**Data Required to Support Reservoir Water Quality Modeling**

The recommendations contained within this document are intended to assist with developing field data collection programs that can support reservoir water quality modeling activities. The assumption is made that reservoir water quality modeling will include the effects of nutrients and primary production on other water quality variables, e.g., dissolved oxygen (DO). This document will not address all questions regarding reservoir water quality sampling, but it is a first step in that direction.

Reservoir water quality models (and other water quality models, as well) require the following types of data:

1) boundary conditions
2) initial conditions
3) site description/geometry/bathymetry
4) parameters (e.g., coefficients)
5) in-pool/release observations (for calibration/verification)

The requirements for boundary conditions and observations are discussed below. Requirements for initial conditions are similar to those for in-pool observations, thus they are not discussed. Additionally, initial conditions are not critical for modeling many systems. However, the longer the residence time of the system, the more important initial conditions become. Parameters are selected and adjusted during model calibration so are not discussed here. Similarly, site details are handled during model application. Bathymetry can be obtained from either sediment range surveys or topographic maps.

<u>Boundary conditions</u>. The types of boundary conditions required for water quality models consist of the following:

1) inflowing tributaries
2) other non-point source runoff
3) point source loadings
4) outflows
5) meteorology
6) sediment fluxes (for the older models)

Item 2 may be neglected or assumed negligible for many applications. Non-point sources are usually distributed around the water body and consist of those local loads that can not be accounted for by the major tributaries. Many CE reservoirs may not have point source loads. In all cases, water quality loadings are mass inputs per unit time and can be accounted for in two ways: 1) flow rate and concentrations (thus, loading is flow times concentration) and 2) mass loading rate. The software, FLUX (which can be obtained from Dr. Robert Kennedy, WES) is very useful for interpolating loadings over time from intermittent samples. For reservoirs, outflow boundary conditions consist of the flow rate and location (e.g., elevation or port) of the withdrawal.

Meteorological data required for heat exchange, reaeration, and light penetration are wind speed/direction, dry bulb temperature, wet bulb or dew point temperature, cloud cover, and barometric pressure. Short wave radiation measurements can be used if available, but it is usually computed from cloud cover, time of year/day, and latitude/longitude. Met data can be obtained for the nearest weather station from NOAA through an arrangement the CE has with the Air Force. Some climate data is now available on CD-ROM.

Sediment flux data are useful for specifying benthic flux boundary conditions for the older models and for calibrating benthic flux predictions for the newer models that contain benthic diagensis submodels. These measurements require special capabilities that are not commonly available, thus, this type of data collection is not discussed herein. Reservoir water quality models can be applied without benthic flux data by calibrating against in-pool observations. However, the availability of benthic flux data provides greater confidence in model predictions.

Tributary monitoring needs are shown below. Contaminants and pathogens are excluded here but would be required if there is a problem. Only significant/major inflow tributaries are sampled. Data required for tributary sampling are broken down into two lists: minimum necessary and more complete as shown below. **The variables shown in the "more complete" list are in addition to the minimum list**. Variables are grouped below for convenience.

| Minimum | More complete | Frequency |
|---|---|---|
| Q = flow rate | C = conductivity | D or C |
| T = temperature | DO = dissolved oxygen | D or C |
| | pH | D or C |
| | TDS = total diss. Solids (enough samples to correlate to C) | |
| TOC = total organic carbon | DOC or POC = dissolved or particulate org. carbon | W |
| | Given enough time and money, it is nice to obtain BOD5 and BOD20 (both unseeded) (a few samples, e.g., once a month in summer, to characterize degradable organic matter) | |
| SRP = sol. reactive P | TDP = total dissolved P | W |
| TP = total P | TIP = total inorg. P (i.e., total reactive and acid-hydrolyzable P) | W |
| | DIP = dissolved inorg. P (can get organic forms from these) | W |
| $NO_2$+$NO_3$-N = nitrite + nitrate nitrogen | TKN = total Kjeldahl N | W |
| $NH_4$-N = Ammonium N | Filtered TKN | W |
| | TSS = total suspended solids | W |
| | ISS or VSS = inorganic or volatile suspended solids (These are not critical unless turbidity and its impacts are of concern. SS do affect P partitioning in some models, light, and water density) | W |
| | Chl a = chlorophyll a | W |
| | ALK = alkalinity | W |
| | Si = dissolved silica | W |

Note: D = daily, W = weekly or on that order, C = continuous recording

Note: The observations designated with W should be frequent enough to account for most of the loadings entering over the study period. Thus, it is important to account for loads that enter during high flows. Some studies have sampled every two weeks. However, it may be more effective to sample less frequently during low flow periods and more frequently during high flow periods. See references by Gaugush (1986 and 1987) for information on sample design and frequency.

<u>In-Pool/Release Observations</u>. Observations are required from within the reservoir pool and preferably in

the release for model calibration and verification. One study period (e.g., a year) is typically used for calibration, and another period (e.g., another year with a much different hydrology) is used for verification. Some in-pool observation profiles should be taken at frequent depth intervals (e.g., one meter), while others can be less detailed. Depth intervals for the less detailed profiles (i.e., grab samples for chemical analysis) should be detailed enough to characterize sharp gradients in concentration. This will require, as a minimum, samples from the epilimnion, hypolimnion, and several from the metalimnion. The detailed profiles of T and DO should provide insight for determining the depths for grab samples. The time frequency for in-pool profiles should be the same for all variables. It is suggested that profiles be obtained at least monthly during the stratification season, preferably every two or three weeks. Monthly or greater profiling may be sufficient for non-stratification periods. Again, refer to Gaugush (1986 and 1987) for proper statistical design. One in-pool station should be near the dam (about several hundred meters from dam) and over the channel. Two or more stations should be placed at other locations, e.g., mid pool and headwaters.

Release temperature and DO should be monitored (primarily for selective withdrawal verification) daily, as a minimum, at conventional dams; hourly recordings are preferred at peaking hydropower dams. It is not absolutely necessary to sample releases for chemical analysis. If the in-pool profiles have sufficient detail, and the selective withdrawal characteristics can be adequately predicted, then the release quality can be estimated. Continuous T and DO recorders are often used in reservoir tailwaters.

As with the tributary inflows, minimum necessary and more complete lists are provided, and **the variables shown in the "more complete" list are in addition to the minimum list**. All of the variables below are for in-pool profiles.

<u>In-pool profiles</u>

| <u>Minimum necessary</u> | <u>More complete</u> |
|---|---|
| <u>In-situ</u> | |
| T, DO, C, pH at about 1.0 meter intervals depending on depth. Need to characterize sharp gradients | None |

<u>Samples for chemical analysis (depth intervals can be less frequent than those for in-situ profiles.</u>

| <u>Minimum necessary</u> | <u>More complete</u> |
|---|---|
| Chl a | algal biomass (dry) and type (Janik et al. 1981) |
| TOC | DOC or POC |

Given enough time and money, it is nice to obtain BOD5 and BOD20 (both unseeded) (a few samples, e.g., once a month in summer from epilimnion and metalimnion, to characterize degradable organic matter)

| <u>Minimum necessary</u> | <u>More complete</u> |
|---|---|
| SRP<br>TP | TDP<br>TIP<br>DIP<br>(can get organic forms from these) |

$NO_2$+$NO_3$-N
$NH_4$-N

TKN
Filtered TKN

light trans, e.g., Secchi depth

TDS (enough samples to correlate to cond., C)

TIC = total inorg. carbon or $CO_2$
ALK

Si

TSS, ISS or VSS
(These are not critical unless turbidity and its impacts are of concern. SS do affect P partitioning in some models, light, and water density)

diss. (i.e., reduced) Fe
total Fe
diss. (i.e., reduced) Mn
total Mn
total diss. sulfide
sulfate, $SO_4$
iron sulfide, FeS

Notes:

1) TDS important only if concentrations are high enough to affect water density or impact water supply uses.

2) Fe, Mn, S, FeS, and $SO_4$ important if concerned about the effect of anoxia on the release of these problem constituents from bottom sediments and possible release to the downstream environment.

Comments

Specification of the frequency of data collection is not an easy question to address. There are techniques available for addressing this question (see references at end).

It is recognized that reservoir water quality data collection is an expensive undertaking. A year-long data set can easily cost $100K, or more, per reservoir. Good water quality data sets are critical to calibrating models that include nutrient/algal interactions. These interactions are critical to properly simulating the effects of nutrient loadings on DO dynamics. However, once a model has been set up, calibrated, and verified with reasonable confidence, it becomes a powerful tool for evaluating all sorts of questions and alternatives, including future data collection design.

Data sets for reservoir tailwater studies usually focus on T, DO, and constituents that adversely impact DO and tailwater quality, e.g., $NH_4$, Fe, Mn, and S. The emphasis is usually on oxidation or removal of problem constituents and DO recovery (i.e., reaeration) and not so much on primary production and nutrient cycling. Refer to the reference by Nix et al. (1991) for the types of data collected during a tailwater study.

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## References

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