**CE-QUAL-W2 Water Quality Modeling Workshop**

**Case Study and Workshop Projects**

## 1. DeGray Reservoir

**1). Objectives**

This case study is used to

* Review the W2 model inputs
* Run the W2 model
* Review the W2 model outputs
* Evaluate how the spatial resolutions (Dx and Dz) of the W2 model domain affect the model results of water temperature and dissolved oxygen in a reservoir

**2). W2 model grids**

DeGray Reservoir is located on the Caddo River in south central Arkansas, DeGray is classified as a monomictic, deep storage reservoir.

DeGray Reservoir was originally modeled as a one-branch system with no tributary inflows. The outlet location is in layer 13.

* Branch length **30 km**
* Segment lengths **1000 m**
* Maximum width **5530 m**
* Layer height **2 m**
* Upstream segment **2**
* Downstream segment **31**

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**W2 model segment layout for the DeGray Reservoir.**

Chart

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**W2 model vertical layers (Δz = 2m) for the DeGray Reservoir.**

**3). W2 model input files**

**w2\_DeGray.xmls 🡪 w2\_con.csv**

|  |  |
| --- | --- |
| **File type** | **File name** |
| QGT FILE QGTFN - gate | qgt.npt |
| WSC FILE WSCFN - wind sheltering | wsc.npt |
| SHD FILE SHDFN - shading | shade.npt |
| BTHFN bathymetry file | bth1.csv |
| METFN meteorological file | met.npt |
| EXTFN light extinction | ext\_1.npt |
| QINFN branch inflow | qin\_br1\_equal.npt |
| TINFN branch temp inflow | tin\_br1.npt |
| CINFN branch conc inflow | cin\_br1.csv |
| QOTFN branch structure outflow | qot\_br1\_equal.npt |

Original model bathymetry was changed with the following two different layer thickness heights:

* Layer height = 1 m (bth1-1m.csv)
* Layer height = 4 m (bth1-4m.csv)

Chart, bar chart

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**W2 model vertical layers (Δz = 4m) for the DeGray Reservoir.**

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**W2 model vertical layers (Δz = 1m) for the DeGray Reservoir.**

**4) W2 model output files**

After running w2\_v5beta.exe, the following model outputs are created.

**a) TSR PLOT- time series plot output**

The time series outputs at a user specified segment for

* active constituent concentrations
* derived constituent concentrations
* instantaneous kinetic flux rates
* instantaneous algae growth rate limitation fractions for P, N, and light [0 to 1] for each algal group.

**tsr\_1\_seg31.csv**

**b) SPR PLOT - spreadsheet output**

The spreadsheet profile output file consists of variable name, Julian date, depth below water surface, elevation, and temperature and/or concentrations for the output segment.

**spr.csv**

**c) FLUXES- water quality kinetic flux output**

The fluxes represent the average flux in kg/day over the time interval of flux output (FLX FREQ) and is in the same output format as the Snapshot [**SNP**] file. A summation of all active fluxes for each waterbody over all segments and layers is output to another file with a filename “**kflux\_wb#.csv**” where # is the waterbody number.

**flx.opt**

**kflux\_wb1.csv**

**d) WITH OUTPUT- withdrawal output**

The withdrawal outflow file [WDOFN] for outflow, outflow temperature, outflow constituent concentrations, outflow derived constituent concentrations, and vertical distribution of layer-specific outflow rates.

**qwo\_31.csv**

**two\_31.csv**

**cwo\_31.csv**

**dwo\_31.csv**

**qwo\_layers\_31\_wdo.csv**

**e) Water level output**

The file consists of Julian day followed by the water surface elevation at each model segment in m.

**wl.csv**

**f) Flow balance output**

This file is a summary of the flow balance for each waterbody based on the output interval for Contour output or CPL output.

**flowbal.csv**

**g) N and P mass balance output**

**massbal.csv**

**h) DSI W2Linkage File for W2Post (**The installation ofW2\_Post.exe is required.**)**

**degray.w2l**

**i) HDF5 File (**The installation ofHDF5 Viewer is required. It can be freely downloaded from https://www.hdfgroup.org/downloads/hdfview/)

**W2\_output.hdf5**

**j) SNP PRINT - Snapshot print**

**snp.opt**

**2. Bonneville Dam**

**1). Objectives**

This case study is used to demonstrate Total Dissolved Gas (SYSTDG) modeling capabilities in W2 model.

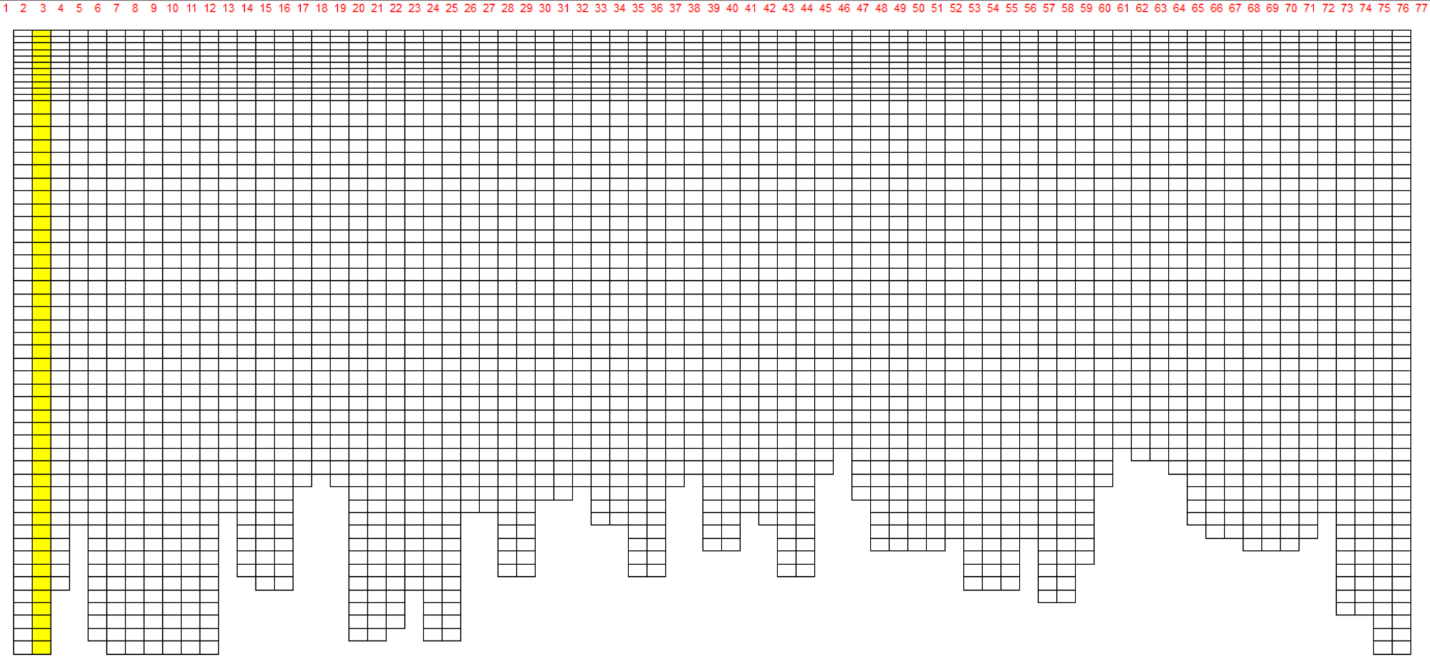
Bonneville reservoir on the lower Columbia River was selected as a demonstration site for validating the TDG prediction. Bonneville Dam is located on Columbia River Mile (RM) 146.1 and is a run-of-river dam. The reservoir is 48 miles long, from Bonneville Dam to the foot of Dalles Dam upstream, with a surface area of 29.5 square miles, and a capacity of 537,000 acre-feet. The full forebay elevation is 77 feet, and the maximum forebay elevation is 82.5 feet. The Dam is 171 feet high and 2,477 feet long. Bonneville Dam is equipped with 2 powerhouse units, 18 spillbays, and 1 fish ladder.

**2). W2 model grids**

The Bonneville W2 model domain extends upstream for 45.9 river miles to the Dalles Dam and has 75 longitudinal segments of varying widths and 56 vertical layers of varying heights. The model includes 2 powerhouse units and 18 spillbays. Powerhouse No. 1 flows were modeled as a “line” source 313 m in length. Powerhouse No. 2 flows were modeled as a “line” source 300.5 m in length, but limited to 242 m by the model’s geometry at the discharge elevation. The spillway flows were modeled as a “line” source 442 m in length, limited by the model width of 316 m at the discharge depth. The fish ladder flow and any flows not accounted for in the spillway and powerhouse were combined into a single miscellaneous flow category. Only incoming flow to the reservoir considered in the model was the upstream Columbia River, as no other significant tributaries are present in the system.



**W2 model segment layout for the Bonneville reservoir.**



**W2 model vertical layers for the Bonneville reservoir.**

**3). W2 model input files**

* **w2\_con.csv**
* **w2\_systdg.npt**

|  |  |  |
| --- | --- | --- |
| **File type** | | **File name** |
| **Wind sheltering** | WSC FILE WSCFN | BON\_WSC.npt |
| **Shading** | SHDFN | BON\_SHD\_1.npt |
| **Bathymetry** | BTHFN | BON\_NAVD88\_BTH\_2011.csv |
| **Meteorological** | METFN | BON\_2011\_2015\_MET.csv |
| **Branch inflow** | QINFN branch inflow | DALLES\_OUTFLOW.csv |
| TINFN branch temp | two\_41\_TDA.opt |
| CINFN branch conc | cwo\_41\_TDA.opt |
| QDTFN Distributed flow | BON\_DistributedTribInflow.npt |
| TDTFN Distributed temp | two\_41\_TDA.opt |
| CDTFN Distributed conc | cwo\_41\_TDA.opt |
| **Spillway/Gate** | QGTFN | QGT\_BON\_2011\_2015.csv |

**4). Hands-on exercises**

a) Review the model inputs

b) Run the model and review the model outputs of withdrawal TDG in **dwo\_76.csv**

c) Compare TDG computed from “N2+DO” and observed data (**CCIW\_TDG\_Temp\_2011-2015.csv**).

d) Change the following water quality parameters and rerun the model and see the difference of TDG in **dwo\_76.csv**

TDG production coefficients:

Eq 1:

Eq 4:

**3. Detroit Lake**

**1). Objectives**

This case study is used to demonstrate selective withdrawal blending algorithms in W2 model. The W2 model estimates the temperatures released by those flows through the priority outlets, then adjusts the temperature target for the blended releases accordingly.

This project includes 4 outlets:

1: floating weir, priority 1, 2.3 m depth, minimum 400 cfs, maximum 5600 cfs

2: spillway, priority -1 (nonblended)

3: lower power outlet, priority 1, maximum 5600 cfs

4: regulating outlet, priority -1 (nonblended), maximum 5600 cfs

Outlets 2 and 4 represent outlets used to "spill" excess flow that the other outlets cannot handle. These two outlets of the same priority balancing flows from a fixed elevation (outlet #3) and from a floating outlet (#1).

Detroit lake captures several rivers that drain an area on the western slopes of Mt. Jefferson in the Cascade Range, and impounds 455,100 acre-ft of water at full pool, making it one of the largest reservoirs in the Willamette River Basin. The North Santiam River is one of several major tributaries to the Willamette River. The fixed-elevation outlet was given a centerline elevation of 408.4 m (1,340 ft). The floating outlet was given a depth (DEPTH) of 2 m (6.56 ft) and a minimum flow of 11.327 m3/s (400 ft3/s).

**2). W2 model grids**

Detroit lake CE-QUAL-W2 model has 4 branches and 58 segments. The vertical layer height is about 2 meters. The spatial layout of the branches and inflows is shown below.

Diagram

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**W2 model segment layout for the Detroit Lake.**

Chart, table

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**W2 model vertical layers for the Detroit Lake.**

**3). W2 model input files**

* **w2\_con.csv**
* **w2\_selective.npt**

|  |  |  |  |
| --- | --- | --- | --- |
| **File type** |  | **File name** |  |
| **Wind sheltering** | WSCFN | wsc.npt |  |
| **Shading** | SHDFN | shade.npt |  |
| **Bathymetry** | BTHFN | bth1.csv |  |
| **Met** | METFN | 0609\_met\_stay\_raws.npt |  |
| **Tributary inflow** | QTRFN - tributary flow | 0609\_french\_q\_est.npt | 0609\_boxCan\_q\_est.npt |
| TTRFN - tributary temp | 0609\_french\_t\_est.npt | 0609\_boxCan\_t\_est.npt |
| **Branch inflow** | QINFN branch inflow | 0609\_nsboulder\_q.npt | 0609\_breitenbush\_q.npt | 0609\_blowout\_q.npt | 0609\_kinney\_q\_est.npt |
| TINFN branch temp | 0609\_nsboulder\_t.npt | 0609\_breitenbush\_t.npt | 0609\_blowout\_t.npt | 0609\_kinney\_t\_est.npt |
| QDTFN Distributed flow | 0609\_qdt\_br1\_est.npt | 0609\_qdt\_br2.npt | 0609\_qdt\_br3.npt | 0609\_qdt\_br4.npt |
| TDTFN Distributed temp | 0609\_tdt\_br1\_est.npt | 0609\_tdt\_br2.npt | 0609\_tdt\_br3.npt | 0609\_tdt\_br4.npt |
| **Precipitation** | PREFN flow | 0609\_pre\_detroit.npt | 0609\_pre\_detroit2.npt | 0609\_pre\_detroit3.npt | 0609\_pre\_detroit4.npt |
| TPRFN temp | 0609\_tpr\_detroit.npt | 0609\_tpr\_detroit2.npt | 0609\_tpr\_detroit3.npt | 0609\_tpr\_detroit4.npt |
| **Structure outflow** | QOTFN | 0609\_qot\_det\_max.npt |  |  |  |

**4). Hands-on exercises**

a) Review the W2 model inputs

b) Run the W2 model and review the model outputs of structure water temperature

c) Turn on selective withdrawal in the control file ---> “USGS”

d) Review the USGS selective withdrawal control file: w2\_selective.npt

e) Rerun the W2 model

h) Change the following parameters in the selective input file (w2\_selective.npt) and rerun the W2 model and see the difference of withdrawal water temperatures in **two\_34.csv**.

Temperature target:

**10 oC**

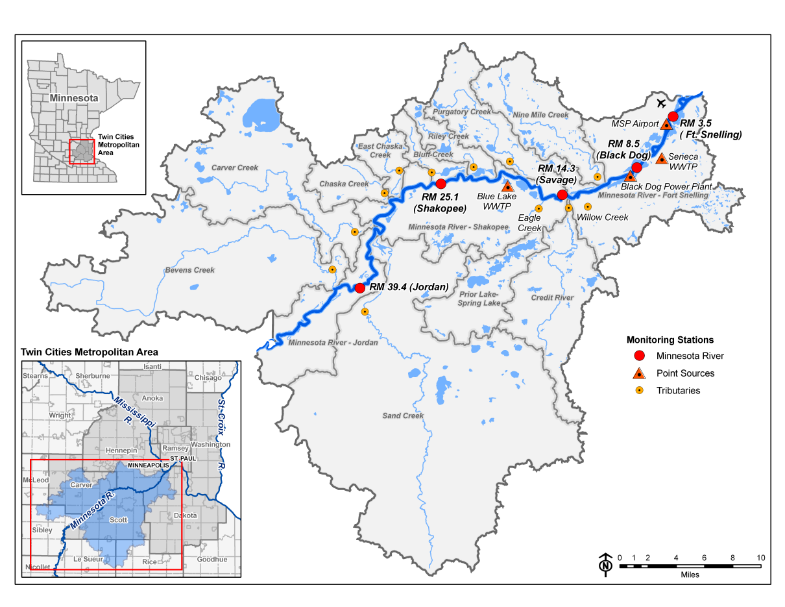
**15 oC**

**4. Lower Minnesota River**

**1). Objectives**

This case study is used to demonstrate the model calibration and validation for dissolved oxygen, algae, nutrients, etc.

The CE-QUAL-W2 model domain encompasses the lower forty miles of the Minnesota River. Eleven tributaries were identified for their contribution to this reach. There are numerous point source discharges from industrial facilities and small wastewater treatment plants (WWTP). Four monitoring stations at RM 25.1, 14.3, 8.5, and 3.5 from the downstream mouth were used for evaluating model performance during calibration. RM 3.5 station near Fort Snelling contains the most complete observed water quality data set.



**Lower Minnesota River.**

**2). W2 model grids**

The Lower Minnesota River (LMNR) CE-QUAL-W2 model domain was split into two branches and was modeled with 90 longitudinal segments, varying in length from 134.0-2321.4 m, and 111 vertical segments, varying in height from 0.2-0.6 m. Four monitoring stations at RM 25.1, 14.3, 8.5, and 3.5 correspond to segment numbers in W2 model are 23, 46, 68 and 83.

Shape

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**W2 model segment layout for the LMNR.**

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**W2 model vertical layers for the lower Minnesota river.**

**3). W2 model input files**

* **w2\_con.csv**

|  |  |  |  |
| --- | --- | --- | --- |
| **File type** | | **File name** | |
| **Wind sheltering** | WSCFN | wsc.npt |  |
| **Shading** | SHDFN | shd.npt |  |
| **Bathymetry** | BTHFN | bth1.csv |  |
| **Meteorological** | METFN | WY01\_MET\_CLOUD.NPT |  |
| **Tributary inflow** | QTRFN - tributary flow | 01QT355.INP  01QT341.INP  01QD205.INP  01QT137.INP  01QT125.INP  01QD107H.INP  01QD076H.INP  01QD065.INP  01QD041.INP  01QD038.INP  01QD030.INP |  |
| TTRFN - tributary temp | 01TT355H.INP  01TT341H.INP  01TD205D.INP  01TT137H.INP  01TT125H.INP  01TD107H.INP  01TD076H.INP  01TD065D.INP  01TD041.INP  01TD038.INP  01TD030.INP |  |
| CTRFN - tributary conc | 01CTR\_355\_RUN06.NPT  01CTR\_341\_RUN06.NPT  01CTR\_205\_RUN04.NPT  01CTR\_137\_RUN06.NPT  01CTR\_125\_RUN06.NPT  01CTR\_107\_RUN06\_REF.NPT  01CTR\_076\_RUN06\_REF.NPT  01CTR\_065\_RUN04.NPT  01CTR\_041\_RUN04.NPT  01CTR\_038\_RUN04.NPT  01CTR\_030\_RUN04.NPT |  |
| **Branch inflow** | QINFN branch inflow | 01QR394.INP |  |
|  | TINFN branch temp | 01TR394H.INP | 01TR035H.INP |
|  | CINFN branch conc | 01CIN\_394\_RUN06.NPT |  |
|  | EDHFN Downstream head |  | BR2\_WSL.npt |
|  | TDHFN Downstream temp |  | BR2\_T.NPT |
|  | CDHFN Downstream conc |  | BR2\_C.NPT |

**W2 model input files**

|  |  |  |  |
| --- | --- | --- | --- |
| QTRFN - tributary flow file | 01QT355.INP | 01QT341.INP | 01QD205.INP |
| TTRFN - tributary temperature file | 01TT355H.INP | 01TT341H.INP | 01TD205D.INP |
| CTRFN - tributary concentration file | 01CTR\_355\_RUN06.NPT | 01CTR\_341\_RUN06.NPT | 01CTR\_205\_RUN04.NPT |

|  |  |  |  |
| --- | --- | --- | --- |
| 01QT137.INP | 01QT125.INP | 01QD107H.INP | 01QD076H.INP |
| 01TT137H.INP | 01TT125H.INP | 01TD107H.INP | 01TD076H.INP |
| 01CTR\_137\_RUN06.NPT | 01CTR\_125\_RUN06.NPT | 01CTR\_107\_RUN06\_REF.NPT | 01CTR\_076\_RUN06\_REF.NPT |
| 01QD065.INP | 01QD041.INP | 01QD038.INP | 01QD030.INP |
| 01TD065D.INP | 01TD041.INP | 01TD038.INP | 01TD030.INP |
| 01CTR\_065\_RUN04.NPT | 01CTR\_041\_RUN04.NPT | 01CTR\_038\_RUN04.NPT | 01CTR\_030\_RUN04.NPT |

|  |  |  |
| --- | --- | --- |
| QWD FILE QWDFN - withdrawals | 01QW088.INP |  |
| BTHFN bathymetry file | bth06\_90seg.NPT |  |
| METFN meteorological file | WY01\_MET\_CLOUD.NPT |  |
| QINFN branch inflow | 01QR394.INP |  |
| TINFN branch temp inflow | 01TR394H.INP | 01TR035H.INP |
| CINFN branch conc inflow | 01CIN\_394\_RUN06.NPT |  |
| EDHFN Downstream head file | edh\_br1.npt | BR2\_WSL.npt |
| TDHFN Downstream temperature file | tdh\_br1.npt | BR2\_T.NPT |
| CDHFN Downstream concentration file | cdh\_br1.npt | BR2\_C.NPT |

**4). Hands-on exercises**

a) Review the model inputs

b) Run the model and review the model outputs of DO, CHLA, NH4, NO3, PO4 from Segment 83.

The location at RM3.5 corresponds to W2 model Segment 83, modeled time series results for Segment 83 are included in **LMNR\_tsr\_8\_seg83.csv**, observed water quality data along the river are provided in **LMNRsegmentobservedWQ.xlsx.** Comparations of modeled DO, CHLA, PO4, NH4 and observed data at RM3.5 are given below:

A graph of a graph showing different types of modeled

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A graph with orange lines

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c) Change the following parameters in the input file and rerun the model and see the difference of DO, NH4, PO4 from Segment 83

AG - maximum algal growth rate (d-1)

POM settling rate (m d-1)

PO4R - sediment release rate of PO4

NH4REL - sediment release rate

NO3S - denitrification rate from sediments (m d-1)