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Impacts of a thermal power plant on the phosphorus TMDL of a reservoir

Carl W. Chen[a,*], Laura H.Z. Weintraub[a], Joel Herr[a], Robert A. Goldstein[b]

[a]*Systech Engineering, Inc., 3180 Crow Canyon Place, Suite 260, San Ramon, CA 94583, USA*
[b]*Electric Power Research Institute Palo Alto, CA 94303, USA*

Abstract

The Watershed Analysis Risk Management Framework (WARMF) was applied to calculate the total maximum daily load of total phosphorus discharged to a reservoir without violating the water quality criteria of 20 μg/l of chlorophyll-a (algae). In addition to a hydroelectric plant at the dam, the reservoir has a thermal power plant on the shore. To simulate the impact of the thermal power plant, WARMF withdraws 113 cms of cooling water from the lake bottom, adds heat to it, and discharges the thermal effluent to the reservoir surface. The circulating water brings the hypolimnion water, which is typically rich in nutrients but low in algae, to the epilimnion. The surface water is enriched in phosphorus but diluted with respect to algae concentration. For the example case, the dilutional effect on algae was found to be more significant than the stimulatory effect of phosphorus. As a result, the total maximum daily load of phosphorus was higher with a thermal power plant than without. Policy makers can learn, through this type of scientific analysis, about the impacts of a thermal power plant and make rational decisions about phosphorus TMDL.

Keywords: TMDL; Phosphorus; Criterion; Chlorophyll-a; Reservoir; Model

1. Introduction

Section 303 d of the US Water Quality Act requires the determination of the total maximum daily load (TMDL) of a pollutant that can be discharged to a water body, without violating the water quality criterion for its intended use. Total daily maximum daily load (TMDL) is the sum of point and nonpoint source loads. While the point source load can be measured, the nonpoint source load is often simulated. To determine a TMDL, it is necessary to have a watershed model that can simulate nonpoint source load, accept point source load, and simulate hydrology and water quality of the receiving water. The model must also be able to adjust the loading until the simulated water quality can barely meet the criterion.

Watershed Analysis Risk Management Framework (WARMF) is a software tool with such capabilities. This paper describes the application of WARMF to evaluate the cumulative impacts of a thermal power plant on the calculation of a phosphorus TMDL for a reservoir. An example watershed-reservoir system is used to demonstrate the methodology.

2. WARMF

Fig. 1 shows the content of the decision support system WARMF. WARMF has Data, Engineering, Knowledge, TMDL and Consensus modules, integrated by a Windows based graphical user interface. They work and support each other.

The Engineering module is a working module,

* Corresponding author. Tel.: +1-925-355-1780; fax: +1-925-355-1778.
E-mail address: carl@systechengineering.com (C.W. Chen).

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which performs hydrologic and water quality simulations, using data provided by the Data module. The TMDL module is a decision module that provides a step-by-step procedure for calculating TMDLs. During this procedure, scientific calculations are performed by the Engineering module. The TMDL module may produce multiple possible solutions for a TMDL. The Consensus module is a decision module that provides a road map for stakeholders to select a preferred TMDL that is most acceptable after taking into account cost, pollution trading, social, and political factors.

The documentation report for WARMF has been published (Chen et al., 1998). The application of WARMF to calculate a TMDL of BOD to maintain a dissolved oxygen concentration above 5 mg/l for river segments has appeared in a technical journal (Chen et al., 1999). Currently, WARMF is being applied to the Cheat River Basin of West Virginia to calculate the TMDL of aluminum, zinc, iron, and manganese from acid mine drainage (Chen et al., 2000). It is also being applied to the Truckee River Basin of California and Nevada and the Catawba River Basin of North and South Carolina. The Cheat and Truckee applications prompted EPA Regions 3 and 9 to request a peer review of WARMF. Under the auspices of EPA and Electric Power Research Institute, Professor Arturo A. Keller, Bren School of Environmental Science and Management, University of California Santa Barbara, is conducting the peer review according to the EPA guidelines (USEPA, 1994). The peer review panel was derived from universities, research institutes, and regulatory agencies.

3. Model set-up

In order for WARMF to simulate runoff and nonpoint source load, USGS digital elevation map (DEM) data for the watershed was imported into WARMF. The watershed was divided into catchments, river segments, and reservoir layers. A land use shape file was imported to define the surface coverage of each catchment. Underneath the surface, the soil can have four layers. The soil characteristic data was compiled from the US Natural Resources Conservation Services. Ten meteorology stations are available within the watershed. Their data was compiled from the National Climate Data Center. The data from these ten stations was assigned to each catchment and adjusted to account for orographic effects.

The reservoir has a depth of 31 m. It was divided into 30 layers for heat budget and mass balance calculations. The cross-sectional area of each layer was determined by the bathymetric curve of the reservoir.

Fig. 2 provides a schematic sketch of the reservoir. WARMF simulates the runoff and nonpoint source load from each catchment and routes them through stream segments to eventually enter the reservoir. The outlet elevations and daily outflows are specified as diversions to water supply (0.15 cms at 10 m from the reservoir surface) and hydropower release (varied daily at 5 m from the reservoir bottom). The thermal effluent (113 cms) of the thermal power plant is a point source discharge. However, we can designate it as a recycled flow and specify its intake elevation as 5 m from the reservoir bottom. WARMF will withdraw the water from there, calculate its temperature, add a ΔT of 10°C, and discharge it to the reservoir surface.

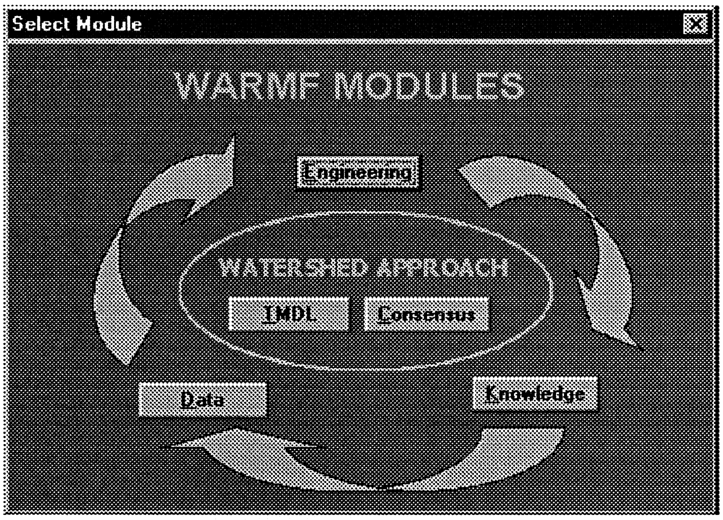

Fig. 1. Content of WARMF software tool.