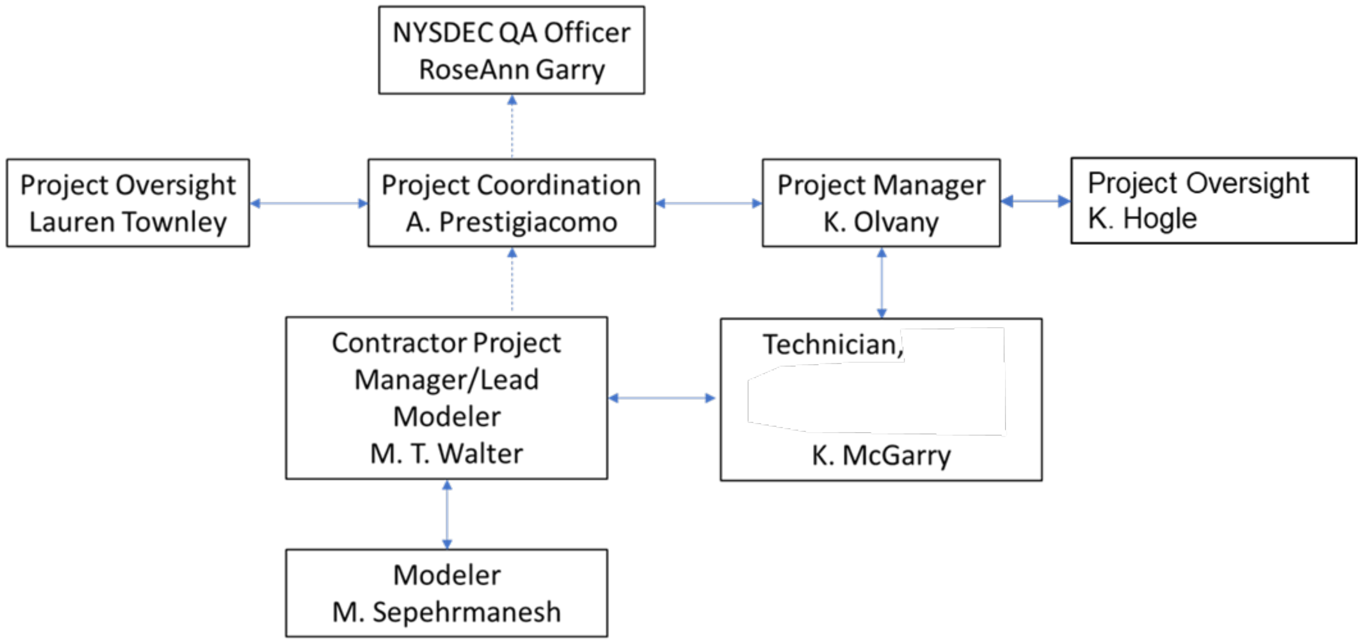

Figure 1. Project Organizational Chart

Changes to planning and project documents will receive technical and management review by the Project Manager. Project planning will involve data users including technical staff and review of this QAPP is subject to conformity to expectations for the project.

1.5 Problem Definition/Background

Canandaigua Lake is a critical asset to our community, providing drinking water, recreational opportunities, a critical tax base, and a high quality of life. Watershed management and planning efforts for the last 20 years have sought to protect the lake from existing and emerging threats to ensure the lake and its watershed will continue to support a vast array of ecosystem services. Non-point source pollution continues to be the major source of concern for the lake. Specifically, nutrient pollution contributes to harmful algal blooms and nuisance weed growth, impacting drinking water quality and recreational opportunities. Modeling will provide information on relative loading of nutrients throughout the watershed and will inform watershed managers on the scale and scope of best management practices needed to reduce nutrient loading to the lake. The results of the model will be utilized as an addendum for the 2014 Comprehensive Update to the Canandaigua Lake Watershed Management Plan to meet the requirements of an EPA Nine Element Plan. Therefore, the goal of the Canandaigua Lake Watershed SWAT Model is to assess nutrient and sediment loading under current conditions and predict potential load reductions from the implementation of best management practices.

The Canandaigua Lake Watershed Council leads lake and watershed monitoring and management efforts. The Council has monitored base flow and storm events on 17 major tributaries for nutrients and suspended sediment for the past 20 years and has conducted segment analysis on numerous tributaries. Monitoring is the best tool for understanding nutrient dynamics within the watershed, because it provides actual concentrations and has greater potential to account for all of the nuances of land use and management, weather, soil conditions, and topography. However, monitoring will never be able to capture the pollutant dynamics from every gully or stream reach over the breadth of storm and melt events that occur in a year given that the watershed is approximately 109,000 acres and has hundreds of miles of tributaries. The

SWAT model will complement monitoring data to further our understanding of nutrient and sediment loading over a longer time period and at a higher geographic resolution. The model will highlight specific subwatersheds that contribute relatively large loads to the lake and help prioritize areas for management (i.e., critical source areas (CSAs)).

The watershed model will be utilized to evaluate the potential benefits from best management practices. First, best management practices will be modeled across the watershed to assess the scale and scope required for discernible nutrient reductions when compared to modeled existing conditions. Implementation is voluntary, so this is just an evaluation of potential benefits for different levels of implementation. Second, we will utilize the model to assess the benefits of specific projects in the future.

The modeling results will be utilized to complete an addendum to the existing watershed management plan to meet the 9 Element Plan criteria. NYS DEC staff analyzed our watershed management plan on June 8, 2017 and determined that modeling was needed to achieve Element B (expected load reductions for solutions identified). Nine Element Plans are becoming a higher priority for funding best management practices, and we need to maximize water quality funding to build resiliency against harmful algal blooms.

1.6 Project/Task Description and Schedule

The overarching project goal is to complete a Soil and Water Assessment Tool (SWAT) watershed model for the Canandaigua Lake watershed to identify sources of nutrient and sediments to the lake. SWAT was chosen primarily because it is widely used for such applications and accepted for 9E and TMDL projects. Also, SWAT estimates a uniquely wide range of important water quality analytes and is flexible enough to capture the region's somewhat unique hydrology. The Cornell Soil and Water Lab has been using this model for several years within central NY, so there is institutional expertise and an established network of modelers from previous projects who can provide support. The SWAT model will be used to estimate nutrient (phosphorus and nitrogen) and sediment inputs to Canandaigua Lake which will be key information for the management of the watershed and Canandaigua Lake water quality, including HABs. Model results will also be used to complete a 9 Element Plan. The project's tasks are described below. Together, these tasks will result in a tested model of sufficient quality that will be focused on quantifying the nutrient and sediment loading to Canandaigua Lake. These tasks are listed below with task details outlined in the subsequent sub-sections.

A. Satisfy quality assurance (QA) requirements through the preparation of an approvable QAPP, and execution of the various QA elements stipulated therein,
B. Data compilation and quality review for initial model setup, model calibration, and model validation and facilitate additional data collection if necessary. This will be done using the Secondary_Data_Matrix_Modeling_NYSDEC2019.xlsx template provided by NYSDEC,
C. Set-up, calibrate, and testing of a SWAT model to achieve the overarching objective (above). The model will have enough spatial resolution for proper and effective watershed management decisions,
D. Development of hydrology and nutrient loading drivers for the model calibration year and selected validation year(s),
E. Conduct model simulations under NYSDEC guidance, and
F. Prepare final modeling report

Project Tasks

This section expands on the tasks, listed above, providing related sub-tasks or components.

A. Satisfy quality assurance (QA) requirements through the preparation of an approvable QAPP (this document), (Spring 2020)
B. Data compilation and quality review (Spring 2020)
    a. All sources of data will be documented and summarized in the final report, including source, process for verification, validation, and final usability assessment of model input, calibration, and validation datasets
    b. Summary will, at a minimum, include: agency responsible for collection, data type (field or laboratory), appropriate metadata (i.e., dates, station number, physical locations, notes, etc.), ELAP and/or NELAC certifications for laboratory analysis, data use as it pertains to the modeling project (e.g., initial setup, calibration, etc.), QAPP and/or project numbers that the data were collected under (if applicable).
    c. Utilize NYSDEC Secondary_Data_Matrix_Modeling_NYSDEC2019.xlsx template
C. Set-up, calibrate, and testing of a SWAT model (Spring 2020)
    a. Soil and Water Assessment Tool, 2012, version 10.21
    b. Utilize existing modeling efforts in the Canandaigua Lake watershed to guide SWAT setup,
    c. Set-up Hydrologic Response Units (HRUs) to accurately reflect watershed characteristics and allow for effective watershed management
    d. Acquire model input information for multiple years and establish appropriate data file
    e. Specify meteorological conditions - air temperature, wind speed and direction, dew point temperature and precipitation.
D. Development of external loading drivers for the model calibration year selected and validation year(s). (TBD based on data availability and quality) (Summer and Fall 2020)
    a. Flow. Estimates will be made using a combination of existing modeling, USGS, CLWC or academic gage data, and point discharge measurements.
    b. Nutrient concentrations. As part of Objective B, nutrient data usability will be determined by all parties involved in this project (Section 1.3) after the approval of this QAPP and completion of the NYSDEC Secondary Data Matrix Modeling_
E. Conduct model simulations under NYSDEC guidance (Summer and Fall 2020), and
    a. A limited number of simulations will be conducted under NYSDEC guidance where various best management practices will be theoretically implemented in SWAT in order to evaluate the resulting loading reductions
F. Prepare final modeling report (Winter 2020)
    a. The report will summarize the development and testing of the sub-models and overall modeling project (see Section 5).

A description of the SWAT model and preliminary approaches to model setup and calibration are provided in the Table below. These are subject to change upon secondary data evaluation and review.

Model Selection	**Description**
Model name, version number, source	Soil and Water Assessment Tool, 2012, version 10.21

<table>
<tr><th>Model Selection</th><th>Description</th></tr>
<tr><td>Preliminary data evaluation and gap analysis</td><td>Existing data for consideration include:
Basin Hydrology:
<u>1. Lake Mass Balance Model</u>
Developed by Watershed Council. Approved by DEC as part of a Water Supply Permit Application. Data are available from 2000 to 2009. Permit ID: 8-3202-00016/00003 - 2011
Daily watershed inflows were developed during this time period using measured data.
Will be used to estimate entire flow budget to Canandaigua Lake to calibrate SWAT model
Represents a wide range of weather and seasonal conditions
The Lake Mass Balance Model utilizes measured data from reputable sources, including: daily lake level as measured using the USGS lake gage that is managed by the City of Canandaigua, precipitation from 5 official gages- data came from the Northeast Regional Climate Center, outlet flow from USGS gage and feeder canal gage, daily water withdrawal from 6 purveyors, and pan evaporation rates from the Northeast Regional Climate Center and converted to lake evaporation based on literature review
<u>Individual Sub-basin Hydrology</u>
1. Stream stage from Deep Run utilizing pressure transducers and velocity measurements collected under the Canandaigua Lake Watershed Tributary Monitoring FLLOWPA QAPP (2019)

2. USGS gage on the West River in the Town of Middlesex in April 2019 (04234398)

3. Instantaneous discharge measurements from NYSDEC 2019 monitoring. Approximately 15 discharge measurements from Naples Creek, Fall Brook, and Sucker Brook.

4. Finger Lakes Community College recently installed a pressure transducer in Fall Brook, which may be used if necessary and if it meets CLWC and DEC's quality requirements. CLWC may take discharge measurements to develop the rating curve.

Total Phosphorus, Nitrate/Nitrite, and Suspended Solids:

<u>Baseflow and storm event water quality monitoring by CLWC</u>
Total phosphorus, nitrate/nitrite and suspended solids data were analyzed at a NYSDOH ELAP certified lab and collected by SUNY Brockport (1997-2001) and CLWC staff (2002-2019)
Methodologies detailed in 2005 and 2009 Watershed Council/FLCC reports and 2014 Watershed Plan. Brockport produced reports in 1999, 2000 and 2001 for the data they collected. Methodologies were detailed in those reports as well.
QAPP developed for FLLOWPA funding in 2015 and updated in 2018. The 2019 accepted QAPP follows the new FLLOWPA template for tributary monitoring and is being updated in 2020 to reflect minor changes to the</td></tr>
</table>

Model Selection	Description
	FLLOWPA template. The QAPPs outline the existing sampling methodologies that have been in place since the beginning of the sampling program. • Report for data - https://docs.wixstatic.com/ugd/a5c0cd_055cc8bbc2d1404db6611203d86438d9.pdf • Monitored 17 major tributaries that cover approximately 70% of the watershed and are well mapped during storm events for total phosphorus, TSS and nitrate/nitrite (majority of samples from 1997 to 2017) - most storms were sampled from 2010 and earlier • Completed 12 baseline samples in 2007/2008 on those same 17 streams • Final data usability will be assessed using DEC Secondary Matrix and Data Usability Report Baseflow and storm event water quality monitoring by NYS DEC • NYSDEC Rapid Assessment Surveys in 2019 on the West River, Sucker Brook, Fall Brook, and Naples Creek Segment analysis monitoring by CLWC • Deep Run and Fall Brook – Samples collected from 2016 -2018 during 5 storm events. Approximately 10 segments per stream were sampled. All data were analyzed at a NYSDOH ELAP certified lab, were collected by CLWC staff and was covered by FLLOWPA funding QAPP. • Sucker Brook - Sampled at 23 locations from Sept. 2008 – July 2010 (N=7 sampling events). Analytes were TP, TKN, NOx, TSS. • Eelpot Creek - Sampled at 11 locations from Sept. 2006 – Feb. 2009 (N=7 sampling events). Analytes were TP, NOx, TSS.

New data collection if existing data is insufficient or outdated.	New data to be collected and/or acquired includes:
	• Extension of the Lake Mass Balance Model
	  o Will utilize the same approach to increase the record to include 2009 to 2020 for model validation
	• Continuation of stream gages by USGS and CLWC
	• Continuation of base flow and storm event monitoring by CLWC
	  o The goal is to collect samples from 5 baseflow and 4 storm events at 5 locations in 2020, however, the number and location of samples will depend on weather conditions and runoff patterns
	  o Utilizes a NYSDOH ELAP certified lab and is covered by the Canandaigua Lake Watershed Tributary Monitoring QAPP (accepted FLLOWPA template 2019 with minor updates in 2020)
	• Continuation of NYSDEC Rapid Assessment Surveys
	
	After the Secondary Evaluation Matrix is complete, project partners will decide if additional hydrological or nutrient data is required for calibration/validation.

Setup Timeframe	More information on model calibration and validation is detailed in Section 4. Model Setup and Calibration – Rainfall-Runoff Parameters: 2000-2008 daily data from a DEC-approved Lake Mass Balance Model, as part of a Water Supply Permit Application, will be used to calibrate the SWAT model. These

<table>
<tr><th>Model Selection</th><th>Description</th></tr>
<tr><td></td><td>
data span an acceptable time span to capture weather variability and allows for a model warm up period. The 2000 data will be used for model warm up. The 2001 to 2008 data will be used for model calibration of rainfall-runoff parameters.
Model Validation – Rainfall-Runoff Parameters:
The expanded lake mass balance model for 2009 to 2020 will be used for validation. This data has a much longer time period than our direct stream discharge measurements, which allows us to capture more year to year variability for the validation process. We will use the direct stream stage and/or discharge data as an additional, secondary validation step to confirm the mass balance model methodology provided acceptable model calibration and validation. For this second validation step, we will use discharge from the USGS gage in the West River from April 2019 to 2020.
Model Setup and Calibration – Nutrients and Suspended Solids:
Total suspended solids, total phosphorus, and nitrate/nitrite from the CLWC tributary dataset will be used for model set up. Approximately 70% of the samples from this dataset will be used for initial model set up, where the goal is to reduce the initial (and wide) ranges for parameters that control water quality constituents within SWAT, but not to identify the optimal parameter values of the model. That is, the CLWC data will only be used to reduce the initial uncertainty of SWAT parameters and identify behavioral parameter values that lead to plausible model simulations (i.e. rule out ranges of SWAT parameter that perform very poorly with respect to CLWC data). Then, model calibration will be run on the model using the following data: 1) NYS DEC Rapid Assessment Surveys from 4 locations from 2019 and 2) samples collected through the CLWC monitoring program in 2020. The calibration data will meet all of the QA/QC measures required by DEC. The calibration will further refine the behavioral parameter ranges identified in model set up and tailor the final parameter values to the DEC-approved data. If necessary, a final calibration step will utilize both datasets and the identified parameter ranges.
Model Validation – Nutrients and Suspended Solids:
The remaining 30% of the data from the CLWC monitoring dataset (from before 2020) will be used for model validation for total phosphorus, suspended solids and nitrate/nitrite. The DEC 2020 data will also be used in validation.
Summary:
<table>
<tr><th></th><th>Calibration</th><th>Validation</th></tr>
<tr><td>Discharge</td><td>Inflow to the lake (2000-2008)</td><td>Inflow to the lake (2009-2020)
USGS Gage at West River (2019-2020)</td></tr>
<tr><td>Water Quality</td><td>70% of CLWC data at 17 tributaries (2001-2007) - Model Set Up
DEC data at 4 sampling location (2019) and DEC-</td><td>Remaining 30% of CLWC data at 17 tributaries (2008-2016)
DEC data at 4 sampling locations (2020)</td></tr>
</table>
</td></tr>
</table>

Model Selection	Description
	approved data that will be collected by CLWC (2020) - Calibration
Basin characteristics	The 2014 Comprehensive Update to the Canandaigua Lake Watershed Management Plan provides a summary of the watershed characteristics. The plan can be found at: https://docs.wixstatic.com/ugd/a5c0cd_a3ab4bacf88f4f1898dd38435c60e50c.pdf. Briefly, the Canandaigua Lake watershed is approximately 109,000 acres, and the soils, slopes and land cover vary throughout this large geographic area. The far majority of soils fall into the C or D hydrologic soil groups and are therefore prone to runoff. The topography ranges from steep cliffs to very flat areas. The watershed contains a mixture of forest, agriculture, densely populated areas and rural residential areas. The SWAT model will delineate the watershed sub-basins based on DEM topography and with constraints placed at water quality sampling locations.
Major streams	The Canandaigua Lake Watershed is broken into 34 major subwatersheds, including both stream drainage basins and direct drainage basins (areas that encompass multiple gullies that outlet directly into the lake). Seventeen of these sub-watersheds are monitored as part of the long term monitoring program and encompass more than 70% of the watershed area. The SWAT model will break down the Canandaigua Lake watershed into more than 34 subwatersheds. However, the model sub-basins will incorporate the 17 major subwatersheds from the monitoring program to allow water quality data to be used in model calibration. The Canandaigua Lake Watershed is a HUC 10 watershed (Canandaigua Lake - 0414020102). The National Watershed Boundary dataset breaks down the Canandaigua Lake Watershed into 5 HUC 12 subwatersheds, including: • Sucker Brook – Canandaigua Lake (041402010401) • Deep Run – Canandaigua Lake (041402010205) • West River (041402010203) • Bristol Springs – Canandaigua Lake (041402010204) • Naples Creek (041402010202)
Sub-basins	It is estimated that the SWAT model will utilize approximately 142 sub-basins. The goal is to delineate sub-basins that correspond to approximately 1000 HRUs across the entire watershed and have on average 1 to 10 HRUs per sub-basin. This level of modeling resolution balances the need for detailed model results for planning and management purposes with the computing requirements needed for additional sub-basins and HRUs.

Model Selection	**Description**
	Sub-basin delineation will incorporate the 17 subwatersheds utilized in the Canandaigua Lake tributary monitoring program. This will allow for easier calibration of water quality parameters.
Meteorology	All meteorological data will be retrieved from the National Climate Data Center land-based station archive. CANANDAIGUA 3 S station will be used for air temperature. For the SWAT model, 4 weather stations will be used, including: Canandaigua 3 S, Dansville, Hemlock, and Geneva. The Mass Balance Model (used in calibration and validation) utilizes an average precipitation from 5 stations, including Canandaigua 3 S, Hemlock, Geneva Research Farm, Bristol Harbor, and Dansville. There are 4 other stations, CANANDAIGUA 2.6 SSW, BRISTOL HARBOUR, BRISTOL SPRINGS, and GANNETT HILL, close by that can be used as the model input if additional data is needed.
+Land uses	The model will utilize the 2016 National Land Cover Dataset. However, additional land cover data is available to utilize in the model, if necessary, to achieve model quality control results, including: - 2011 Canandaigua Lake Watershed Land Cover Dataset (NLCD2011) - Local highly detailed 2004 land cover dataset for the watershed - Local highly detailed 2018 land cover dataset for the watershed
Slope classes	5 slope categories will be used in model set up: 0-1%, 1-5%, 5-10%, 10-20%, >20%. Fewer categories cannot represent the watershed appropriately and more than 5 classes will not be practical in SWAT modelling.
Manure spreading assumptions and schedules	We will use general assumptions for farming practices across the Finger Lakes Region. As a baseline, manure spreading assumptions and schedules will be based on Menzies Pluer et al. 2019. This study worked with Cornell Pro-Dairy to develop generalized manure spreading amounts and schedules for the Fall Creek subwatershed of Cayuga Lake. These spreading amounts and schedules will be modified with local information from our Soil and Water Conservation Districts and rates utilized in other Finger Lakes SWAT models.
Urban/residential assumptions, Other	We will utilize general assumptions for residential practices across the Finger Lakes Region. Residential wastewater will be lumped together at the sub-basin level.

Project Deliverables

SWAT will be applied to the entire ~109,000 acre watershed for Canandaigua Lake. This modeling project will include the following products:

- Calibrated and validated SWAT 2012 model for the Canandaigua Lake watershed

- Stream discharge on a daily time step for existing conditions for each sub basin
- Estimates of concentration and loading of suspended sediment, nitrogen, and phosphorus at a daily time step for existing conditions for each sub basin
- Stream flow and concentration and loading of sediment, nitrogen and phosphorus on a daily time step under various best management practice scenarios

1.7 Quality Objectives and Criteria for Measurement Data and Models

Streamflow, meteorology, physical parameters (land use, slope, etc.) and field parameters do not require analysis by a NYSDOH ELAP certified laboratory. The initial construction of the model (model setup and testing) may occur with appropriately vetted data, however, all accompanying documentation will include language clearly specifying its status as draft pending final calibration using data that was analyzed by a NYSDOH ELAP certified laboratory. To be accepted as complete, the SWAT model will be calibrated and validated using chemistry data that were analyzed by a NYSDOH ELAP certified laboratory.

The overall project quality assurance objective is to setup, calibrate, and validate a watershed hydrology and water quality model that can assist in the development of a 9 Element Plan Addendum to the 2014 Comprehensive Update to the Canandaigua Lake Watershed Management Plan. Models are only a representation of reality, as it is impossible to account for all of the nuances of land cover, artificial and natural drainage patterns, and soil conditions. Understanding these limitations, the objective of this modeling project are to 1) assess relative pollutant loading to Canandaigua Lake from subwatersheds to highlight and prioritize areas for management, 2) gain an understanding of the scope and scale of best management practices required to reduce nutrient and sediment loading to the lake, and 3) meet the criteria for a 9 Element Plan.

For data analysis and modeling, the Data Quality Objectives (DQOs) are qualitative and quantitative statements that:

- clarify the intended use of data,
- define the type of data needed to support a decision,
- identify the conditions of collecting the data

The data quality objectives for input data and model output outlined below reflect the overall project objectives. These objectives will be achieved by: (1) using existing literature values or ranges for model setup, (2) experience of the modelers acquired from developing SWAT models from the Finger Lakes region, and (3) by using established metrics of model performance to complete model development.

The DQOs for input data for the model are:

- Data quality for key model inputs (e.g., meteorological, hydrological, external constituent loads) will be representative to support specification of representative driving conditions within the watershed model.
- Data quality for model variable(s) will be representative to provide a robust test of model performance.
- Data quality for variables will be representative seasonally and for multiple years

While the watershed modeling group at Cornell strives to create and utilize models that require little direct calibration, the SWAT model must be calibrated so that the output for stream flow and pollutant concentrations match existing records. The SWAT model is robust and is regularly used across New York State to assess pollutant loading to lakes. However, there are limitations in representing the true physical and biological processes in a watershed. These limitations are well-understood in the modeling community and will be summarized in the final report.

The DQOs for model output (e.g., predictions, simulations) include both qualitative and quantitative perspectives.

- Output will be consistent with well accepted mass balance constraints
- Patterns of output in time and space will be consistent with the topographic and biogeochemical features of the watershed
- Appropriate responses of the model to reasonable variations in model inputs
- Performance, according to metrics widely reported in similar modeling initiatives, is consistent with levels reported for other similar efforts

In watershed modeling, it is most important to obtain a good calibration of the streamflow, because it has a much larger impact on nutrient and sediment loading than changes in concentrations. We will run a sensitivity analysis to determine which model parameters have the largest impact on calibration.

To assess model performance for streamflow, our primary objective function will be the Nash-Suttcliffe Efficiency (NSE). The NSE assesses how well the model predicts measured data, as compared to the mean of the measured data. A value of 1 equates to a perfect fit between model output and observed data, while a negative value indicates the overall mean better predicts measured data than the model. Ideally, we would like to achieve a Nash-Sutcliffe Efficiency (NSE) greater than 0.36 for modeling at the daily time step for discharge, a threshold commonly agreed to indicate satisfactory calibration/validation (Tang et al. 2012).

One unique aspect of this specific project is that there are very few tributary discharge measurements so we will calibrate SWAT to an overall watershed water budget developed by the Watershed Council and approved by DEC as part of a Water Supply Permit Application (Permit ID: 8-3202-00016/00003 - 2011). There is substantial reduced precision in these calibration data because, for example, the lake water level, which was used to approximate changes in internal storage, is influenced by non-water budget factors like wind. Thus, we acknowledge that we may have difficulty achieving our target NSE value.

The model will also be calibrated for total suspended solids (TSS), total phosphorus (TP), and nitrate (N). Based on our previous modeling experiences and the literature, we expect the NSE for water quality parameters to be lower than the NSE for modeled flow (e.g., Knighton et al. 2017). Our target NSE values are based on a SWAT synthesis by Chaubey and Migliaccio (2021) and the Cornell Soil and Water Lab's most recently published SWAT study by Menzies et al. (2019). Based these, our target NSE values relative to our flow NSE values are: TSS NSE = 0.71 Flow NSE, TP NSE = 0.70 Flow NSE, and N = 0.60 Flow NSE – Note: we removed all published NSE values that were negative in developing these thresholds. Using our flow NSE = 0.36, the corresponding pollutant NSE values would be: TSS NSE = 0.26, TP NSE = 0.25, and N NSE = 0.22.

All software to be used for this project (SWAT and SWAT_CUP) are developed, maintained and version controlled by external organizations. We will not be performing software-update QA/QC as part of this project.

1.7.1 Objectives and Project Decisions

As stated in Section 1.6, the objectives of this modeling project are to 1) assess relative pollutant loading to Canandaigua Lake from subwatersheds to highlight and prioritize areas for management, 2) gain an understanding of the scope and scale of best management practices required to reduce nutrient and sediment loading to the lake, and 3) meet the criteria for a 9 Element Plan. The quality objectives driving model development reflect the overall project objectives.

1.7.2 New Data Measurement Performance Criteria/Existing Data Acceptance Criteria

As discussed in detail in Section 2.1, all data utilized in this project are considered non-direct measurements because they were collected under previous projects, under separate QAPPs or by a governmental entity that conducts its own quality control. The DEC Secondary Data Matrix outlines specific criteria used to determine if secondary input data meets data quality objectives. This includes information on methodology, documentation, QA/QC procedures and documentation, and an overall assessment of data quality. The DEC, Cornell and Canandaigua Lake Watershed Council will jointly determine the usability of evaluated data sets.

1.8 Special Training Requirements/Certification

No further training is needed by CLWC or Cornell modeling staff. Dr. Walter and his lab have highly specialized expertise in their respective modeling and data analysis tasks. They have completed the SWAT model for other New York State lakes. The staff has been involved in watershed data analysis and SWAT model development and calibration for many years.

1.9 Documents and Records

The data analysis and modeling teams will be responsible for documenting analyses, model development, testing, and findings, data files and software. Each modeling staff member will be responsible for documenting all assumptions and supporting analyses. Progress will be documented as part of the technical meetings between technical staff and Project Manager. Record keeping for each step of the modeling process will consist of various types of information, in the form of progress presentations and multiple forms of graphics. Examples are given below:

Documentation for the SWAT model will include, at a minimum, the following:

- model assumptions
- parameters and rate constants and their source
- land use and management practice assumptions (e.g., manure management within CAFO and AFO-sized farms)
- conceptual model designs and evolution (for each model tested, a short description of what was tested and why it was not chosen)
- input used, their sources, and any action to compensate for missing data
- setup input and output files
- calibration and verification files (predicted vs. observed)
- model assessment values (e.g. Nash-Suttcliffe Efficiency)

All files from the modeling study will be maintained for auditing purposes and post-project reuse, including

- source code and executable code
- output from model runs
- interpretation of output
- setup and testing procedures and results
- Input GIS layers and datasets

No modifications of code are expected for this project. However, if any modifications are necessary, all modifications of the source code will be tested and documented in internal memos. Such modifications would be tested throughout the setup process by experienced modelers reviewing the model output to determine that it demonstrates expected behavior and responds in the expected manner for each model run.

At completion of the model, all project records, documents, and files will be transmitted to the Canandaigua Lake Watershed Council. Final reports will be distributed to the Department of Environmental Conservation and Department of State and will be stored by the Canandaigua Lake Watershed Council. The final report will be submitted in electronic format. All electronic records discussed in this section will be stored on a secure server, write protected, and backed up for a period of five years beyond completion of the project.

1.9.1 QA Project Plan Distribution

Any changes in this QAPP during the study period will be documented and noted in the revision table at the beginning of this document. After approval by the appropriate persons, the revised QAPP will be sent to each person listed on the distribution list. This QAPP is a controlled document and will be managed by the Project Manager. The QAPP will be reviewed as needed.

2.0 DATA GENERATION AND ACQUISITION

2.1 Data Acquisition Requirements (Non-Direct Measurements)

The water quality component of SWAT will only be calibrated and validated using chemistry data that was analyzed by a NYSDOH ELAP certified laboratory.

The SWAT model requires a variety of spatial, weather, land management, and field data for the setup, calibration and validation process. All of the data utilized in this model is considered secondary, as it was collected for a separate project, was collected by a separate agency, or is covered under a separate QAPP. The Lake Mass Balance Model will be used for model setup, calibration and validation, with the model setup/calibration period from 2000 to 2008, and the model validation from 2009 to 2020. The model will utilize 70% of the CLWC tributary monitoring dataset for model set up, with calibration using the DEC Rapid Assessment Survey from 2019 and the CLWC monitoring data from 2020. Calibration data meets DEC QA/QC standards. If necessary, a final calibration step will utilize both datasets and the identified parameter ranges. The remaining 30% of the CLWC monitoring data will be used for model validation, along with the DEC Rapid Assessment Survey from 2020. See Section 4.0 for the full methodology.

All of the secondary data will be assessed by the Canandaigua Lake Watershed Council, Cornell University, and NYS DEC using the DEC Secondary Data Matrix. This matrix covers the source, analytical metric and description, data history and location, quality assessment/quality control documentation, and a formal assessment based on these criteria. Only data that is deemed to be acceptable through this process will be utilized for model setup, calibration and validation. All input data and associated project and quality objectives are summarized below.

The following are non-direct measurements required for the SWAT model setup in the Canandaigua Lake Watershed:

Type of Input Data	Use	Data used in model	Additional data available if needed	Source
Land surface elevation model	establish elevation of HRUs and slope	USGS DEM	LiDAR data provided by	USGS

			Canandaigua Lake Watershed Council	
Land cover	Model set up	NLCD 2016	Local land use maps provided by Canandaigua Lake Watershed Council for 2004 and 2018	Multi-Resolution Land Characteristics Consortium (federal agencies)
Soil type	Model set up	STATSGO - Preloaded into SWAT model		
Dairy Manure Application Rates	Water chemistry calibration	Generalized assumptions for the Finger Lakes Region utilized in other SWAT models using Menzies Pluer et al. 2019 as a baseline and updated with local knowledge from Soil and Water Conservation Districts and rates utilized in other Finger Lakes SWAT models.		Menzies Pluer et al. 2019
Fertilizer	Water chemistry calibration	Generalized assumptions for the Finger Lakes Region utilized in other SWAT models		
Air temperature (min and max)	Model set up - hydrology	NCDC CANANDAIGUA 3 S station	Numerous other stations available - CANANDAIGUA 2.6 SSW, BRISTOL HARBOUR, BRISTOL SPRINGS, and GANNETT HILL	NCDC
Precipitation	Model set up - hydrology	4 Stations - Canandaigua 3 S, Hemlock, Geneva and Dansville		NCDC

The following procedures will be used in the acquisition and use evaluation of secondary data in this modeling project.

A literature review and data search will be conducted to review and locate potential sources of data for use in model development/setup. Documented sources of data will include published peer-reviewed manuscripts, published reports, or from documented academic research. The data will be assembled in a matrix of all available information and data sets according to the NYSDEC Secondary Data Evaluation for Modeling Matrix Template (NYSDEC 2019). The first step is to define and describe the data of interest, including:

1. Analytical metrics of interest and their description
   - Parameter and matrix (e.g., nitrate, water sample)
   - Laboratory/Field
   - Measurement Type
   - Describe Data Type (if Misc)
   - Analysis Method
   - Laboratory Name/ID

The above must be known and documented for any data set to be considered for use in this project. These categories are key to building the foundation upon which to verify, validate, and assess the soundness, applicability and utility of secondary data for this project (USEPA 2003a).

In addition:

1. The water quality component of the model will only be calibrated and validated using chemistry data that was analyzed by a NYSDOH ELAP certified laboratory. The name of the laboratory used to analyze the data must be provided with the NYSDOH ELAP accreditation number.
2. The methods used to measure the parameter of interest must be recognized by the EPA (40 CFR-Part 136), NYSDOH, or NYSDEC as official field or laboratory methods to be considered for as secondary data for any NYSDEC project (https://www.epa.gov/cwamethods).

The second step is to describe the data's history and location of collection. This is critical to ensure that the data is consistent with the current project needs. The following categories will be documented for all secondary data under consideration:

2. Data History and Location
   - Waterbody/Watershed
   - WI/PWL Segment ID
   - Site Name and Description
   - Latitude, Longitude
   - Year(s)
   - Program Description and Original Data Use
   - Data Source
   - Funding Source

The above must be known and documented for any data set to be considered for use in this project. These categories are key to building the foundation upon which to and assess applicability, utility, traceability and bias of secondary data for this project (USEPA, 2003b). In addition:

1. The physical location of the data must be verifiable for consideration of use in this project; including system and site name, GPS coordinates or a physical description or address sufficient to verify the data's source, and the NYSDEC Waterbody Inventory/Priority Water Body ID number and URL link. Also, the dates and times of collection, original program description and original data use will be documented to determine usability for the current project.

2. If the original collection location and/or original data use is inconsistent with this project, the data will not be used. As an example, if the data was collected near a SPDES discharge outfall that is unrepresentative of the waterbody being modeled, this data will be excluded from use as it is unrepresentative of the waterbody.
3. The organization responsible for collecting the data and the funding source must be known and verified.

3. Quality Assessment and Quality Control Documentation

It is expected that the data compiled will be in various states of QA/QC documentation and acceptability. Listed below are the items that will be reviewed as part of this project's QA/QC evaluation:

- QAPP or DUAR
- Quality Assessment/ Quality Control Samples
- Field Notes
- Link to Reports

As a critical component of any data being considered, the QA/QC review will be described as part of the Secondary Data Evaluation for Modeling Matrix Template (NYSDEC, 2019) and the lack of sufficient QA/QC documentation will influence final data usability. Reference or hyperlinks to the original data and reports must be included in the final assembled data matrix to allow for traceability.

If a data set lacks a full QC evaluation, water quality data may be used for model setup, testing, and validation if it can be determined that the data is of sufficient quality through graphical and statistical analysis compared to data of known quality. Specifically, the DEC 2019-2020 and the CWLC 2020 water quality datasets meet all of the quality control criteria for DEC through approved QAPPs and will serve as the accepted datasets for comparison. The 2001 to 2018 CLWC water quality samples were run at a NYSDOH ELAP certified lab and have all of the documentation on location, collector, and methodology. However, this dataset lacked field/equipment blanks and duplicates. Therefore, we will need to validate this dataset for use in the model for model testing, set up and validation. Specifically, we will conduct the following to validate the dataset:

- Equipment blanks and duplicates collected by CLWC in 2020 under an approved QAPP meets quality criteria. The same person collected the samples using the same methodology as the 2001 to 2018 dataset. This result provides some confidence that the older dataset would have similar quality to that of the contemporary program.
- We will statistically compare baseflow water quality samples between the two datasets. Monthly baseflow samples were collected by CLWC in 2007 and 2008, but lacked the duplicates and blanks required by DEC. Subsequent baseflow water quality samples were collected by CLWC and DEC in 2019 and 2020 that meet the quality control requirements outlined in DEC-approved QAPPs. The comparison will be conducted for 5 subwatersheds using the Mann Whitney U Test to test for statistically significant differences in the median concentrations on each. The older dataset will be considered usable if it is statistically similar to the dataset collected under the approved QAPP. A comparison of water quality data during baseflow conditions is important, as it substantially reduces the inherent variability of rainfall distribution in the watershed, timing of sample collection, etc, that can impact storm and melt event sample concentrations.
- Due to the inherent variability found during storm event sampling, we will evaluate the storm/melt event datasets through a qualitative, visual assessment of concentration verses flow plots for each parameter. We will assess whether the 2001 to 2018 CLWC dataset had consistent characteristics to the 2020 CLWC and 2019-2020 DEC datasets by plotting concentrations versus the simulated flow. We will look to see if these two datasets provide visually consistent characteristics in terms of range of parameter concentrations at different levels of stream flow. We will compare data from

all of the subwatersheds and then will also focus on individual subwatersheds that were included in both datasets. The older dataset will be considered usable if it is qualitatively similar to the dataset collected under the approved QAPP. The 2001 to 2018 dataset has significantly more data points across a greater set of conditions and more subwatersheds, so we expect some variability between the datasets.

Final usability will be determined by Cornell, Canandaigua Lake Watershed Council, and NYSDEC and will be documented in the final modeling report.

4. Data Verification Summary

The Secondary Data Evaluation for Modeling Matrix Template evaluates each of the categories below that reflect the level of data verification (USACE, 2003).

1. Overall Quality of and Level of Detail in Report(s)
- Manuscripts, published reports, agency name, researcher or academic institution
- Public or private
2. Formal Documentation of Procedures
- Standard operating procedures, QAPPs, etc.
- Equipment used, including probe type or technique
- Laboratory method documented
- Calibration records

3. Analytical Methods Used and Detection Limits Achieved (https://www.epa.gov/cwamethods).

5. Data Validation Summary
The Secondary Data Evaluation for Modeling Matrix Template evaluates each of the categories below that reflect the level of data validation (USACE, 2003).

1. Field Calibration Records/Availability
2. Data Review, Validation, and Quality Assurance
3. Assessment of Data Quality Indicators

The assessment factors as presented above are intended to apply to individual parameters. This is considered a "weight-of-evidence" approach which will consider all relevant information in an integrative assessment which will be used to determine final data usability.

Cornell and CLWC, in consultation with NYSDEC, will apply careful judgment when evaluating secondary data for quality and relevance in the context of model development and testing. The use of data with significant uncertainty may have to be weighed against the cost of using default assumptions or committing additional resources to generating new information.

Additional secondary data evaluation criteria

Soundness	The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application.
Applicability and Utility	The extent to which the information is relevant for the intended use.

Clarity and Completeness	The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented.
Uncertainty and Variability	The extent to which the variability and uncertainty (quantitative and qualitative) in the information or in the procedures, measures, methods or models are evaluated and characterized.
Evaluation and Review	The extent of independent verification, validation and peer review of the information or of the procedures, measures, methods or models.
Traceability	The ability to verify the history, location, or application of an item by means of documented recorded identification
Bias	The action of supporting or opposing a particular conclusion in an unfair way, because of allowing personal opinion to influence judgment

2.2 Data Management

Data management will be completed by Cornell's Soil and Water Lab. The modelers will record the original source of input files and any alterations completed to these input files for use in the model. All input data will be checked to ensure the units are compatible and for consistency in how the date is determined on temporal data (e.g. corrections if rainfall is recorded for the previous 24 hours).

Data Management and Hardware/Software Configuration

- Data Management: Data pre- and post-processing will be performed within the Matlab and R scripting languages to minimize manual data entry error.
- Hardware/Software Configuration: The following is a list of the software to be used on this project:
    - Matlab R2014a
    - R Scripting Language
    - RStudio
    - Microsoft Excel
    - Microsoft Word
    - Notepad++
    - Soil and Water Assessment Tool (SWAT) v2012
    - SWAT-CUP
- All data processed in this software will be converted to an excel or text file, so it can be reviewed without the need of specialized software beyond Microsoft Office or GIS.

Hardware/Software Assessments: No code testing will be performed. All software to be used is developed, controlled, and maintained by external organizations.

Hardware/Software Configuration Tests: No code testing will be performed. All software to be used is developed, controlled, and maintained by external organizations.

Records of hard copy data will be maintained by CLWC staff. Electronic data will be stored on a secured computer accessible to CLWC staff only. Electronic backups of the data will be maintained. The data will be formatted into the appropriate input files for analysis and modeling. The original data, as well as the input files and QA/QC graphs, will be maintained by CLWC in hardcopy and electronic format to document the data management process. All data will be maintained for at least 5 years beyond completion of the project. Kevin Olvany will be responsible for overall data management as discussed in Section 1.4 and Kim McGarry will be providing on-going assistance.

3.0 ASSESSMENT AND OVERSIGHT

3.1 Assessments/Oversight and Response Actions

All modeling and pre- and post-processing will be completed by Mahnaz Sepehrmanesh of Cornell University. Project oversight will be provided by Dr. Todd Walter (Cornell University). Modeling progress will be documented weekly in a short email from Cornell University to the Project Manager. A more detailed review of the status of the model will be conducted monthly between Cornell and the Project Manager.

Model performance assessments will be made frequently by Cornell during model development. Model input data will be graphed and reviewed to ensure the data falls within expected ranges/patterns and is formatted appropriately for the model. Model output will be compared to observed and proxy data and will be reviewed to ensure it makes sense and is consistent with historic data. Periodic review of model performance criteria will be conducted, including the Nash-Suttcliffe Efficiency. If model performance falls below the stated criteria, Cornell and the Canandaigua Lake Watershed Council will work with the NYS DEC to select the best course of corrective action.

The NYS DEC will be periodically updated on the modeling progress. Peer review of the model will be conducted by Tony Prestigiacomo of NYS DEC to ensure that the model is technically adequate, properly documented and meets established quality requirements through the review of assumptions, calculations, extrapolations, methodology, and acceptance criteria.

4.0 MODEL APPLICATION

This modeling endeavor is unique and likely to be increasingly common. Specifically, there are very limited tributary discharge data and these data are critical to calibrating watershed models. We are proposing this approach that provides for daily watershed discharge based on relatively common precipitation, lake level, water purveyor and pan evaporation data (Lake Mass Balance Model approved by DEC as part of the Water Supply Permit). Here we use the inferred data to setup, calibrate and validate SWAT.

Our approach is in contrast to other models that often calibrate to a single long-term dataset from a USGS gage. Modeling a large watershed is more complex and will inherently have more error. However, our novel approach will allow us to capture the basic signature and peaks of flow, TSS and nutrients within tributaries without the need to wait years to collect additional stream flow data. This approach could be applied to other watersheds throughout the region that lack long-term flow data from multiple tributaries but do have long-term data on other hydrologic parameters such as lake level.

We will set up and calibrate stream flow and water quality parameters simultaneously so that the parameters that effect both flow and water quality do not overly emphasize a good fit for one at the expense of another. In addition, our water quality data is at the sub-basin level, so running these simultaneously helps ensure we are not overly generalizing flow parameters and that we are capturing sub-basin processes.

4.1 Model Setup and Initialization

This project will model the entire Canandaigua Lake watershed using the SWAT 2012 version 10.21 model. Model setup is outlined in Section 1.6, including model input data sources, slope classifications, and numbers of sub-basins and HRUs. For water quality parameters, we will utilize manure and fertilizer management practices established as part of the Cayuga Lake TMDL processes (e.g., Knighton et al. 2017, Pluer et al. 2019), along with rates utilized in the other Finger Lakes SWAT models and local knowledge, for input into the SWAT model. We will utilize the default settings from SWAT for other land use inputs.

For model setup, we will run the flow and water quality parameters on the CLWC data from 2000 to 2008 to determine the parameter range. We will use the discharge from the Mass Balance Model from 2000 to 2008. The year 2000 will act as the model warm up period, and the 2001 to 2008 data will be the model setup period. The Canandaigua Lake Watershed Council has monitored 17 major tributaries, which account for over 70% of the watershed area, for water quality during storm and baseflow events. We will run the model setup using 70% of the data (from 2001 to 2007) from the CLWC monitoring dataset to reduce the initial uncertainty of SWAT parameters and identify behavioral parameter values that lead to plausible model simulations (i.e. rule out ranges of SWAT parameters that perform very poorly with respect to the CLWC data). Because SWAT needs nutrient data in terms of loads, we will convert the nutrient concentrations to loads by normalizing the inflows from the lake mass balance model for sub-basin area.

4.2 Model Parameterization (Calibration)

We will run the model calibration for the water quality parameters using the 2019 DEC data and the 2020 CLWC data. The parameters will be constrained by the parameter ranges from the model setup. This calibration run will provide a parameter range with the fully approved data. Because SWAT needs nutrient data in terms of loads, we will convert the nutrient concentrations to loads by normalizing the inflows from the lake mass balance model for sub-basin area. If the results are not satisfactory after this calibration, we will run another calibration, constraining the parameter ranges using the average of the parameter ranges from the set up and calibration runs, and utilizing the entire dataset in the calibration (2001 to 2007 CLWC, 2019 DEC and 2020 CLWC data).

SWAT will be calibrated using SWAT-CUP and will generally follow the guidance provided by Abbaspour et al., 2004, 2005, and 2007. This is a standard approach to SWAT calibration. It includes a sensitivity analysis. Ideally, we would like to achieve a Nash-Sutcliffe Efficiency (NSE) greater than 0.36, a threshold commonly agreed to indicate satisfactory calibration/validation at the daily timestep for flow (e.g., Tang et al. 2012). A paired daily time series will be graphed of the SWAT model output and the Mass Balance Model to visually inspect model performance. For pollutants, our target NSE values relative to our flow NSE values are: TSS NSE = 0.71 Flow NSE, TP NSE = 0.70 Flow NSE, and N = 0.60 Flow NSE. Using our flow NSE = 0.36, the corresponding pollutant NSE values would be: TSS NSE = 0.26, TP NSE = 0.25, and N NSE = 0.22.

We will also compare calibrated parameters to those that were used on Cayuga and Owasco Lakes for TMDL and 9E plans, respectively. Having modeled several watersheds, we have found that the model parameters have not varied much regionally, so we anticipate Canandaigua Lake's watershed parameters should be reasonably similar. While we have no specific thresholds beyond the NSE, these other approaches to validation are important to report given this novel situation (having limited direct discharge measurements).

See Attachment 2 for more details

4.3 Model Corroboration (Validation and Simulation)

Model Validation

To validate the model, we will assess the model performance for discharge during an independent 10-year time period using the parameters from the calibration. The Lake Mass Balance Model from 2009 to 2020 will act as the primary validation data. This dataset has a much longer time period than any measured stream discharge, which allows us to capture more year to year variability during the validation process. The model validation performance assessment will focus on achieving satisfactory NSE values. Model output and the Lake Mass Balance Model will be graphed together on a paired daily time series to visually assess model performance. If the NSE is below our threshold, model calibration will be modified based on data availability and the validation process will be repeated with updated model parameters.

Given the unique methodology of calibrating to the Mass Balance Model, we will then run a second validation analysis (a correlation analysis) on the West River sub-basin to ensure the model also works at the sub-basin level. This second analysis will utilize discharge from the USGS West River gage from April 2019 to 2020.

For water quality parameters, we will validate the model to the remaining 30% of CLWC data that was not used in calibration and the DEC 2020 data. Because SWAT needs nutrient data in terms of loads, we will convert the nutrient concentrations to loads by normalizing the inflows from the lake mass balance model for sub-basin area.

We will generally compare our results to the thresholds of model acceptance presented in SWAT-CUP manual.

Model Scenarios

The SWAT model will also be used to assess potential pollutant load reductions from a variety of best management practice scenarios. The model output from 2009 to 2019 will act as the existing conditions. Then, best management practice scenarios will be applied to the watershed and the model run using the same parameters. The percent reductions will be calculated to compare the best management practice scenario to existing conditions.

See Attachment 3 for more details

4.4 Reconciliation with User Requirements

As previous stated, the objectives of this modeling project are to 1) assess relative pollutant loading to Canandaigua Lake from subwatersheds to highlight and prioritize areas for management, 2) gain an understanding of the scope and scale of best management practices required to reduce nutrient and sediment loading to the lake, and 3) meet the criteria for a 9 Element Plan. Our data quality objectives for the model reflect these model uses. Regardless, all models have limitations, and these will be noted when using model results.

If any model performance analysis is outside of our acceptable range, we will check for errors in model setup parameters and recalibrate the model. We have multiple sources of input data available for topography and land cover, so we can try to recalibrate with the alternative input data source to see if model performance improves. Furthermore, the SWAT model allows the user to define the number of sub-basins and HRUs, with the benefit of balancing computing requirements with the resolution for model processing. We can also try changing the number of sub-basins and HRUs and then recalibrating to determine if this improves model performance.

If the model fails to perform adequately, after attempts at recalibration, the best results will be presented to the Project Manager. Any deviation from the expected model performance criteria will be documented in the final report.

4.5 Reports to Management

Cornell University will provide updates on the modeling process and results to the Canandaigua Lake Watershed Council through monthly meetings. As the modeling process proceeds, we will conduct quarterly meeting with NYSDEC to review progress, discuss current or anticipated issues. During the NYSDEC guided simulation phase, we anticipate including NYSDEC in our monthly meetings. Communications will include the sharing of graphical output via emails and phone conferences. The Project Manager will be responsible for organizing reporting to NYSDEC. The final report requires review and approval by NYSDEC before any release, publication (electronic or hardcopy) or public presentation concerning modeling results. A final report will be completed at the end of the project, as specified in Section 5.0.

5.0 REPORTS

Completed and submitted modeling reports must include each of the following:

1. *Introduction and Background*
2. *Purpose of Modeling/Modeling Objectives*
   a. *Scope and Approach for Each Model Used (including):*
   b. *Physical Setting (and Hydrology, if applicable)*
3. *Observational Data Used to Support Modeling*
   a. *Quality of Acquired Data (and references to data quality reports)*
   b. *Achievement in Meeting Data Acceptance Criteria*
   c. *References to Monitoring Data*
   d. *Discussion on Excluded Data and Basis for Exclusion*
   e. *Description of the Model (including):*
4. *Documentation of Candidate Model Assessments*
   a. *Model Configuration (discusses how model was applied, including):*
      i. *Spatial and Temporal Resolution*
      ii. *Nature of Grid, Network Design or Sub-watershed Delineation*
      iii. *Application of Sub-models (if applicable)*
      iv. *Model Inflows Loads and Forcing Functions*
      v. *Key Assumptions (and associated limitations, if any)*
      vi. *Changes and Verification of Changes Made in Code*
   b. *Model Parameterization (Calibration) and Corroboration (Validation)*
      i. *Objectives, Activities and Methods*
      ii. *Parameter Values and Sources*

   iii. *Rational for Parameter Values Estimated in the Absence of Data*
   iv. *Calibration Variables and Targets*
   v. *Measures of Calibration Performance*
   vi. *Calibration Input, Output and Results Analysis*
   vii. *Model Validation Results*
  c. *Model Use Scenario Analysis and Results (should relate to purpose)*
   i. *Output of Model Runs and Interpretation*
   ii. *Summary of Assessments and Response Actions, if any*
   iii. *Soundness of the Calibration, Validation and Simulations*
   iv. *Review of Initial Assumptions and Model Suitability Evaluation*
  d. *Performance Against the Performance Criteria Including:*
   i. *Model Parameterization (Calibration) and Corroboration (Validation)*
   ii. *Model Sensitivity and Uncertainty Analyses*
5. *Pre- and Post-Processing Software Development*
6. *Maps, Photographs and Drawings*
7. *Deviations from the QAPP Including a List of Non-Applicable Reporting Elements with Explanations*
8. *Conclusions, Recommendations, References and Appendices*

6.0 REFERENCES

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APPENDIX A - EPA Council for Regulatory and Environmental Modeling (CREM) Guidelines for Model Development

Note: ***Detailed guidance on model development, evaluation and application may be found in the EPA Council for Regulatory and Environmental Modeling (CREM) document at the following address:***
http://www.epa.gov/crem/library/cred_guidance_0309.pdf

Summary of Recommendations for Model Development

►Regulatory models should be continually evaluated as long as they are used.
►Communication between model developers and model users is crucial during model development.
►Each element of the conceptual model should be clearly described (in words, functional expressions, diagrams, and graphs, as necessary), and the science behind each element should be clearly documented.
►When possible, simple competing conceptual models/hypotheses should be tested.
►Sensitivity analysis should be used early and often.
►The optimal level of model complexity should be determined by making appropriate tradeoffs among competing objectives.
►Where possible, model parameters should be characterized using direct measurements of sample populations.
►All input data should meet data quality acceptance criteria in the QA project plan for modeling.

Introduction

Model development begins after problem identification i.e., after identification that an environmental problem needs to be addressed and after determining that models may provide useful input for the decision making needed to address the problem. In this guidance, model development comprises the steps involved in (1) confirming whether a model is, in fact, a useful tool to address the problem; what type of model would be most useful; and whether an existing model can be used for this purpose; as well as (2) developing an appropriate model if one does not already exist. Model development sets the stage for model evaluation, an ongoing process in which evaluates the appropriateness of the existing or new model to help address the environmental problem.

Model development can be viewed as a process with three main steps: (a) specify the environmental problem (or set of issues) the model is intended to address and develop the conceptual model, (b) evaluate or develop the model framework (develop the mathematical model), and (c) parameterize the model to develop the application tool. Model development is a collaborative effort involving model developers, intended users, and decision makers (the "project team"). The perspective and skills of each group are important to develop a model that will provide an appropriate, credible, and defensible basis for addressing the environmental issue of concern.

A "graded approach" should be used throughout the model development process. This involves repeated examination of the scope, rigor, and complexity of the modeling analysis in light of the intended use of results, degree of confidence needed in the results and resource constraints.

APPENDIX B – QAPP Guidelines for Use of Models for Comparative Purposes

Occasionally, comparative modeling is used, for example, to evaluate potential water flow and water quality benefits from combinations of storm water management practices and designs that have yet to be implemented. A cost benefit analysis of varying designs and design combinations may be the basis for this type of modeling. In these types of instances, the following should be addressed in the quality assurance project plan (QAPP) and included in a report.

- Definition of the Base Line Conditions - the specific conditions, parameters and values that define the baseline condition.
- Criteria for Comparisons - the terms for comparing the model simulation results to the base line condition. For example, the terms may be found in quantities or percentages of runoff, infiltration or storm water contaminant loads.
- Identify Significant Change from Baseline - the application of statistical tools and criteria used to determine if there are significant differences between the baseline condition and model simulation results.
- Identify Simulation Scenarios from Sensitivity Analysis - how the simulation scenarios take into account what is understood from the model sensitivity analysis.
- Corroboration of Model Outputs - use of literature searches, calculations and, for example, the growing number of storm water performance databases to "ground truth" the projected water flow and/or water quality benefits from storm water management designs. Some examples include the following:

1. EPA Urban Best Management Practices Performance Tool http://cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm
2. University of New Hampshire Stormwater Center http://www.unh.edu/erg/cstev/pubs_specs_info.htm
3. University of Massachusetts Stormwater Technologies Clearinghouse http://www.mastep.net/
4. International Stormwater Database http://www.bmpdatabase.org/
5. National Pollutant Removal Performance Database, September 2007 http://www.cwp.org/Downloads/bmpwriteup_092007_v3.pdf
6. Center for Watershed Protection http://www.cwp.org/PublicationStore/special.htm#pollut2
7. Boston Metropolitan Area Planning Council - Massachusetts Low Impact Development Tool Kit http://www.mapc.org/regional_planning/LID/LID_Links_References.html#national
8. EPA Low Impact Development Literature Review http://www.epa.gov/owow/nps/lid/lid.pdf and http://newmoa.org/prevention/webconferences/stormwaterweb/stormwaterresources.pdf

APPENDIX C - Useful Project Plan Guidelines for Model Evaluation and Documentation

The following list provides additional useful project plan specifications, as appropriate, for model evaluation and documenting the results of model evaluation as conducted during model development and application (EPA 2009, NRC 2007):

Peer review

Document any critical review of a model or its application conducted by qualified individuals who are independent of those who performed the work, but who collectively have at least equivalent technical expertise to those who performed the original work. Peer review attempts to ensure that the model is technically adequate, competently performed, properly documented, and satisfies established quality requirements through the review of assumptions, calculations, extrapolations, alternate interpretations, methodology, acceptance criteria, and/or conclusions pertaining from a model or its application (modified from EPA 2006a).

To be most effective and maximize its value, external peer review should begin as early in the model *development* phase as possible (EPA 2006b). Because peer review involves significant time and resources, these allocations must be incorporated into components of the project planning and any related contracts. Peer review in the early stages of model development can help evaluate the conceptual basis of models and potentially save time by redirecting misguided initiatives, identifying alternative approaches, or providing strong technical support for a potentially controversial position (SAB 1993, EPA 1993). Peer review in the later stages of model development is useful as an independent external review of model code (i.e., model verification). External peer review of the *applicability* of a model to a particular set of conditions should be considered well in advance of any decision making, as it helps avoid inappropriate applications of a model for specific regulatory purposes (EPA 1993).

Test cases

Provide for basic model runs where an analytical solution is available or an empirical solution is known with a high degree of confidence to ensure that algorithms and computational processes are implemented correctly.

Corroboration of model results with observations.

Include comparison of model results with data collected in the field or laboratory to assess the model's accuracy and improve its performance.

Benchmarking against other models.

Include comparison of model results with other similar models.

Sensitivity and uncertainty analysis.

Conduct investigation of the parameters or processes that drive model results, as well as the effects of lack of knowledge and other potential sources of error in the model.

Model resolution capabilities.

Identify the level of disaggregation of processes and results in the model compared to the resolution needs from the problem statement or model application. The resolution includes the level of spatial, temporal, demographic, or other types of disaggregation.

ATTACHMENT 1. Project/Task Description and Schedule

For completion of Section 1.6. Project/Task Description and Schedule

Table is included in Section 1.6

ATTACHMENT 2. Documentation of Watershed Model Flow and Chemistry Calibration

For completion of Section 4.2. Model Parameterization (Calibration-Hydrology)

Category	**Description**
Gaging stations	2000-2008 Lake Mass Balance Model data, which was developed by Watershed Council and approved by DEC as part of a Water Supply Permit Application, will be used as the measured data for modelling purposes.
Calibration locations	Lake outlet
Calibration timeframe	2000-2008
Number of flow data points	9 years of daily data (2000-2008) from water balance document will be used as the flow at the lake outlet
Flow Calibration tolerance	• Nash Sutcliffe Model Efficiency (NSE) > 0.36 for overall flow, which is used as a threshold for satisfactory in peer-reviewed literature •
Flow Calibration documentation	• Paired daily time series of observed versus predicted flow data • NSE value

For completion of Section 4.2. Model Parameterization (Calibration-Chemistry)

Category	Description
Chemistry parameters	• Total phosphorus • Total suspended solids TSS • NO3 yield
Number of points for initial setup	• 17 major tributaries monitored by CLWC during storm events for total phosphorus, TSS and nitrate/nitrite – will utilize 70% of this dataset If additional points are needed, data from segment analyses may be utilized: • Deep Run and Fall Brook – Samples collected from 2016 -2018 during 5 storm events. Approximately 10 segments per stream were sampled. All data was analyzed at a NYSDOH ELAP certified lab, was collected by CLWC staff and was covered by FLLOWPA funding QAPP. • Sucker Brook - Sampled at 23 locations from Sept. 2008 – July 2010 (N=7 sampling events). Analytes were TP, TKN, NOx, TSS. • Eelpot Creek - Sampled at 11 locations from Sept. 2006 – Feb. 2009 (N=7 sampling events). Analytes were TP, NOx, TSS.
Number of points for calibration	• DEC Rapid Assessment Program data from 2019 • 2020 CLWC monitoring data from 7 streams
Chemistry Calibration tolerance	• TSS NSE = 0.26 • TP NSE = 0.25 • N NSE = 0.22
Chemistry Calibration documentation	• Paired daily time series of chemistry observed and modeled • NSE value

ATTACHMENT 3. Documentation of Watershed Model Flow and Chemistry Validation

For completion of Section 4.3. Model Collaboration (Validation and Simulation)

Category	Description
Flow Validation	• 10 years of daily data (2009-2020) from water balance document will be used as the flow at the lake outlet • Discharge from USGS stream gage on the West River in the Town of Middlesex installed in 2019
Flow Validation Documentation	• Paired daily time series of observed versus predicted flow data • NSE value

• Chemistry Validation	• 17 major tributaries monitored by CLWC during storm events for total phosphorus, TSS and nitrate/nitrite – will utilize remaining 30% of this dataset that was not used in initial calibration • 2020 DEC Rapid Assessment Survey
Chemistry Validation documentation	• Paired daily time series of chemistry observed and modeled