Memorandum

Date:	March 7, 2017
To:	Forrest Westall, UNRBA
From:	Alix Matos and Matt Van de Bogert, Cardno; Chris Wallen and Katie van Werkhoven, Dynamic Solutions, LLC
RE:	Conceptual Modeling Plan prepared for the UNRBA Modeling and Regulatory Support Project

Executive Summary

The UNRBA has initiated a Modeling and Regulatory Support project as part of the reexamination of the Falls Lake Nutrient Management Strategy. The Nutrient Management Strategy requires very large reductions in nutrient loading to the lake. Because the modeling used to develop the rules was developed on a compressed schedule with limited data, there is a lot of uncertainty in the loading targets. For this reason, the rules allow for a "reexamination" of the required nutrient load reductions.

The UNRBA developed a plan for conducting the reexamination in 2013[1]. This plan includes four to five years of water quality monitoring in the watershed and the lake. The UNRBA began collecting water quality data in 2014. A main purpose for collecting this data is to support revised and new models as part of the reexamination.

The UNRBA recently selected different types of models to support the reexamination. The watershed model will predict the amount of nutrient loading to the lake from various sources and jurisdictions in the watershed. These loads will be input to the lake nutrient response models to predict the growth of algae in response to nutrient loads. Because the prediction of algal growth in the lake will be used to evaluate the revised nutrient load reductions, the UNRBA has decided to develop multiple lake nutrient response models. Having multiple models reduces the reliance on a single model and provides corroboration for the results. One of the lake models is directly linked to the watershed model, which will allow for faster evaluation of the impacts of watershed management on lake water quality. Output from this simpler model will be considered with the cost benefit analysis to identify viable management scenarios. This leads to greater confidence in the projected nutrient loading targets and proposed management options.

Two of the lake nutrient response models will predict water quality in the lake, but they will not quantify how changes in water quality will affect designated uses such as drinking water, aquatic life, and recreation. A statistical model will be developed with input from subject matter experts to describe the relationships between nutrient loading, lake water quality, and designated uses. This model will predict lake water quality using data and statistical regressions. This statistical model can be used to compare the effects of various management strategies on lake water quality and designated uses.

The UNRBA is also considering development of an ecosystem model to provide additional information on the aquatic life designated use. Ecosystem models predict how changing water quality in the lake affects

[1] Cardno, 2013a

the biomass of fish. Additional information is being compiled about the data requirements and costs of developing such a model.

After the models are developed, they will be used to evaluate the impacts of different management options on lake water quality and designated uses. A cost benefit analysis will also be conducted to assess the technical and financial feasibility of the management options. The reexamination will integrate the model outputs and cost benefit information to develop a revised nutrient management strategy for Falls Lake. Depending upon the initial results, the strategy may be modified to include the evaluation of regulatory options such as site specific criteria or revisions to designated uses.

Types of Modeling to Support the Reexamination

For receiving waterbodies like Falls Lake, management actions in the watershed are often required to improve water quality by reducing the amount of nutrients entering the lake. The UNRBA will develop a watershed model to estimate sources of nutrients from the land surface in the watershed. Nutrients from point sources such as wastewater treatment plants will also be included. Once the selected watershed model package is applied to Falls Lake and the conditions between 2005 and 2018, it can be used to test management actions. Those management actions affect nutrients in streams and rivers that connect to Falls Lake. Nutrient levels predicted by the watershed model can be used to provide information to a lake model.

In addition to a model for the watershed, the water quality in Falls Lake itself will be simulated using a lake nutrient response model. This type of model can be used to predict how changes in nutrient loading from streams and rivers affects lake nutrient concentrations and algae. Once the lake nutrient response model is set up to represent existing conditions, it can be used to test a range of management scenarios and future conditions (e.g., land use).

Conventional models such as the ones described above are typically developed to predict nutrient loads and changes in water quality parameters. These model packages do not directly address how the uses of the lake are affected. The uses include drinking water, aquatic life, recreation, and flood control. The UNRBA reexamination strategy includes the development of a statistical model to look at how the uses are affected by lake water quality. This model will be primarily data driven (empirical). Expert opinion is often used to define this type of model and the relationships that are difficult and/or costly to measure. The UNRBA has identified experts in the fields of water chemistry,

Background

Falls Lake was constructed by the US Army Corps of Engineers in the late 1970s. The designated uses of Falls Lake are drinking water supply, recreation, fishing, aquatic life, and wildlife. In 2010, the Environmental Management Commission (EMC) passed the Falls Lake Nutrient Management Strategy (the Strategy)[1]. The Strategy requires two stages of nutrient reductions for Falls Lake. The goal of Stage I is to achieve compliance with the chlorophyll a standard in the lower half of the lake (below Highway 50). The goal of Stage II is to comply with the chlorophyll a standard everywhere in the lake. The Strategy dictates load reduction requirements for local governments and other entities, which were based on a lake nutrient response model developed by NCDWR.

The Strategy requires two Stages of nutrient load reductions. Based on NCDWR's fiscal analysis[1], the cost of Stage I is expected to exceed $500 million for the parties affected by the rules (agriculture, local governments, state and federal agencies). Implementation costs for Stage II are expected to approach $1 billion for the regulated entities. Currently, the reduction goals for Stage II are infeasible and beyond the limits of technology[1]. For these reasons, the Upper Neuse River Basin Association (UNRBA) began planning for a reexamination of the required nutrient load reductions in 2011.

lake processes, drinking water treatability, and evaluation of impacts to recreational uses.

The UNRBA is also considering development of an ecosystem model. This type of model would be used to further evaluate the aquatic life designated use. Data requirements and costs are being evaluated. This information will be provided to the UNRBA to inform decisions regarding development of this type of model.

Many models of each type exist, each with its own set of strengths and weaknesses. Although it is cost-prohibitive to develop and use every possible model, there are advantages to developing more than one model. The UNRBA has proposed a multi-modeling approach for the lake nutrient response modeling[2]. Because the lake nutrient response modeling will be used to calculate the revised load reduction targets, this component of the modeling will rely on more than one model. A complex, process-based model and a simpler model will be developed. Having multiple models reduces the reliance on a single model and provides corroboration for the results.

The UNRBA has been collecting water quality data in the watershed and the lake since August 2014 to support the reexamination. Other organizations also collect data that will be considered. The additional data and several special studies conducted by the UNRBA will provide the basis for the revised watershed and lake nutrient response modeling. The existing modeling predicts that very large nutrient reductions are needed to comply with the chlorophyll *a* criterion in Falls Lake. Therefore, it is in the interest of the stakeholders in the watershed to reduce the uncertainty of the model inputs and predictions. All models rely on assumptions and best professional judgment in their development. It is typically not possible to collect site-specific data for every variable and parameter. There are several key issues and data gaps that the UNRBA has been working to address. Additional information about the UNRBA Monitoring Program is available online at https://www.unrba.org/monitoring-program.

The UNRBA reexamination plans to use monitoring and other available data in revised watershed modeling, revised lake nutrient response modeling, and modeling to predict how changes in lake water quality affect the drinking water, recreation, and aquatic life uses of the lake. The additional data collected from the UNRBA monitoring program will be used to develop and calibrate these models.

Conceptual Multi-modeling Plan

The framework for the reexamination relies on linking management actions to water quality in the lake and finally to designated uses. Watershed loading and lake nutrient response models are useful tools for conducting these assessments. Models are developed, calibrated, and verified using existing data to represent current conditions. Once the models have been developed, they can be used to test different scenarios and management strategies. For example, a watershed model could be used to test the outcomes of future land use changes or implementation of nutrient reduction activities. A lake nutrient response model could be used to test the impacts of altered loading from the watershed on chlorophyll *a* and carbon concentrations in the lake. The output from model scenarios along with assessment of the technical and financial feasibility of various nutrient management options will be used to support the reexamination. A cost benefit analysis will also be conducted to weigh the "benefits" of the actions taken against the "costs" of achievement.

Based on the multi-modeling approach described above, the reexamination will be supported by four to five modeling frameworks. The purposes and interactions among the models are described below. Figure 1 depicts the interactions among models and reexamination process.

[2] Cardno, 2013b

- To support the UNRBA reexamination, a watershed model will be developed to simulate flows and pollutant loading to Falls Lake. These loads will be allocated among the subwatersheds, jurisdictions, and sources of loading in the watershed. Outputs from the watershed model may provide inputs to the lake nutrient response models and the statistical model. This model will also be used to evaluate management scenarios for reducing pollutant loading to the lake. The WARMF model was selected as the watershed model package. This is the same modeling package that was used by DWR to allocate loads among sources and jurisdictions. The City of Durham is in the process of revising WARMF models for three of its subwatersheds. The UNRBA will update the WARMF modeling for the entire watershed.
- Two process-based (mechanistic) lake nutrient response models will simulate how pollutant loading and other processes affect concentrations of nutrients, carbon, and chlorophyll *a* in Falls Lake. The UNRBA has selected EFDC and WARMF-LAKE. EFDC is a complex model that can predict water quality at a very fine resolution. WARMF-LAKE is a simpler model that predicts average conditions for large segments of the lake. Both models will be used to evaluate the impacts of changing nutrient loads on lake water quality. Because EFDC uses a modeling grid, its output can be used to compare with water quality observations conducted in the lake at specific locations. This model will be calibrated under existing conditions to match observations in the lake. WARMF-LAKE is a simpler model that predicts average water quality for large segments of the lake. The WARMF-LAKE model will be used to corroborate the results of EFDC. Because WARMF-LAKE is part of the WARMF package, it is easier to predict how changes in loading from the watershed will affect water quality in the lake. Because it is a simpler model, it has shorter run times. WARMF-LAKE can be used for model sensitivity analyses and scenario runs more easily than EFDC.
- The statistical model will evaluate the impacts of improved lake water quality on the designated uses of the lake. This model will evaluate the drinking water, aquatic life use, and recreation uses. This model will be primarily data driven with supplemental information provided from subject matter experts.
- An optional ecosystem model is being considered to simulate the response of aquatic life to changing lake water quality conditions. This model could be developed to use the output provided by EFDC. An ecosystem model is being considered to provide an additional assessment of the aquatic life designated use.

The modeling results and outcomes will allow decision makers to weigh costs and benefits of management actions. This type of analysis is important for making appropriate public policy decisions. The reexamination will aim to achieve water quality benefits while assuring the wise use of resources. Documentation of the process will provide a solid foundation and increase transparency for other scientists, regulatory agencies, watershed stakeholders, and the public.

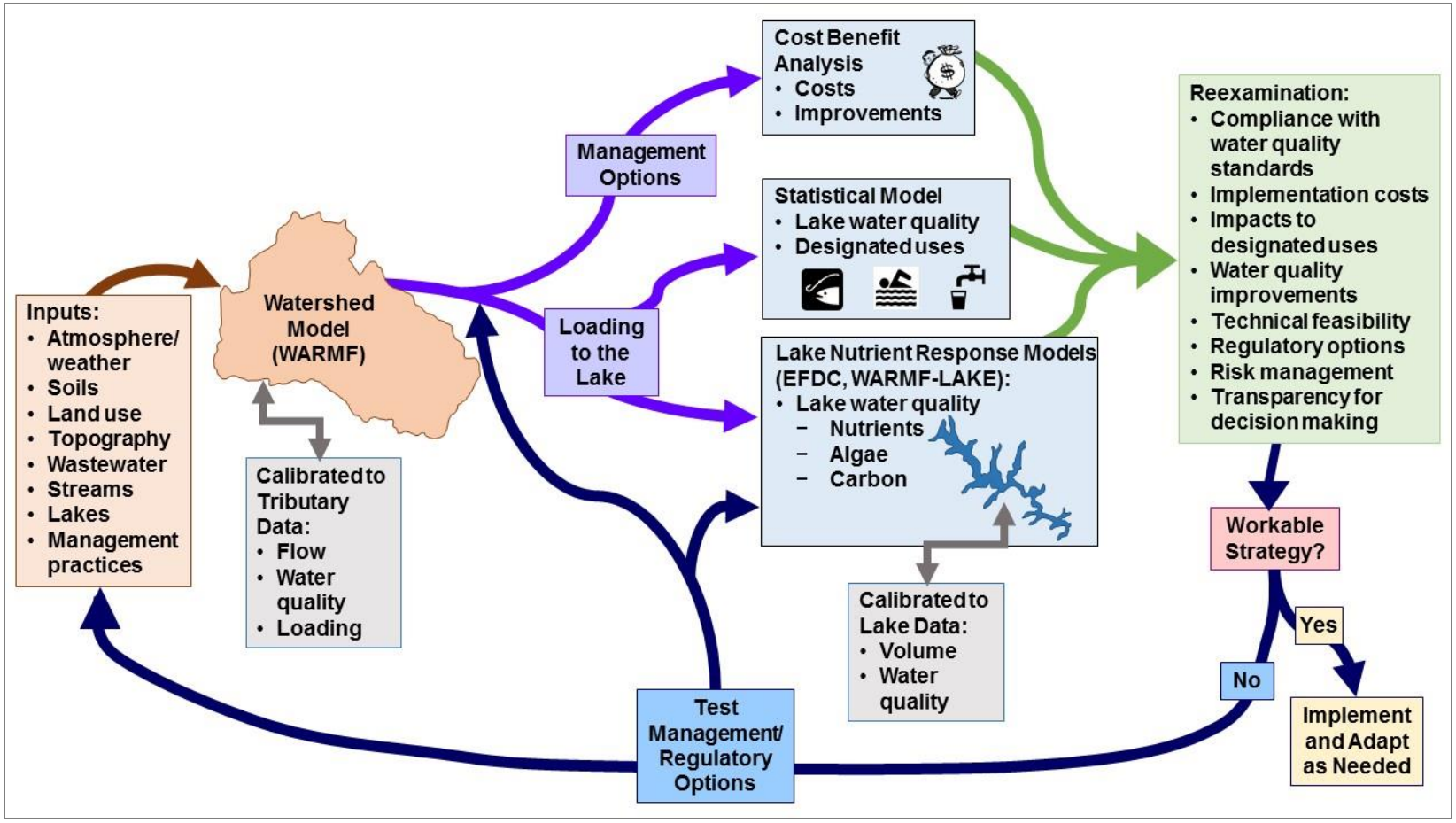

Figure 1. Conceptual Multi-Modeling Plan for the UNRBA Reexamination

Summary

Extensive work has been conducted by the UNRBA to support the reexamination process. The lake and watershed monitoring program has been underway for over two years. The data and special studies from this program will be used to reduce the uncertainty of the revised and new models. Recently the UNRBA selected the watershed and lake nutrient response models that will be used to support the reexamination process. These efforts are important in making sure that the reexamination balances improving water quality with the resources available. The reexamination will also consider the constraints and unique characteristics of the Lake and its watershed such as the shallowness of the upper part of the lake and the large majority of land in undisturbed uses.

The UNRBA has selected the WARMF watershed model to simulate loading to Falls Lake from various sources and jurisdictions in the watershed. Two lake nutrient response models (EFDC and WARMF-LAKE) will predict how algae responds to changing nutrient loads. In addition to these models, a statistical model will be developed to link lake water quality to designated uses such as drinking water and recreation. The statistical model goes beyond predicting water quality in the lake to understand how changes in water quality affect the number of recreational visits, the costs of drinking water treatment, etc. The UNRBA is considering an optional model to simulate ecosystem response to further evaluate the aquatic life use. After these models have been set up for Falls Lake and its watershed, alternative management strategies will be evaluated. A cost benefit analysis will evaluate the costs and effectiveness of management strategies. The results of these analyses will be used to reassess the technical and financial feasibility of the revised load reductions. The modeling will be used to test the feasibility of meeting the water quality standard for chlorophyll *a* throughout the lake under a range of management scenarios. The models may also be used to evaluate attainment of existing and proposed use classifications and to evaluate alternative water quality standards.

References

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