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Developing and Calibrating the Hydrodynamic and Water Quality Model
CE-QUAL-W2 for Banks Lake Washington

By

Andrew John McCulloch

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Civil and Environmental Engineering

Thesis Committee:
Scott Wells, Chair
Chris Berger
Mark Sytsma

Portland State University
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ABSTRACT

Located in central Washington State, Banks Lake serves as an irrigation storage reservoir for the Columbia Basin Irrigation Project and is home to a diverse fisheries population. The current hydrologic management strategies used for Banks Lake have been chosen to serve two purposes: to adequately store and provide irrigation water for the Columbia Basin Irrigation Project and to maintain a healthy aquatic environment suitable for the growth and habitation of local flora and fauna. Increased needs for irrigation water within arid central Washington poses additional challenges to reservoir managers so that irrigation needs are met without damaging the present aquatic environment within Banks Lake. Future plans by the Washington Department of Ecology to use Banks Lake storage as an additional source of irrigation water in lieu of the depleted ground water reserves of the Odessa Subarea aquifer have required an investigation into how increased seasonal drawdown may affect fish growth, fish habitat and overall limnology of Banks Lake.

The goal of this project is to produce a hydrodynamic and water quality model of Banks Lake that can predict the impacts of management strategies on the lake's water quality and the linkage of lake management to fish habitat.

Acknowledgements

Funds for this project were provided by the Washington Department of Ecology. Andy Miller of the Spokane Tribe of Indians, Dr. Ross Black of Eastern Washington University, Jama Hamel of the US Bureau of Reclamation, Matt Polacek and Danny Didricksen of the Washington Department of Fish and Wildlife provided data water quality and meteorological data for Banks Lake and Lake Roosevelt. Patrick O’Callaghan, Cory Stolsig and David Cordner of the US Bureau of Reclamation provided bathymetric data for Banks Lake and helped with system interpretation. Dr. Scott Wells, Dr. Chris Berger and Vanessa Wells of the Portland State University Water Quality Research Group provided technical assistance and advice for the hydrodynamic and water quality model.

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Abbreviations

BLFEP	Banks Lake Fisheries Evaluation Program
cfs	Cubic Feet Per Second (ft ³ /s)
DEM	Digital Elevation Model
DRYW	Dry Falls Dam, Washington AGRIMET Weather Station
EWU	Eastern Washington University
FDRW	Grand Coulee Dam Forebay Hydromet Water Gage
GCDW	Grand Coulee Dam, Washington AGRIMET Weather Station
GIS	Geographical Information System
hp	Horsepower
LRFEP	Lake Roosevelt Fisheries Evaluation Program
MASW	Manson, Washington AGRIMET weather station
MW	Megawatt
NAVD88	North American Vertical Datum 1988
ODSW	Odessa, Washington AGRIMET Weather Station
rad	Radians
RH	Relative Humidity
RM	River Mile
STOI	Spokane Tribe of Indians
Tair	Air Temperature
TDS	Total Dissolved Solids
Tdew	Dew Temperature

USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WDFW	Washington Department of Fish and Wildlife

Project Overview

The current hydrologic management strategies used for Banks Lake have been chosen to serve two purposes: to adequately store and provide irrigation water for the Columbia Basin Irrigation Project and to maintain a healthy aquatic environment suitable for the growth and habitation of local flora and fauna. Increased needs for irrigation water within arid central Washington poses additional challenges to reservoir managers so that irrigation needs are met without damaging the present aquatic environment within Banks Lake. Future plans by the Washington Department of Ecology (WDOE) to use Banks Lake storage to irrigate land located in the Odessa Subarea have required an investigation into how increased seasonal drawdown may affect fish growth, fish habitat and overall limnology of Banks Lake.

The following steps will be taken

1. Set up a CE-QUAL-W2 (Cole and Wells, 2010) model for Banks Lake
2. Calibrate the model for hydrodynamics, temperature, water quality, algae and zooplankton
3. Use the model to evaluate potential management scenarios for fish habitat and water quality

Banks Lake Overview

Banks Lake was created in 1951 by the US Bureau of Reclamation as an equalizing reservoir for the Columbia Basin Irrigation Project. Water from Lake Roosevelt was pumped into the adjacent upper Grand Coulee and retained by two earthen dams. The Grand Coulee was created when the Columbia River was diverted south of its current path by an ancient ice dam and scoured deep into the basalt bedrock.

Banks Lake resides within the central Washington State, on the border between Grant and Douglas County (Figure 1). Banks Lake is located approximately 134 km (83 mi) west of Spokane, Washington, 132 km (82 mi) South of the US-Canada border and 220 km (137 mi) East of Seattle, Washington. The cities of Grand Coulee and Electric City border the lake on its northeast banks and Coulee City on the lake's southeast bank. Surrounding land cover classifications include agriculture, scrub/shrub and urban developed land.

Figure 1. Model study area and Washington State
 (Image taken from

http://www.washingtonstatesearch.com/Washington_maps/Washington_State_map.html)

Figure 2. Banks Lake with Grand Coulee Dam, North Dam and Dry Falls Dam

Banks Lake is bordered by North Dam to the north and Dry Falls Dam to the south.

Figure 2 shows the location of both dams relative to the main body of water. Banks Lake provides irrigation water storage/distribution, hydroelectric power generation and outdoor/aquatic tourism opportunities. Source water is pumped from Lake Roosevelt to Banks Lake and then is distributed to the greater central Washington State area for

agriculture. Waters from Lake Roosevelt and Banks Lake irrigate roughly 2200 km² (550,000 acres) of agricultural land within the Columbia Irrigation Project. Since Banks Lake is an off stream reservoir and has a relatively small watershed, it is not used for flood control. Banks Lake hydroelectric power generation is operated by returning flow to Lake Roosevelt through turbines and by allowing outflow to run through a low head generator located at Dry Falls Dam.

Lake Geometry

Figure 3 shows how Banks Lake can be characterized into three sub-pools: the North Pool, the Middle Pool and the South Pool. The North Pool is characterized by the area south of North Dam to the southern tip of Steamboat Rock. The North Pool is surrounded by steep cliffs and contains a large pool area on the western border of Steamboat Rock. The Middle Pool contains the area south of Steamboat Rock to where the cliffs on the East bank subside to a gentle slope. The South Pool consists of the area North of Dry Falls Dam meeting the Middle Pool at the beginning of the East Bank cliffs.

In relation to the NAVD88 vertical datum, Banks Lake full pool elevation is measured at 479 m (1570 ft). At full pool Banks Lake has a volume of approximately $1.6 \times 10^9 \text{ m}^3$. While the mean depth at full pool is 14 m, several deep pools exist, mostly in the southern half of the North Pool, the southern tip of the Middle Pool and most of the Southern Pool. At full pool a maximum depth of 54 meters occurs at Devils Lake, a cove located northwest of Steamboat Rock in the Middle Pool. Table 1 shows a summary of Banks Lake dimensions.

Figure 3. Banks Lake sub-pools and Devil's Lake

Table 1. Banks Lake dimensions

Surface Area	108.81 km ²	10881 ha
Shoreline Length	218 km	135.5 mi
Max Depth	54 m	177 ft
Mean Depth	14 m	46 ft
Max Volume	1.65 x 10 ⁹ m ³	56.3 x10 ⁹ ft ³
Length	43 km	27 mi

Hydraulic Structures

Figure 4 shows a map of upper Columbia Basin Irrigation project with bodies of water and hydraulic structures of interest labeled.

Figure 4. Map of hydraulic structures within the greater extent of the Banks Lake study area

Feeder Canal & North Dam

Figure 5 shows the south end of the Feeder Canal draining into Banks Lake. The 24.4 m (80.1 ft) wide and 7.6 m (25 ft) deep concrete lined Feeder Canal spans the 2.9 km (1.8 mi) distance from the end of the pumping pipes to the head works of the North Dam. The Feeder Canal can operate at a maximum flow rate of $736.24 \text{ m}^3/\text{s}$ (26,000 cfs). The North dam is 442 m (1450 ft) long and has a crest height of 44.2 m (145 ft) at an elevation of 481.6 m (1580 ft) (NAVD88).

Figure 5. Banks Lake Feeder canal, facing South
(Photo by Dr. Chris Berger)

Lake Roosevelt Pumping Plant

Water is drawn from Lake Roosevelt via 4.26 m (14 ft) diameter intake pipes and pumped uphill 83.5 m (274 ft) via twelve 3.66 m (12 ft) diameter pipes to the Banks Lake Feeder Canal. The center line of each pump's intake pipe is located at 363.74 m (1193.27 ft) (NAVD 88), providing 29.48 m (96.73 ft) of head when Lake Roosevelt is at full pool. Figure 6 shows a side view schematic of a generic pump/generator found at the pumping plant. Pumps one through six were installed at the beginning of operations in 1951, each rated at 65,000 horsepower and $45.31 \text{ m}^3/\text{s}$ (1600 cfs). Construction began in 1961 on what would become six additional pumps also capable of power generation through return flow to Lake Roosevelt. Pumps seven through nine were installed in 1973, pumps ten and eleven were installed in 1983 and pump twelve was installed in 1984. Pumps seven and eight are rated at 67,500 horsepower, $45.31 \text{ m}^3/\text{s}$ and are capable of producing 50 MW of electrical power. Pumps nine through twelve are rated at 70,000 horsepower, $45.45 \text{ m}^3/\text{s}$ and are able to produce 53.5 MW of electrical power. Table 2 shows the power rate, pumping rate, power generation potential and year of installation for all pumps. The total capacity for power generation at the Grand Coulee Pump Generating Plant is 314 MW.

Figure 6. Side view of a generic pump/turbine from the Lake Roosevelt pumping plant (Hubbard, 1995)

Table 2. Lake Roosevelt pump summary

Pump #	Power Rating (hp)	Maximum Flow Rate (m ³ /s)	Power Generation Potential (MW)	Year of Installation
1	65,000	45.31	0	1951
2	65,000	45.31	0	1951
3	65,000	45.31	0	1951
4	65,000	45.31	0	1951
5	65,000	45.31	0	1951
6	65,000	45.31	0	1951
7	67,500	45.45	50	1973
8	67,500	45.45	50	1973
9	70,000	48.14	53.5	1973
10	70,000	48.14	53.5	1983
11	70,000	48.14	53.5	1983
12	70,000	48.14	53.5	1984

Main Canal & Dry Falls Dam

Water used for irrigation exits the lake through Dry Falls Dam via the Main Canal at the southern end of the lake. During times of peak energy consumption flow can be diverted through the Dry Falls Dam spillway turbine for energy production. Dry Falls Dam is 2,987 m (9800 ft) long, has a crest height of 37.5 m (123 ft) at an elevation of 481.6 m (1580 ft) (NAVD 88) and supports a two lane highway. The unlined and concrete lined Main Canal is 29,612 m (18.4 miles) long and can support a maximum flow rate of 46.52 m³/s (19,300 cfs). Water leaving Banks Lake travels 2,896 m (1.8) down the Main Canal before entering the Bacon Siphon. The Bacon Siphon consists of two 1000 ft long siphons and two tunnels each two miles long which lead irrigation water underground to the Billy Clap Lake storage reservoir. Figure 7 and Figure 8 show a top view and a side view schematic of Dry Falls Dam and the headworks of the Main Canal.

Figure 7. A side view schematic of the Dry Falls Dam powerhouse and the Main Canal headworks

Figure 8. A top view schematic of Dry Falls Dam and the Main Canal headworks

Work Impetus

The Odessa Subarea is located approximately 90 miles west of Spokane, Washington and is considered to be within the eastern boundary of Columbia Basin Project (CBP). The Washington State legislature officially recognized in 1967 that over pumping had led to significant declines of water table elevation and subsequently designated the Odessa Subarea as a groundwater management area. Continued irrigation pumping within the area has resulted in an overall decrease in the water table elevation and an increase in the surface extent of the affected land. Recent direction from the Washington State Legislature to the Washington State Department of Ecology (WDOE) to direct attention towards developing alternative water sources for users in the Odessa Subarea has prompted the development of a draft environmental impact statement (EIS) (USBR and WDOE, 2010). The EIS aims to evaluate the impact and feasibility of potential alternatives that would supply surface water for irrigation within the Odessa Subarea.

The draft EIS outlines eight potential action alternatives and one no-action alternative. The action alternatives are split into two groups: partial and complete irrigation of the Odessa Subarea. The partial alternatives (group 2) are estimated to irrigate 57,000 acres of land and the complete alternatives (group 3) to irrigate 102,600 acres of land. Groups 2 and 3 are further divided into 4 water source combinations, listed as water source A, B, C, and D. Table 3 shows the action alternatives and their water sources. Water source A uses only Banks Lake, source B uses a combination of Banks Lake and Lake Roosevelt water, source C involves Banks Lake and the use of a yet to be constructed retention

reservoir named Rocky Coulee Reservoir and source D would use a combination of all three water bodies. Each action alternative is additionally mandated by the draft EIS to be evaluated under 4 flow years. The draft EIS outlines 1995 as an average flow year, 1982 as a wet flow year, 1998 as a dry flow year and 1931 as a drought flow year.

Table 3. EIS action alternatives

Alternative 1	No-Action Alternative
Alternative 2A	Partial-Banks
Alternative 2B	Partial-Banks+FDR
Alternative 2C	Partial-Banks+Rocky
Alternative 2D	Partial-Combined
Alternative 3A	Full-Banks
Alternative 3B	Full-Banks+FDR
Alternative 3C	Full-Banks+Rocky
Alternative 3D	Full-Combined

This project will evaluate each of the 8 action alternatives under 4 flow years and the no-action alternative, for a total of 33 model runs. The CE-QUAL-W2 model will be used to assess the suitability of each management alternative for providing fish habitat and water quality.

The management scenarios will be assessed through evaluating the following:

- 1.) Percent of total reservoir volume that meets dissolved oxygen and temperature levels that agree with the optimal growth conditions for selected sport fish species
- 2.) Mass flow rate of zooplankton entrainment from Dry Falls Dam

- 3.) Effects of changing water surface elevations on temperature stratification
- 4.) Effects of management scenarios on the abundance of dissolved oxygen in the reservoir system
- 5.) Use of a fish bioenergetics model to evaluate output from CE-QUAL-W2 to predict fish growth in kokanee salmon (*Oncorhynchus nerka*).

Overview of Models Used

CE-QUAL-W2 Overview

CE-QUAL-W2 (Cole and Wells, 2010) is a two dimensional laterally averaged hydrodynamic and water quality model. Originally developed in 1975 as the LARM (Laterally Averaged Reservoir Model) by Edinger and Buchak (1975), the model's source code has steadily improved under the development of researchers, such as T. Cole and S. Wells, into a commonly used, powerful and open source hydrodynamic and water quality model. Modifications to the model have included improvements to computational efficiency and accuracy, transport and mixing schemes, as well as additional water quality algorithms, hydraulic structures and the ability to connect multiple water bodies. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water quality gradients such as Banks Lake.

•The application of CE-QUAL-W2 requires knowledge in the following areas according to Cole and Wells (2010):

1. Hydrodynamics
2. Aquatic biology
3. Aquatic chemistry
4. Numerical methods

5. Computers and FORTRAN coding

6. Statistics

7. Data assembly and reconstruction

•CE-QUAL-W2 includes the following state variables according to Cole and Wells (2010):

1. Water Temperature

2. any number of generic constituents defined by a 0th and/or a 1st order decay rate and/or a settling velocity and/or an Arrhenius temperature rate multiplier that can be used to define any number of the following:

a. conservative tracer(s)

b. water age or hydraulic residence time

c. coliform bacteria(s)

d. contaminant(s)

3. any number of inorganic suspended solids groups

4. any number of phytoplankton groups

5. any number of epiphyton groups

6. any number of CBOD groups

7. ammonium

8. bioavailable phosphorus (commonly represented by orthophosphate or soluble reactive phosphorus)

9. labile dissolved organic matter

10. refractory dissolved organic matter
11. labile particulate organic matter
12. refractory particulate organic matter
13. total inorganic carbon
14. alkalinity
15. total iron
16. dissolved oxygen
17. organic sediments
18. zooplankton
19. macrophytes

Hydrodynamic & Water Quality Governing Equations

The governing equations are listed in Table 4. Assumptions made are:

1. Incompressible fluid
2. Centripetal acceleration is a minor correction to gravity
3. Boussinesq approximation
4. Lateral homogeneity

Table 4. CE-QUAL-W2 governing equations (Cole and Wells, 2010)

Equation	Governing Equation
x-momentum	$\frac{\partial UB}{\partial t} + \frac{\partial UUB}{\partial x} + \frac{\partial WUB}{\partial z} = gB \sin \alpha$ $+ g \cos \alpha B \frac{\partial \eta}{\partial x} - \frac{g \cos \alpha B}{\rho} \int_{\eta}^z \frac{\partial \rho}{\partial x} dz +$ $\frac{1}{\rho} \frac{\partial B \tau_{xx}}{\partial x} + \frac{1}{\rho} \frac{\partial B \tau_{xz}}{\partial z} + qBU_x$
z-momentum	$0 = g \cos \alpha - \frac{1}{\rho} \frac{\partial P}{\partial z}$
continuity	$\frac{\partial UB}{\partial x} + \frac{\partial WB}{\partial z} = qB$
state	$\rho = f(T_w, \Phi_{TDS}, \Phi_{ss})$
free surface	$B_{\eta} \frac{\partial \eta}{\partial t} = \frac{\partial}{\partial x} \int_{\eta}^h UB dz - \int_{\eta}^h qB dz$
Mass(heat)	$\frac{\partial \bar{c}}{\partial t} + \bar{u} \frac{\partial \bar{c}}{\partial x} + \bar{v} \frac{\partial \bar{c}}{\partial y} + \bar{w} \frac{\partial \bar{c}}{\partial z} = D \left[\frac{\partial^2 \bar{c}}{\partial x^2} + \frac{\partial^2 \bar{c}}{\partial y^2} + \frac{\partial^2 \bar{c}}{\partial z^2} \right]$ $- \frac{\partial}{\partial x} (\overline{u'c'}) - \frac{\partial}{\partial y} (\overline{v'c'}) - \frac{\partial}{\partial z} (\overline{w'c'}) + \bar{S}$
U = horizontal velocity m/s W = vertical velocity m/s B = channel width p = pressure	Tx = x-direction lateral average shear stress Ty = y-direction lateral average shear stress ρ = density η = water surface

Lake Roosevelt Fish Bioenergetics Model Review

This project desires to use the Lake Roosevelt fish bioenergetics model developed by McKillip (2008) to model fish growth in association with the CE-QUAL-W2 model output. The following covers a brief background of the bioenergetics model (Bevelhimer and Adams, 1993).

Model Background

The overall goal of bioenergetics models is to adequately trace energy within an organism, from metabolism to growth to waste. In many ways, bioenergetics is treated like a mass balance equation. Equation 1 outlines the energy budget used in the Lake Roosevelt bioenergetics model (Kitchell, et al., 1977):

$$G = C - (R + F + U) \quad \text{Eq. 1}$$

where G ($\text{g} \cdot \text{g}^{-1} \cdot \text{day}^{-1}$) is the specific growth rate, C ($\text{cal} \cdot \text{g}^{-1} \cdot \text{day}^{-1}$) is the specific rate of consumption, R is the specific rate of respiration ($\text{g} \cdot \text{g}^{-1} \cdot \text{day}^{-1}$), F is the specific rate of egestion ($\text{g} \cdot \text{g}^{-1} \cdot \text{day}^{-1}$) and U is the specific rate of excretion ($\text{g} \cdot \text{g}^{-1} \cdot \text{day}^{-1}$). Most bioenergetics models either use known consumption rates to measure growth, or they use known growth rates to predict metabolism. Additional complications arise as use of bioenergetics models advance in complexity. Variability among typical species size, weight and metabolic costs are not factored into most bioenergetics models. Therefore

the potential for large errors in predicting population growth does exist. In most situations, a bioenergetics model is considered successful if it is able to predict data values within a 50% error margin.

Banks Lake Data Summary

This section summarizes available data used to develop the Banks Lake CE-QUAL-W2 model. Data used for this model focused on the calibration time period of 2002-2009. A more detailed description of the model data can be accessed from the report “Banks Lake Model: Boundary Conditions and Model Set-up (McCulloch, Berger and Wells, 2011) which contains:

- Physical Lake Description and Background
- Bathymetry Data and Grid Set-Up
- Hydraulic Boundary Conditions
- Water Temperature Boundary Conditions
- Water Quality Boundary Conditions
- Meteorological Data
- Dynamic Topographical Shading
- Abiotic Water Quality Data
- In-Lake nutrient Analysis
- Algae data
- Zooplankton Data
- Fish Data

Bathymetry Data & Grid Development

The primary bathymetric data used to create the model grid was a USBR generated DEM file with a 5 meter resolution. Data used to develop the DEM was collected by the USBR prior to inundation during the 1940's via surface surveying methods. Original data was collected to develop five foot contours from the elevation of 1490 ft to 1530 ft and two foot contours from the elevation of 1530 ft to 1580 ft based on the NAVD 29 datum.

Processing the DEM file included converting the DEM raster file to a contour map using ArcGIS. The developed contour map was arranged in alignment with the UTM ZONE 11 N spatial coordinate projection (WGS84 datum) and NAVD 88 vertical datum.

The preliminary contour map displayed some irregularly shallow areas within the bathymetry data. Prior to the inundation of Banks Lake in 1951, several small lakes existed in the coulee. Figure 9 shows an aerial photograph of Devil's Lake and an adjacent lake prior to inundation. When surveyors collected the surface elevation data of the coulee used to develop the USBR DEM file in the 1940's, the land covered by these small lakes were assigned the surface elevation of their corresponding lake's shoreline. This assumption led to data loss in some areas of the DEM. The data loss was not significant in most areas, but all of Devil's Lake was found to be shallow. Additional 1-foot resolution bathymetric data were acquired via NAVIONICS HOT MAPS, an independent company that produces high resolution fishing maps. Using the NAVIONICS HOT MAPS as a guide, the Devil's lake bathymetry was repaired by hand

digitizing correct bathymetry elevations. Figure 10 shows contour maps of Devil's Lake before and after the bathymetry data correction.

The updated bathymetry data was then used to develop the two-dimensional grid. The bathymetry contour map was delineated into one main branch extending the length of the lake from the Feeder Canal to the Main Canal. Nine complimentary branches that extend from the main branch through a cove to the shoreline were also delineated. Branch delineation was performed by hand digitizing the most likely path of flow through the thalweg. Using the branch delineation data and by specifying the direction of flow, the two-dimensional grid surface layer was created with 182 segments. Table 5 shows a summary of branch lengths and geometry. The surface grid laterally and longitudinally divides the two dimensional bathymetry data into individual and workable pieces. Figure 11 shows the model grid segments and the direction of flow covering part of branch 1 and all of branch 7 near Steamboat Rock. Each segment is a surface representation of the lake's bathymetry and represents an area which CE-QUAL-W2 assumes water quality constituents to be laterally and longitudinal homogenous.

The three dimensional grid was then created by adding depth to the newly developed two dimensional grid. Through selecting a maximum water surface elevation of 470 m (NAVD88) , minimum bathymetry elevation of 425 m(NAVD88) and using the bathymetry data contained within the two dimensional grid, a series of layers were added to each segment independent of other segments. Figure 12 and Figure 13 show a lateral view of branch 7 and the end view of the three dimensional grid, respectively. The final

model grid consists of one meter deep cells that extend to the maximum depth of each segment as dictated by the bathymetry overlaid by the two dimensional grid surface layer, resulting in a three dimensional representation of the Banks Lake bathymetry.

Figure 9. USGS aerial photograph of Devil's Lake prior to the creation of Banks Lake
(Image taken from <http://edcsns17.cr.usgs.gov/EarthExplorer/>)

Figure 10. Contour map of Devil's Lake before and after correcting USBE bathymetry data

Table 5. Summary of model grid layout and dimensions

Branch #	Starting Segment	Ending Segment	Segment Length (m)	Branch Length (m)
1	2	107	503.3	52850.7
2	110	117	536.2	3753.4
3	120	124	596.6	2386.4
4	127	131	536.0	2144.1
5	134	138	571.8	2287.2
6	141	144	441.0	1323.0
7	147	156	500.9	4507.8
8	159	162	259.9	779.6
9	165	169	295.6	1182.2
10	172	177	572.2	2861.1

Figure 11. Close up view of the surface polygons with polygon numbers and direction of flow

Figure 12. Model grid side view of branch 7

Figure 13. Model grid end view

Hydraulic Boundary Conditions

Figure 14 shows the locations of flow gages on the boundary of Banks Lake. Table 6 lists the name, station ID, management agency, coordinates, data frequency and data range from each boundary condition flow gage.

Figure 14. Banks Lake flow gage locations

Table 6. Banks Lake flow gage summary

Station Name	Station ID	Agency	Latitude	Longitude	Data Frequency	Data Range
Feeder Canal	12435500	*USGS	47° 57' 05"	118° 59' 40"	Daily	1/1/2002-12/31/2009
Main Canal	Main Canal	USBR	47° 37' 02"	119° 18' 00"	Sub-Hourly & Daily	1/1/2002-12/31/2009

*Gage is registered as a USGS gage but data is collected by USBR

Feeder Canal Inflow

Feeder Canal inflow data was collected as daily average flow (m^3/s). Source water for the Feeder Canal is withdrawn from Lake Roosevelt via the Lake Roosevelt Pumping Plant. Pumping is continuous from late March to late October with some rare days of zero flow. Occasionally pumping will occur during winter months. Pumping was most active in 2008 with 260 days of pumping. The highest volume of water was pumped in 2007 and 2008, both years having the highest annual average flow rate of $122 \text{ m}^3/\text{s}$. Peak flows took place mostly from late March to mid-July and ranged from $481.4 - 574.2 \text{ m}^3/\text{s}$. The average flow for days when flow was measured was highest in 2004 with $184.8 \text{ m}^3/\text{s}$ and lowest in 2006 with $168.4 \text{ m}^3/\text{s}$. Table 7 summarizes Feeder Canal flow rates and pumping time periods. Figure 15 shows Feeder Canal flow for 2008.

Table 7. Feeder Canal inflow summary statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Number of Days With Flow	237	236	223	235	237	241	260	237
Begin Flow Date	20-Mar	14-Mar	4-Apr	27-Mar	14-Mar	7-Apr	25-Mar	14-Mar
End Flow Date	23-Oct	22-Oct	3-Oct	23-Oct	18-Oct	26-Oct	5-Nov	23-Oct
Max Flow (m^3/s)	455.9	458.7	574.8	481.4	523.9	521	556.1	574.2
Annual Average Flow (m^3/s)	111.6	112.1	113.1	109.8	109.3	122	122	119.7
Average Flow When Flow Was Measured (m^3/s)	171.8	173.3	184.8	170.5	168.4	183.3	171.7	183.6

Figure 15. Feeder Canal daily average inflow rates (m^3/s & ft^3/s) 2008

Feeder Canal Return Flow

Feeder Canal return flow data was collected as daily average flow (m^3/s). Most of the return flow at the Feeder Canal took place during winter months with the exception of 2009 which had most of its flow between May and August. Continuous pumping normally lasted no more than one day, but occasionally reached up to four days. Return flow was most active in 2008 with 52 days of flow. The highest volume of water was pumped back to Lake Roosevelt in 2007 which had an annual average flow rate of 7.9 m^3/s . The average flow of days when flow was measured was highest in 2004 with 127.2 m^3/s and lowest in 2008 with 10.9 m^3/s . Table 8 summarizes Feeder Canal return flow rates and days when return flow occurred. Figure 16 shows Feeder Canal return flow for 2008.

Table 8. Feeder Canal return flow annual statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Number of Days With Flow	20	23	9	12	19	37	52	53
Max Flow (m^3/s)	148.1	199.4	229.4	129.1	202.2	243	108.5	166
Annual Average Flow (m^3/s)	3.1	4.6	3.1	1.2	4.1	7.9	1.5	6.8
Average of Days Flow Was Measured (m^3/s)	55.7	72.3	127.2	36.5	77.9	78	10.9	46.7

Figure 16. Feeder Canal daily average return flow rates (m^3/s & ft^3/s) 2008

Main Canal Outflow

Flow at the Main Canal is continuous from mid March to late October and was measured at a sub hourly time interval. Peak flows took place from mid-May to mid-August and ranged from 242.1 – 317.7 m³/s. Average flow of days when flow was measured was highest in 2007 with 171.9 m³/s and lowest in 2006 with 162.4 m³/s. Table 9 summarizes Main Canal outflow rates and days when outflow occurred. Figure 17 shows Feeder Canal return flow for 2008.

Table 9. Main Canal annual flow annual statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Number of Days With Flow	223	220	138	227	223	226	231	234
Flow Begin Date	15-Mar	17-Mar	13-Mar	14-Mar	17-Mar	14-Mar	12-Mar	12-Mar
Flow End Date	23-Oct	23-Oct	26-Oct	26-Oct	25-Oct	25-Oct	28-Oct	31-Oct
Max (m³/s)	242.1	243.8	257.2	242.9	244.9	317.7	262.1	246.5
Annual Average (m³/s)	165.2	169.8	170.4	161.8	161.6	171.1	168.2	165.5
Average of Days Flow Was Measured (m³/s)	166.8	171.4	171.8	162.5	162.4	171.9	168.9	166.1

Figure 17. Main Canal daily average flow rates (m³/s & ft³/s) 2008

Water Surface Elevation

Water surface elevation data was collected daily by the USBR at the North Dam.

Average annual water surface elevation was consistent around 478.0 meters (NAVD88) and daily data ranged from 476.7 – 478.5 meters (NAVD88). Table 10 summarizes the maximum, minimum and average water surface elevation for 2002-2009. Figure 18 shows daily water surface elevation for 2002-2009. Figure 19 shows daily water surface elevation for 2002 with the only water surface elevation data gap, which was filled by linear interpolation. Water surface elevation was steady during the first half of most years followed by a late summer drawdown beginning around August.

Table 10. Banks Lake annual water surface elevation summary statistics (m-NAVD88)

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	478.3	478.5	478.5	478.5	478.5	478.5	478.5	478.5
Min	477	477	476.7	476.9	477	477	477	476.5
Average	477.9	478	477.8	477.9	478	478	478	477.9

Figure 18. Banks Lake daily average water surface elevation 2002-2009

Figure 19. Banks Lake daily average water surface elevation 2002-2004

Boundary Condition Water Temperature Data

Inflow water temperature was not available at the Feeder Canal, so water temperature at the Lake Roosevelt Pumping Plant intake pipes was estimated. To approximate water temperature at the depth from which the Lake Roosevelt Pumping Plant withdrawals water (29.6 m) (97.1 ft), a linear regression was fit between daily average surface water temperature data at hydromet station FDRW and water temperature profile data measured at the Spring Canyon Boat Ramp. Figure 20 shows the regression relationship between the surface water temperature at the Grand Coulee Dam forebay (FDRW) and water temperature measured from a depth of 30 meters at Spring Canyon. The regression between Lake Roosevelt forebay surface water temperature (FDRW) and Spring Canyon water temperature profile data was limited by the number of profile samples collected between 2002 and 2009. The regression used 81 points and yielded a goodness of fit of 0.98. From the regression equation a time series of daily average water temperatures at a depth of 30 m at the Grand Coulee dam was calculated.

This approach assumes that stratification/mixing processes are consistent longitudinally from hydromet station FDRW to Spring Canyon and laterally from the Lake Roosevelt Pumping Plant to the hydromet station FDRW. This approach also assumes that heat attenuation/cooling while the waters of Lake Roosevelt are in transit to the Banks Lake Feeder Canal is negligible

Lake Roosevelt surface water temperature was available from the hydromet station FDRW. Hydromet station FDRW is located at the forebay of Grand Coulee Dam, approximately 0.9 km (0.6 mi) east of the Lake Roosevelt Pumping Plant (Figure 21). Surface water temperature was measured at hourly time intervals for the entire 1/1/02 – 12/31/09 time period without data gaps. Table 11 shows the maximum, minimum and average surface water temperature at the Grand Coulee Dam forebay (FDRW).

The Spring Canyon boat ramp is located in a cove of Lake Roosevelt, approximately 4.2 km (2.6 mi) upstream from Grand Coulee Dam (Figure 21). Profile data were collected by the Spokane Tribes of Indians (STOI) on a monthly basis from 1/16/02 – 10/10/07. Figure 22 shows an isopleths plot of water temperature taken from Spring Canyon for 2002. Spring Canyon water temperature profile data show that the lower pool of Lake Roosevelt is typically isothermal from January to March and warms slowly until stratification begins to set in around mid June. Stratification temperatures of up to 20 °C extended to depths of 80 meters in most years with temps of 22-24 °C present within the upper 10 meters of the epilimnion. The stratification process was less pronounced in 2007.

Table 12 shows the maximum, minimum, average and average deviation of the calculated water temperature values from the measured surface water temperature data collected at the Grand Coulee Dam forebay. Figure 23 shows the Grand Coulee Dam forebay surface water temperature with the calculated water temperature at the intake to the Lake Roosevelt Pumping Plant for 2002. Grand Coulee Dam forebay surface water

temperatures ranged from 1.5 – 25 °C. Temperatures calculated at the Lake Roosevelt Pumping Station intake pipes were typically 0.5°C cooler and followed a similar annual trend to the forebay temperature data. Annual average forebay water temperature ranged from 11-11.5 °C, except for 2002 which had a cooler average temperature of 10.4 °C. The regression equation accurately shows this drop in annual average water temperature in the calculated annual average water temperature for 2002.

Figure 20. Linear regression used to predict feeder canal inflow temperatures where Y is Spring Canyon water temperature (°C) at a depth of 30 meters and X is the Grand Coulee Dam forebay daily average surface water temperature (°C)

Table 11. Lake Roosevelt Dam forebay surface water temperature (°C) annual summary statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	18.8	24	25	23.5	21.7	21.2	21.8	22.8
Min	2.5	3.3	2.2	2.8	3.4	2.1	2.1	1.5
Average	10.4	11.6	11.9	11.5	11.7	11.3	11.1	11.2

Figure 21. Boundary condition temperature gages

Table 12. Annual summary statistics for the calculated water temperature (°C) at the intake to the Lake Roosevelt pumping plant

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	18.2	23.3	24.3	22.8	21	20.5	21.1	22.1
Min	2	2.8	1.7	2.3	2.9	1.6	1.6	1
Average	9.9	11.1	11.3	11	11.1	10.8	10.6	10.6
Average Difference from Observed Forebay Temperature	-0.55	-0.57	-0.57	-0.57	-0.57	-0.57	-0.56	-0.56

Figure 22. Spring Canyon water temperature (°C) isopleths 2002

Figure 23. Surface water temperature (°C) for hydromet station FDRW and calculated inflow temperatures (°C) at the Lake Roosevelt Pumping Plant 2002

Meteorological Data

Meteorological data were gathered from four AGRIMET weather stations: Grand Coulee Dam (GCDW), Odessa (ODSW) Dry Falls Dam (DRYW) and Manson (MASW) (Table 13). AGRIMET is a satellite based network of automated weather stations operated and maintained by the U.S. Bureau of Reclamation. Figure 24 shows the proximity of these AGRIMET stations to Banks Lake. The Odessa, Manson and Grand Coulee Dam AGRIMET stations are 56.8 km (35.3 mi), 69.6 km (43.2 mi) and 44.5 km (27.6 mi) from the Dry Falls Dam AGRIMET station, respectively.

Table 13. AGRIMET stations summary

Station Location	Station ID	Agency	Elevation, m (NAVD88)	Latitude	Longitude	Meteorological Parameters
Grand Coulee Dam, WA	GCDW	AGRIMET (Bureau Of Reclamation)	402.3	47.945278	118.95361	Air Temperature, Humidity, Wind Speed, Wind Direction, Precipitation, Solar Radiation
Dry Falls Dam	DRYW	AGRIMET (Bureau Of Reclamation)	376.4	47.614167	119.29917	Air Temperature, Wind Speed, Wind Direction, Precipitation
Odessa, WA	ODSW	AGRIMET (Bureau Of Reclamation)	502.9	47.312778	118.8725	Air Temperature, Humidity, Solar Radiation, Wind Speed, Wind Direction
Manson, WA	MASW	AGRIMET (Bureau Of Reclamation)	601.1	47.917222	120.13167	Humidity

The majority of meteorological data were gathered as hourly data from the Grand Coulee Dam AGRIMET station from 4/16/02 through 12/31/09. The GCDW station had the most complete record of hourly data of all AGRIMET stations located near Banks Lake. Limited meteorological data was available at DRYW from 4/1/07 to 7/9/2009. Meteorological data gathered from DRYW superseded the use of data collected at GCDW due to the proximity of the DRYW AGRIMET station to the main body of Banks Lake. Small data gaps were filled using linear interpolation. Larger gaps were filled with data generated by linear regressions between GCDW and the ODSW AGRIMET station or the MASW AGRIMET station; other substantial data gaps where linear regressions were not appropriate were filled by direct data substitution from other AGRIMET stations.

Statistical summaries of complete meteorological data records are provided for air temperature (Table 14), relative humidity (Table 15), dew point temperature (Table 16), wind speed (Table 17), cloud cover (Table 18), shortwave solar radiation (Table 19) and cumulative annual precipitation (Table 20).

Figure 24. AGRIMET weather station locations

Table 14. Banks Lake air temperature (°C) summary statistics 2002-2009

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	40.5	39.5	39.3	37.2	41.5	39.8	41	38.6
Min	-5.2	-8.1	-24	-16.1	-14.3	-12	-17.3	-12.8
Median	10.8	11	11.6	11.1	10.6	10.8	10.1	9.7
Average	12.19	12.05	12.04	11.21	11.79	11.41	10.67	10.86

Table 15. Relative humidity (%) summary statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	100	100	100	100	100	100	100	99.7
Min	10.1	9.4	11.8	9.5	8.7	9.1	9.3	7.2
Median	65	63.6	65.8	67.5	67.1	61.5	59.3	60.2
Average	63.8	62.7	63.7	65	64.2	60.4	58.9	59.1

Table 16. Calculated dew point temperature (°C) summary statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	17.9	19.9	22.5	5.58	18.1	17.6	16.9	16.2
Min	-4.6	-7.4	-18.7	-14.1	-9.6	-10.6	-12.2	-10.3
Median	5.7	5.6	5.9	5.8	5.7	5.2	4.6	4.6
Average	5.88	5.52	5.83	5.58	5.65	4.81	4.3	4.37

Table 17. Wind speed (m/s) statistics summary

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	38.45	10.28	9.52	1.8	8.69	19.84	10.53	12.19
Min	0	0	0	0	0.01	0	0	0
Median	1.79	1.51	1.44	1.53	1.51	0.8	1.62	1.76
Average	2.17	1.82	1.75	1.8	1.82	1.29	1.97	2.06

Table 18. Cloud cover data calculated from solar data (W/m²) 2002-2009

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	10	10	10	4.56	10	10	10	10
Min	0	0	0	0	0	0	0	0
Median	3.62	4.43	4.19	3.91	3.86	2.37	2.39	1.47
Average	4.35	4.69	4.51	4.56	4.56	4.28	4.16	4.1

Table 19. Short wave solar radiation (W/m²) summary statistics 2002-2009

Year	2002	2003	2004	2005	2006	2007	2008	2009
Max	984.6	984.6	1017	169.1	1057	1019	1068	1003
Min	0	0	0	0	0	0	0	0
Median	10.6	8.1	8.1	8.1	8.1	8.1	8.6	8.6
Average	169.6	166.2	165.8	169.1	169.5	170.6	170.9	173

Table 20. Annual precipitation (cm) summary statistics

Year	2002	2003	2004	2005	2006	2007	2008	2009
Rainfall	13.71	16.78	17.7	29.74	31.03	14.88	11.43	17.62

Topographical and Vegetative Shading

CE-QUAL-W2 is able to calculate the amount of topographic and vegetative shading that takes place on Banks Lake. Referencing Figure 25, when the angle of solar inclination (α) is less than that of the angle of topographical or vegetative inclination (α_t) the model will reduce short wave solar radiation intensity by 90%, leaving 10% to account for diffuse radiation. Figure 26 shows the maximum, minimum and average angles of inclination of Banks Lake while traveling downstream from the Feeder Canal. This feature is useful for water bodies surrounded by mountains or water bodies located within deep canyons, such as Banks Lake. Due to the lack of shoreline vegetation surrounding Banks Lake, vegetative shading was not considered in the model. Further discussion on CE-QUAL-W2 topographical shading is available in Cole and Wells (2010).

Figure 25. CE-QUAL-W2 dynamic topographic shading angles diagram

Figure 26. Banks Lake maximum, minimum and average angles of inclination moving downstream from the Feeder Canal

Water Quality Data

Water quality data that were relevant to the development and evaluation of the Banks Lake CE-QUAL-W2 model were shown in McCulloch, Berger and Wells (2011).

In-reservoir water quality profile data and chlorophyll-a data were collected by the WDFW during 2002, 2003, 2008 and 2009. Profile data were measured on a monthly to bimonthly basis from April to December with occasional profiles taken in January. Profile data were gathered from eleven sample sites throughout Banks Lake. Table 21 and Figure 27 show the location of the WDFW sample sites.

In-reservoir orthophosphorus, nitrate and chlorophyll-a data were collected by Dr. Ross Black of Eastern Washington University (EWU) from 2002 through 2004 (Black et al., 2008). Sampling frequency was site specific, but most sites were sampled on a monthly to bi-monthly basis during spring, summer and fall months. In-reservoir nitrate, orthophosphorus and chlorophyll-a data were sampled from the same sites used by the WDFW, so for the purpose of this report these sample sites will be referred to as Lim sites 1-11.

Table 21. WDFW Banks Lake water quality sampling sites

In-Reservoir Sampling Sites					
Washington State Department of Fish and Wildlife					
Station	Site Name	Latitude	Longitude	Start	End
Lim 1	North Basin	47.935036	-119.067857	2/21/2002	12/3/2009
Lim 2	Kruk's Bay	47.897731	-119.089652	6/4/2003	11/5/2009
Lim 3	Mid-Reservoir	47.884251	-119.138469	2/21/2002	12/3/2009
Lim 4	Devil's Punch Bowl	47.858729	-119.112952	6/4/2003	12/3/2009
Lim 5	Million Dollar Mile North	47.729784	-119.261919	2/21/2002	12/3/2009
Lim 6	Goose Island-Southwest	47.664420	-119.301624	6/4/2003	12/3/2009
Lim 7	Devil's Lake	47.896469	-119.115290	5/8/2008	12/3/2009
Lim 8	Osborne Bay	47.928174	-119.060059	4/24/2008	12/3/2009
Lim 9	Million Dollar Mile South	47.831916	-119.179253	5/8/2008	12/3/2009
Lim 10	Middle Barrier Net	47.621845	-119.298556	4/24/2008	12/3/2009
Lim 11	S. Tern Island on Barrier	47.621667	-119.306959	5/8/2008	12/3/2009
Eastern Washington State University					
Lim 1	North Basin	47.935036	-119.067857	4/23/2002	8/19/2004
Lim 2	Kruk's Bay	47.897731	-119.089652	6/4/2003	8/19/2004
Lim 3	Mid-Reservoir	47.884251	-119.138469	4/23/2002	8/19/2004
Lim 4	Devil's Punch Bowl	47.858729	-119.112952	6/4/2003	8/19/2004
Lim 5	Million Dollar Mile North	47.729784	-119.261919	4/23/2002	8/19/2004
Lim 6	Goose Island-Southwest	47.664420	-119.301624	6/4/2003	8/19/2004
Lim 7	Devil's Lake	47.896469	-119.115290	5/12/2009	11/27/2009
Lim 8	Osborne Bay	47.928174	-119.060059	5/12/2009	11/27/2009

Figure 27. WDFW Banks Lake water quality sampling sites

WDFW Water Quality Data

Figure 28 shows Banks Lake 2009 water temperature profile data for Lim site 1. Water temperature profile data were available for Lim sites 1, 3 and 5 in 2002, Lim sites 1-6 in 2003 and Lim sites 1-11 for 2008 and 2009. Summer highs often reached 20°C, sometimes as high as 28°C, and annual lows ranged 0-5°C. Most summer heating trends showed the onset of stratification from late June to mid July and lasting through September. Warming of upstream Lim sites 1, 2 and 8 showed less prominent summer stratification, most likely due to the seasonal pumping and mixing from Lake Roosevelt water coming into the system. Available winter water temperature data showed no winter stratification.

Figure 29 shows Banks Lake 2009 dissolved oxygen profile data for Lim site 1. Dissolved oxygen profile data were available for Lim sites 1, 3 and 5 in 2002, Lim site 1-6 in 2003 and Lim sites 1-11 for 2008 and 2009. Annual highs were measured during late winter/early spring months or during mid-summer algal blooms and ranged from 10 to 15 mg/l. Most Lim sites experienced some hypolimnetic dissolved oxygen depletion beginning around July and lasting throughout September with concentrations ranging 0.5-4 mg/l. Lim site 7 showed oxygen depletion in both the hypolimnion and at the thermocline during summer and fall months.

Figure 30 shows Banks Lake 2009 pH profile data for Lim site 1. pH profile data were available for Lim sites 1, 3 and 5 in 2002, Lim sites 1-6 in 2003 and Lim sites 1-11 for

2008 and 2009. pH extrema ranged from 5.1-9.0 but most values fell between 7.5-8.5.

Annual trends show a general drop in pH values during summer months in the hypolimnion and occasionally in the lower epilimnion. Data show these summer drops in pH to be more pronounced during 2008, reaching values as low as 6.38 at Lim site 7.

Figure 31 shows Banks Lake chlorophyll-a profile data. Chlorophyll-a profile data were available for Lim sites 1-8 in 2004 and Lim sites 1-7 in 2005. Limited chlorophyll-a data was available for 2003 with most sites sampled only two or three times annually, during the late summer or early fall. Maximum and minimum concentrations for 2003 ranged from 0.1 to 5.7 $\mu\text{g/l}$, but most values measured between 2-3 $\mu\text{g/l}$. Data from 2004 covered May through October and showed most sites had high algae growth during late spring months followed by intermediate growth through October. Maximum and minimum values for 2005 ranged from 0.4-10.3 $\mu\text{g/l}$ with most values measured between 2-3 $\mu\text{g/l}$. Most sites showed algal production was highest at depths of 6-12 meters. Consistently Lim site 4 was the most productive site sampled.

Figure 28. Banks Lake 2009 water temperature (°C) isopleths: Lim site 1

Figure 29. Banks Lake 2009 dissolved oxygen (mg/l) isopleths: Lim site 1

Figure 30. Banks Lake 2009 pH isopleths: Lim site 1

Figure 31. Banks Lake 2005 chlorophyll-a ($\mu\text{g/l}$) isopleths: Lim site 1

EWU Water Quality Data

Eastern Washington University (EWU) sampled Lim sites 1-8 from 2002 through 2004. Most sites were only sampled during the summer months of 2003 and 2004, but Lim sites 1, 3 and 5 were also samples throughout the fall and winter months of 2002.

Chlorophyll-a samples were collected in triplicate at a depth of 5 meters from Lim sites 1, 3 and 5 from 9/2002-6/2003. Chlorophyll-a profile data were collected from 6/2003-8/2004 and 5/2004-8/2004 for Lim sites 1-6 and Lim sites 7-8, respectfully. All orthophosphate and nitrate samples were collected in triplicate at a depth of 5 meters. Continued discussion of EWU nutrient data continues in the following section: EWU Nutrient Data Analysis

Figure 32 shows chlorophyll-a grab samples data from 2002-2003 for Lim sites 1, 3 and 5. Figure 33 shows chlorophyll-a profile data from 2003-2004 for Lim 4. Chlorophyll-a samples taken from 5 meters ranged from 0.88-5.14 $\mu\text{g/l}$. Lim site 1 chlorophyll-a concentrations peaked during the winter and spring months of 2003, Lim site 3 peaked during 10/2002, 12/2002 and 6/2003, and Lim site 5 concentrations peaked during 11/2002. Profile chlorophyll-a data normally ranged between 0-4 $\mu\text{g/l}$ for all dates sampled, with short peak concentrations exceeding 4 $\mu\text{g/l}$ occurring during the summer of 2004 for Lim sites 1, 5 and 6. Lim site 4 showed higher chlorophyll-a production from 2/2004-6/2004 with concentrations increasing from 4 $\mu\text{g/l}$ to 7 $\mu\text{g/l}$. Limited profile data collected at Lim site 8 also showed high concentrations ranging from 2-8.5 $\mu\text{g/l}$ during the summer of 2004. Lim site 4 and 8 were shown to have the highest productivity.

Figure 32. Banks Lake 2002-2003 chlorophyll-a concentrations ($\mu\text{g/l}$) measured at 5 meters

Figure 33. Banks Lake 2003-2004 chlorophyll-a ($\mu\text{g/l}$) isopleths: Lim site 4

EWU Nutrient Data Analysis

Orthophosphate and nitrate grab samples were collected by EWU at Lim sites 1-8 over 9/2002-8/2004 from a depth of 5 meters. EWU orthophosphate and nitrate concentrations ranged from 0-400 µg/l and 0-3.5 mg/l, respectively. Figure 34 and Figure 35 show orthophosphate and nitrate concentrations collected by EWU at Lim site 1. While these were the only Banks Lake nutrient data available during the calibration time period, the legitimacy of the magnitude of the EWU nutrient data required some further investigation. Ultimately, the EWU nutrient data were discarded and nutrient calibration for Banks Lake was not attempted. The following explains how the nutrient data was examined and also shows why the nutrient data collected by EWU was not used.

- The orthophosphate and nitrate concentrations of Banks Lake's source water in Lake Roosevelt ranged from 1-7 µg/l and 0.02-0.15 mg/l over the same time period the EWU data was collected, respectively. Figure 36 and Figure 37 show scatter plots of Lake Roosevelt phosphorus and nitrate concentrations from 2002-2008. This comparison suggests that either a large nutrient source exists within the Banks Lake watershed or the EWU nutrient data were incorrect. Further investigation found that both major municipalities within the Banks Lake watershed (Coulee City and Electric City) have waste water treatment sites, neither of which discharge into Banks Lake. Also, a significant portion of the Banks Lake watershed has been developed for agricultural production and would pose a high risk for non-point source nutrient discharge into the lake, but scant

precipitation records would suggest that not a likely possibility (McCulloch et al., 2011).

- Historical records from 1974-1976 produced by the U.S. Bureau of Reclamation (USBR) show orthophosphate concentrations ranging from 0-25 $\mu\text{g/l}$ (Stober et al., 1976). Figure 38 shows a scanned image of the orthophosphate graph published by the USBR.

- The orthophosphate field samples were processed colorimetrically within 8 hours of sampling using a HACH DR/850 colorimeter (Black et al., 2003). Analysis with the HACH DR/850 involved using the HACH Phosver 3 method (Black et al., 2003). According to the Hach website, using the HACH DR/850 with the HACH Phosver 3 method yields an estimated detection limit of 70 $\mu\text{g/l}$. This instrument would allow the researchers at EWU to accurately detect, at best, nutrient levels that would be considered highly eutrophic ($>> 20 \mu\text{g/l}$) and nothing less than that (Chapra, 1997).

- The EWU orthophosphate data would classify Banks Lake as highly eutrophic ($>> 20 \mu\text{g/l TP}$) while the chlorophyll-a data collected by both EWU and WDFW would classify Banks Lake as mesotrophic (4-10 $\mu\text{g/l CHLA}$) (Chapra, 1997). To better show this lack of nutrient agreement, EWU orthophosphate data was compared against theoretical total phosphorus concentrations that were calculated from in-lake chlorophyll-a data.

Equation 2 was taken from Dillion and Rigler (1974), equation 3 was taken from Rast and Lee (1978) and equation 4 was taken from Bartsch and Gakstatter (1978), where TP is total phosphorus in µg/l and Chl α is chlorophyll-a in µg/l.

$$\log(\text{TP}) = 0.69\log(\text{Chl}\alpha) + 0.783 \quad \text{Eq. 2}$$

$$\log(\text{TP}) = 1.315\log(\text{Chl}\alpha) + 0.341 \quad \text{Eq. 3}$$

$$\log(\text{TP}) = 1.239\log(\text{Chl}\alpha) + 0.24 \quad \text{Eq. 4}$$

Figure 39 shows a scatter plot of the EWU orthophosphate data plotted with the theoretically calculated total phosphorus concentrations for Lim site 1.

Figure 34. Orthophosphate data collected by EWU at Lim site 1: 2002-2004

Figure 35. Nitrate data collected by EWU at Lim site 1: 2002-2004

Figure 36. Lake Roosevelt orthophosphorus and total phosphorus concentrations 2002-2008

Figure 37. Lake Roosevelt nitrite, nitrate and total nitrogen concentrations 2002-2008

Figure 4.13 Mean monthly orthophosphate concentrations for Station 1, Stations 2 and 3 combined, and Stations 4, 5, and 6 combined; with the occurrence of feeder canal pumping or pump-generation from May 1974 to March 1976.

Figure 38. Historical orthophosphate concentrations for 1974-1976 (Stober et al., 1976)

Figure 39. Theoretical total phosphorus concentrations based on observed chlorophyll-a data and ortho-phosphorus data collected by EWU for Lim site 1

Biological Data

Algae

Algae data were collected by the Washington Department of Fish and Wildlife (WDFW) on roughly a monthly basis from 9/2002-8/2004. Lim sites 1, 3 and 5 were sampled monthly from 9/2002-12/2002, Lim sites 1-6 were sampled monthly during all of 2003 and Lim sites 1-8 were sampled monthly from 3/2004-8/2004. Algae samples were collected in triplicate at a depth of 5 meters. Samples were classified and separated by phylum, then measured as biovolume (mm^3/l). Table 22 shows the total annual biovolume and the percent of total annual algae biovolume for each algae group. Figure 40 shows algae biovolume data at Lim site 1 from 2002-2004.

Chrysophytes (diatoms) were the dominate group for all years with 70%, 79% and 59% of the total biovolume for 2002, 2003 and 2004 respectively. The cryptophytes were the second most abundant phyla with 16%, 12% and 24% of the total biovolume for 2002, 2003 and 2004 respectively. Chlorophyta were the third most frequently sampled algal group with an annual percentage of the total biovolume ranging from 3-7%.

Chrysophytes populations were highest during late winter/early spring months and would typically begin to decrease during mid to late summer. Pyrrophyta showed little presence for all years and euglenaopyta were measured only four times at Lim 2 and Lim 4 during late summer months. Eubacteria (bluegreen) would typically bloom during mid to late

summer months. Eubacteria made up at least 10% of the total sample abundance at Lim site 5 and 6 for all years.

Since CE-QUAL-W2 reads and outputs algae data as mass per volume concentrations, algae data collected by the WDFW were converted from biovolume (mm^3/l) to mass concentration (mg/l). The two most dominant algal groups, including the chrysophytes and cryptophytes, were converted to mass concentrations and used in the CE-QUAL-W2 model. Although the eubacteria and the chlorophyta did not make up a large percentage of the total sampled algal biovolume, their biovolumes were combined and converted to mass concentrations to make the third algal group used in the CE-QUAL-W2 model.

Figure 41 shows the converted algae mass concentrations for Lim 1. Figure 42 shows the exponential curve equation developed by Reynolds (1984) that was used to convert algal biovolume to mass. The Reynolds biovolume to mass equation (equation 5) was developed using algae mass to biovolume relationships among multiple taxonomic groups, where Y is mass in pictograms and X is biovolume in cubic millimeters.

$$Y = 0.47 \cdot X^{0.99} \quad \text{Eq. 5}$$

Thus, within certain biovolume ranges the conversion from biovolume to mass will be more accurate for some algal groups over others. The conversion equation was not published with any error statistics, so it should be noted that although using equation 5 is assumed to be reliable, some leeway should be also assumed in its conversion accuracy.

The alternative of using an empirically based conversion equation did not present itself, as there were no available algal mass data to accompany the algal biovolume data.

Table 22. Washington Fish and Wildlife phytoplankton summary statistics, average biovolume (mm^3/l)

	2002		2003		2004	
	Total	Ratio	Total	Ratio	Total	Ratio
Chlorophyta	0.44	0.03	2.26	0.04	2.26	0.07
Chrysophyta	11.58	0.7	39.79	0.75	18.81	0.59
Cryptophyta	2.69	0.16	6.48	0.12	7.58	0.24
Pyrrophyta	0.04	0	0.82	0.02	0.66	0.02
Euglenophyta	0	0	0.01	0	0	0
Eubacteria	1.78	0.11	3.97	0.07	2.37	0.07

Figure 40. Banks Lake phytoplankton biovolume concentrations (mm^3/l): Lim sites 1

Figure 41. Banks Lake phytoplankton mass concentrations (mg/l) converted from biovolume (mm^3/l): Lim site 1

Figure 42. Algae biovolume to mass conversion curve and equation where X is algae biovolume (mm^3) and Y is algae mass (pg) (Reynolds, 1984).

Zooplankton

Zooplankton data were collected by the Washington Department of Fish and Wildlife from Lim sites 1-11 on a mostly bi-monthly basis from 4/2008-11/2008 and 4/2009-11/2009. All Lim sites were sampled three times for each day sampled via a 0.15 meter radius zooplankton tow net. Samples were sorted by genus and counted. To achieve an accurate representation of zooplankton abundance in the water column the total number of zooplankton counted were then divided by the volume of water sampled by each tow, resulting in a zooplankton density of organisms per liter (organisms/l).

Copepodas were the dominate group for both years with 58% and 57% of the total density for 2008 and 2009 respectively. The rotoiferas were the second most abundant zooplankton group with 25% and 26% of the total density for 2008 and 2009 respectively. Copepoda populations peaked either in late spring or late fall depending on the Lim site. Rotoifera populations peaked during late spring and dropped to annual lows during late summer and early fall. Daphnia populations consistently made up 10-20% of the total zooplankton density for all Lim sites, except for Lim 2 where daphnia made up 26 % and 29% of the total zooplankton population for 2008 and 2009 respectively. Table 23 shows Banks Lake annual zooplankton density summaries. Figure 43 shows Banks Lake zooplankton densities for Lim site 1.

While the CE-QUAL-W2 modeling software reads and outputs zooplankton data in mass per volume concentrations, zooplankton density data collected by the WDFW were

converted to mass using regression equations developed with the monthly average zooplankton mass concentrations and densities from Lake Roosevelt collected by the Lake Roosevelt Fisheries Evaluation Program (LRFEP). Since the LRFEP collected mass and density data for only copepoda and daphnia groups, they were the groups that were converted to mass concentration values for Banks Lake. Figure 44 shows the converted zooplankton mass concentrations for Lim 1. Figure 45 and Figure 46 show the linear regressions used to convert zooplankton density data for daphnia and copepoda into mass concentration values. It should be noted that although the regression conversion equations are assumed to be accurate and have relatively high R^2 values, there is the potential for high levels of error in these conversions since density data does not provide any information into the size or length of the individual zooplankton organisms counted in each sample.

Table 23. Washington Fish and Wildlife zooplankton density summary statistics (organisms/l)

		Copepoda	Rotoifera	Daphnia	Other Cladocera
2008	Total Count	9078.87	3961.92	2248.90	415.73
	Ratio	0.58	0.25	0.14	0.03
2009	Total Count	6699.45	3016.53	1764.41	267.88
	Ratio	0.57	0.26	0.15	0.02

Figure 43. Banks Lake zooplankton densities (organisms/l): Lim 1

Figure 44. Banks Lake zooplankton concentrations (mg/m³) converted from density: Lim 1

Figure 45. Correlation between Lake Roosevelt monthly averaged Daphnia biomass and monthly averaged densities, where Y is Daphnia biomass (mg/m³) and X is Daphnia density (#/m³)

Figure 46. Correlation between Lake Roosevelt monthly averaged Copepoda biomass and monthly averaged densities, where Y is Copepoda biomass (mg/m³) and X is copepoda density (#/m³)

Banks Lake CE-QUAL-W2 Model Calibration

The Banks Lake model calibration period lasted from January 1st, 2002 to December 31st, 2009. The calibration time period was determined by data availability and data frequency. Model calibration consisted of first evaluating reservoir hydrodynamics, followed by water temperature, abiotic water quality constituents and then biotic water quality constituents. Table 24 shows the water quality constituents used for calibration and their data types. Calibration coefficients and setup are shown as the model control file in Appendix A.

Table 24. Water quality constituents and data types

Calibration Constituent	Data Type
Water Surface Elevation	Daily Time series, meters
Water Temperature	Vertical Profiles, °C
Dissolved Oxygen	Vertical Profiles, mg/l
pH	Vertical Profiles
Chlorophyll-a	Grab Sample, µg/l
Algae	Grab Sample, mg/l
Zooplankton	Net Tows, mg/l

Hydrodynamic Calibration

Hydrodynamic calibration was achieved by balancing inflow rates with outflow discharges while reproducing the corresponding water surface elevations for the given calibration period. Inaccurate flow gages, ground water seepage and evaporation act as sinks to the flow regime, and are accounted for in the calibration process by adding a user created distributed tributary. The distributed tributary is capable of adding or subtracting water from the system when needed, thus allowing for accurate water surface elevation predictions. Further discussion on hydrodynamic boundary conditions is available in McCulloch, Berger and Wells (2011).

Water surface elevation error statistics and average distributed tributary flows are shown in Table 25. Model predicted water surface elevations and observed water surface elevations for 2002 are plotted in Figure 47. Outflows from the Main Canal at Dry Falls Dam and distributed tributary flows for 2002 are plotted in Figure 48. Figure 49 shows model predicted and observed water surface elevations with distributed tributary flows for the entire 2002-2009 calibration period.

Table 25. Water surface elevation and distributed tributary flow statistics: 2002-2009

Year	Mean Error, m	Absolute Mean Error, m	Root Mean Square Error, m	Average Annual Distributed Tributary Flow, m ³ /s
2002	0.005	0.03	0.051	-4.92
2003	0.014	0.035	0.052	-4.41
2004	0.01	0.024	0.037	-4.22
2005	0.028	0.048	0.075	-4.9
2006	0.028	0.051	0.078	-5.72
2007	0.026	0.043	0.058	-5.74
2008	0.036	0.045	0.061	-11.85
2009	0.035	0.051	0.064	-4.95
Average	0.023	0.041	0.06	-5.84

Figure 47. Model predicted water surface elevation with observed data from Banks Lake, 2002

Figure 48. Outflow discharge from the Main Canal at Dry Falls Dam with water balance flows, 2002

Figure 49. Model predicted water surface elevation (red) with observed data (black) and distributed tributary flow (blue), 2002-2009

Light Extinction

Light extinction data were collected as secchi depths at all 11 Lim sites from 2008-2009.

The secchi depths can be converted to light extinction coefficients by using two

theoretical equations from the literature. The Poole and Atkins (1929) equation is $\lambda =$

$1.7/S_d$ where λ is the light extinction coefficient in meters^{-1} and S_d is the secchi depth in

meters. The Williams et al. (1980) equation is $\lambda = 1.11S_d^{-0.73}$. Both equations were used

to convert the secchi depths to light extinction coefficient values and then compared

against light extinction coefficient data calculated by CE-QUAL-W2 on the same day

that secchi depths were measured. Table 26 shows the average secchi depth, the average

model predicted light extinction coefficients and the theoretically calculated light

extinction coefficients for Lim Sites 1-11 during 2008-2009. Figure 50 shows the secchi

depths, the model predicted light extinction coefficients and the light extinction

coefficients theoretically calculated from Poole and Atkins (1929) and Williams et al.

(1980) for Lim site 2 during 2008-2009. The model typically over calculated the light

extinction coefficients with an average error of 0.08 m^{-1} when compared to the Williams

et al. (1980) light extinction coefficients and a mean error of 0.06 m^{-1} when compared to

the Poole and Atkins (1929) light extinction coefficients. Light extinction coefficients

are shown in the control file located in Appendix A, under the subheading “EX COEF”.

Table 26. Comparison of secchi disk depths, theoretical light extinction coefficients and model predicted light extinction coefficients

Lim Site	Average Secchi Depth, m	Average Model Predicted Light Extinction Coefficient, m ⁻¹	Average Light Extinction Coefficient (Williams, et al. 1980), m ⁻¹	Average Light Extinction Coefficient (Poole and Atkins, et al. 1980), m ⁻¹
1	5.27	0.44	0.35	0.35
2	3.56	0.46	0.46	0.51
3	4.46	0.48	0.40	0.43
4	3.52	0.47	0.46	0.52
5	4.72	0.47	0.37	0.36
6	5.44	0.47	0.33	0.33
7	4.84	0.46	0.36	0.37
8	3.75	0.44	0.45	0.50
9	4.86	0.47	0.36	0.37
10	4.71	0.48	0.36	0.37
11	5.06	0.48	0.35	0.35

Figure 50. Secchi depths (m), model predicted light extinction coefficients and theoretical light extinction coefficients for Lim 2 during 2008-2009 (Williams 1980) (Poole & Atkins 1929).

Water Temperature Calibration

Calibrating water temperature consisted of matching model profile predictions to water temperature profile data that was collected by the WDFW. Major drivers that dictate correct water temperature calibration include:

- 1.) Developing a correct bathymetry grid that is representative of the actual bathymetry and facilitates water and energy flow that is true to nature
- 2.) Accurately calibrating the hydrodynamics of the system through the use of distributed tributary flows and using correct boundary condition flows
- 3.) Using accurate and spatially relevant meteorological input data. Daily heating from short wave solar radiation and cooling from evaporation can have substantial effects on the energy budget of the lake

Further fine tuning of water temperature profile data was executed by altering the wind sheltering coefficients (WSC), which are used to increase or decrease the magnitude of wind driven mixing on a segment by segment basis through multiplying the current wind velocity by a user defined coefficient. The wind sheltering coefficient is vital in reproducing mixing characteristics for larger system such as Banks Lake since wind data are often measured offsite. Correct wind data will also provide for more correct evaporation rates. Figure 51 shows a comparison of the effects two different wind sheltering coefficients have on water temperature profiles predicted by the model. Figure 52 show the wind sheltering coefficients used in model calibration.

The calibrated model did well to match temperature data on days that were relatively isothermal. On days when stratification was prominent the model would typically do well to match either or both the epilimnion and hypolimnion temperatures but then miss parts of the thermocline. This is most likely attributed to incorrect wind driven mixing. The majority of available wind data used in the model was collected from the Grand Coulee Dam AGRIMET station (GCDW), which has a predominant east-west wind direction, where the actual prominent wind direction at Banks Lake is South-North.

Table 27 shows model-data error statistics and the number of model-data comparisons for temperature. Figure 53 shows a regression plot of model predicted water temperature profile data regressed against corresponding field data. Temperature calibration model-data vertical profile plots are shown in Appendix B.

Figure 51. Effect of wind on predicted water temperature profile for Lim site 9 on 7/2/2008 with a wsc=0.8 and wsc=1.5

Figure 52. Wind sheltering coefficients used for model temperature calibration

Table 27. Model–data error statistics for water temperature profile data for 2002, 2003, 2008 and 2009

Station	Model Segment	Number of Days with Data	Number of Comparisons	Mean Error, °C	Absolute Mean Error, °C	Root Mean Square Error, °C	Years
1	15	60	612	-0.73	0.79	0.84	2002, 2003, 2008 & 2009
2	173	34	108	-0.7	0.82	0.91	2003, 2008 & 2009
3	39	59	570	-0.68	0.98	1.09	2002, 2003, 2008 & 2009
4	158	39	203	-0.1	0.91	1.02	2003, 2008 & 2009
5	82	58	689	0.15	1.08	1.2	2002, 2003, 2008 & 2009
6	99	39	425	0.18	1.03	1.19	2003, 2008 & 2009
7	147	29	670	0.46	1.1	1.33	2008 & 2009
8	181	33	124	0.05	0.73	0.86	2008 & 2009
9	54	32	357	0.16	0.76	0.88	2008 & 2009
10	109	31	115	0.84	0.99	1.02	2008 & 2009
11	110	30	177	0.81	1.09	1.15	2008 & 2009
AVE				0.04	0.94	1.04

Figure 53. A regression plot of model predicted water temperature profile data and water temperature profile data collected by WDFW

Dissolved Oxygen Calibration

Calibrating dissolved oxygen consisted of matching model profile predictions to dissolved oxygen profile data that were collected by the WDFW. Figure 54 shows a flow chart of dissolved oxygen sources and sinks which include:

Source

1.) Reaeration from the atmosphere through diffusion and turbulent mixing.

Reaeration can be controlled in the CE-QUAL-W2 model by either selecting predetermined reaeration equations that are suited for different water systems, or there is the option of creating a user defined equation.

2.) Algal photosynthesis

Sinks

1.) Algal and zooplankton respiration

2.) Biological/sediment oxygen demand (BOD/SOD)

3.) Nitrification

4.) Diffusion into the atmosphere

Dissolved oxygen calibration proved to be challenging in that when in error, the model would most commonly produce too little dissolved oxygen and thus result in an overall negative mean error. More specifically, the model had a difficult time reproducing dissolved oxygen levels when the field data were shown to have been supersaturated.

This under production of dissolved oxygen is most likely due to occurring algal blooms

that were not reproduced by the model or perhaps changes in wind's effect on mixing that was not reproduced by the model. To help facilitate model oxygen production the model default reaeration equation for lakes was changed to a more conservative equation which would lose oxygen to the atmosphere less quickly. Also the oxygen production capacity of all algal groups was increased. Despite the need to increase overall dissolved oxygen concentrations, sediment oxygen demand (SOD) ($\text{g O}_2/\text{m}^2 \cdot \text{day}$) was increased for some segments. An increase in SOD would result in a slight decrease in hypolimnetic dissolved oxygen and also help shape the model's dissolved oxygen profile to more resemble the field data. SOD and algal photosynthesis rates are shown in the model control file in Appendix A under sub heading "STOICH 2" and "S DEMAND" respectively. Figure 55 shows a comparison of the effects two different sediment oxygen demand coefficients have on predictions of dissolved oxygen.

Table 28 shows model-data error statistics and the number of model-data comparisons for dissolved oxygen. Figure 56 shows a regression plot of model predicted dissolved oxygen profile data regressed against corresponding field data. Dissolved oxygen model-data vertical profile plots are shown in Appendix C.

Figure 54. A flow chart of dissolved oxygen sources and sinks (Cole and Wells, 2010)

Figure 55. Effects of SOD on dissolved oxygen profile predictions for Lim site 6 on 7/30/2008 with a SOD=0.3 and SOD=0.50

Table 28. Model–data error statistics for dissolved oxygen profile data 2002, 2003, 2008 and 2009

Station	Model Segment	Number of Days with Data	Number of Comparisons	Mean Error, mg/l	Absolute Mean Error, mg/l	Root Mean Square Error, mg/l	Years
1	15	55	551	-1.34	1.45	1.50	2002, 2003, 2008 & 2009
2	173	34	109	-0.71	1.24	1.24	2003, 2008 & 2009
3	39	55	522	-0.69	1.16	1.16	2002, 2003, 2008 & 2009
4	158	39	201	-0.40	1.13	1.13	2003, 2008 & 2009
5	82	53	622	-0.58	1.06	1.06	2002, 2003, 2008 & 2009
6	99	38	413	-0.39	1.02	1.02	2003, 2008 & 2009
7	147	29	669	-0.17	1.37	1.37	2008 & 2009
8	181	32	120	-1.51	1.65	1.65	2008 & 2009
9	54	32	357	-0.71	1.24	1.24	2008 & 2009

Figure 56. A regression plot of model predicted dissolved oxygen profile data and dissolved oxygen profile data collected by WDFW

pH Calibration

Calibrating for pH consisted of matching model profile predictions to pH profile data that were collected by the WDFW. While pH levels are primarily controlled by carbonate chemistry, pH calibration consisted of little more than providing good boundary condition data. Alkalinity, pH and back calculated total inorganic carbon data were gathered as boundary condition data from the Lake Roosevelt Fisheries Evaluation Program (LRFEP). In addition to correct boundary condition data, side effects of other calibration process such as increasing the respiration rate of algae and zooplankton or changing the reaeration equation would allow for more diffusion of CO₂ into the water thus resulting in a lower pH.

Table 29 shows model-data error statistics and the number of model-data comparisons for pH. Figure 57 shows a regression plot of model predicted pH profile data regressed against corresponding field data. pH model-data vertical profile plots are shown in Appendix D.

Table 29. Model–data error statistics for pH profile data 2002, 2003, 2008 and 2009

Station	Model Segment	Number of Days with Data	Number of Comparisons	Mean Error	Absolute Mean Error	Root Mean Square Error	Years
1	15	55	578	-0.3	0.55	0.56	
2	173	30	82	-0.08	0.46	0.47	2008 & 2009
3	39	54	539	-0.27	0.44	0.46	2002, 2003, 2008 & 2009
4	158	34	173	-0.08	0.31	0.34	2008 & 2009
5	82	53	654	-0.09	0.34	0.37	2002, 2003, 2008 & 2009
6	99	34	386	0.06	0.26	0.27	2008 & 2009
7	147	29	670	0.01	0.24	0.3	2008 & 2009
8	181	33	124	-0.09	0.43	0.44	2008 & 2009
9	54	32	357	-0.08	0.32	0.36	2008 & 2009
10	109	32	118	0.16	0.24	0.24	2008 & 2009
11	110	31	180	0.14	0.23	0.24	2008 & 2009
AVE				-0.05	0.35	0.37

Figure 57. A regression plot of model predicted pH profile data and pH profile data collected by WDFW

Chlorophyll-a Calibration

Chlorophyll-a calibration consisted of matching chlorophyll-a model prediction time series to chlorophyll-a data that was collected by the WDFW and Eastern Washington University (EWU). Chlorophyll-a data was collected at Lim sites 1-8 by EWU from 9/02-9/04 and by WDFW from 9/04-11/05. Although some of the chlorophyll-a data was collected as profile data, all data collected in 2002 and part of 2003 were single grab samples from a depth of 5 meters. Therefore, calibration used model output from a depth of 5 meters to compare against either field grab samples or profile data measured at a depth of 5 meters.

CE-QUAL-W2 calculates chlorophyll-a as a fixed ratio of predicted algal mass (mg algae/ μ g Chla). Calibration for chlorophyll-a consisted of fine tuning the algal mass to chlorophyll-a ratios for each algal group so that field data concentrations could be met. Algal group 1 had a ratio of 0.22 (mg algae/ μ g Chla), algal group 2 had a ratio of 0.11 (mg algae/ μ g Chla) and algal group 3 had a ratio of 0.14 (mg algae/ μ g Chla). The model did well to match seasonal fluxes in chlorophyll-a concentration across all Lim sites. Winter 2002-03 field data from Lim sites 1, 3 and 5 showed a summer-like algal bloom that was not captured by the model. This miss by the model is a result of it not capturing the correct algal production for winter 2002-03.

Figure 58 shows a regression plot of model predicted chlorophyll-a data regressed against corresponding field data. Figure 59 and Figure 60 show a comparison of model predicted

time series of chlorophyll-a data and field data collected by WDFW and EWU at a depth of 5 meters at Lim site 1-8 during 2002-2005.

Figure 58. A regression plot of model predicted chlorophyll-a data and chlorophyll-a data collected by WDFW and EWU at a depth of 5 meters

Figure 59. Chlorophyll-a model predictions compared against data collect by EWU and WDFW at a depth of 5 meters for Lim sites 1, 2, 3 and 4

Figure 60. Chlorophyll-a model predictions compared against data collect by EWU and WDFW at a depth of 5 meters for Lim sites 5, 6, 7 and 8

Algae Calibration

The Banks Lake CE-QUAL-W2 model used three algal groups:

Algae 1: Diatoms

Algae 2: Cryptophyta

Algae 3: Other (Green/Blue Green Algae)

The first two algal groups represent the most dominant algal groups taken from the data and the third algal group includes all other algal groups of interest. Calibrating for algae used 5 main parameters which allowed to custom fit different algal groups within the model to match the life characteristics of their natural algal taxonomy group. Each group was assigned a specific maximum daily growth rate, a temperature range within which each group would grow at their maximum growth rate, a daily sinking rate, a daily mortality rate, and specific algal nutrient stoichiometry. These calibration parameters are shown in the control file located in Appendix A under subheading "ALGAL RATE" "ALGAL TEMP" and "ALGAL STOI". Proper use of these parameters allows for each algal group to bloom during the appropriate time of year, compete with each other for available nutrients, remain in the water column long enough to provide additional oxygen production or die and contribute to the nutrient cycle or add to the biological oxygen demand. Default values were used first for the algal parameters, and then as calibration progressed each parameter value was altered to achieve the best results.

Algae 1-Diatoms

Figure 61 shows a regression plot of model predicted algae 1 mass concentrations against field data collected at a depth of 5 meters by the WDFW. Model-data comparisons of algae 1 mass concentrations measured at a depth of 5 meters are shown in Figure 62 and Figure 63 for Lim sites 1-8.

Figure 61. A regression plot of model predicted Algae 1(diatoms) (mg/l) and Algae 1 data (mg/l) collected by the WDFW at a depth of 5 meters

Figure 62. Algal group 1 (Diatoms) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 1, 2, 3 and 4

Figure 63. Algal group 1 (Diatoms) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 5, 6, 7 and 8

Algae 2-Cryptophyta

Figure 64 shows a regression plot of model predicted algae 2 mass concentrations against field data collected at a depth of 5 meters by the WDFW. Model-data comparisons of algae 2 mass concentrations measured at a depth of 5 meters are shown in Figure 65 and Figure 66 for Lim sites 1-8.

Figure 64. A regression plot of model predicted Algae 2 (Cryptophyta) (mg/l) and Algae 2 data (mg/l) collected by the WDFW at a depth of 5 meters

Figure 65. Algal group 2 (Cryptophyta) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 1, 2, 3 and 4

Figure 66. Algal group 2 (Cryptophyta) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 5, 6, 7 and 8

Algae 3-Green & Blue Green Algae

Figure 67 shows a regression plot of model predicted algae 3 mass concentrations against field data collected at a depth of 5 meters by the WDFW. Model-data comparisons of algae 3 mass concentrations measured at a depth of 5 meters are shown in Figure 68 and Figure 69 for Lim sites 1-8.

Figure 67. A regression plot of model predicted Algae 3(Green & Bluegreen) (mg/l) and Algae 3 data (mg/l) collected by the WDFW at a depth of 5 meters

Figure 68. Algal group 3 (Green and Bluegreen) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 1, 2, 3 and 4

Figure 69. Algal group 3 (Green and Bluegreen) model predictions compared against data that was collected by the WDFW at a depth of 5 meters for Lim sites 5, 6, 7 and 8

Zooplankton Calibration

The Banks Lake CE-QUAL-W2 model used two zooplankton groups:

Zooplankton 1: Copepod

Zooplankton 2: Daphnia

Zooplankton samples collection took place at all 11 Lim sites over 2008-2009. Samples were collected with a mesh tow net and the depth of tows among each Lim site would often vary throughout the year. For each tow the total number of individual zooplankton organisms were counted and then averaged over the total volume of water sampled by the tow net, resulting in a volume weighted density. Evaluating zooplankton abundance this way has the potential to dilute a sample's density if the tow was taken from a depth beyond the epilimnion where fewer zooplankton reside.

Zooplankton calibration, like algae calibration, involved multiple parameters that are used to fine tune zooplankton groups within the model to mimic the behavior and propagation of real zooplankton. The main calibration tools used included, a maximum daily growth rate, a temperature range within which each group would grow at their maximum growth rate, specific zooplankton nutrient stoichiometry, a daily mortality rate, algal prey feeding preference, zooplankton prey feeding preference, and a feeding assimilation efficiency coefficient. The algal and zooplankton feeding preference parameter allows the user to control each zooplankton group's like and dislike for certain

prey items (i.e., diatoms vs blue green algae). The feeding assimilation efficiency parameter allows the user to determine the proportion of food assimilated to food consumed for each zooplankton group. These zooplankton calibration coefficients are listed within the control file in Appendix A under subheadings “ZOOP RATE”, “ZOOP ALGP”, “ZOOP ZOOP”, “ZOOP TEMP” and “ZOOP STOP”.

Zooplankton densities are often spotty in distribution within natural systems and concentrations can vary multiple orders of magnitude within a 24 hour period. When modeling zooplankton, it is often the goal of the modeler to produce model predictions within an order of magnitude of the field data. The following zooplankton plots intend to show the model’s ability to reproduce measured zooplankton concentrations and show how zooplankton concentrations vary with depth.

Figure 70, Figure 71, Figure 72 and Figure 73 show a range of model predicted zooplankton time series beginning at a depth of 5 meters and extending to a depth comparable to the tow depths used to collect zooplankton data at that particular Lim site, with the volume weighted mass concentrations field data of zooplankton group 1.

Figure 74, Figure 75, Figure 76 and Figure 77 show a range of model predicted zooplankton time series beginning at a depth of 5 meters and extending to a depth comparable to the tow depths used to collect zooplankton data at that particular Lim site, with the volume weighted mass concentrations field data of zooplankton group 2.

Figure 70. Zooplankton group 1 (copepods) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 1, 2 and 3

Figure 71. Zooplankton group 1 (copepods) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 4, 5 and 6

Figure 72. Zooplankton group 1 (copepods) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 7, 8 and 9

Figure 73. Zooplankton group 1 (copepods) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 10 and 11

Figure 74. Zooplankton group 1 (daphnia) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 1, 2 and 3

Figure 75. Zooplankton group 1 (daphnia) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 4, 5 and 6

Figure 76. Zooplankton group 1 (daphnia) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 7, 8 and 9

Figure 77. Zooplankton group 1 (daphnia) model predictions at multiple depths compared against zooplankton tow data collected by the WDFW for Lim sites 10 and 11

Alternative Action Management Scenarios

Alternative Action Management Scenario Background & Data

The Odessa Subarea Special Study draft EIS outlines eight action alternative management scenarios and one no-action alternative that involve altering the monthly drawdown schedule of Banks Lake. To anticipate the effects of various flow years on the proposed action alternative management scenarios, four previous flow years were selected to represent a range of conditions:

Wet: 1982

Average: 1995

Dry: 1998

Drought: 1931

To determine the effect of each alternative scenario on Banks Lake, the Banks Lake CE-QUAL-W2 model was run for one year (January 1 through December 31) under the drawdown guidelines of each action alternative outlined in the Banks Lake Draft EIS. This approach involved using the appropriate daily averaged Feeder Canal inflow for each wet, average, dry and drought run (see Table 31). All action alternatives were run using meteorological data from 2007 since meteorological data for all 1931, 1982, 1995 and 1998 were not available. Comparing annual meteorological data within the 2002-2009 model simulation showed that 2007 meteorological data were neither high nor low

in any category, rather all max, min and average annual meteorological values from 2007 were near the overall average value for the entire eight year model simulation (Table 30). Since the dry flow reference year (1931) preceded the inundation of Banks Lake, flow records were not available from the Feeder Canal and flow from the drought flow reference year (1998) was used instead.

Feeder canal flow records show a gradual increase in total annual flow entering Banks Lake from 1982 to 2009, but there is little correlation between feeder canal flow rates and the type of flow reference year (see Figure 78). Therefore, the no-action alternative model run was based on 2008 flow records, since the 2008 water elevation records follow an August drawdown similar to the no-action alternative guidelines (see Figure 79).

Each model run began with its prescribed initial water surface elevation (mostly 1570 ft, 478.536 m) and followed the feeder canal flow regime as outlined in Table 31.

Water level draw-downs were controlled primarily through the use of the dynamic weir application. The dynamic weir application accesses a user defined time series of desired water surface elevations, which raises or lowers a weir at the lake's outlet over time.

This method allows for altering the water surface elevation of the lake through controlling the outflow at Dry Falls Dam while maintaining the specific Feeder Canal flow rates for the given hydraulic year. CE-QUAL-W2 calculates the discharge spilling over the weir with a weir flow rating curve, where Q is flow leaving via the weir, ΔH is the head difference between the water level of the segment upstream of the weir and the weir crest elevation, α is a user defined variable and β is a user defined variable.

$$Q = \alpha \Delta H^\beta \quad \text{Eq. 6}$$

Using the weir equation allows for control of how quickly the water surface elevation responds to changes in the weir crest height as well as provide that the water discharge at the weir never exceeds the maximum flow rate of the Main Canal (546 m³/s). Rather than simulate water spilling over the dynamic weir whenever there is a positive head difference at the weir crest, the creation of unwanted currents was avoided by instead pulling water from the system at a fixed elevation of 471 m (NAVD88). In addition to the dynamic weir outlet, the original outlet structure at Dry Falls dam was used to constantly discharge a flow rate 90% that of the daily average inflow at the Feeder Canal. By releasing 90% of the Feeder Canal inflow through the Main Canal in combination with the dynamic weir, outflow leaving the Dry Falls Dam was less subject to occasional spikes which happen when large volumes of water are released during periods of high inflow or during periods of substantial draining from the lake.

Figure 78. Banks Lake Feeder Canal flow annual totals

Figure 79. Banks Lake water surface elevation: 2008

Table 30. Banks Lake 2007 and 2008 meteorological summary statistics and comparison

Air Temp			
	Max	Min	Ave
2002-09 Max	41	37.2	39.675
2002-09 Min	-5.2	-24	-13.725
2002-09 Ave	12.2	10.7	11.525
2007	39.8	-12	11.4
2008	41	-17.3	10.7

Humidity			
	Max	Min	Ave
2002-09 Max	100	99.7	99.9625
2002-09 Min	11.8	7.2	9.3875
2002-09 Ave	65	58.9	62.225
2007	100	9.1	60.4
2008	100	9.3	58.9

Dew Point			
	Max	Min	Ave
2002-09 Max	30	16.2	19.8875
2002-09 Min	-4.6	-18.7	-10.9375
2002-09 Ave	5.9	4.6	5.3875
2007	17.6	-10.6	4.8
2008	16.9	-12.2	4.3

Short Wave Solar			
	Max	Min	Ave
2002-09 Max	1067.9	984.6	1017.475
2002-09 Ave	173	165.8	169.3375
2007	1018.6	0	170.6
2008	1067.9	0	170.9

Wind Speed			
	Max	Min	Ave
2002-09 Max	38.4	7.4	12.675
2002-09 Ave	2.2	1.8	1.5625
2007	10.6	0	1.9
2008	8.9	0	1.9

Rainfall			
	Max	Min	Ave
2002-09	31.03	11.43	19.11
2007*	14.88		
2008*	11.43		
* cumulative annual values only			

Table 31. Odessa Subarea Special Study EIS reservoir draw downs for Banks Lake

Run Number	Mgmt. Alternati	Flow Year	Flow Year	Management Scenario Drawdown Schedule (meters)											
				Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	No Action	2008	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.52	0.00	0.00	0.00	0.00
2	2A	1995	Average	0.00	0.00	0.00	-0.06	0.00	-0.30	-0.67	-2.56	-0.49	0.00	0.00	0.00
3	2B	1995	Average	0.00	0.00	0.00	-0.12	-0.34	-0.64	-0.91	-2.44	-0.91	0.00	0.00	0.00
4	2C	1995	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.55	-0.12	0.00	0.00	0.00
5	2D	1995	Average	0.00	0.00	0.00	0.00	-0.15	-0.15	-0.15	-2.44	-1.52	0.00	0.00	0.00
6	3A	1995	Average	0.00	0.00	0.00	-0.03	0.00	-0.79	-1.74	-4.11	-1.86	-0.40	0.00	0.00
7	3B	1995	Average	0.00	0.00	0.00	-0.03	-0.37	-0.91	-0.91	-2.44	-0.91	-0.06	0.00	0.00
8	3C	1995	Average	-0.52	0.00	0.00	0.00	0.00	-0.30	-0.73	-3.05	-1.58	-0.85	0.00	0.00
9	3D	1995	Average	0.00	0.00	0.00	0.00	-0.21	-0.52	-0.91	-2.44	-1.52	-0.79	0.00	0.00
10	2A	1998	Dry	0.00	0.00	0.00	-0.12	-0.34	-0.64	-1.01	-2.99	-0.85	0.00	0.00	0.00
11	2B	1998	Dry	0.00	0.00	0.00	-0.12	-0.34	-0.64	-0.91	-2.44	-0.91	0.00	0.00	0.00
12	2C	1998	Dry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.68	-0.24	0.00	0.00	0.00
13	2D	1998	Dry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.44	-1.52	0.00	0.00	0.00
14	3A	1998	Dry	-0.58	-0.58	0.00	-0.09	-0.43	-1.22	-2.16	-4.57	-2.23	-0.64	-0.64	-0.64
15	3B	1998	Dry	0.00	0.00	0.00	-0.09	-0.43	-0.91	-0.91	-2.44	-0.91	-0.03	0.00	0.00
16	3C	1998	Dry	-1.19	-1.19	0.00	0.00	0.00	-0.34	-1.25	-3.60	-2.01	-1.16	-1.16	-1.16
17	3D	1998	Dry	0.00	0.00	0.00	0.00	0.00	-0.34	-0.91	-2.44	-1.52	-0.73	0.00	0.00
18	2A	1982	Wet	0.00	0.00	0.00	-0.06	0.00	0.00	-0.37	-2.23	-0.18	0.00	0.00	0.00
19	2B	1982	Wet	0.00	0.00	0.00	-0.12	-0.34	-0.64	-0.91	-2.44	-0.91	0.00	0.00	0.00
20	2C	1982	Wet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.55	0.00	0.00	0.00	0.00
21	2D	1982	Wet	0.00	0.00	0.00	0.00	-0.15	-0.30	-0.30	-2.44	-1.52	0.00	0.00	0.00
22	3A	1982	Wet	0.00	0.00	0.00	-0.03	0.00	0.00	-0.91	-3.23	-1.04	0.00	0.00	0.00
23	3B	1982	Wet	0.00	0.00	0.00	-0.03	-0.34	-0.91	-0.91	-2.44	-0.91	-0.06	0.00	0.00
24	3C	1982	Wet	0.00	0.00	0.00	0.00	0.00	0.00	-0.40	-2.26	-0.85	-0.12	0.00	0.00
25	3D	1982	Wet	0.00	0.00	0.00	0.00	-0.18	-0.91	-0.91	-2.44	-1.52	-0.79	0.00	0.00
26	2A	1998	Drought	0.00	0.00	0.00	-0.12	-0.34	-0.64	-1.01	-2.93	-0.79	0.00	0.00	0.00
27	2B	1998	Drought	0.00	0.00	0.00	-0.12	-0.34	-0.64	-0.91	-2.44	-0.91	0.00	0.00	0.00
28	2C	1998	Drought	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.68	-0.24	0.00	0.00	0.00
29	2D	1998	Drought	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-2.44	-1.52	0.00	0.00	0.00
30	3A	1998	Drought	-0.82	-0.82	-0.79	-0.88	-1.25	-2.10	-3.08	-5.58	-3.20	-1.65	-1.65	-1.65
31	3B	1998	Drought	-0.82	-0.82	-0.82	-0.91	-0.91	-0.91	-0.91	-2.44	-0.91	-0.91	-0.91	-0.91
32	3C	1998	Drought	-1.77	-1.77	-1.77	-1.49	-1.31	-1.68	-2.62	-5.06	-3.51	-2.68	-2.68	-2.68
33	3D	1998	Drought	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-2.44	-1.52	-0.91	0.00	0.00

Alternative Action Management Scenario Preparation

In preparation of evaluating the effects of the alternative management scenarios on the water quality and fisheries population of Banks Lake, all management scenarios were first prepared to produced the water level elevation changes outlined in the Odessa Subarea Special Study draft EIS. Preparing the model for each scenario was an iterative process, running the model then making changes to either the weir equation or weir crest elevation, then running the model again. Special care was taken to avoid exceeding the 546 m³/s maximum discharge rate allowed by the Main Canal and to achieve the desired water surface elevation on the appropriate date. Avoiding discharge rates in excess of 546 m³/s was sometimes difficult at the beginning of the summer drawdown when large volumes of water were being released by the dynamic weir, also in situations when a constant surface elevation needed to be maintained while inflow rates from the Feeder Canal exceeded 546 m³/s. Figure 80, Figure 81, Figure 82, Figure 83, Figure 84, Figure 85, Figure 86, Figure 87 and Figure 88 show the prepared water surface elevation and flows of the no-action alternative and management scenarios Average-2A, Average-3B, Dry-2A, Dry-3A, Drought-2A, Drought-3A, Wet-2A and Wet-3B alternative action management scenarios.

Figure 80. Prepared water surface elevations and flows rates for the no-action alternative

Figure 81. Prepared water surface elevations and flows rates for management scenario Average 2A

Figure 82. Prepared water surface elevations and flows rates for management scenario Average 3A

Figure 83. Prepared water surface elevations and flows rates for management scenario Dry 2A

Figure 84. Prepared water surface elevations and flows rates for management scenario Dry 3A

Figure 85. Prepared water surface elevations and flows rates for management scenario Drought 2A

Figure 86. Prepared water surface elevations and flows rates for management scenario Drought 3A

Figure 87. Prepared water surface elevations and flows rates for management scenario Wet 2A

Figure 88. Prepared water surface elevations and flows rates for management scenario Wet 3A

Alternative Action Management Scenario Results and Discussion

The next section will discuss the results and implications of the alternative action management scenarios as outlined in the Odessa Subarea Draft EIS. The management scenarios were evaluated by measuring the following:

- 1.) Effects of alternative action management scenarios on temperature stratification
- 2.) Change in the percent of total reservoir volume over time that meets both dissolved oxygen and temperature criteria which promote optimal growth habitat conditions for selected sport fish species
- 3.) Effects of management scenarios on dissolved oxygen concentrations in the reservoir
- 4.) Mass flow rate of zooplankton entrainment from Dry Falls Dam
- 5.) Use of a fish bioenergetics model to evaluate output from CE-QUAL-W2 to predict fish growth in kokanee

Effect of Alternative Action Management on Temperature Stratification

The effects of alternative management scenarios on reservoir temperature characteristics were examined by plotting model predicted vertical temperature profiles from the Banks Lake CE-QUAL-W2 model. Lim site 3, located west of Steamboat Rock in the middle pool, was selected to represent a pelagic environment and Lim site 4, located within Devil's Punch Bowl due east of Steamboat Rock, was selected to represent the littoral zone. Model predicted water temperature data was recorded on April 15th, August 31st, and November 15th at both sites under all management scenarios. The temperature profiles were then compared with the no-action alternative and the mean difference between temperature profiles of the action alternative and the no-action alternative were calculated with equation 7.

$$\frac{\text{Action Alternative temperature} - \text{No Action Alternative Temperature}}{\# \text{ of comparisons}} = \text{Mean Temp. Difference} \quad \text{Eq. 7}$$

Table 32 and Table 33 show the mean temperature difference for all action alternative temperatures compared with the no-action alternative for Lim site 3 and 4 respectively. Figure 89 through Figure 96 show water temperature profiles for Lim site 3 and Figure 97 through Figure 104 shows water temperature profiles for Lim site 4.

Results of the temperature profile comparisons showed that water temperature changed relatively little under the management scenarios vs. the no-action alternative. The average change in profile temperatures measured from the action alternatives compared to the no-action alternative exceeded 1°C. Trends in the profile comparisons showed that

the action alternatives were consistently warmer than the no-action alternative at Lim sites 3 and 4 during April, colder during the November and mixed during the August water temperature measurements. Stand out scenarios include all average flow year scenarios run during April which were consistently 0.48-0.49 °C and 0.74-0.76 °C warmer than the no-action alternative at Lim site 3 and 4 respectively. Also, alternatives 3A and 3C consistently showed a negative mean difference when comparing August temperature profiles to the no-action alternative. Although unusual, the drop in temperature during the summer months was not a significant drop from the no-action alternative. Additionally, alternatives 3A and 3C contain the largest single month drops in water surface elevation among all management scenarios. A typical July to August decrease in water surface elevation for scenarios 3A and 3C range from 1.86 – 2.5 meters. Such a drop in water surface elevation would create turbulence in the reservoir system and thus mix the warmer epilimnetic waters with the colder waters of the hypolimnion. Figure 105 shows the predicted outflow discharge rates at Dry Falls Dam for the no-action alternative and the Drought-3A alternative from August 1st to August 31st.

Table 32. The mean difference for all action alternative temperatures compared with the no action alternative at Lim 3 (Action Alternative temp. – No Action Alternative temp.)

Lim Site 3									
April 15th-JDAY 105									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	0.49	0.49	0.48	0.48	0.48	0.48	0.48	0.48	<u>0.48</u>
Drought	0.30	0.30	0.29	0.36	0.25	0.27	0.55	0.41	<u>0.34</u>
Dry	0.30	0.30	0.29	0.29	0.34	0.30	0.28	0.29	<u>0.30</u>
Wet	0.41	0.42	0.41	0.41	0.41	0.41	0.41	0.41	<u>0.41</u>
Mean	<u>0.38</u>	<u>0.38</u>	<u>0.37</u>	<u>0.39</u>	<u>0.37</u>	<u>0.37</u>	<u>0.43</u>	<u>0.40</u>	
August 31-JDAY 243									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	0.18	0.24	0.40	0.01	-0.43	-0.15	0.20	0.21	<u>0.08</u>
Drought	-0.32	0.19	0.40	0.03	-0.93	0.29	-0.58	0.46	<u>-0.06</u>
Dry	0.23	0.19	0.39	-0.07	-0.66	-0.14	-0.52	0.10	<u>-0.14</u>
Wet	-0.05	0.13	0.40	0.03	-0.43	0.17	-0.03	0.15	<u>0.04</u>
Mean	<u>0.01</u>	<u>0.19</u>	<u>0.40</u>	<u>0.00</u>	<u>-0.61</u>	<u>0.04</u>	<u>-0.23</u>	<u>0.23</u>	
November 15th-JDAY 319									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	-0.07	-0.11	-0.06	-0.15	-0.21	-0.15	-0.22	-0.16	<u>-0.14</u>
Drought	-0.05	0.11	-0.06	-0.15	-0.29	-0.17	-0.39	-0.14	<u>-0.14</u>
Dry	-0.08	-0.07	-0.06	-0.09	-0.15	-0.09	-0.21	-0.14	<u>-0.11</u>
Wet	-0.07	-0.11	-0.05	-0.10	-0.09	-0.14	-0.10	-0.13	<u>-0.10</u>
Mean	<u>-0.07</u>	<u>-0.05</u>	<u>-0.06</u>	<u>-0.12</u>	<u>-0.18</u>	<u>-0.14</u>	<u>-0.23</u>	<u>-0.14</u>	

Table 33. The mean difference for all action alternative temperatures compared with the no-action alternative at Lim 4 (Action Alternative temp. – No Action Alternative temp.)

Lim Site 4									
April 15th-JDAY 105									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	0.76	0.76	0.74	0.74	0.74	0.74	0.74	0.74	<u>0.74</u>
Drought	0.46	0.47	0.45	0.54	0.38	0.39	0.71	0.52	<u>0.49</u>
Dry	0.47	0.47	0.46	0.45	0.51	0.46	0.47	0.45	<u>0.47</u>
Wet	0.41	0.42	0.41	0.41	0.58	0.58	0.58	0.58	<u>0.50</u>
Mean	<u>0.52</u>	<u>0.53</u>	<u>0.51</u>	<u>0.54</u>	<u>0.55</u>	<u>0.54</u>	<u>0.63</u>	<u>0.57</u>	
August 31-JDAY 243									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	0.11	0.40	0.23	-0.12	-0.36	0.15	0.48	0.36	<u>0.16</u>
Drought	0.10	0.03	0.23	-0.12	-0.50	0.34	-0.39	0.16	<u>-0.02</u>
Dry	0.43	0.03	0.23	-0.19	-0.47	-0.15	-0.44	-0.05	<u>-0.08</u>
Wet	-0.05	0.13	0.40	0.03	-0.42	0.37	-0.14	-0.01	<u>0.04</u>
Mean	<u>0.15</u>	<u>0.15</u>	<u>0.27</u>	<u>-0.10</u>	<u>-0.44</u>	<u>0.18</u>	<u>-0.13</u>	<u>0.12</u>	
November 15th-JDAY 319									
	2A	2B	2C	2D	3A	3B	3C	3D	Mean
Average	-0.06	-0.09	-0.05	-0.11	-0.19	-0.11	-0.18	-0.15	<u>-0.12</u>
Drought	-0.05	-0.10	-0.06	-0.11	-0.36	-0.26	-0.78	-0.19	<u>-0.24</u>
Dry	-0.07	-0.06	-0.06	-0.07	-0.11	-0.07	-0.45	-0.08	<u>-0.12</u>
Wet	-0.07	-0.11	-0.05	-0.10	-0.07	-0.10	-0.09	-0.12	<u>-0.09</u>
Mean	<u>-0.06</u>	<u>-0.09</u>	<u>-0.05</u>	<u>-0.10</u>	<u>-0.18</u>	<u>-0.13</u>	<u>-0.38</u>	<u>-0.14</u>

Figure 89. Water temperature profiles at Lim 3 under action alternative Average 2A, 2B, 2C 2D and the no-action alternative on April 15th, August 31th and November 15th

Figure 90. Water temperature profiles at Lim 3 under action alternative Drought 2A, 2B, 2C 2D and the no-action alternative on April 15th, August 31th and November 15th

Figure 91. Water temperature profiles at Lim 3 under action alternative Wet 2A, 2B, 2C 2D and the no-action alternative on April 15th, August 31th and November 15th

Figure 92. Water temperature profiles at Lim 3 under action alternative Dry 2A, 2B, 2C 2D and the no-action alternative on April 15th, August 31th and November 15th

Figure 93. Water temperature profiles at Lim 3 under action alternative Average 3A, 3B, 3C 3D and the no-action alternative on April 15th, August 31th and November 15th

Figure 94. Water temperature profiles at Lim 3 under action alternative Drought 3A, 3B, 3C 3D and the no-action alternative on April 15th, August 31th and November 15th

Figure 95. Water temperature profiles at Lim 3 under action alternative Dry 3A, 3B, 3C 3D and the no-action alternative on April 15th, August 31th and November 15th

Figure 96. Water temperature profiles at Lim 3 under action alternative Wet 3A, 3B, 3C 3D and the no-action alternative on April 15th, August 31th and November 15th

Figure 97. Water temperature profiles at Lim 4 under action alternative Wet 2A, 2B, 2C 2D and the no-action alternative on April15th, August 31th and November 15th

Figure 98. Water temperature profiles at Lim 4 under action alternative Drought 2A, 2B, 2C 2D and the no-action alternative on April15th, August 31th and November 15th

Figure 99. Water temperature profiles at Lim 4 under action alternative Dry 2A, 2B, 2C 2D and the no-action alternative on April15th, August 31th and November 15th

Figure 100. Water temperature profiles at Lim 4 under action alternative Average 2A, 2B, 2C 2D and the no-action alternative on April15th, August 31th and November 15th

Figure 101. Water temperature profiles at Lim 4 under action alternative Average 3A, 3B, 3C 3D and the no-action alternative on April15th, August 31th and November 15th

Figure 102. Water temperature profiles at Lim 4 under action alternative Drought 3A, 3B, 3C 3D and the no-action alternative on April15th, August 31th and November 15th

Figure 103. Water temperature profiles at Lim 4 under action alternative Dry 3A, 3B, 3C 3D and the no-action alternative on April15th, August 31th and November 15th

Figure 104. Water temperature profiles at Lim 4 under action alternative Wet 3A, 3B, 3C 3D and the no-action alternative on April15th, August 31th and November 15th

Figure 105. Discharge from the Dry Falls dam under the no-action alternative and alternative action scenario 3A

Environmental Criteria: Annual Summary

Within the environmental performance criteria tool, CE-QUAL-W2 can calculate the temporal and volume weighted average of water quality constituents over the entire model domain and simulation time period (Cole and Wells, 2010). This tool allows for a macro comparison of water quality constituents among management scenario model runs for the whole lake system over the entire model run. Figure 106 shows the temporal and volume weighted water temperature for all management scenarios and the no-action alternative. Figure 106 shows that there is little overall variability in total average water temperature between management scenarios. Scenario 3A showed the lowest overall water temperature for all flow years, while scenario 2C showed all flow years to be the warmest at 10 °C. Nonetheless, the difference in average water temperature between model scenarios and flow years is minimal and furthermore all management scenarios produced an average temperature comparable to the no-action alternative. Figure 107 shows the temporal and volume weighted dissolved oxygen for all management scenarios and the no-action alternative. Average dissolved oxygen concentrations showed slightly more variability between scenarios, but still relatively little overall change. Almost consistently the wet flow year had the highest overall dissolved oxygen concentration whereas the average flow year always produced the lowest average dissolved oxygen concentrations for all management scenarios.

Figure 106. Temporal and volume weighted average water temperature for each one year management scenario run.

Figure 107. Temporal and volume weighted average dissolved oxygen concentration for each one year management scenario run.

Environmental Criteria: Dissolved Oxygen Management Scenarios

Implementing new action alternative management plans and increasing summer water surface elevation draw downs in Banks Lake can have substantial effects on the limnology and available fish habitat within the lake. To evaluate the potential effects of these management scenarios on dissolved oxygen concentrations within the lake the CE-QUAL-W2 environmental performance criteria tool was used. The environmental performance criteria tool can output the time averaged volume fraction of any state variable used by CE-QUAL-W2 for the time period covered by the specific model run. Figure 108, Figure 109, Figure 110 and Figure 111 show histograms of the one year time averaged volume fraction of dissolved oxygen concentrations for Banks Lake average flow years, drought flow years, dry flow years and wet flow years.

The difference in the time averaged volume fraction of dissolved oxygen between management scenarios was found to be small. All management scenarios for all flow years showed the majority of dissolved oxygen concentrations to be either 9 mg/l or 13 mg/l. Among the lower dissolved oxygen concentrations (< 8 mg/l) all management scenarios for all flow years showed very little difference. The management scenario runs for the average flow year showed less over all dissolved oxygen within the 13 mg/l range but a higher distribution within the 12 mg/l range when compared to other flow years. The management scenarios run during the wet flow year had a higher distribution of dissolved oxygen concentrations within the 13 mg/l range than all other flow years. Management scenarios 3A through 3D for the dry and drought flow years showed less

dissolved oxygen within the 9 mg/l range than other management scenarios within the same flow years.

Figure 108. Average flow year time averaged volume fraction of dissolved oxygen for all scenarios

Figure 109. Drought flow year time averaged volume fraction of dissolved oxygen for all scenarios

Figure 110. Dry flow year time averaged volume fraction of dissolved oxygen for all scenarios

Figure 111. Wet flow year time averaged volume fraction of dissolved oxygen for all scenarios

Fish Habitat Analysis

The effects of the proposed action alternative management scenarios on fish habitat availability were explored by using the fish habitat algorithm in CE-QUAL-W2. By specifying the preferred water temperature range and a desired dissolved oxygen concentration for any fish species or group of species, CE-QUAL-W2 calculates a time series of the percent of the total reservoir volume that meets the criteria. The Banks Lake model calculated optimal growth habitat for four popular sport fish found in Banks Lake: rainbow trout, kokanee, walleye and smallmouth bass. Table 34 shows the optimal growth temperatures and dissolved oxygen concentrations taken from literature.

Table 34. Optimal growth habitat criteria for Banks Lake sport fish

	Temperature, oC			Dissolved Oxygen, mg/l	
	Temp-Low	Temp-High	Reference	Optimal DO, mg/l	Reference
Rainbow Trout	14	16	Piper, 1989	>7	Cooke and Welch, 2008
Kokanee	10	15	Scott and Crossman, 1973	>7	Cooke and Welch, 2008
Walleye	20	25	Koenst and Smith, 1976	>5	Cooke and Welch, 2008
Smallmouth Bass	21	28.5	Koenst and Smith, 1976	>6	Cooke and Welch, 2008

Initial results did not show a definitive change in fish habitat among the different action alternative management scenarios. Figure 112, Figure 113, Figure 114, Figure 115 and Figure 116 show line plots of the initial results from the alternatives average-2A, drought-2A, dry-2A, wet-2A and the no-action alternative, respectively. Although finer details of how fish habitat volumes changed are not completely visible from the line plots, they do show the seasonal peaks and drop offs in available fish habitat. The cold water rainbow trout and kokanee have ample habitat though winter, spring and early summer while the warm water walleye and smallmouth have only a short window of optimal growth during midsummer. It should be noted that as a result of the narrowed optimal growth desired temperature ranges, the model did not calculate any available fish habitat prior to April 8th or after November 18th.

To better quantify available fish habitat in Banks Lake, the time series of the percent of the total reservoir volume that met fish habitat criteria were calculated into annual average percents. Figure 117, Figure 118, Figure 119 and Figure 120 show histograms of the annual average percent of the reservoir volume that were found to be optimal for kokanee, rainbow trout, walleye and smallmouth bass, respectively.

Kokanee were found to have the most optimal habitat with 21.5% to 24% of the reservoir found to be favorable. Kokanee habitat was consistently more available during wet flow years and was the least plentiful during drought years. Rainbow trout habitat was also most available during wet flow years with annual average percent volume values ranging from 8.5%-9.5% and at its lowest during drought years or any other management

scenario that involved a large summer drawdown of the water surface elevation. The walleye and smallmouth bass habitat were generally more present during average flow years but also responded well to wet flow years.

It seems that management scenarios 2A, 2B and 2C produce consistent habitat percent results for each species, while management scenarios 2D, 3A, 3B, 3C and 3D have more variable effects within each species. The model results would suggest that kokanee habitat is affected the least by the changes in dissolved oxygen and water temperature that are attributed to the management scenarios, while their habitat percentages were never greatly impacted by the management scenarios that include a large summer drawdown. However, the rainbow trout, walleye and smallmouth bass habitat all responded relatively poorly to at least one management scenario, which would suggest that extra care be taken in the future during the implementation of any action alternative so that fisheries population are not affected.

Figure 112. Percent of reservoir volume that is optimal fish habitat for scenario Average-2A

Figure 113. Percent of reservoir volume that is optimal fish habitat for scenario Drought-2A

Figure 114. Percent of reservoir volume that is optimal fish habitat for scenario Dry-2A

Figure 115. Percent of reservoir volume that is optimal fish habitat for scenario Wet-2A

Figure 116. Percent of reservoir volume that is optimal fish habitat for the no-action alternative

Figure 117. Annual average percent of reservoir volume that is optimal fish habitat for kokanee

Figure 118. Annual average percent of reservoir volume that is optimal fish habitat for rainbow trout

Figure 119. Annual average percent of reservoir volume that is optimal fish habitat for walleye

Figure 120. Annual average percent of reservoir volume that is optimal fish habitat for smallmouth bass

Zooplankton Entrainment

The Banks Lake Fisheries Evaluation project currently collects zooplankton entrainment data from the tail waters of the Dry Falls Dam inside the Main Canal. During parts of the year when the Feeder Canal pumps are operational it is not uncommon for hydraulic residence time in the reservoir to drop below 50 days, thus posing a great risk of losing large zooplankton populations in a relatively short period of time. CE-QUAL-W2 has the capability to calculate the outflow discharge of water leaving the system at the Dry Falls dam as well as calculate multiple water quality constituents for the segment where the discharge structure is located. With this data a time series of zooplankton mass flow rates leaving Banks Lake can be calculated. Figure 121 shows a time series of model predicted mass concentrations of zooplankton group 1 and group 2 at Dry Falls Dam, and the calculated mass flow rate of zooplankton group 1 and group 2 leaving the Banks Lake system via the Main Canal. Figure 122 and Figure 123 show annual average mass discharge rates leaving via the Main Canal for zooplankton group 1 and group 2 respectively. Table 35 and Table 36 show monthly and annual averages zooplankton mass flow rates under all management scenarios for zooplankton group 1 and group 2.

Zooplankton group 1 had significant losses during the Dry-3A, Dry-3B, Dry-3C, Drought-3A and Drought-3C management scenarios. Conversely, zooplankton 1 was not lost at high levels during average and wet flow years. All management scenarios caused for zooplankton group 2 to lose less mass than the no-action alternative. Entrainment was at its lowest for zooplankton group 2 during average flow years and scenarios Dry-

2C, Dry-2D, Dry-3A and Dry-3B. Zooplankton group 2 had its highest mass flow rate during Drought-3A, Wet-3B and Wet-3D.

Figure 121. Zooplankton concentrations (mg/l) and mass flow rates (g/s) into the Main Canal for the no-action alternative

Figure 122. Annual average mass flow rate of zooplankton group 1 through the Main Canal (g/s)

Figure 123. Annual average mass flow rate of zooplankton group 2 through the Main Canal (g/s)

Table 35. Zooplankton group 1 monthly average mass flow rates through the Main Canal (g/s)

Average Mass Discharge: Zooplankton 1													
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
No-Action Alt.	0.01	0	0.06	1.08	5.62	22.7	29	12.9	8.7	14.7	2.7	1.84	8.27
Average-2A	0	0.27	0.77	0.94	5.61	14.8	19	13.4	2.77	7.78	0.12	2.03	5.63
Average-2B	0	0.27	0.07	0.91	5.81	15.4	20.1	13.5	4.42	4.49	0.38	1.7	5.59
Average-2C	0	0.27	0.08	0.88	5.61	13.9	17	9.99	3.2	8.55	0.32	1.79	5.13
Average-2D	0	0.26	0.07	0.88	5.74	14.1	17.5	11.9	5.89	1	0.41	1.68	4.96
Average-3A	0	0.27	0.77	0.89	5.4	16.5	25.4	20.7	3.74	2.1	0.36	2.25	6.53
Average-3B	0	0.26	0.07	0.89	5.9	16.4	22.4	21.6	4.58	6.7	0.57	2.23	6.79
Average-3C	0	0.24	0.07	0.88	5.58	14.9	19.4	14.7	3.77	6.13	0.36	1.99	5.67
Average-3D	0	0.26	0.07	0.88	5.79	15.3	20.2	13.5	6.3	6.3	0.74	2.05	5.95
Dry-2A	0.02	0	0.05	1.01	4.99	23.8	29.7	20.2	4.42	5.52	5.58	0.16	7.96
Dry-2B	0.02	0	0.05	1.01	4.98	23.8	29.2	18	6.52	5.48	5.68	0.17	7.92
Dry-2C	0.02	0	0.47	0.97	4.64	21.7	25	15.6	5.32	8.51	5.4	0.17	7.31
Dry-2D	0.02	0	0.47	0.97	4.66	21.7	25.2	17.5	7.87	1.3	5.95	0.16	7.15
Dry-3A	0.01	0	0.01	1.03	5.05	26.8	37.1	19.3	6.11	0.69	6.56	0.2	8.58
Dry-3B	0.02	0	0.04	1	5.12	25.1	34.6	24.5	6.99	6.06	6.07	0.24	9.14
Dry-3C	0.01	0	0.01	1.02	4.77	22.5	30.6	21.1	7.85	7.6	7.2	0.23	8.58
Dry-3D	0.01	0	0.04	0.97	4.67	23.5	29.5	17.1	8.4	6.79	1.41	0.31	7.72
Drought-2A	0.02	0	0.05	1.01	4.98	23.8	29.8	19.1	5.12	6.57	5.48	0.18	8
Drought-2B	0.02	0	0.05	1.01	4.98	23.8	29.2	18.1	6.26	5.18	5.59	0.17	7.86
Drought-2C	0.02	0	0.04	0.97	4.66	21.7	25.2	15.6	5.29	8.51	5.42	0.17	7.3
Drought-2D	0.02	0	0.47	0.99	4.69	21.8	25.7	17.4	7.51	0.79	6.03	0.16	7.13
Drought-3A	0.02	0	0.48	1.02	5.46	27	37.1	20.2	7.77	1.72	7.06	0.23	9
Drought-3B	0.01	0	0.48	1.03	4.99	21.9	25.5	15.5	6.25	10.5	5.52	0.19	7.66
Drought-3C	0.01	0	0.04	0.96	4.88	23.7	38	21.7	13.3	10.6	8.68	0.27	10.2
Drought-3D	0.01	0	0.04	1.03	5.1	22.1	26.7	15.4	7.76	7.14	0.41	0.33	7.17
Wet-2A	0	0	0.03	0.58	4.48	28	25.4	14.6	1.59	10.5	5.44	2.69	7.78
Wet-2B	0	0	0.26	0.59	4.73	30.8	27.2	15.3	3.65	6.34	0.31	0.09	7.44
Wet-2C	0	0	0.03	0.56	4.49	28.2	23.6	13.1	2.65	10.7	0.11	0.08	6.96
Wet-2D	0	0	0.02	0.56	4.64	29.5	24.6	15.4	5.23	1.94	0.34	0.08	6.86
Wet-3A	0	0	0.03	0.57	4.51	28.1	28.3	17.2	1.56	5.75	0.32	0.09	7.2
Wet-3B	0	0	0.03	0.57	4.8	32.5	26.1	15.1	3.66	7.12	1.27	0.29	7.61
Wet-3C	0	0	0.26	0.56	4.5	28.2	25.6	14.7	3.6	7.14	0	0.2	7.06
Wet-3D	0	0	0.02	0.56	4.68	32.9	25.9	15	5.74	8.06	0.52	0.3	7.8

Table 36. Zooplankton group 2 monthly average mass flow rates through the Main Canal (g/s)

Average Mass Discharge: Zooplankton 2													
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
No-Action Alt.	0.02	0	0.14	2.6	15.4	62.1	60.8	29.8	20.6	14.4	0.94	0.39	17.27
Average-2A	0	0.58	0.17	2.4	20.9	53.6	52.4	34.9	6.5	9.51	0.07	0.61	15.13
Average-2B	0	0.58	0.17	2.4	21.7	54.7	53.5	34.6	10.6	5.66	0.19	0.57	15.39
Average-2C	0	0.58	0.18	2.34	20.7	50.1	47.1	27.2	10	13.4	0.16	0.63	14.36
Average-2D	0	0.58	0.17	2.34	21.3	50.6	48	31.6	14.8	0.93	0.19	0.49	14.25
Average-3A	0	0.58	0.17	2.36	20.2	58.8	62.6	31.3	4.7	1.27	0.04	0.28	15.2
Average-3B	0	0.58	0.17	2.36	22	57.8	55.5	27.4	5.6	5.03	0.13	0.42	14.75
Average-3C	0	0.52	0.18	2.33	20.6	53.4	52.4	36.1	8.26	7.12	0.11	0.58	15.13
Average-3D	0	0.58	0.17	2.34	21.5	54.4	53.8	34.4	14.3	7.28	0.25	0.61	15.8
Dry-2A	0.4	0	0.13	2.42	13.6	59.6	54.1	38	8.58	5.13	2	0.04	15.33
Dry-2B	0.04	0	0.13	2.42	13.6	59.6	53.2	35	14.3	4.98	1.98	0.04	15.43
Dry-2C	0.04	0	0.13	2.36	12.4	55.2	47.8	31.5	13	10.2	2.24	0.04	14.57
Dry-2D	0.04	0	0.13	2.36	12.5	55.3	47.8	35	16	0.84	1.86	0.03	14.31
Dry-3A	0.31	0	0.02	2.5	13.8	66.3	61.3	31.9	8.6	0.27	1.27	0.03	15.52
Dry-3B	0.04	0	0.13	2.4	14	62.3	56.5	26.1	7.45	3.84	1.39	0.03	14.51
Dry-3C	0.03	0	0.02	2.52	13	58	57.8	30.7	9.37	4.34	1.47	0.02	14.77
Dry-3D	0.04	0	0.13	2.36	12.5	59.3	54.5	33.6	18.2	6.2	0.41	0.06	15.61
Drought-2A	0.04	0	0.13	2.4	13.6	59.6	54.1	36.5	10.8	5.12	1.81	0.03	15.34
Drought-2B	0.03	0	0.13	2.4	13.6	59.7	53.1	35.1	13.9	4.85	2	0.03	15.39
Drought-2C	0.04	0	0.13	2.36	12.5	55.3	47.9	31.4	12.9	10.2	2.24	0.04	14.58
Drought-2D	0.04	0	0.13	2.38	12.8	55.5	48.7	34.8	15.8	0.72	2.26	0.03	14.42
Drought-3A	0.03	0	0.13	2.4	15.7	67.8	63.7	31.2	10	0.56	0.96	0.03	16.04
Drought-3B	0.04	0	0.13	2.41	14.2	56.6	50	31.9	14.7	12.2	2.17	0.04	15.37
Drought-3C	0.04	0	0.13	2.24	14.5	61	66.7	24.3	12.9	3.85	0.91	0.03	15.54
Drought-3D	0.04	0	0.14	2.39	15	56.6	51.7	31.8	18.3	7.49	0.1	0.07	15.29
Wet-2A	0	0	0.08	1.55	11.6	72	47.1	30.3	4.38	12.8	2.46	0.69	15.24
Wet-2B	0	0	0.08	1.59	12.3	77.7	48.8	31.1	9.29	7.5	0.16	0.02	15.72
Wet-2C	0	0	0.08	1.51	11.6	71.4	43.8	27.2	7.4	14.5	0.06	0.02	14.8
Wet-2D	0	0	0.08	1.51	12.1	75	44.7	31.6	12.4	1.87	0.16	0.02	14.95
Wet-3A	0	0	0.08	1.53	11.7	72.1	52	34.9	3.97	6.12	0.14	0.02	15.21
Wet-3B	0	0	0.08	1.53	12.6	81.5	46.4	29.9	9.15	8.36	0.48	0.07	15.84
Wet-3C	0	0	0.08	1.51	11.6	72.2	47.3	30.6	9.21	8.59	0	0.05	15.1
Wet-3D	0	0	0.08	1.51	12.2	82.7	46.2	29.9	13.4	8.64	0.13	0.07	16.23

Summary

The goal of this project was to produce a hydrodynamic and water quality model of Banks Lake that had the ability to predict the impacts of new management strategies on fish habitat and apply it to Banks Lake to determine whether certain proposed action alternatives would negatively impact the fish populations. This project has accomplished the following:

- 1.) Creation of a Banks Lake CE-QUAL-W2 model
- 2.) Calibration of the model for hydrodynamic, temperature, water quality, primary producers and secondary producers
- 3.) Documentation of model inputs and calibration
- 4.) Application of the model for the purpose of evaluating proposed management scenarios as outline in the Odessa Subarea Draft EIS.

During the development of this project, a substantial amount of water quality data, boundary condition data and meteorological data were gathered, processed, observed and ultimately used to develop/calibrate the Banks Lake CE-QUAL-W2 water quality model. Pertinent data that were missing or unavailable were obtained by either interpolating from existing data or through the development of regression analyses with multiple existing data sets. The data collection/modification processes are discussed in McCulloch, Berger and Wells (2010).

Calibration of the CE-QUAL-W2 model for all relevant water quality constituents was carried out in order to reduce error in model predictions and to produce as accurate a representation of the natural system as possible. While no model can predict the responses of a natural system 100% of the time, the Banks Lake CE-QUAL-W2 model has been calibrated to within a tolerable range of error that is consistent with current modeling calibration standards. Furthermore, adequate calibration of the hydrodynamics and other abiotic constituents allowed for additional model calibration of biological constituents such as algae and zooplankton. The Banks Lake CE-QUAL-W2 model calibration process may review in McCulloch, Berger and Wells (2011).

Model application to the action alternatives outlined by the draft EIS for the Odessa Subarea did not show a substantial negative effect on water quality nor fish habitat. Water temperature profiles did reveal that under some scenarios, such as 3A, a slight cooling of the water column may take place during summer months. Conversely, water temperature profile analysis showed that most management scenarios exhibited slight warming during spring months and some cooling of the water column during fall months. Regardless, most heating and cooling of the water column was found to be minimal when compared to data collected from the no-action alternative.

Additional analysis of the distribution of dissolved oxygen concentrations throughout the reservoir over time did not show much change between management scenarios and the no-action alternative. Some selected cases, such as scenarios run during wet years, tended to have a higher ratio of dissolved oxygen at higher concentrations more

frequently throughout the year, but similar to the water temperature profile analysis, the differences that existed were not significant. Additionally, the temporal/spatial average temperature and dissolved oxygen concentrations from each management scenario did not yield definitive results.

Zooplankton entrainment analysis did offer some variability in results among management scenarios. Zooplankton group 1 was not affected by scenarios 2A, 2B, 2C or 2D, however scenarios 3A, 3B and 3C run during dry and drought flow years were found to discharge 0.5-1.0 g/s more of zooplankton group 1 than the no-action alternative. Zooplankton group 2 was affected the most by scenarios 3A and 3D for all flow years, but in general when compared to the no-action alternative; zooplankton group 2 was not negatively affected by any scenario.

Fish habitat analysis showed that kokanee habitat was relatively abundant for most management scenarios especially all scenarios run during the wet flow year. Moderate negative impacts to the kokanee habitat occurred only on scenarios 3A, 3B, 3C and 3D during drought, dry and average flow years. The rainbow trout habitat decreased the most during scenarios drought/average 2-D and average 3-C while benefiting the most during wet flow years. Walleye habitat was favored by average flow years for all scenarios except 3A. Conversely, walleye habitat plummeted with scenario 3A for all flow years except the wet flow year. The smallmouth bass habitat was also the most plentiful for management scenarios run with the average flow year and was significantly affected only by scenarios 3A and 3C run with a drought flow year. In summary it seems

that fish habitat is affected the least by management scenarios which require less drawdown of the water surface elevation such as scenarios 2A, 2B, 2C, 2D, and are run on either a wet or average flow year.

Future work could include evaluating the available fish habitat for more species, or perhaps instead of using optimal growth conditions to evaluate fish habitat, use acute and/or chronic temperature and dissolved oxygen criteria. Also, utilizing the Lake Roosevelt fish bioenergetics model to predict fish growth would also be a realistic goal for further understanding how the management scenarios affect fish behavior and growth. The FORTRAN source code routine for the Lake Roosevelt fish bioenergetics model is show in Appendix F (McKillip, 2008).

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Appendix A: CE-QUAL-W2 Control File

W2 Model Version 3.7

TITLE CTITLE.....
Banks Lake - January 1, 2002 through December 31, 2009

GRID	NWB	NBR	IMX	KMX	NPROC	CLOSEC			
	1	10	182	56	2	OFF			
IN/OUTFL	NTR	NST	NIW	NWD	NGT	NSP	NPI	NPU	
	0	1	0	1	0	0	0	0	
CONSTITU	NGC	NSS	NAL	NEP	NBOD	NMC	NZP		
	3	1	3	0	0	0	2		
MISCELL	NDAY	SELECTC	HABTATC	ENVIRPC	AERATEC	INITUWL			
	12500	OFF	OFF	OFF	OFF	OFF			
TIME CON	TMSTRT	TMEND	YEAR						
	1.00000	2923.00	2002						
DLT CON	NDT	DLTMIN	DLTINTR						
	11	1.00000	OFF						
DLT DATE	DLTD	DLTD	DLTD	DLTD	DLTD	DLTD	DLTD	DLTD	DLTD
	1.00000	344.00	359.00	728.00	742.00	1503.00	1517.00	2087.00	2101.00
	2163.00	2177.00							
DLT MAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX	DLTMAX
	115.00	30.0	115.0	30.0	115.0	30.0	115.0	30.0	115.0
	30.0	115.0							
DLT FRN	DLTF	DLTF	DLTF	DLTF	DLTF	DLTF	DLTF	DLTF	DLTF
	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000	0.70000
	0.70000	0.70000							
DLT LIM1	VISC	CELC							
WB 1	ON	ON							
BRANCH G	US	DS	UHS	DHS	UQB	DQB	NLMIN	SLOPE	SLOPEC
BR1	2	111	0	0	0	0	1	0.00000	0.000
BR2	114	121	0	60	0	0	1	0.00000	0.000
BR3	124	128	0	47	0	0	1	0.00000	0.000
BR4	131	135	0	40	0	0	1	0.00000	0.000
BR5	138	142	0	134	0	0	1	0.00000	0.000
BR6	145	148	0	37	0	0	1	0.00000	0.000
BR7	151	160	0	34	0	0	1	0.00000	0.000
BR8	163	166	0	29	0	0	1	0.00000	0.000
BR9	169	173	0	28	0	0	1	0.00000	0.000
BR10	176	181	0	14	0	0	1	0.00000	0.000
LOCATION	LAT	LONG	EBOT	BS	BE	JBDN			
WB 1	47.8000	119.200	425.000	1	10	1			
INIT CND	TEMPI	ICEI	WTYPEC	GRIDC					
WB 1	2.5000	0.00000	FRESH	RECT					
CALCULAT	VBC	EBC	MBC	PQC	EVC	PRC			
WB 1	ON	ON	ON	OFF	ON	ON			
DEAD SEA	WINDC	QINC	QOUTC	HEATC					
WB 1	ON	ON	ON	ON					

INTERPOL	QINIC	DTRIC	HDIC							
BR1	OFF	OFF	OFF							
BR2	ON	ON	ON							
BR3	ON	ON	ON							
BR4	ON	ON	ON							
BR5	ON	ON	ON							
BR6	ON	ON	ON							
BR7	ON	ON	ON							
BR8	ON	ON	ON							
BR9	ON	ON	ON							
BR10	ON	ON	ON							
HEAT EXCH	SLHTC	SROC	RHEVAP	METIC	FETCHC	AFW	BFW	CFW	WINDH	
WB 1	TERM	ON	OFF	ON	OFF	9.20000	0.46000	2.00000	2.0000	
ICE COVE	ICEC	SLICEC	ALBEDO	HWICE	BICE	GICE	ICEMIN	ICET2		
WB 1	ON	DETAIL	0.25000	10.0000	0.60000	0.07000	0.05000	3.00000		
TRANSPOR	SLTRC	THETA								
WB 1	ULTIMATE	0.55000								
HYD COEF	AX	DX	CBHE	TSED	FI	TSEDF	FRICC	Z0		
WB 1	1.00000	1.00000	0.30000	5.0000	0.00000	0.00000	MANN	0.00100		
EDDY VISC	AZC	AZSLC	AZMAX	FBC	E	ARODI	STRCKLR	BOUNDFR	TKECAL	
WB 1	W2	IMP	1.00000	3	9.53500	0.43000	24.0000	10.0000	IMP	
N STRUC	NSTR									
BR1	1									
BR2	0									
BR3	0									
BR4	0									
BR5	0									
BR6	0									
BR7	0									
BR8	0									
BR9	0									
BR10	0									
STR INT	STRIC	STRIC	STRIC	STRIC	STRIC	STRIC	STRIC	STRIC	STRIC	
BR 1	OFF									
BR 2										
BR 3										
BR 4										
BR 5										
BR 6										
BR 7										
BR 8										
BR 9										
BR 10										
STR TOP	KTSTR	KTSTR	KTSTR	KTSTR	KTSTR	KTSTR	KTSTR	KTSTR	KTSTR	
BR1	2									
BR2										
BR3										
BR4										
BR5										
BR6										
BR7										
BR8										
BR9										
BR10										
STR BOT	KBSTR	KBSTR	KBSTR	KBSTR	KBSTR	KBSTR	KBSTR	KBSTR	KBSTR	
BR1	17									
BR2										
BR3										
BR4										
BR5										

BR6
BR7
BR8
BR9
BR10

STR	SINK	SINKC	SINKC	SINKC	SINKC	SINKC	SINKC	SINKC	SINKC	SINKC
BR1		POINT								
BR2										
BR3										
BR4										
BR5										
BR6										
BR7										
BR8										
BR9										
BR10										

STR	ELEV	ESTR	ESTR	ESTR	ESTR	ESTR	ESTR	ESTR	ESTR	ESTR
BR1	471.000									
BR2										
BR3										
BR4										
BR5										
BR6										
BR7										
BR8										
BR9										
BR10										

STR	WIDT	WSTR	WSTR	WSTR	WSTR	WSTR	WSTR	WSTR	WSTR	WSTR
BR1	28.0000									
BR2										
BR3										
BR4										
BR5										
BR6										
BR7										
BR8										
BR9										
BR10										

PIPES	IUPI	IDPI	EUPI	EDPI	WPI	DLXPI	FPI	FMINPI	WTHLC
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PIPE UP	PUPIC	ETUPI	EBUPI	KTUPI	KBUPI
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PIPE DOWN	PDPIC	ETDPI	EBDPI	KTDPI	KBDPI
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SPILLWAY	IUSP	IDSP	ESP	A1SP	B1SP	A2SP	B2SP	WTHLC
----------	------	------	-----	------	------	------	------	-------

SPILL UP	PUSPC	ETUSP	EBUSP	KTUSP	KBUSP
----------	-------	-------	-------	-------	-------

SPILL DOWN	PDSPC	ETUSP	EBUSP	KTDSP	KBDSP
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SPILL GAS	GASSPC	EQSP	AGASSP	BGASSP	CGASSP
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GATES	IUGT	IDGT	EGT	A1GT	B1GT	G1GT	A2GT	B2GT	G2GT	WTHLC
-------	------	------	-----	------	------	------	------	------	------	-------

GATE WEIR	GTA1	GTB1	GTA2	GTB2	DYNVAR	GTIC
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GATE UP	PUGTC	ETUGT	EBUGT	KTUGT	KBUGT				
GATE DOWN	PDGTC	ETDGT	EBDGT	KTDGT	KBDGT				
GATE GAS	GASGTC	EQGT	AGASGT	BGASGT	CGASGT				
PUMPS 1	IUPU	IDPU	EPU	STRTPU	ENDPU	EONPU	EOFFPU	QPU	WTHLC
PUMPS 2	PPUC	ETPU	EBPU	KTPU	KBPU				
WEIR SEG	IWR	IWR	IWR	IWR	IWR	IWR	IWR	IWR	IWR
WEIR TOP	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR	KTWR
WEIR BOT	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR	KBWR
WD INT	WDIC OFF	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC	WDIC
WD SEG	IWD 2	IWD	IWD	IWD	IWD	IWD	IWD	IWD	IWD
WD ELEV	EWD 476.5	EWD	EWD	EWD	EWD	EWD	EWD	EWD	EWD
WD TOP	KTWD 2	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD	KTWD
WD BOT	KBWD 6	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD	KBWD
TRIB PLA	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC	PTRC
TRIB INT	TRIC OFF	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC	TRIC
TRIB SEG	ITR	ITR	ITR	ITR	ITR	ITR	ITR	ITR	ITR
TRIB TOP	ELTRT	ELTRT	ELTRT	ELTRT	ELTRT	ELTRT	ELTRT	ELTRT	ELTRT
TRIB BOT	ELTRB	ELTRB	ELTRB	ELTRB	ELTRB	ELTRB	ELTRB	ELTRB	ELTRB
DST TRIB BR 1 BR 2 BR 3 BR 4 BR 5 BR 6 BR 7 BR 8 BR 9 BR 10	DTRC ON OFF OFF OFF OFF OFF OFF OFF OFF OFF	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC	DTRC
HYD PRIN NVIOL U	HPRWBC OFF OFF	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC	HPRWBC

W	OFF								
T	ON								
RHO	OFF								
AZ	OFF								
SHEAR	OFF								
ST	OFF								
SB	OFF								
ADMX	OFF								
DM	OFF								
HDG	OFF								
ADMZ	OFF								
HPG	OFF								
GRAV	OFF								
SNP PRINT	SNPC	NSNP	NISNP						
WB 1	OFF	1	26						
SNP DATE	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD	SNPD
WB 1	1.0								
SNP FREQ	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF	SNPF
WB 1	7.5								
SNP SEG	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP	ISNP
WB 1	2	12	23	27	32	37	42	52	60
	70	80	90	100	110	115	120	125	134
	140	147	153	158	164	171	177	181	
SCR PRINT	SCRC	NSCR							
WB 1	ON	1							
SCR DATE	SCRD	SCRD	SCRD	SCRD	SCRD	SCRD	SCRD	SCRD	SCRD
WB 1	1.0000								
SCR FREQ	SCRF	SCRF	SCRF	SCRF	SCRF	SCRF	SCRF	SCRF	SCRF
WB 1	0.20000								
PRF PLOT	PRFC	NPRF	NIPRF						
WB 1	ON	1	11						
PRF DATE	PRFD	PRFD	PRFD	PRFD	PRFD	PRFD	PRFD	PRFD	PRFD
WB 1	1.5								
PRF FREQ	PRFF	PRFF	PRFF	PRFF	PRFF	PRFF	PRFF	PRFF	PRFF
WB 1	1.00000								
PRF SEG	IPRF	IPRF	IPRF	IPRF	IPRF	IPRF	IPRF	IPRF	IPRF
WB 1	15	173	39	158	82	99	147	181	54
	109	110							
SPR PLOT	SPRC	NSPR	NISPR						
WB 1	OFF	1	11						
SPR DATE	SPRD	SPRD	SPRD	SPRD	SPRD	SPRD	SPRD	SPRD	SPRD
WB 1	1.5								
SPR FREQ	SPRF	SPRF	SPRF	SPRF	SPRF	SPRF	SPRF	SPRF	SPRF
WB 1	1.00000								
SPR SEG	ISPR	ISPR	ISPR	ISPR	ISPR	ISPR	ISPR	ISPR	ISPR
WB 1	15	173	39	158	82	99	147	181	54
	109	110							
VPL PLOT	VPLC	NVPL							
WB 1	OFF	0							
VPL DATE	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD	VPLD
WB 1									

VPL FREQ WB 1	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF	VPLF
CPL PLOT WB 1	CPLC OFF	NCPL 1	TECPLOT ON						
CPL DATE WB 1	CPLD 1.0	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD	CPLD
CPL FREQ WB 1	CPLF 1.00000	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF	CPLF
FLUXES WB 1	FLXC OFF	NFLX 1							
FLX DATE WB 1	FLXD 1	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD	FLXD
FLX FREQ WB 1	FLXF 0.50000	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF	FLXF
TSR PLOT	TSRC ON	NTSR 1	NITSR 11						
TSR DATE	TSRD 1	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD	TSRD
TSR FREQ	TSRF 0.04166	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF	TSRF
TSR SEG	ITSR 15 109	ITSR 173 110	ITSR 39	ITSR 158	ITSR 82	ITSR 99	ITSR 147	ITSR 181	ITSR 54
TSR LAYE	ETSR 5.00000 5.00000	ETSR 5.00000 5.00000	ETSR 5.00000	ETSR 5.00000	ETSR 5.00000	ETSR 5.00000	ETSR 5.00000	ETSR 5.00000	ETSR 5.00000
WITH OUT	WDOC OFF	NWDO 0	NIWDO 0						
WITH DAT	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD	WDOD
WITH FRE	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF	WDOF
WITH SEG	IWDO	IWDO	IWDO	IWDO	IWDO	IWDO	IWDO	IWDO	IWDO
RESTART	RSOC ON	NRSO 1	RSIC OFF						
RSO DATE	RSOD 99.0	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD	RSOD
RSO FREQ	RSOF 100.0	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF	RSOF
CST COMP	CCC ON	LIMC ON	CUF 3						
CST ACTIVE	CAC ON								
TDS	OFF								
Gen1	ON								
Gen2	OFF								
Gen3	ON								
ISS1	OFF								
PO4	ON								

NH4	ON									
NO3	ON									
DSI	OFF									
PSI	OFF									
FE	OFF									
LDOM	ON									
RDOM	ON									
LPOM	ON									
RPOM	ON									
ALG1	ON									
ALG2	ON									
ALG3	ON									
DO	ON									
TIC	ON									
ALK	ON									
ZOO1	ON									
ZOO2	ON									
LDOM-P	ON									
RDOM-P	ON									
LPOM-P	ON									
RPOM-P	ON									
LDOM-N	ON									
RDOM-N	ON									
LPOM-N	ON									
RPOM-N	ON									
CST DERI	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC	CDWBC
DOC	OFF									
POC	OFF									
TOC	OFF									
DON	OFF									
PON	OFF									
TON	OFF									
TKN	OFF									
TN	ON									
DOP	OFF									
POP	OFF									
TOP	OFF									
TP	ON									
APR	OFF									
CHLA	ON									
ATOT	OFF									
%DO	ON									
TSS	ON									
TISS	OFF									
CBOD	OFF									
pH	ON									
CO2	OFF									
HCO3	OFF									
CO3	OFF									
CST FLUX	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC	CFWBC
TISSIN	OFF									
TISSOUT	OFF									
PO4AR	ON									
PO4AG	ON									
PO4AP	ON									
PO4ER	ON									
PO4EG	ON									
PO4EP	ON									
PO4POM	ON									
PO4DOM	ON									
PO4OM	ON									
PO4SED	ON									
PO4SOD	ON									
PO4SET	ON									
NH4NITR	ON									
NH4AR	ON									
NH4AG	ON									

NH4AP	ON
NH4ER	ON
NH4EG	ON
NH4EP	ON
NH4POM	ON
NH4DOM	ON
NH4OM	ON
NH4SED	ON
NH4SOD	ON
NO3DEN	ON
NO3AG	ON
NO3EG	ON
NO3SED	ON
DSIAG	ON
DSIEG	ON
DSIPIS	OFF
DSISED	OFF
DSISOD	OFF
DSISET	OFF
PSIAM	OFF
PSINET	OFF
PSIDK	OFF
FESET	OFF
FESED	OFF
LDOMDK	OFF
LRDOM	OFF
RDOMDK	OFF
LDOMAP	OFF
LDOMEF	OFF
LPOMDK	OFF
LRPOM	OFF
RPOMDK	OFF
LPOMAP	OFF
LPOMEF	OFF
LPOMSET	OFF
RPOMSET	OFF
CBODDK	OFF
DOAP	ON
DOAR	ON
DOEP	ON
DOER	ON
DOPOM	ON
DODOM	ON
DOOM	ON
DONITR	ON
DOCBOD	ON
DOREAR	ON
DOSED	ON
DOSOD	ON
TICAG	OFF
TICEG	OFF
SEDDK	OFF
SEDAS	OFF
SEDLPOM	OFF
SEDSET	OFF
SODDK	OFF

CST	ICON	C2IWB	C2IWB	C2IWB	C2IWB	C2IWB	C2IWB	C2IWB	C2IWB
TDS		87.7000							
Gen1		100.000							
Gen2		0.00000							
Gen3		10.0000							
ISS1		2.00000							
PO4		0.00600							
NH4		0.00500							
NO3		0.14900							
DSI		0.00000							
PSI		0.00000							
FE		0.10000							

LDOM	0.22813
RDOM	0.22813
LPOM	0.22813
RPOM	0.22813
ALG1	0.27000
ALG2	0.01000
ALG3	0.00500
DO	13.6000
TIC	15.4200
ALK	60.8000
ZOO1	0.00109
ZOO2	0.00243
LDOM-P	0.00019
RDOM-P	0.00019
LPOM-P	0.00019
RPOM-P	0.00019
LDOM-N	0.01725
RDOM-N	0.01725
LPOM-N	0.01725
RPOM-N	0.01725

CST PRIN	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC	CPRWBC
TDS	ON								
Gen1	OFF								
Gen2	ON								
Gen3	OFF								
ISS1	OFF								
PO4	ON								
NH4	ON								
NO3	ON								
DSI	OFF								
PSI	OFF								
FE	OFF								
LDOM	OFF								
RDOM	OFF								
LPOM	OFF								
RPOM	OFF								
ALG1	ON								
ALG2	ON								
ALG3	ON								
DO	ON								
TIC	ON								
ALK	ON								
ZOO1	ON								
ZOO2	ON								
LDOM-P	OFF								
RDOM-P	OFF								
LPOM-P	OFF								
RPOM-P	OFF								
LDOM-N	OFF								
RDOM-N	OFF								
LPOM-N	OFF								
RPOM-N	OFF								

CIN CON	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC	CINBRC
TDS	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen3	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ISS1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PO4	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
NH4	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								

NO3	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
FE	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG1	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG3	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DO	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
TIC	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALK	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO1	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
CTR CON	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC	CTRTRC
TDS	OFF								
Gen1	OFF								
Gen2	OFF								
Gen3	OFF								
ISS1	OFF								
PO4	OFF								
NH4	OFF								
NO3	OFF								
DSI	OFF								
PSI	OFF								
FE	OFF								
LDOM	OFF								
RDOM	OFF								
LPOM	OFF								
RPOM	OFF								
ALG1	OFF								
ALG2	OFF								
ALG3	OFF								
DO	OFF								

TIC	OFF
ALK	OFF
ZOO1	OFF
ZOO2	OFF
LDOM-P	OFF
RDOM-P	OFF
LPOM-P	OFF
RPOM-P	OFF
LDOM-N	OFF
RDOM-N	OFF
LPOM-N	OFF
RPOM-N	OFF

CDT CON	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC	CDTBRC
TDS	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen3	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ISS1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PO4	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
NH4	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
NO3	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
FE	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG1	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG3	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DO	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
TIC	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALK	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO1	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO2	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM-P	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

	OFF								
RDOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM-N	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
CPR CON	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC	CPRBRC
TDS	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
Gen3	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ISS1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PO4	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
NH4	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
NO3	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
PSI	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
FE	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALG3	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
DO	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON								
TIC	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ALK	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
ZOO2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-P	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM-P	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-P	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RPOM-P	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LDOM-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
RDOM-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
LPOM-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								

RPOM-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
	OFF								
EX COEF	EXH2O	EXSS	EXOM	BETA	EXC	EXIC			
WB 1	0.30000	0.01000	0.20000	0.45000	OFF	OFF			
ALG EX	EXA	EXA	EXA	EXA	EXA	EXA			
	0.15000	0.15000	0.15000						
ZOO EX	EXZ	EXZ	EXZ	EXZ	EXZ	EXZ			
	0.20000	0.20000							
MACRO EX	EXM	EXM	EXM	EXM	EXM	EXM			
	0.01000								
GENERIC	CGQ10	CG0DK	CG1DK	CGS					
CG 1	0.00000	0.00000	0.00000	0.00000					
CG 2	0.00000	-1.0000	0.00000	0.00000					
CG 3	1.04000	0.00000	1.40000	0.00000					
S SOLIDS	SSS	SEDRC	TAUCR						
SS# 1	1.00000	OFF	0.00000						
ALGAL RATE	AG	AR	AE	AM	AS	AHSP	AHSN	AHSSI	ASAT
ALG1	2.50000	0.04000	0.04000	0.10000	0.12000	0.00240	0.01400	0.00000	90.000
ALG2	2.70000	0.04000	0.04000	0.10000	0.12000	0.00220	0.01400	0.00000	90.000
ALG3	2.50000	0.04000	0.04000	0.10000	0.00900	0.00320	0.01400	0.00000	90.000
ALGAL TEMP	AT1	AT2	AT3	AT4	AK1	AK2	AK3	AK4	
ALG1	1.50000	7.00000	24.0000	30.0000	0.10000	0.99000	0.99000	0.10000	
ALG2	3.00000	15.0000	26.0000	30.0000	0.10000	0.99000	0.99000	0.10000	
ALG3	3.00000	20.0000	28.0000	30.0000	0.10000	0.99000	0.99000	0.10000	
ALG STOI	ALGP	ALGN	ALGC	ALGSI	ACHLA	ALPOM	ANEQN	ANPR	
ALG1	0.00500	0.0800	0.55000	0.00000	0.22000	0.80000	2	0.00100	
ALG2	0.00500	0.0800	0.55000	0.00000	0.11000	0.80000	2	0.00100	
ALG3	0.00500	0.0800	0.55000	0.00000	0.14000	0.80000	2	0.00100	
EPIPHYTE	EPIC	EPIC	EPIC	EPIC	EPIC	EPIC	EPIC	EPIC	EPIC
EPI1	OFF								
EPI PRIN	EPRC	EPRC	EPRC	EPRC	EPRC	EPRC	EPRC	EPRC	EPRC
EPI1	OFF								
EPI INIT	EPICI	EPICI	EPICI	EPICI	EPICI	EPICI	EPICI	EPICI	EPICI
EPI1	10.0000								
EPI RATE	EG	ER	EE	EM	EB	EHSP	EHSN	EHSSI	
EPI1	2.00000	0.04000	0.04000	0.10000	0.00100	0.00300	0.01400	0.00000	
EPI HALF	ESAT	EHS	ENEQN	ENPR					
EPI1	150.000	15.0000	2	0.00100					
EPI TEMP	ET1	ET2	ET3	ET4	EK1	EK2	EK3	EK4	
EPI1	1.00000	3.00000	20.0000	30.0000	0.10000	0.99000	0.99000	0.10000	
EPI STOI	EP	EN	EC	ESI	ECHLA	EPOM			
EPI1	0.00500	0.08000	0.45000	0.00000	0.05000	0.80000			
ZOOP RATE	ZG	ZR	ZM	ZEFF	PREFP	ZOOMIN	ZS2P		
Zoo1	0.76950	0.10000	0.04000	0.48000	0.50000	0.01000	0.30000		
Zoo2	0.75000	0.10000	0.01000	0.50000	0.50000	0.01000	0.30000		
ZOOP ALGP	PREFA	PREFA	PREFA	PREFA	PREFA	PREFA	PREFA	PREFA	PREFA
Zoo1	0.60000	0.60000	0.20000						
Zoo2	0.75000	0.75000	0.20000						
ZOOP ZOOP	PREFZ	PREFZ	PREFZ	PREFZ	PREFZ	PREFZ	PREFZ	PREFZ	PREFZ
Zoo1	0.00000	0.10000							

Zoo2	0.00000	0.00000							
ZOOP TEMP	ZT1	ZT2	ZT3	ZT4	ZK1	ZK2	ZK3	ZK4	
Zoo1	5.00000	10.0000	17.0000	23.0000	0.10000	0.90000	0.98000	0.10000	
Zoo2	5.00000	8.0000	20.0000	22.0000	0.10000	0.90000	0.98000	0.10000	
ZOOP STOI	ZP	ZN	ZC						
Zoo1	0.01500	0.08000	0.45000						
Zoo2	0.01500	0.08000	0.45000						
MACROPHYT	MACWBC	MACWBC	MACWBC	MACWBC	MACWBC	MACWBC	MACWBC	MACWBC	MACWBC
Mac1	ON								
MAC PRINT	MPRWBC	MPRWBC	MPRWBC	MPRWBC	MPRWBC	MPRWBC	MPRWBC	MPRWBC	MPRWBC
Mac1	ON								
MAC INI	MACWBCI	MACWBCI	MACWBCI	MACWBCI	MACWBCI	MACWBCI	MACWBCI	MACWBCI	MACWBCI
Mac1	0.00000								
MAC RATE	MG	MR	MM	MSAT	MHSP	MHSN	MHSC	MPOM	LRPMAC
Mac1	0.30000	0.05000	0.05000	30.0000	0.00000	0.00000	0.00000	0.90000	0.20000
MAC SED	PSED	NSED							
Mac1	0.50000	0.50000							
MAC DIST	MBMP	MMA							
Mac1	40.0000	500.000							
MAC DRAG	CDDRAG	DMV	DWSA	ANORM					
Mac1	3.00000	70000.0	8.00000	0.30000					
MAC TEMP	MT1	MT2	MT3	MT4	MK1	MK2	MK3	MK4	
Mac1	7.00000	15.0000	24.0000	34.0000	0.10000	0.99000	0.99000	0.01000	
MAC STOICH	MP	MN	MC						
Mac1	0.00500	0.08000	0.45000						
DOM	LDOMDK	RDOMDK	LRDDK						
WB 1	0.08000	0.00100	0.01000						
POM	LPOMDK	RPOMDK	LRPDK	POMS					
WB 1	0.08000	0.00100	0.00100	0.50000					
OM STOIC	ORGP	ORGN	ORGC	ORGS					
WB 1	0.00500	0.08000	0.45000	0.18000					
OM RATE	OMT1	OMT2	OMK1	OMK2					
WB 1	4.00000	30.0000	0.10000	0.99000					
CBOD	KBOD	TBOD	RBOD	CBODS					
BOD 1	0.25000	1.01500	1.85000	0.00000					
CBOD STOIC	BODP	BODN	BODC						
BOD 1	0.00500	0.08000	0.45000						
PHOSPHOR	PO4R	PARTP							
WB 1	0.01500	0.00000							
AMMONIUM	NH4R	NH4DK							
WB 1	0.15000	0.05000							
NH4 RATE	NH4T1	NH4T2	NH4K1	NH4K2					
WB 1	5.00000	25.0000	0.10000	0.99000					
NITRATE	NO3DK	NO3S	FNO3SED						
WB 1	0.05000	0.00000	0.37000						
NO3 RATE	NO3T1	NO3T2	NO3K1	NO3K2					
WB 1	5.00000	25.0000	0.10000	0.99000					

QGT FILE.....QGTFN.....
qgt.npt - not used

WSC FILE.....WSCFN.....
wsc.npt

SHD FILE.....SHDFN.....
shade.npt

BTH FILE.....BTHFN.....
WB 1 bth.npt

MET FILE.....METFN.....
WB 1 met.npt

EXT FILE.....EXTFN.....
WB 1 ext_1.npt - not used

VPR FILE.....VPRFN.....
WB 1 vpr.npt - not used

LPR FILE.....LPRFN.....
WB 1 lpr.npt - not used

QIN FILE.....QINFN.....
BR1 qin_br1.npt
BR2 qin_br2.npt
BR3 qin_br3.npt
BR4 qin_br4.npt
BR5 qin_br5.npt
BR6 qin_br6.npt
BR7 qin_br7.npt
BR8 qin_br8.npt
BR9 qin_br9.npt
BR10 qin_br10.npt

TIN FILE.....TINFN.....
BR1 tin_br1.npt
BR2 tin_br2.npt
BR3 tin_br3.npt
BR4 tin_br4.npt
BR5 tin_br5.npt
BR6 tin_br6.npt
BR7 tin_br7.npt
BR8 tin_br8.npt
BR9 tin_br9.npt
BR10 tin_br10.npt

CIN FILE.....CINFN.....
BR1 cin_br1.npt
BR2 cin_br2.npt
BR3 cin_br3.npt
BR4 cin_br4.npt
BR5 cin_br5.npt
BR6 cin_br6.npt
BR7 cin_br7.npt
BR8 cin_br8.npt
BR9 cin_br9.npt
BR10 cin_br10.npt

QOT FILE.....QOTFN.....
BR1 qot_br1.npt

QTR FILE.....QTRFN.....
TR1 qtr_tr1.npt - not used

TTR FILE.....TTRFN.....
TR1 ttr_tr1.npt - not used

```

CTR FILE.....CTRFN.....
TR1      ctr_tr1.npt - not used

QDT FILE.....QDTFN.....
BR1      qdt_br1.npt

TDT FILE.....TDTFN.....
BR1      tdt_br1.npt

CDT FILE.....CDTFN.....
BR1      cdt_br1.npt

PRE FILE.....PREFN.....
BR1      pre_br1.npt
BR2      pre_br2.npt
BR3      pre_br3.npt
BR4      pre_br4.npt
BR5      pre_br5.npt
BR6      pre_br6.npt
BR7      pre_br7.npt
BR8      pre_br8.npt
BR9      pre_br9.npt
BR10     pre_br10.npt

TPR FILE.....TPRFN.....
BR1      tpr_br1.npt
BR2      tpr_br2.npt
BR3      tpr_br3.npt
BR4      tpr_br4.npt
BR5      tpr_br5.npt
BR6      tpr_br6.npt
BR7      tpr_br7.npt
BR8      tpr_br8.npt
BR9      tpr_br9.npt
BR10     tpr_br10.npt

CPR FILE.....CPRFN.....
BR1      cpr_br1.npt
BR2      cpr_br2.npt
BR3      cpr_br3.npt
BR4      cpr_br4.npt
BR5      cpr_br5.npt
BR6      cpr_br6.npt
BR7      cpr_br7.npt
BR8      cpr_br8.npt
BR9      cpr_br9.npt
BR10     cpr_br10.npt

EUH FILE.....EUHFN.....
BR1      euh_br1.npt - not used

TUH FILE.....TUHFN.....
BR1      tuh_br1.npt - not used
B

CUH FILE.....CUHFN.....
BR1      cuh_br1.npt - not used

EDH FILE.....EDHFN.....
BR1      edh_br1.npt - not used

TDH FILE.....TDHFN.....
BR1      tdh_br1.npt - not used

CDH FILE.....CDHFN.....
BR1      cdh_br1.npt - not used

SNP FILE.....SNPFN.....
WB 1     snp.opt

```



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PRF FILE.....PRFFN.....
WB 1    prf.opt

VPL FILE.....VPLFN.....
WB 1    vpl.opt

CPL FILE.....CPLFN.....
WB 1    cpl.opt

SPR FILE.....SPRFN.....
WB 1    spr.opt

FLX FILE.....FLXFN.....
WB 1    flx.opt

TSR FILE.....TSRFN.....
      tsr.opt

WDO FILE.....WDOFN.....
      wdo.opt

```

Appendix B: Water Temperature Calibration Profiles

Appendix C: Dissolved Oxygen Calibration Profiles

Appendix D: pH Calibration Profiles

Appendix E: Alternative Action Management Scenario Fish Habitat Percentages

Percent Total Volume Optimal Fish Habitat- No-Action Alternative												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R. Trout	0	0	0	0.3	12.9	18.9	16.3	5.7	20.1	36	0	0
Kokanee	0	0	0	14.5	41.4	40.4	29.7	9	0.4	88	48	0
Walleye	0	0	0	0	0	3.1	20.3	36.5	4.6	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15.1	23.4	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-2A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	18.2	16.1	4.7	16.8	35.5	0	0
Kokanee	0	0	0	16.4	42.8	39.6	27.8	4.6	0.2	87.6	45.9	0
Walleye	0	0	0	0	0	2.8	21.4	37.1	5.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16	23.5	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-2B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.1	18.9	16.6	4.5	17.4	31.2	0	0
Kokanee	0	0	0	16.3	43.3	40.3	27.8	4.3	0.4	88.4	44.6	0
Walleye	0	0	0	0	0	2.5	21	38	7.2	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15.3	23.5	1.2	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-2C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15.3	17.9	15.5	5	17.1	37	0	0
Kokanee	0	0	0	16.5	43	39.5	27.6	5.1	0.2	87.2	46.3	0
Walleye	0	0	0	0	0	3	22.2	39.1	5.2	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	17	25.7	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-2D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15.2	18.3	15.8	4.9	19	26.1	0	0
Kokanee	0	0	0	16.5	43.1	39.7	27.6	4.9	1.6	92.5	43.3	0
Walleye	0	0	0	0	0	2.9	22	37.8	5.8	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16.8	24.5	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-3A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15.3	18.5	17.7	6.8	18.4	27.1	0	0
Kokanee	0	0	0	16.4	42.9	39.7	28.8	5.9	1.5	88.4	42.6	0
Walleye	0	0	0	0	0	2.4	19.3	32.5	4	0	0	0
S. Mouth Bass	0	0	0	0	0	0.5	15.4	23.1	0.5	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-3B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15	19.1	17.2	8.3	18.1	26.6	0	0
Kokanee	0	0	0	16.4	43.4	40.6	28.1	7.1	0.7	89.5	44	0
Walleye	0	0	0	0	0	2.2	19.8	34.8	6.8	0	0	0
S. Mouth Bass	0	0	0	0	0	0.5	15.6	25.8	1	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-3C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15.4	18.2	16.2	4.5	17.9	25.7	0.1	0
Kokanee	0	0	0	16.5	43	39.6	27.9	4.8	1.1	87.6	41.6	0
Walleye	0	0	0	0	0	2.8	21.3	38.2	7.9	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16	23.8	0.9	0	0	0

Percent Total Volume Optimal Fish Habitat- Average-3D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.4	15.2	18.7	16.5	4.5	18	30.5	0	0
Kokanee	0	0	0	16.5	43.2	39.9	27.9	4.5	0.4	88.9	44.7	0
Walleye	0	0	0	0	0	2.6	21.1	37.9	7.1	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15.5	23.4	1.2	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-2A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.4	18	16.6	5.1	19.4	32.6	0	0
Kokanee	0	0	0	15.5	42.9	39	27.5	5.1	0.5	89.3	46.4	0
Walleye	0	0	0	0	0	2.7	20.5	36.1	6.9	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15	21.6	0.9	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-2B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.4	18	16.6	5.1	17.7	34.7	0	0
Kokanee	0	0	0	15.5	42.9	39.1	27.5	5.1	0.3	87.8	46.8	0
Walleye	0	0	0	0	0	2.7	20.6	35.7	5.2	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15.2	21.4	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-2C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.6	17.4	15.6	5.6	18.5	34.5	0	0
Kokanee	0	0	0	15.6	42.5	38.3	27.6	6.5	0.3	88.5	46.9	0
Walleye	0	0	0	0	0	3.3	22	36.3	5.3	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.6	22.2	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-2D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.6	17.4	15.5	5.6	19.2	31.1	0	0
Kokanee	0	0	0	15.6	42.5	38.3	27.4	6.4	0.6	89.2	46	0
Walleye	0	0	0	0	0	3.3	21.9	35.1	4.6	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.6	21.3	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-3A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.5	18.5	16	5	18.8	31.4	0	0
Kokanee	0	0	0	15.7	43.2	39.7	27.6	5.4	0.5	88.8	44.8	0
Walleye	0	0	0	0	0	2.3	20.9	33.9	3.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16.4	20.6	0.5	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-3B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.4	18.3	16.9	7.5	18.1	31.4	0	0
Kokanee	0	0	0	15.5	43	39.5	27.9	7.4	0.5	88.1	46.1	0
Walleye	0	0	0	0	0	2.4	18.3	34.5	4.6	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	14.8	25.4	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-3C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.7	17.3	16.5	6.8	21.1	31	0.1	0
Kokanee	0	0	0	15.7	42.6	38.6	27.7	6.8	0.5	89.3	42.5	0
Walleye	0	0	0	0	0	3	20.4	34.6	3.7	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	15	25.2	0.5	0	0	0

Percent Total Volume Optimal Fish Habitat-Dry-3D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.6	17.4	16.3	5	16.9	30.6	0	0
Kokanee	0	0	0	15.6	42.5	38.4	27.8	5.6	0.2	88.3	44.8	0
Walleye	0	0	0	0	0	3	20.8	35.3	5.1	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	15.4	20.9	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat-Drought-2A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.4	18	16.6	5.1	16.3	35.9	0	0
Kokanee	0	0	0	15.5	42.9	39.1	27.5	5	0.2	87	47.3	0
Walleye	0	0	0	0	0	2.6	20.5	34.8	4.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15	20.4	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat-Drought-2B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.4	18	16.6	5	16.8	35.7	0	0
Kokanee	0	0	0	15.5	42.9	39	27.4	5	0.2	87.3	47.1	0
Walleye	0	0	0	0	0	2.7	20.6	35.8	5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	15.1	21.4	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat-Drought-2C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.6	17.4	15.5	5.6	18.5	34.6	0	0
Kokanee	0	0	0	15.6	42.5	38.3	27.5	6.4	0.3	88.4	46.9	0
Walleye	0	0	0	0	0	3.3	21.9	36.3	5.3	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.6	22.3	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat-Drought-2D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	14.6	17.7	15.9	5.2	15.1	24.6	0	0
Kokanee	0	0	0	15.4	43	38.8	27.4	5.6	1.1	89	44.2	0
Walleye	0	0	0	0	0	3	21.4	35.2	5.6	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.3	21.1	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Drought-3A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15	18	16.4	4.4	18.2	29.3	0	0
Kokanee	0	0	0	16.2	43.6	40.9	27.5	3.8	0.7	89.3	41.5	0
Walleye	0	0	0	0	0	2.3	20.8	31.7	3.1	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16.3	17.2	0.4	0	0	0

Percent Total Volume Optimal Fish Habitat- Drought-3B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	17	16.2	4.8	17.9	33.5	0	0
Kokanee	0	0	0	16.3	43.3	39.5	26.8	3.8	0.3	88.4	44.5	0
Walleye	0	0	0	0	0	3.4	22.3	37.4	7	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.8	22.5	1.1	0	0	0

Percent Total Volume Optimal Fish Habitat- Drought-3C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.6	17.7	17.8	5.9	19.4	28	0.1	0
Kokanee	0	0	0	16.6	44.7	40.9	27.1	4.1	0.9	89.5	37.8	0
Walleye	0	0	0	0	0	2.7	18.7	31.6	2.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	14.9	21.5	0.3	0	0	0

Percent Total Volume Optimal Fish Habitat- Drought-3D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	17.7	17	4.4	14.2	35.3	0	0
Kokanee	0	0	0	15.8	44.5	40.7	26.1	2.8	0.1	86.6	45.1	0
Walleye	0	0	0	0	0	2.9	21.3	36.7	5.3	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.2	21.4	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-2A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	18.1	15.8	5.6	17.6	36	0	0
Kokanee	0	0	0	16.3	44.5	41.5	29.3	7.1	0.2	87.9	48.5	0
Walleye	0	0	0	0	0	3.1	21.5	37.6	5.2	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.5	23.8	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-2B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.1	19.1	16.7	5.3	14.5	31.2	0	0
Kokanee	0	0	0	16.3	44.6	42.7	29.5	6.3	0.4	86.4	44.7	0
Walleye	0	0	0	0	0	0	0	0	2.5	5.1	20.6	37.1
S. Mouth Bass	0	0	0	0	0	0.6	15.2	23	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-2C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.4	18.1	15.5	5.7	17	37.5	0	0
Kokanee	0	0	0	16.4	44.4	41.4	29	7.2	0.2	87.1	46.6	0
Walleye	0	0	0	0	0	3.1	21.9	38.9	5.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.7	25.3	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-2D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	18.6	16	5.5	16.8	30.8	0	0
Kokanee	0	0	0	16.4	44.6	42	29	6.7	0.5	88.3	44.7	0
Walleye	0	0	0	0	0	2.8	21.4	37.8	4.9	0	0	0
S. Mouth Bass	0	0	0	0	0	0.6	16.3	23.8	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-3A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	18.1	16.2	5.4	19.3	32.3	0	0
Kokanee	0	0	0	16.4	44.6	41.7	29.5	6.8	0.5	89.2	45.2	0
Walleye	0	0	0	0	0	3.1	20.9	35.6	4.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	15.8	21.5	0.6	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-3B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.2	19.3	17.1	5.4	15.5	29.3	0	0
Kokanee	0	0	0	16.4	44.7	42.9	29.9	6.3	0.5	86.7	44.5	0
Walleye	0	0	0	0	0	2.2	21.1	38.7	7.5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.5	15.8	24.3	1.2	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-3C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.4	18	15.8	5.5	17.5	34	0	0
Kokanee	0	0	0	16.4	44.4	41.4	29.3	7	0.4	88.2	45.4	0
Walleye	0	0	0	0	0	3	21.5	37.7	5	0	0	0
S. Mouth Bass	0	0	0	0	0	0.7	16.4	23.7	0.7	0	0	0

Percent Total Volume Optimal Fish Habitat- Wet-3D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout	0	0	0	0.3	15.3	19	17	5.3	16.4	33.3	0.1	0
Kokanee	0	0	0	16.4	44.7	42.6	29.9	6.4	0.4	87.2	45.5	0
Walleye	0	0	0	0	0	2.3	21.1	38.2	5.2	0	0	0
S. Mouth Bass	0	0	0	0	0	0.5	15.8	24.3	0.7	0	0	0

Appendix F: Lake Roosevelt Fish Bioenergetics FORTRAN Source Code Routine

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! PROGRAM BIOENERGETICS
! MIKE MCKILLIP (2006)
! STOCKWELL AND JOHNSON APPROACH, AS SUGGESTED BY MAZUR AND BEAUCHAMP
! STAND ALONE PROGRAM FOR TESTING MODULES TO BE INCORPORATED WITH THE W2 CODE

! *****
! TASK B.1. MODULE DECLARATION
! *****
MODULE MAINW2 ! REPETITION OF W2-CODE VARIABLES
REAL*8,          ALLOCATABLE, DIMENSION (:,:) :: DEPTHM,T1,GAMMA,BH,EL
REAL*8,          ALLOCATABLE, DIMENSION (:,:,) :: C2
REAL JDAY,JEND !BIOF = FREQUENCY OF BIOEXP OUTPUT
REAL FBIONXT ! NEXT DAY TO GET CALCULATION INPUTS
INTEGER,         ALLOCATABLE, DIMENSION(:) :: BIOINFN
INTEGER,         ALLOCATABLE, DIMENSION(:) :: KTI,KBI
INTEGER KMX, IMX,NUNIT,NZP,K,I,DLT,JI,NWB
INTEGER NCT,JZ,NZOOS,NZOOE,NOD
CHARACTER*72,    ALLOCATABLE, DIMENSION(:) :: BIOINNAME
CHARACTER*72 FRED,SEGNUM
END MODULE MAINW2
MODULE ROOSEVELT !THIS MODULE TAKEN FROM W2-ROOSEVELT; ALLOWS THE W2_ANC_CON.NPT TO BE READ
INTEGER,         ALLOCATABLE, DIMENSION(:) :: IBIO,BIOPD,BIOEXPFN
REAL*8,          ALLOCATABLE, DIMENSION(:) :: BIOD, BIOF
INTEGER,         ALLOCATABLE, DIMENSION(:,:) :: NVIOL_LOC
CHARACTER*8 NVIOLC, BIOC
LOGICAL BIOEXP
INTEGER NBIO,NIBIO
REAL*8 NXBIO,NXTBIO,GAMMAB
CHARACTER*72 BIOFN,WEIGHTFN
END MODULE ROOSEVELT
MODULE FISH ! FOR FISH BIOENERGETICS ROUTINE (DIRECT INCLUSION)
REAL*8,          ALLOCATABLE, DIMENSION(:) :: EZOO,LZOO,MZOO,FTL,F1I
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: FCON,FVEL,FACT,GAMMAFDC,FVELAVE,FACTAVE
REAL*8,          ALLOCATABLE, DIMENSION(:,:,) :: F1
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: F2,AVEC,MINC,MAXC
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: F_F,F_U,F_D,F_R,F_S,F_C,F_G,F_W ! UNITS OF J
(DAILY SCALE)
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: F_G2
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: F_DINI,F_DCON,F_DUNDIG
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: DAYC,SRCHVOL,RDZ
REAL*8,          ALLOCATABLE, DIMENSION(:,:,) :: C1Z
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: F_FC,F_UC,F_DC,F_RC,F_SC,F_CC ! UNITS OF J
(TIME-STEP SCALE)
REAL*8,          ALLOCATABLE, DIMENSION(:) :: ZAVAIL, ZAVAILNX,CEFF,Z1Z,L1Z,CELL_PER
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: T1Z
REAL*8,          ALLOCATABLE, DIMENSION(:,:) :: FCONMAXGG,FCONGG,FCONMAXJ,FCONJ,DAYCM,FCONP
REAL*8,          ALLOCATABLE, DIMENSION(:) :: T1BZ
REAL NXTFISH,NXTFOPT,FG1,FG2,FKA,FKB,FL1,FL2,DIGK,JUNK, FDLTM,FDLTH,FOXYCAL
REAL FISHT1,FISHT2,FISHT3,FISHT4,FISHK1,FISHK2,FISHK3,FISHK4 ! TEMPERATURE RATE TERMS
REAL FJDAYNXT,HANDLE,FVELA,FVELB,FVELE,THRESHV,DAP_IN,JAVAIL,FGPD,FGPF
REAL FBIODAYNXT,FBIOSUBNXT,FBIODAYLST,ZAVJD,ZAVNX
REAL GIM, BIM, DIM, GALP, BALP, DALP, GTI, BTI, DTI
REAL F1M,F1J,WILMA1,WILMA2
INTEGER,         ALLOCATABLE, DIMENSION(:) :: ZDEPTH,DATA_FILENUM,BIOOUTFN, CELL_POS,
CELL_NEG,FGPFN
INTEGER,         ALLOCATABLE, DIMENSION(:,:) :: FULLSTO
INTEGER,         ALLOCATABLE, DIMENSION(:) :: KBIP
INTEGER CUR_FJDAY, FJDAYINT,ZHOLDNUM,DIAGLOGFN, JJZ,FOPTNUM,THRESHZ,ZAVFN,BIOCON,NUMSTEPS,FUF
CHARACTER*72,    ALLOCATABLE, DIMENSION(:) :: BIOOUTNAME,FGPFNAME
INTEGER FXNFN(3)
CHARACTER*72 ZAVFNAME
CHARACTER*8 FHEAD(30),FUNIT(20),FCALC,FGPC,CMAXC
CHARACTER*8 GENMTP,BESTMTP,DIELMTP
CHARACTER*72 FXNFNAME(3)
LOGICAL,         ALLOCATABLE, DIMENSION(:) :: FIRST_BIO,THRESHFEED
LOGICAL SAMEDAY,FIRSTLIGHT,FIRST_OUTPUT,DAILY_FISH_OPT,BIOSUB_CALC, BIODAY_CALC
LOGICAL HAPPY, NEWDAY,FBIOCALC,FGPPLOT,FISHCALC,THRESHOLD,CMAXCALC
LOGICAL
GMTPCCELL,GMTPFIXN,GMTPUSER,GMTPFIXED,BMTPSEG,BMTPFXN,BMTPUSER,BMTPFIXED,DMTPSEG,DMTPFXN,DMTPUSER,DMTPFI
XED
LOGICAL GMTOK,BMTOK,DMTOK
END MODULE FISH
MODULE FISH2 ! FOR USE WITH THIS PROGRAM; WILL NEED TO BE ALTERED FOR INCORPORATION WITH W2-CODE
REAL LUX, LUX1, LUX2 ! TEMPORARY LIGHT DATA TERMS
REAL LJDAY1,LJDAY2

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INTEGER LIGHTNUM
END MODULE FISH2
MODULE BIOEXPDATATransFORM ! FOR CONVERTING THE BIOEXP DATA OUTPUT INTO W2 ARRAYS AND VARIABLES
REAL ZDAY1,ZDAY2
INTEGER FIRSTK, LASTK, SEGK, GRCT
CHARACTER*20 GREGORY(1000)
LOGICAL,          ALLOCATABLE, DIMENSION(:)      :: FIRSTREAD
END MODULE BIOEXPDATATransFORM
MODULE GROWTH_ANIMATION
INTEGER ANIMFN, ANIMFN2, ZONECNT, ZONEFIRST, NNODE, NELEM
CHARACTER*52 HEADER1, HEADER2
REAL LEFT(999), RIGHT(999)
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: DISTL, DISTR, BOTTIME
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: GELEV, X1, X2, X3, X4, Y1, Y2, Y3, Y4
REAL    VLL, VLR
INTEGER,          ALLOCATABLE, DIMENSION(:)    :: BOTSEG
LOGICAL,          ALLOCATABLE, DIMENSION(:)    :: ANIMEXP
END MODULE GROWTH_ANIMATION
MODULE DIAGNOSTIC
REAL*8,          ALLOCATABLE, DIMENSION(:,:,:)  :: DIET
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: VISIBLE
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: MAXG, MAXM
INTEGER BYSEGMFN, BYSEGGFN, BYSEGGMFN2, BYSEGGFN2, BYSEGGMFN3, BYSEGGFN3, SURFSEGGMFN, SURFSEGGFN
INTEGER TLCALCFN
CHARACTER*8 FDIAGC, THRESHC, SURFC, TLC
LOGICAL FDIAG, BYSEG, SURFDIAG
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: MF_GI, MF_RI, MF_DI, MF_CI, MF_WI, MF_SI
CHARACTER*8 FISHC, BIOPARC, CONSC, DIGC, RESPC, SINGLEC
LOGICAL FISHDIAG, BIOPARDIAG, CONSDIAG, DIGDIAG, RESPDIAG, SINGLEDIAG, TLCALC
INTEGER SINGFN, SINIBIO
END MODULE DIAGNOSTIC
MODULE MOVEMENT
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BFCN, BFVEL, BFACT
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BFVELAVE, BFACTAVE
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: DFCON, DFVEL, DFACT
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: DFVELAVE, DFACTAVE
REAL*8,          ALLOCABTABLE, DIMENSION(:,:,:)  :: BF1, DF1, BDIET, DDIET
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BF_F, BF_U, BF_D, BF_R, BF_S, BF_C, BF_G, BF_W
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: DF_F, DF_U, DF_D, DF_R, DF_S, DF_C, DF_G, DF_W
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BF_FC, BF_UC, BF_DC, BF_RC, BF_SC, BF_CC
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: DF_FC, DF_UC, DF_DC, DF_RC, DF_SC, DF_CC
REAL*8,          ALLOCATABLE, DIMENSION(:)      ::
BF_GI, BF_RI, BF_DI, BF_CI, BF_WI, BF_SI, BF_UI, BF_FI
REAL*8,          ALLOCATABLE, DIMENSION(:)      ::
DF_GI, DF_RI, DF_DI, DF_CI, DF_WI, DF_SI, DF_UI, DF_FI
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BDAYC, BSRCHVOL, BRDZ
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: DDAYC, DSRCHVOL, DRDZ
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BCELL_PER, DCELL_PER
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BESTG, TEPI, THYPO
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    ::
BFCNMAXGG, BFCONGG, BFCNMAXJ, BFCONJ, BDAYCM, BFCNPF
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    ::
DFCNMAXGG, DFCONGG, DFCNMAXJ, DFCONJ, DDAYCM, DFCNPF
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BAVEC, BMINC, BMAXC
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: DAVEC, DMINC, DMAXC
REAL*8,          ALLOCATABLE, DIMENSION(:)      ::
BFCNMAXJI, BFCNMAXGGI, BFCONI, BFCNPI, BFDAYCI, BFDAYCMI, BFCONJI, BFCONGGI
REAL*8,          ALLOCATABLE, DIMENSION(:)      ::
DFCNMAXJI, DFCNMAXGGI, DFCONI, DFCNPI, DFDAYCI, DFDAYCMI, DFCONJI, DFCONGGI
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BDAYCI, BDAYCMI
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: DDAYCI, DDAYCMI
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BF_DC_EXT, BF_G_EXT
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: DF_DC_EXT, DF_G_EXT
REAL GMAXG, DIELLUX, DIELG, DIELS, RMIN, CMAX
INTEGER,          ALLOCATABLE, DIMENSION(:)    :: BCELL_POS, BCELL_NEG, BFULLSTOI
INTEGER,          ALLOCATABLE, DIMENSION(:)    :: DCELL_POS, DCELL_NEG, DFULLSTOI
INTEGER,          ALLOCATABLE, DIMENSION(:,:)    :: BESTK, DIELK, BFULLSTO, DFULLSTO
INTEGER GMAXK, BESTSTEP, KDIEL, RMINK, CMAXK, KBEST
CHARACTER*8 BESTC, DIELC, DEPTHC
LOGICAL BESTCALC, DIELCALC, DIELDEEP, DAYLIGHT, DEPTHCALC
REAL*8,          ALLOCATABLE, DIMENSION(:)      :: BVISIBLE, DVISIBLE
REAL*8,          ALLOCATABLE, DIMENSION(:,:)    :: BDIETI, DDIETI
INTEGER BESTDIAGFN
LOGICAL,          ALLOCATABLE, DIMENSION(:)      :: FORAY
END MODULE MOVEMENT

! *****
!   TASK B.2.0 MAIN PROGRAM DECLARATIONS
! *****

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PROGRAM BIOENERGETICS
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATRANSFORM; USE GROWTH_ANIMATION; USE DIAGNOSTIC; USE
ROOSEVELT; USE MOVEMENT
!****TEMPORARY FILES
OPEN(999,FILE='TEMP.DAT',STATUS='UNKNOWN')
OPEN(998,FILE='TEMP2.DAT',STATUS='UNKNOWN')

!****VARIABLE/ ARRAY ALLOCATION & INITIAL VALUES****
NOD = 100
! ROOSEVELT
OPEN(12,FILE='W2_CON_ANC.NPT',STATUS='OLD')
DO II = 1,16
  READ(12,'(A8)') BIOC
END DO
ALLOCATE (BIOD(NOD), BIOF(NOD),BIODP(NOD))
! BIOENERGETICS OUTPUT CARDS
READ(12,'(/(8X,A8,2I8))') BIOC,NBIO,NIBIO
ALLOCATE (BIOEXPFN(NIBIO),IBIO(NIBIO))
ROO2 = 0.0; C2W = 0.0
READ(12,'(/(8X,9F8.0))') (BIOD(II),II=1,NBIO)
READ(12,'(/(8X,9F8.0))') (BIOF(II),II=1,NBIO)
READ(12,'(/(8X,9I8))') (IBIO(II),II=1,NIBIO)
READ(12,'(/(8X,A72))') BIOFN
CLOSE(12)
! END ROOSEVELT
! MAINW2
IMX = 583; KMX = 76; NUNIT = 100; NWB = 1; FBIONXT = 366.5
JDAY = 366.0; JEND = 400.5; DLT = 1; NCT = 22; NZOOS = 20; NZOOE = 22; NZP = 3
ALLOCATE (DEPTHM(KMX,IMX),T1(KMX,IMX),GAMMA(KMX,IMX),BH(KMX,IMX),EL(KMX,IMX))
ALLOCATE (C2(KMX,IMX,NCT),KTI(IMX),KBI(IMX))
ALLOCATE (BIOINNAME(NIBIO),BIOINFN(NIBIO)) ! ULTIMATELY, IMX (& NEW VARIABLE)
! FISH
ALLOCATE (BIOOUTFN(NIBIO),EZOO(NZP),LZOO(NZP),MZOO(NZP))
ALLOCATE (BIOOUTNAME(NIBIO),FCON(KMX,IMX),FVEL(KMX,IMX),FACT(KMX,IMX),FLI(3))
ALLOCATE (F1(KMX,IMX,5)) ! 1 = MASS; 2 = LENGTH; 3 = STOMACH CONTENT; 4 = ENERGY DENSITY OF FISH; 5 =
STOMACH CAPACITY
ALLOCATE (FTL(KMX),SRCHVOL(KMX,IMX),RDZ(KMX,IMX),F2(KMX,IMX))
ALLOCATE (CELL_POS(IMX),CELL_NEG(IMX),CELL_PER(IMX),FULLSTO(KMX,IMX))
ALLOCATE (F_F(KMX,IMX),F_U(KMX,IMX),F_D(KMX,IMX),F_R(KMX,IMX),F_S(KMX,IMX),F_C(KMX,IMX))
ALLOCATE (F_G(KMX,IMX),F_W(KMX,IMX),DAYC(KMX,IMX))
ALLOCATE (F_FC(KMX,IMX),F_UC(KMX,IMX),F_DC(KMX,IMX),F_RC(KMX,IMX),F_SC(KMX,IMX),F_CC(KMX,IMX))
ALLOCATE (T1Z(KMX,IMX),C1Z(KMX,IMX,NZP),Z1Z(KMX),L1Z(KMX),ZDEPTH(KMX))
ALLOCATE (FIRST_BIO(NIBIO),GAMMAFDC(KMX,IMX))
ALLOCATE (ZAVAIL(NZP),ZAVAILNX(NZP),CEFF(KMX))
ALLOCATE (FGPFN(NWB),FGPFNAME(NWB),GELEV(KMX,IMX),DISTL(IMX),DISTR(IMX))
ALLOCATE (X1(KMX,IMX),X2(KMX,IMX),X3(KMX,IMX),X4(KMX,IMX))
ALLOCATE (Y1(KMX,IMX),Y2(KMX,IMX),Y3(KMX,IMX),Y4(KMX,IMX))
ALLOCATE (DIET(KMX,IMX,NZP),THRESHFEED(KMX),VISIBLE(KMX,IMX))
ALLOCATE (ANIMEXP(NIBIO),BOTSEG(IMX),BOTTOE(IMX))
ALLOCATE (MAXG(IMX),MAXM(IMX),KBIP(IMX))
ALLOCATE (FCONMAXGG(KMX,IMX),FCONGG(KMX,IMX),FCONMAXJ(KMX,IMX),FCONJ(KMX,IMX),FCONP(KMX,IMX))
ALLOCATE (F_DINI(KMX,IMX),F_DCON(KMX,IMX),F_DUNDIG(KMX,IMX),DAYCM(KMX,IMX))
ALLOCATE (FVELAVE(KMX,IMX),FACTAVE(KMX,IMX))
ALLOCATE (AVEC(KMX,IMX),MINC(KMX,IMX),MAXC(KMX,IMX))
ALLOCATE (F_G2(KMX,IMX))
! IF(SINGLEDIAG) THEN
  ALLOCATE (MF_GI(KMX),MF_RI(KMX),MF_DI(KMX),MF_CI(KMX),MF_WI(KMX),MF_SI(KMX))
  MF_GI = 0.0; MF_RI = 0.0; MF_DI = 0.0; MF_CI = 0.0; MF_WI = 0.0; MF_SI = 0.0
! END IF
TLCALC = .FALSE.
F1(:,4) = 5821.9*4.1868 ; F1(:,5) = 3.64 ; FCON = 0.0
F_R = 0.0; F_D = 0.0; F_C = 0.0; F_F = 0.0; F_U = 0.0; F_S = 0.0; F_G = 0.0; F_W = 0.0
F_RC = 0.0; F_DC = 0.0; F_CC = 0.0; F_FC = 0.0; F_UC = 0.0; F_SC = 0.0
F_DINI = 0.0; F_DCON = 0.0; F_DUNDIG = 0.0; DAYCM = 0.0
AVEC = 0.0; MINC = 0.0; MAXC = 0.0
FVELAVE = 0.0; FACTAVE = 0.0
KBIP = 1
FBIOSUBNXT = 366.0; FBIODAYNXT = 367.0; FBIODAYLST = 366.0
CELL_POS = 0; CELL_NEG = 0; DAYC = 0.0; CELL_PER = 0.0; FULLSTO = 0
DAP_IN = 0.0; RDZ = 0.08; GAMMAFDC = 0.0
FCONMAXGG = 0.0; FCONGG = 0.0; FCONMAXJ = 0.0; FCONJ = 0.0
BIOSUB_CALC = .FALSE.; BIODAY_CALC = .FALSE.; HAPPY = .TRUE.; NEWDAY = .TRUE.; FIRSTLIGHT =
.TRUE.
FIRST_OUTPUT = .TRUE.; DAILY_FISH_OPT = .FALSE.; FBIOCALC = .FALSE.; FIRST_BIO = .TRUE.
GMTPCCELL = .FALSE.; GMTPFIXN = .FALSE.; GMTPUSER = .FALSE.; GMTPFIXED = .FALSE.; BMTPSEG =
.FALSE.; BMTPFIXN = .FALSE.
BMTPUSER = .FALSE.; BMTPFIXED = .FALSE.; DMTPSEG = .FALSE.; DMTPFIXN = .FALSE.; DMTPUSER =
.FALSE.; DMTPFIXED = .FALSE.
GMTOK = .FALSE.; BMTOK = .FALSE.; DMTOK = .FALSE.

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SINGLELDIAG = .FALSE.;SURFDIAG = .FALSE.
FISHDIAG = .FALSE.; BIOPARDIAG = .FALSE.; CONSDIAG = .FALSE.; DIGDIAG = .FALSE.; RESPDIAG =
.FALSE.;SINGLELDIAG = .FALSE.
  F_G2 = 0.0
  ! FISH2
  LJDAY1 = 360.0; LJDAY2 = 361.0; LUX = 0.0 ! TEMPORARY SET UP VALUES
  MAXG = -999.0; MAXM = -999.0; DIELDEEP = .TRUE.;CMAXCALC = .FALSE.
  ! BIOEXP
  ALLOCATE (FIRSTREAD(NIBIO))
  FIRSTREAD = .TRUE.
  ! GROWTH ANIMATION
  HEADER1 = 'TITLE ="Lake Roosevelt"'
  HEADER2 = 'VARIABLES = "Distance, km", "Elevation, m", "FGP"'
  GELEV = 0.0; DISTL = 0.0; DISTR = 0.0
  ZONECNT = 0 ; ZONEFIRST = INT(JDAY)
  DIET = 0.0 ; THRESHFEED = .FALSE.; VISIBLE = 0.0
  OPEN(13,FILE='CHANNEL_BOT.OPT',STATUS='OLD')
  READ(13,*) BESTC
  DO I = 1,IMX
    READ(13, '(I10,50X,F10.0)',END=1199) BOTSEG(I),BOTTOME(I)
  END DO
  1199 CONTINUE
  CALL GETFISHDATA
  FDLTM = FUF*1.0 ! IN MINUTES
  FDLTH = FDLTM/60.0; ZHOLDNUM = 4+NZP; NUMSTEPS = 1440/FUF
  GRCT = 1
  ANIMEXP = .TRUE.; ANIMEXP(12) = .FALSE.; ANIMEXP(21) = .FALSE.; ANIMEXP(24) = .FALSE.
  ! BYSEG
  BYSEG = .TRUE.
  ! MOVEMENT
  IF(BESTCALC) THEN
    ALLOCATE (BFCON(KMX,IMX),BFVEL(KMX,IMX),BFACT(KMX,IMX),BF1(KMX,IMX,5))
    ALLOCATE (BF_F(KMX,IMX),BF_U(KMX,IMX),BF_D(KMX,IMX),BF_R(KMX,IMX),BF_S(KMX,IMX),BF_C(KMX,IMX))
    ALLOCATE (BF_G(KMX,IMX),BF_W(KMX,IMX),BDAYC(KMX,IMX),BDAYCM(KMX,IMX))
    ALLOCATE (BF_FC(KMX,IMX),BF_UC(KMX,IMX),BF_DC(KMX,IMX),BF_RC(KMX,IMX),BF_SC(KMX,IMX),BF_CC(KMX,IMX))
    ALLOCATE (BSRCHVOL(KMX,IMX),BRDZ(KMX,IMX))
    ALLOCATE (BCELL_POS(IMX),BCELL_NEG(IMX),BCELL_PER(IMX))
    ALLOCATE (BESTK(IMX,NUMSTEPS+1),BESTG(IMX))
    ALLOCATE (BDIETI(IMX,NZP),BDIET(KMX,IMX,NZP))
    ALLOCATE (BF_GI(IMX),BF_RI(IMX),BF_DI(IMX),BF_CI(IMX),BF_WI(IMX),BF_SI(IMX),BF_UI(IMX),BF_FI(IMX))
    ALLOCATE (BFCONMAXGG(KMX,IMX),BFCONGG(KMX,IMX),BFCONMAXJ(KMX,IMX),BFCONJ(KMX,IMX),BFCONP(KMX,IMX))
    ALLOCATE (BFULLSTO(KMX,IMX),BFULLSTOI(IMX),BVISIBLE(IMX))
    ALLOCATE (BFVELAVE(IMX),BFACTAVE(IMX))
    ALLOCATE (BAVEC(IMX),BMINC(IMX),BMAXC(IMX))
    ALLOCATE
    (BFCONMAXJI(IMX),BFCONMAXGGI(IMX),BFCONI(IMX),BFCONPI(IMX),BFDAYCI(IMX),BFDAYCMI(IMX),BFCONGGI(IMX),BF
    CONJI(IMX))
    ALLOCATE (BDAYCI(IMX),BDAYCMI(IMX))
    ALLOCATE (BF_DC_EXT(KMX,IMX),BF_G_EXT(KMX,IMX))
    ALLOCATE (T1BZ(IMX))
    BFCON = 0.0 ;BF1 = F1; BDAYC = 0.0; BFULLSTO = 0; BFULLSTOI = 0
    BCELL_POS = 0; BCELL_NEG = 0; BESTSTEP = 0
    BVISIBLE = 0.0; BDIET = 0.0; BESTK = 0
    BF_F = 0.0 ;BF_U = 0.0 ;BF_D = 0.0 ;BF_R = 0.0 ;BF_S = 0.0 ;BF_C = 0.0 ;BF_G = 0.0 ;BF_W = 0.0
    BF_FC = 0.0;BF_UC = 0.0;BF_DC = 0.0;BF_RC = 0.0;BF_SC = 0.0;BF_CC = 0.0
    BF_GI = 0.0;BF_RI = 0.0;BF_DI = 0.0;BF_CI = 0.0;BF_WI = 0.0;BF_SI = 0.0; BF_UI = 0.0; BF_FI = 0.0
    BFVELAVE = 0.0; BFACTAVE = 0.0
    BAVEC = 0.0; BMINC = 0.0; BMAXC = 0.0
    BFCONMAXJI = 0.0; BFCONMAXGGI = 0.0; BFCONI = 0.0; BDAYCI = 0.0; BDAYCMI = 0.0; BFCONPI = 0.0;
    BFCONJI = 0.0; BFCONGGI = 0.0
    BF_DC_EXT = 0.0;BF_G_EXT = 0.0
    T1BZ = 0.0
  END IF
  IF(DIELCALC) THEN
    ALLOCATE (DFCON(KMX,IMX),DFVEL(KMX,IMX),DFACT(KMX,IMX),DF1(KMX,IMX,5))
    ALLOCATE (DF_F(KMX,IMX),DF_U(KMX,IMX),DF_D(KMX,IMX),DF_R(KMX,IMX),DF_S(KMX,IMX),DF_C(KMX,IMX))
    ALLOCATE (DF_G(KMX,IMX),DF_W(KMX,IMX),DDAYC(KMX,IMX),DDAYCM(KMX,IMX))
    ALLOCATE (DF_FC(KMX,IMX),DF_UC(KMX,IMX),DF_DC(KMX,IMX),DF_RC(KMX,IMX),DF_SC(KMX,IMX),DF_CC(KMX,IMX))
    ALLOCATE (DSRCHVOL(KMX,IMX),DRDZ(KMX,IMX))
    ALLOCATE (DCELL_POS(IMX),DCELL_NEG(IMX),DCELL_PER(IMX))
    ALLOCATE (DIELK(IMX,NUMSTEPS+1),TEPI(IMX),THYPO(IMX))
    ALLOCATE (DF_GI(IMX),DF_RI(IMX),DF_DI(IMX),DF_CI(IMX),DF_WI(IMX),DF_SI(IMX),DF_UI(IMX),DF_FI(IMX))
    ALLOCATE (DFVELAVE(IMX),DFACTAVE(IMX),DVISIBLE(IMX))
    ALLOCATE (DAVEC(IMX),DMINC(IMX),DMAXC(IMX))
    ALLOCATE
    (DFCONMAXJI(IMX),DFCONMAXGGI(IMX),DFCONI(IMX),DFCONPI(IMX),DFDAYCI(IMX),DFDAYCMI(IMX),DFCONGGI(IMX),DF
    CONJI(IMX))
    ALLOCATE (DDAYCI(IMX),DDAYCMI(IMX))
    ALLOCATE (DF_DC_EXT(KMX,IMX),DF_G_EXT(KMX,IMX))

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ALLOCATE (DFCONMAXGG(KMX,IMX),DFCONGG(KMX,IMX),DFCONMAXJ(KMX,IMX),DFCONJ(KMX,IMX),DFCONP(KMX,IMX))
ALLOCATE (DDIETI(IMX,NZP),DDIET(KMX,IMX,NZP),DFULLSTO(KMX,IMX),DFULLSTOI(IMX))
ALLOCATE (FORAY(IMX))
DFCON = 0.0 ;DF1 = F1; DDAYC = 0.0; DFULLSTO = 0; DFULLSTOI = 0
DCELL_POS = 0; DCELL_POS = 0; DIELK = 0
DF_F = 0.0 ;DF_U = 0.0 ;DF_D = 0.0 ;DF_R = 0.0 ;DF_S = 0.0 ;DF_C = 0.0 ;DF_G = 0.0 ;DF_W = 0.0
DF_FC = 0.0;DF_UC = 0.0;DF_DC = 0.0;DF_RC = 0.0;DF_SC = 0.0;DF_CC = 0.0
DF_GI = 0.0;DF_RI = 0.0;DF_DI = 0.0;DF_CI = 0.0;DF_WI = 0.0;DF_SI = 0.0; DF_UI = 0.0; DF_FI = 0.0
DFVELAVE = 0.0; DFACTAVE = 0.0
DAVEC = 0.0; DMINC = 0.0; DMAXC = 0.0;DVISIBLE = 0
DFCONMAXJI = 0.0; DFCONMAXGGI = 0.0; DFCONI = 0.0; DDAYCI = 0.0; DDAYCMI = 0.0; DFCONPI = 0.0;
DFCONJI = 0.0; DFCONGGI = 0.0
DF_DC_EXT = 0.0;DF_G_EXT = 0.0
FORAY = .FALSE.
END IF

! *****
! * TASK B.2.1 FILE SET UP *
! *****
CALL INITIALFILESETUP
!*****
! TASK B.2.1 PSEUDO W2-TIME CONTROL AND VARIABLE UPDATE
!*****
! TASK B.2.1.1 PSEUDO W2 TIME ADVANCEMENT
2110 CONTINUE
GOTO 2111 ! BY PASS FOR FIXED FISH TIMESTEPS
JDAY = JDAY + DLT/3600.0/24.0
! CHECK FOR END OF SIMULATION
IF(JDAY.GT.JEND) THEN
GOTO 997
END IF
! CHECK FOR ROUTING TO SUB-DAILY CALCULATIONS
IF(JDAY.GE.FBIOSUBNXT) THEN
FBIOSUBNXT = FBIOSUBNXT + 1.0/48.0
BIOSUB_CALC = .TRUE.
IF(JDAY.GE.FBIODAYNXT) THEN
FBIODAYLST = FBIODAYNXT; FBIODAYNXT = FBIODAYNXT + 1.0
BIODAY_CALC = .TRUE.
NEWDAY = .TRUE.; GRCT = GRCT+1
END IF
END IF
IF(BIOSUB_CALC) THEN
CONTINUE
ELSE
GOTO 2110
END IF
2111 continue
JDAY = JDAY + 1.0/48.0
IF(JDAY.GT.JEND) THEN
GOTO 997
END IF
IF(JDAY.GE.FBIOSUBNXT) THEN
!JDAY = INT(JDAY)*1.0 +0.0
FBIOSUBNXT = JDAY + 1.0/48.0
!FBIOSUBNXT = INT(JDAY+1.0)*1.0 + 0.0
BIOSUB_CALC = .TRUE.
IF(JDAY.GE.FBIODAYNXT) THEN
FBIODAYLST = FBIODAYNXT; FBIODAYNXT = FBIODAYNXT + 1.0
JDAY = 1.0*INT(JDAY)
BIODAY_CALC = .TRUE.
NEWDAY = .TRUE.; GRCT = GRCT+1
END IF
END IF
END IF

! *****ZOOPLANKTON AVAILABILITY UPDATE*****
IF(JDAY.GE.ZAVNX) THEN ! THIS UPDATE MUST OCCUR AFTER THE COMPUTATIONS IN W2 OR RISK AN END OF FILE
READ ERROR
ZAVJD = ZAVNX; ZAVAIL = ZAVAILNX
READ(ZAVFN, '( :F8.0,9F8.0) ') ZAVNX, (ZAVAILNX(II),II=1,NZP)
END IF
!*****
! TASK B.2.2 SUBDAILY CALCULATIONS
!*****
! TASK B.2.2.1 GET UPDATED SOLAR INPUTS
IF(JDAY.LT.LJDAY1) LUX = LUX1
IF(JDAY.LE.LJDAY2) LUX = (LJDAY2-JDAY)/(LJDAY2-LJDAY1)*(LUX2-LUX1)

2200 CONTINUE
IF(JDAY.GE.LJDAY2) THEN

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CALL LIGHTOUT
IF(JDAY.GE.LJDAY1.AND.JDAY.LE.LJDAY2) THEN
  LUX = LUX1 + (LJDAY2-JDAY)/(LJDAY2-LJDAY1)*(LUX2-LUX1)
ELSE
  GOTO 2200
END IF
END IF

LUX = MAX(LUX,0.0) ! REDUDANT CHECK
IF(LUX.GE.1.0) THEN !ARBITRARY; USED FOR VERTICAL MIGRATION
  DAYLIGHT = .TRUE.
ELSE
  DAYLIGHT = .FALSE.
END IF
!NOON CHECK ( FOR DEBUGGING )
IF(JDAY.GT.557.5) THEN
  IF(JDAY.LT.557.51) THEN
    CONTINUE
  END IF
END IF
! BESTCALC TIMESTEP COUNT
IF(BESTCALC) BESTSTEP = BESTSTEP + 1
! *****
! TASK B.2.2.2 SUB-DAILY BIOENERGETICS
! *****
write (999,'(a12,f8.3)') 'JDAY ', jday
! NEED TO MATCH DEPTHS TO K-LAYERS FOR W2 APPLICATION; ! ITERATE BY SEGMENT, SO ONLY K DIMENSION IS
NEEDED
DO JI = 1,NIBIO ! THIS IS THE MAIN W2 LOOP SIMULATION
  I = IBIO(JI)
  KBIP = KTI
  ! GET BIOEXP DATA AND DETERMINE KTI,KBI
  IF(FIRST_BIO(JI)) THEN
    CALL BIOEXPTRANSFORM
  END IF
write(999,'(a12,2i4,f8.2)') "Loop JI, I ",JI,I,t1z(2,I)
! MAIN VERTICAL LOOP
DO K = KTI(I),KBI(I)
  ! GROWTH ANIMATION NODE COUNT
  NELEM = NELEM+1
  ! CONVERT LIGHTOUT DATA AT SURFACE TO DEPTH CORRECTED VALUES
  !** UPDATE WHEN INTEGRATING WITH MAIN W2 CODE
  GAMMAFDC(K,I) = LUX*EXP(-1*DEPTHM(K,I)*0.36) ! ARBITRARY LIGHT EXTINCTION VALUE OF 0.36 /M
  ! DIAGNOSTIC
  IF(GAMMAFDC(K,I).GT.1) THEN
    VISIBLE(K,I) = VISIBLE(K,I) + FDLTM
  END IF
  ! UPDATE REACTION DISTANCE AND SEARCH VOLUME
  FVEL(K,I) = 0.01*9.9*EXP(0.0405*T1Z(K,I)) * F1(K,I,1)**0.13 ! PULLED FROM METABOLISM, NEEDED FOR
SEARCH VOLUME
  FVELAVE(K,I) = FVELAVE(K,I) + FVEL(K,I)*FDLTM/1440
  RDZ(K,I) = 0.01*4.9424*GAMMAFDC(K,I)**0.086 ! METERS
  SRCHVOL(K,I) = 3.141596*RDZ(K,I)*RDZ(K,I)*FVEL(K,I)
  IF(BESTCALC) THEN
    BFVEL(K,I) = 0.01*9.9*EXP(0.0405*T1Z(K,I)) * BF1(K,I,1)**0.13
    BRDZ(K,I) = 0.01*4.9424*GAMMAFDC(K,I)**0.086
    BSRCHVOL(K,I) = 3.141596*BRDZ(K,I)*BRDZ(K,I)*BFVEL(K,I)
  END IF
  IF(DIELCALC) THEN
    DFVEL(K,I) = 0.01*9.9*EXP(0.0405*T1Z(K,I)) * DF1(K,I,1)**0.13
    DRDZ(K,I) = 0.01*4.9424*GAMMAFDC(K,I)**0.086
    DSRCHVOL(K,I) = 3.141596*DRDZ(K,I)*DRDZ(K,I)*DFVEL(K,I)
  END IF

  ! ***** PUT THE TL TERM INTO THE CONSUMPTION TERM; DEVIATES FROM
COMMON FORMULATIONS *****
  ! *** THORNTON-LESSEM FUNCTION
  FL1 = EXP(FG1*(T1Z(K,I)-FISHT1)); FL2 = EXP(FG2*(FISHT4-T1Z(K,I)))
  FKA = (FISHK1*FL1)/(1+FISHK1*(FL1-1)); FKB = (FISHK4*FL2)/(1+FISHK4*(FL2-1)); FTL(K) = FKA*FKB
  ! CHECKING FUNCTION
  IF(SINGLEDIAG) THEN
    RJINT=JDAY-INT(JDAY)
    IF(RJINT.LT.0.1) THEN
      IF(K.EQ.KTI(I)) THEN
        WRITE(TLCALCFN,'(F8.2,F8.4)') T1Z(K,I),FTL(K)
      END IF
    END IF
  END IF
END IF
END IF
! *****

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! *                                TASK ... CONSUMPTION                                *
! *****
! DETERMINE MAXIMUM PRACTICAL FEEDING RATES ! FROM BEAUCHAMP, ET AL 1989, CMAX
FCONMAXJ(K,I) = (0.303*F1(K,I,1)**-0.275)*EZOO(3)*F1(K,I,1)*FTL(K) ! UNITS OF J/DAY
FCONMAXGG(K,I) = (0.303*F1(K,I,1)**-0.275)*FTL(K) ! UNITS OF G/G/ DAY
! CHECK STOMACH CONTENT COMPARED TO CAPACITY
IF(F1(K,I,3).GT.F1(K,I,5)) THEN ! FORAGING
  FCON(K,I) = 0.0 !STOMACH FULL
  FULLSTO(K,I) = FULLSTO(K,I) + 1
ELSE ! FORAGING
  IF(CMAXCALC) THEN ! PRACTICAL FEEDING LIMIT?
    ! FCON(K,I) = FCONMAXGG(K,I)*F1(K,I,1)/MZOO(3)/1440
    WILMA1 = FCONMAXGG(K,I)*F1(K,I,1)/MZOO(3)/1440
    WILMA2 = (SRCHVOL(K,I)*CEFF(K)/(1+SRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
    IF (WILMA2.GT.WILMA1) THEN
      FCON(K,I) = WILMA1
    ELSE
      FCON(K,I) = WILMA2
    END IF
  ELSE
    FCON(K,I) = (SRCHVOL(K,I)*CEFF(K)/(1+SRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
  END IF
  DAYC(K,I) = DAYC(K,I) + FCON(K,I)*FDLTM
  DAYCM(K,I) = DAYC(K,I)*MZOO(3)
  AVEC(K,I) = AVEC(K,I) + FCON(K,I)*FDLTM/1440
  MINC(K,I) = MIN(MINC(K,I),FCON(K,I))
  MAXC(K,I) = MAX(MAXC(K,I),FCON(K,I))
  IF(FDIAG) THEN ! DIET REPORTING
    IF(THRESHFEED(K)) THEN
      DIET(K,I,THRESHZ) = DIET(K,I,THRESHZ) +
FCON(K,I)*C1Z(K,I,THRESHZ)*ZAVAIL(THRESHZ)/CEFF(K)*FDLTM
    ELSE
      DO JJZ = 1,NZP
        DIET(K,I,JJZ) = DIET(K,I,JJZ) + FCON(K,I)*C1Z(K,I,JJZ)*ZAVAIL(JJZ)/CEFF(K)*FDLTM
      END DO
    END IF
  END IF
END IF ! FORAGING
! ACTUAL CONSUMPTION DIAGNOSTIC
FCONJ(K,I) = DAYC(K,I)*MZOO(3)*EZOO(3)
FCONGG(K,I) = DAYC(K,I)*MZOO(3)/F1(K,I,1)
FCONP(K,I) = FCONGG(K,I)/FCONMAXGG(K,I)
! ***** BESTCALC *****
IF(BESTCALC) THEN
  BFCONMAXJ(K,I) = (0.303*BF1(K,I,1)**-0.275)*EZOO(3)*BF1(K,I,1)*FTL(K) ! UNITS OF J/DAY
  BFCONMAXGG(K,I) = (0.303*BF1(K,I,1)**-0.275)*FTL(K) ! UNITS OF G/G/ DAY
  IF(BF1(K,I,3).GT.BF1(K,I,5)) THEN ! FORAGING
    PRINT *, 'FULL STOMACH'
    BFCON(K,I) = 0.0 !STOMACH FULL
    BFULLSTO(K,I) = 1
  ELSE ! FORAGING
    BFCON(K,I) = 0
    IF(CMAXCALC) THEN
      BFCON(K,I) = BFCONMAXGG(K,I)*BF1(K,I,1)/MZOO(3)/1440
      WILMA1 = BFCONMAXGG(K,I)*BF1(K,I,1)/MZOO(3)/1440
      WILMA2 = (SRCHVOL(K,I)*CEFF(K)/(1+SRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
      IF (WILMA2.GT.WILMA1) THEN
        BFCON(K,I) = WILMA1
      ELSE
        BFCON(K,I) = WILMA2
      END IF
    ELSE
      BFCON(K,I) = (BSRCHVOL(K,I)*CEFF(K)/(1+BSRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
    END IF
    BDAYC(K,I) = BFCON(K,I)*FDLTM ! DIFFERS FROM MAIN: ONLY ONE TIMESTEP
    BDAYCM(K,I) = BDAYC(K,I)*MZOO(3)
    IF(FDIAG) THEN ! DIET REPORTING ! DIFFERS FROM MAIN ROUTINE; THIS IS ONLY PER TIMESTEP; BDIETI IS
CUMULATIVE
      IF(THRESHFEED(K)) THEN
        BDIET(K,I,THRESHZ) = BFCON(K,I)*C1Z(K,I,THRESHZ)*ZAVAIL(THRESHZ)/CEFF(K)*FDLTM
      ELSE
        DO JJZ = 1,NZP
          BDIET(K,I,JJZ) = BFCON(K,I)*C1Z(K,I,JJZ)*ZAVAIL(JJZ)/CEFF(K)*FDLTM
        END DO
      END IF
    END IF
  END IF ! FORAGING
  BFCONJ(K,I) = BDAYC(K,I)*MZOO(3)*EZOO(3)
  BFCONGG(K,I) = BDAYC(K,I)*MZOO(3)/BF1(K,I,1)

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      BFCNPF(K,I) = BFCONGG(K,I)/BFCONMAXGG(K,I)
END IF ! BESTCALC
! ***** DIELCALC *****
IF(DIELCALC) THEN
  DFCONMAXJ(K,I) = (0.303*DF1(K,I,1)**-0.275)*EZOO(3)*DF1(K,I,1)*FTL(K) ! UNITS OF J/DAY
  DFCONMAXGG(K,I) = (0.303*DF1(K,I,1)**-0.275)*FTL(K) ! UNITS OF G/G/ DAY
  IF(DF1(K,I,3).GT.DF1(K,I,5)) THEN ! FORAGING
    DFCON(K,I) = 0.0 !STOMACH FULL
    DFULLSTO(K,I) = 1
  ELSE ! FORAGING
    DFULLSTO(K,I) = 0
    IF(CMAXCALC) THEN
      WILMA1 = DFCONMAXGG(K,I)*DF1(K,I,1)/MZOO(3)/1440
      WILMA2 = (SRCHVOL(K,I)*CEFF(K)/(1+SRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
      IF (WILMA2.GT.WILMA1) THEN
        DFCON(K,I) = WILMA1
      ELSE
        DFCON(K,I) = WILMA2
      END IF
    ELSE
      DFCON(K,I) = (DSRCHVOL(K,I)*CEFF(K)/(1+DSRCHVOL(K,I)*CEFF(K)*HANDLE))*60*FTL(K)
    END IF
    DDAYC(K,I) = DFCON(K,I)*FDLTM ! DIFFERS FROM MAIN: ONLY ONE TIMESTEP
    DDAYCM(K,I) = DDAYC(K,I)*MZOO(3)
    IF(FDIAG) THEN ! DIET REPORTING ! DIFFERS FROM MAIN ROUTINE; THIS IS ONLY PER TIMESTEP; BDIETI IS
      CUMULATIVE
      IF (THRESHFEED(K)) THEN
        DDJET(K,I,THRESHZ) = DFCON(K,I)*C1Z(K,I,THRESHZ)*ZAVAIL(THRESHZ)/CEFF(K)*FDLTM
      ELSE
        DO JJZ = 1,NZP
          DDJET(K,I,JJZ) = DFCON(K,I)*C1Z(K,I,JJZ)*ZAVAIL(JJZ)/CEFF(K)*FDLTM
        END DO
      END IF
    END IF
  END IF ! FORAGING
  DFCONJ(K,I) = DDAYC(K,I)*MZOO(3)*EZOO(3)
  DFCONGG(K,I) = DDAYC(K,I)*MZOO(3)/DF1(K,I,1)
  DFCNPF(K,I) = DFCONGG(K,I)/DFCONMAXGG(K,I)
END IF ! DIELCALC

! *****
! * TASK . . . NON-CONSUMPTION PARAMETERS *
! *****
! ****DIGESTION (SDA)
DIGK = 0.014*T1Z(K,I)+0.1135
! ** MAZUR'S B&A
F_DC(K,I) = (F1(K,I,3) + FCON(K,I)*MZOO(3)*FDLTM - (F1(K,I,3)*EXP(-1*DIGK*FDLTH) &
+ FCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH)) ) ) *EZOO(3)
! DIAGNOSTIC: DIGENSTION BY PARTS
F_DINI(K,I) = F1(K,I,3)*EZOO(3)
F_DCON(K,I) = FCON(K,I)*MZOO(3)*FDLTM*EZOO(3)
!F_DUNDIG(K,I) = ((F1(K,I,3)*EXP(-1*DIGK*FDLTH)+FCON(K,I)*MZLW(3)*60/DIGK*(1-EXP(-
1*DIGK*FDLTH))))*EZOO(3)
F_DUNDIG(K,I) = ((F1(K,I,3)*EXP(-1*DIGK*FDLTH)+FCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-
1*DIGK*FDLTH))))*EZOO(3)
! ****EGESTION
F_FC(K,I) = 0.212*(T1Z(K,I)**-0.222)*F_DC(K,I)
! ****EXCRETION
F_UC(K,I) = 0.0233*(T1Z(K,I)**-0.580)*(F_DC(K,I)-F_FC(K,I))
! ****METABOLISM/RESPIRATION (ACTIVITY)
FACT(K,I) = EXP(0.02334*100.0*FVEL(K,I))
FACTAVE(K,I) = FACTAVE(K,I) + FACT(K,I)*FDLTM/1440
F_RC(K,I) = 0.00143*(F1(K,I,1)**-0.209)*EXP(0.086*T1Z(K,I))*FACT(K,I)*FOXYCAL*FDLTM/1440*F1(K,I,1)
! ****SPECIFIC DYNAMIC ACTION
F_SC(K,I) = 0.172*(F_DC(K,I)-F_FC(K,I))
! ****FISH ENERGY DENSITY (IN J/G)
IF(F1(K,I,1).LE.196.0) THEN
  F1(K,I,4) = (1.851*F1(K,I,1)+1250.0)*4.1868
ELSE
  F1(K,I,4) = (0.1254*F1(K,I,1) + 1588.0)*4.1868
END IF
! ****UPDATE STOMACH CONTENT ! THIS CAN PROBABLY BE MOVED INTO THE DIGESTION SECTION, BUT WILL KEEP
SEPARATE FOR CLARITY
F_CC(K,I) = FCON(K,I)*MZOO(3)*FDLTM*EZOO(3)
F1(K,I,3) = F1(K,I,3)*EXP(-1*DIGK*FDLTH)+FCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH))

! ***** BESTCALC *****
IF(BESTCALC) THEN
  BF_DC(K,I) = (BF1(K,I,3) + BFCN(K,I)*MZOO(3)*FDLTM - (BF1(K,I,3)*EXP(-1*DIGK*FDLTH) &

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+ BFCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH)) ) ) *EZOO(3)
BF_DC_EXT(K,I) = BF_DC(K,I) + 0.2*BFCONJ(K,I)
BF_FC(K,I) = 0.212*(T1Z(K,I)**-0.222)*BF_DC(K,I)
BF_UC(K,I) = 0.0233*(T1Z(K,I)**-0.580)*(BF_DC(K,I)-BF_FC(K,I))
BFACT(K,I) = EXP(0.02334*100.0*BFVEL(K,I))
BF_RC(K,I) = 0.00143*(BF1(K,I,1)**-
0.209)*EXP(0.086*T1Z(K,I))*BFACT(K,I)*FOXYCAL*FDLTM/1440*BF1(K,I,1)
BF_SC(K,I) = 0.172*(BF_DC(K,I)-BF_FC(K,I))
IF(BF1(K,I,1).LE.196.0) THEN
  BF1(K,I,4) = (1.851*BF1(K,I,1)+1250.0)*4.1868
ELSE
  BF1(K,I,4) = (0.1254*BF1(K,I,1) + 1588.0)*4.1868
END IF
BF_CC(K,I) = BFCON(K,I)*MZOO(3)*FDLTM*EZOO(3)
BF1(K,I,3) = BF1(K,I,3)*EXP(-1*DIGK*FDLTH)+BFCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH))
END IF !BESTCALC

! ***** DIELCALC *****
IF(DIELCALC) THEN
  DF_DC(K,I) = (DF1(K,I,3) + DFCON(K,I)*MZOO(3)*FDLTM - (DF1(K,I,3)*EXP(-1*DIGK*FDLTH) &
+ DFCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH)) ) ) *EZOO(3)
  DF_DC_EXT(K,I) = DF_DC(K,I) + 0.2*DFCONJ(K,I)
  DF_FC(K,I) = 0.212*(T1Z(K,I)**-0.222)*DF_DC(K,I)
  DF_UC(K,I) = 0.0233*(T1Z(K,I)**-0.580)*(DF_DC(K,I)-DF_FC(K,I))
  DFACT(K,I) = EXP(0.02334*100.0*DFVEL(K,I))
  DF_RC(K,I) = 0.00143*(DF1(K,I,1)**-
0.209)*EXP(0.086*T1Z(K,I))*DFACT(K,I)*FOXYCAL*FDLTM/1440*DF1(K,I,1)
  DF_SC(K,I) = 0.172*(DF_DC(K,I)-DF_FC(K,I))
  IF(DF1(K,I,1).LE.196.0) THEN
    DF1(K,I,4) = (1.851*DF1(K,I,1)+1250.0)*4.1868
  ELSE
    DF1(K,I,4) = (0.1254*DF1(K,I,1) + 1588.0)*4.1868
  END IF
  DF_CC(K,I) = DFCON(K,I)*MZOO(3)*FDLTM*EZOO(3)
  DF1(K,I,3) = DF1(K,I,3)*EXP(-1*DIGK*FDLTH)+DFCON(K,I)*MZOO(3)*60/DIGK*(1-EXP(-1*DIGK*FDLTH))
END IF !DIELCALC
END DO ! MAIN K LOOP

! *****
! * TASK ... DAILY PARAMETER UPDATES *
! *****
! DAILY PARAMETER UPDATES
CELL_POS(I) = 0; CELL_NEG(I) = 0
DO K = KTI(I),KBI(I)
  F_R(K,I) = F_R(K,I) + F_RC(K,I)
  F_D(K,I) = F_D(K,I) + F_DC(K,I)
  F_C(K,I) = F_C(K,I) + F_CC(K,I)
  F_W(K,I) = F_W(K,I) + F_UC(K,I) + F_FC(K,I)
  F_S(K,I) = F_S(K,I) + F_SC(K,I)
  F_G(K,I) = F_G(K,I) + (F_DC(K,I) - (F_SC(K,I) + F_FC(K,I) + F_UC(K,I)) - F_RC(K,I))/F1(K,I,4)
  F2(K,I) = F_G(K,I)/F1(K,I,1)
  IF(F_G(K,I).GT.0) CELL_POS(I) = CELL_POS(I) +1
  IF(F_G(K,I).LT.0) CELL_NEG(I) = CELL_NEG(I) +1
END DO
CELL_PER(I) = (CELL_POS(I)*1.0)/(CELL_POS(I)*1.0+CELL_NEG(I)*1.0)*100.0
! ***** BESTCALC *****
IF(BESTCALC) THEN
  BCELL_POS(I) = 0; BCELL_NEG(I) = 0
  GMAXG = -99999.0; GMAXK = 2
  DO K = KTI(I),KBI(I)
    BF_G(K,I) = (BF_DC(K,I) - (BF_SC(K,I) + BF_FC(K,I) + BF_UC(K,I)) - BF_RC(K,I))/BF1(K,I,4)
    BF_G_EXT(K,I) = (BF_DC_EXT(K,I) - (BF_SC(K,I) + BF_FC(K,I) + BF_UC(K,I)) -
BF_RC(K,I))/BF1(K,I,4)
    F_G2(K,I) = F_G2(K,I) + BF_G(K,I)
    IF(BF_G_EXT(K,I).GT.GMAXG) THEN ! FIND BEST LAYER
      GMAXG = BF_G_EXT(K,I); GMAXK = K
    END IF
    IF(BF_G(K,I).GT.0) BCELL_POS = BCELL_POS + 1
    IF(BF_G(K,I).LT.0) BCELL_NEG = BCELL_NEG + 1
  END DO
  ! APPLY BEST LAYER TO CUMMALATIVE TERMS
  BF_GI(I) = BF_GI(I) + BF_G(GMAXK,I)
  BESTK(I,BESTSTEP) = GMAXK
  BF_RI(I) = BF_RI(I) + BF_RC(GMAXK,I)
  BF_DI(I) = BF_DI(I) + BF_DC(GMAXK,I)
  BF_CI(I) = BF_CI(I) + BF_CC(GMAXK,I)
  BF_WI(I) = BF_WI(I) + BF_UC(GMAXK,I) + BF_FC(GMAXK,I)
  BF_UI(I) = BF_UI(I) + BF_UC(GMAXK,I)
  BF_FI(I) = BF_FI(I) + BF_FC(GMAXK,I)

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      BF_SI(I) = BF_SI(I) + BF_SC(GMAXK,I)
      T1BZ(I) = T1BZ(I) + T1Z(GMAXK,I)/48.0      ! average over a day
! UPDATE DIAGNOSTIC ACCOUNTING TERMS
      BFVELAVE(I) = BFVELAVE(I) + BFVEL(GMAXK,I)*FDLTM/1440
      BFACTAVE(I) = BFACTAVE(I) + BFACT(GMAXK,I)*FDLTM/1440
      BAVEC(I) = BAVEC(I) + BFCN(GMAXK,I)*FDLTM/1440
      BMINC(I) = MIN(BMINC(I),BFCN(GMAXK,I))
      BMAXC(I) = MAX(BMAXC(I),BFCN(GMAXK,I))
      BFULLSTOI(I) = BFULLSTOI(I) + BFULLSTO(GMAXK,I)
      BFCONI(I) = BFCONI(I) + BFCN(GMAXK,I)
      BDAYCI(I) = BDAYCI(I) + BDAYC(GMAXK,I)
      BDAYCMI(I) = BDAYCMI(I) + BDAYCM(GMAXK,I)
      BFCNMAXJI(I) = BFCNMAXJI(I) + BFCNMAXJ(GMAXK,I)/48.0      ! average over a day
      BFCNMAXGGI(I) = BFCNMAXGGI(I) + BFCNMAXGG(GMAXK,I)/48.0  ! average over a day
      BFCNJI(I) = BFCNJI(I) + BFCNJ(GMAXK,I)
      BFCNGGI(I) = BFCNGGI(I) + BFCNGG(GMAXK,I)
      BFCNPI(I) = BFCNGGI(I)/BFCNMAXGGI(I)
IF(SINGLEDIAG.AND.DEPTHCALC) THEN
  IF(I.EQ.SINIBIO) THEN
    WRITE(BIOOUTFN(21),'(F8.3,3I8)') JDAY, I, BESTK(I,BESTSTEP),DIELK(I,BESTSTEP)
  END IF
END IF

! TRANSFER STOMACH CONTENTS
      BFI(:,I,3) = BFI(GMAXK,I,3)
      BCELL_PER(I) = (BCELL_POS(I)*1.0)/(BCELL_POS(I)*1.0+BCELL_NEG(I)*1.0)*100.0
      IF(GAMMAFDC(GMAXK,I).GT.1) THEN
        BVISIBLE(I) = BVISIBLE(I) + FDLTM
      END IF
      DO JJZ = 1,NZP
        BDIETI(I,JJZ) = BDIETI(I,JJZ) + BDIET(GMAXK,I,JJZ)
      END DO
      BDAYC(:,I) = BDAYC(GMAXK,I)
END IF !BESTCALC
! ***** DIELCALC *****
      IF(DIELCALC) THEN
        DCELL_POS(I) = 0; DCELL_NEG(I) = 0
        GMAXG = -99999.0; GMAXK = 2
        RMIN = -99999.0 ; RMINK = 2; CMAX = -99999.0 ; CMAXK = 2
        DO K = KTI(I),KBI(I)
          DF_G(K,I) = (DF_DC(K,I) - (DF_SC(K,I) + DF_FC(K,I) + DF_UC(K,I)) - DF_RC(K,I))/DF1(K,I,4)
          DF_G_EXT(K,I) = (DF_DC_EXT(K,I) - (DF_SC(K,I) + DF_FC(K,I) + DF_UC(K,I)) -
DF_RC(K,I))/DF1(K,I,4)
          IF(DF_G_EXT(K,I).GT.GMAXG) THEN ! FIND BEST LAYER
            GMAXG = DF_G_EXT(K,I); GMAXK = K
          END IF
          IF(DF_R(K,I).LT.RMIN) THEN ! FIND BEST LAYER
            RMIN = DF_R(K,I); RMINK = K
          END IF
          IF(DF_CC(K,I).GT.CMAX) THEN ! FIND BEST LAYER
            CMAX = DF_CC(K,I); CMAXK = K
          END IF
          IF(DF_G(K,I).GT.0) DCELL_POS = DCELL_POS + 1
          IF(DF_G(K,I).LT.0) DCELL_NEG = DCELL_NEG + 1
        END DO
! *****
! APPLY BEST LAYER TO CUMMALATIVE TERMS
      IF(DF_G(GMAXK,I).GT.0.0) THEN
        KBEST = GMAXK
      ELSE
        IF(DAYLIGHT) THEN
          IF(DF_G(CMAXK,I).GE.0.0) THEN
            KBEST = CMAXK
          ELSE
            IF(FORAY(I)) THEN
              IF(T1Z(CMAXK,I).GT.20.0) THEN
                DO KK = CMAXK,KBI(I)-1
                  IF(T1Z(KK,I).GT.20.0) THEN
                    CONTINUE
                  ELSE
                    KBEST = KK
                  EXIT
                END IF
              END DO
            ELSE
              KBEST = CMAXK
            END IF
          FORAY(I) = .FALSE.
        ELSE
          KBEST = RMINK
        END IF
      END IF

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        FORAY(I) = .TRUE.
    END IF
END IF
ELSE
    KBEST = RMINK
END IF
END IF
END IF
    DF_GI(I) = DF_GI(I) + DF_G(KBEST,I)
    DIELK(I,BESTSTEP) = KBEST
    DF_RI(I) = DF_RI(I) + DF_RC(KBEST,I)
    DF_DI(I) = DF_DI(I) + DF_DC(KBEST,I)
    DF_CI(I) = DF_CI(I) + DF_CC(KBEST,I)
    DF_WI(I) = DF_WI(I) + DF_UC(KBEST,I) + DF_FC(KBEST,I)
    DF_UI(I) = DF_UI(I) + DF_UC(KBEST,I)
    DF_FI(I) = DF_FI(I) + DF_FC(KBEST,I)
    DF_SI(I) = DF_SI(I) + DF_SC(KBEST,I)
    ! UPDATE DIAGNOSTIC ACCOUNTING TERMS
    DFVELAVE(I) = DFVELAVE(I) + DFVEL(KBEST,I)*FDLTM/1440
    DFACTAVE(I) = DFACTAVE(I) + DFACT(KBEST,I)*FDLTM/1440
    DAVEC(I) = DAVEC(I) + DFCN(KBEST,I)*FDLTM/1440
    DMINC(I) = MIN(DMINC(I),DFCN(KBEST,I))
    DMAXC(I) = MAX(DMAXC(I),DFCN(KBEST,I))
    DFULLSTOI(I) = DFULLSTOI(I) + DFULLSTO(KBEST,I)
    DFCONI(I) = DFCONI(I) + DFCN(KBEST,I)
    DDAYCI(I) = DDAYCI(I) + DDAYC(KBEST,I)
    DDAYCMI(I) = DDAYCMI(I) + DDAYCM(KBEST,I)
    DFCNMAXJI(I) = DFCNMAXJI(I) + DFCNMAXJ(KBEST,I)/48.0      ! average over a day
    DFCNMAXGGI(I) = DFCNMAXGGI(I) + DFCNMAXGG(KBEST,I)/48.0    ! average over a day
    DFCONJI(I) = DFCONJI(I) + DFCONJ(KBEST,I)
    DFCONGGI(I) = DFCONGGI(I) + DFCONGG(KBEST,I)
    DFCONPI(I) = DFCONGGI(I)/DFCNMAXGGI(I)
    DF1(:,I,3) = DF1(KBEST,I,3)
    DCELL_PER(I) = (DCELL_POS(I)*1.0)/(DCELL_POS(I)*1.0+DCELL_NEG(I)*1.0)*100.0
    IF(GAMMAFDC(KBEST,I).GT.1) THEN
        DVISIBLE(I) = DVISIBLE(I) + FDLTM
    END IF
    DO JJZ = 1,NZP
        DDIETI(I,JJZ) = DDIETI(I,JJZ) + DDIET(KBEST,I,JJZ)
    END DO
    DDAYC(:,I) = DDAYC(KBEST,I)
END IF !DIELCALC

! *****
! *                               TASK ... DAILY CALCULATIONS AND UPDATES                               *
! *****
IF(BIODELAY_CALC) THEN !BIODELAY
    ! IF(KBI(I).GT.KTI(I)+1) F_G(KBI(I)-1,I) = F_G(KBI(I)-2,I)
    ! IF(KBI(I).GT.KTI(I)) F_G(KBI(I),I) = F_G(KBI(I)-1,I)
    IF(FDIAG) CALL FOUTPUT_DAILY
    IF(JI.EQ.NIBIO) then
        print *, 'ji = ', ji
        CALL ANIMATION_DATA
        continue
    end if
    CALL DAILY_GROWTH
    IF(JI.EQ.NIBIO) CALL BY_SEG_OUTPUT
    IF(JI.EQ.NIBIO) PRINT *,JDAY,BF1(2,312,1),T1Z(2,I)
    KBIP(I) = KBI(I)
    CALL BIOEXPTRANSFORM
    ! CHECK FOR CHANGES IN KTI (LAYER ADDITION/SUBTRACTION REQUIRES INITIALIZING): SHOWS UP IN
    ANIMATIONS
    IF(KBI(I).GT.KBIP(I)) THEN
        ! WRITE(999,*) 'INITIALIZING, JDAY, I ',INT(JDAY),I
        DO K = KBI(I),3,-1
            F1(KBI(I),I,:) = F1(KBI(I)-1,I,:)
            F_R(KBI(I),I) = F_R(KBI(I)-1,I)
            F_D(KBI(I),I) = F_D(KBI(I)-1,I)
            F_C(KBI(I),I) = F_C(KBI(I)-1,I)
            F_W(KBI(I),I) = F_W(KBI(I)-1,I)
            F_S(KBI(I),I) = F_S(KBI(I)-1,I)
            F_G(KBI(I),I) = F_G(KBI(I)-1,I)
        END DO
        F1(2,I,:) = F1(3,I,:)
        F_R(2,I) = F_R(3,I)
        F_D(2,I) = F_D(3,I)
        F_C(2,I) = F_C(3,I)
        F_W(2,I) = F_W(3,I)
        F_S(2,I) = F_S(3,I)
        F_G(2,I) = F_G(3,I)

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      END IF
      IF(KBI(I).LT.KBIP(I)) THEN
        ! WRITE(999,*) 'INITIALIZING, JDAY, I ',INT(JDAY),I
        DO K = KBI(I),2,-1
          F1(KBI(I),I,:) = F1(KBI(I)+1,I,:)
          F_R(KBI(I),I) = F_R(KBI(I)+1,I)
          F_D(KBI(I),I) = F_D(KBI(I)+1,I)
          F_C(KBI(I),I) = F_C(KBI(I)+1,I)
          F_W(KBI(I),I) = F_W(KBI(I)+1,I)
          F_S(KBI(I),I) = F_S(KBI(I)+1,I)
          F_G(KBI(I),I) = F_G(KBI(I)+1,I)
        END DO
      END IF
! ***** ANIMATION *****
! ANIMATION ELEVATION DETERMINATION (TEMPORARY APPROACH)
! FIND BOTTOM ELEVATION
DO II = 1,IMX
  IF(I.EQ.BOTSEG(II)) THEN
    GELEV(KBI(I),I) = BOTTIME(II)
    EXIT
  END IF
END DO
! ASSIGN ELEVATIONS
DO K=KBI(I)-1,2,-1
  GELEV(K,I)=GELEV(K+1,I)+2.0
END DO
END IF !BIODAY
FIRST_BIO(JI) = .FALSE.
998 CONTINUE
END DO ! MAIN LOOP (SEGMENT ADVANCEMENT)
! *****
! * TASK .... REZERO CUMMULATIVE DAILY TERMS *
! *****
! REZERO CUMMULATIVE DAILY TERMS
NELEM = 0; NNODE = 0
IF(BIODAY_CALC) THEN
  F_R = 0.0 ; F_D = 0.0 ; F_C = 0.0 ; F_F = 0.0 ; F_U = 0.0 ; VISIBLE = 0.0
  F_S = 0.0 ; F_G = 0.0 ; F_W = 0.0 ; DAYC = 0.0 ; FULLSTO = 0 ; DIET = 0.0
  FVELAVE = 0.0; FACTAVE = 0.0; AVEC = 0.0; MINC = 0.0; MAXC = 0.0
  MAXG = -999.0; MAXM = -999.0; F_G2 = 0.0
  ! ***** BESTCALC *****
  IF(BESTCALC) THEN
    BF_R = 0.0 ; BF_D = 0.0 ; BF_C = 0.0 ; BF_F = 0.0 ; BF_U = 0.0
    BF_S = 0.0 ; BF_G = 0.0 ; BF_W = 0.0 ; BDAYC = 0.0 ; BDIET = 0.0 ; BDIETI = 0.0
    BESTSTEP = 0
    BF_GI = 0.0 ; BF_RI = 0.0 ; BF_DI = 0.0 ; BF_CI = 0.0 ; BF_WI = 0.0 ; BF_SI = 0.0 ; BF_UI = 0.0;
    BF_FI = 0.0
    BFVELAVE = 0.0; BFACTAVE = 0.0; BAVEC = 0.0; BMINC = 0.0; BMAXC = 0.0; BVISIBLE = 0.0
    BFULLSTO = 0; BFULLSTOI = 0
    BFCONMAXJI = 0.0; BFCONMAXGGI = 0.0; BFCONI = 0.0; BDAYCI = 0.0; BDAYCMI = 0.0; BFCONPI = 0.0;
    BFCONJI = 0.0; BFCONGGI = 0.0
    T1BZ = 0.0
  END IF
  ! ***** DIELCALC *****
  IF(DIELCALC) THEN
    DF_R = 0.0 ; DF_D = 0.0 ; DF_C = 0.0 ; DF_F = 0.0 ; DF_U = 0.0
    DF_S = 0.0 ; DF_G = 0.0 ; DF_W = 0.0 ; DDAYC = 0.0 ; DDIET = 0.0 ; DDIETI = 0.0
    DF_GI = 0.0 ; DF_RI = 0.0 ; DF_DI = 0.0 ; DF_CI = 0.0 ; DF_WI = 0.0 ; DF_SI = 0.0 ; DF_UI = 0.0;
    DF_FI = 0.0
    DFVELAVE = 0.0; DFACTAVE = 0.0; DAVEC = 0.0; DMINC = 0.0; DMAXC = 0.0; DVISIBLE = 0.0
    DFULLSTO = 0; DFULLSTOI = 0
    DFCONMAXJI = 0.0; DFCONMAXGGI = 0.0; DFCONI = 0.0; DDAYCI = 0.0; DDAYCMI = 0.0; DFCONPI = 0.0;
    DFCONJI = 0.0; DFCONGGI = 0.0
  END IF
END IF
BIOSUB_CALC = .FALSE.; BIODAY_CALC = .FALSE.

! *****
! * TASK .... END TIME-STEP *
! *****
GOTO 2110 ! RETURN TO JDAY ADVANCEMENT
! *****
! **
! **
! *****
997 CONTINUE
! GROWTH ANIMATION DATE/TEXT

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DO IZ = 1,ZONECNT
  IZZ = IZ+ZONEFIRST-1
  WRITE(ANIMFN,863) IZ,IZZ
  WRITE(ANIMFN,864) IZ,GREGORY(IZ)
END DO
863 FORMAT('TEXT X=0.2, y=0.15, H=3.0, ZN=',i4,',',' C=BLACK','T= "Julian Day ',I6,'"')
864 FORMAT('TEXT X=0.2, y=0.20, H=3.0, ZN=',i4,',',' C=BLACK','T= "',A20,'"')
DO II = 1,NIBIO
  CLOSE(BIOINFN(II))
END DO
CLOSE(LIGHTNUM)
STOP
END !PROGRAM END

!*****
!*****
!**
**
!*****
*****

SUBROUTINE LIGHTOUT

SUBROUTINE LIGHTOUT
  USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE DIAGNOSTIC; USE ROOSEVELT; USE MOVEMENT
  LJDAY1 = LJDAY2; LUX1 = LUX2
  READ(LIGHTNUM,'(10X,F10.0,20X,E10.2)') LJDAY2,LUX2
RETURN
END SUBROUTINE LIGHTOUT

!*****
!*****
!**
**
!*****
*****

SUBROUTINE DAILY_GROWTH

SUBROUTINE DAILY_GROWTH
  USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE DIAGNOSTIC; USE ROOSEVELT; USE MOVEMENT
! UPDATE MASS & STOMACH CAPACITY
! GENERAL EQUATION
IF (GMTPCCELL) THEN
  DO K = KTI(I),KBI(I)
    F1(K,I,1) = F1(K,I,1) + F_G(K,I)
    IF (F1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
      F1(K,I,5) = (14.1-4.95*LOG10(F1(K,I,1)))/100.0*F1(K,I,1)
    ELSE
      F1(K,I,5) = 0.0022*F1(K,I,1)
    END IF
    MAXM(I) = MAX(MAXM(I),F1(K,I,1)) ! MAXMASS
    MAXG(I) = MAX(MAXG(I),F_G(K,I)) ! MAXGROWTH
  END DO
END IF
IF (GMTPPFXN) THEN
  DO K = KTI(I),KBI(I)
    F1(K,I,1) = GIM*EXP(GALP*(JDAY-GTI))
    IF (F1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
      F1(K,I,5) = (14.1-4.95*LOG10(F1(K,I,1)))/100.0*F1(K,I,1)
    ELSE
      F1(K,I,5) = 0.0022*F1(K,I,1)
    END IF
    MAXM(I) = MAX(MAXM(I),F1(K,I,1)) ! MAXMASS
    MAXG(I) = MAX(MAXG(I),F_G(K,I)) ! MAXGROWTH
  END DO
END IF
IF (GMTPFIXED) THEN
  CONTINUE
END IF
IF (GMTPUSER) THEN
  READ(FXNFN(1),'(2F8.0)') F1J,F1M
  F1(:,I,1) = F1M
  IF (INT(JDAY).NE.INT(F1J)) THEN
    PRINT *, 'POSSIBLE PRESCRIBED MASS ERROR :',F1J,JDAY
  END IF
END IF
IF (BESTCALC) THEN
  IF (BMTFSEG) THEN
    DO K = KTI(I),KBI(I)
      BF1(K,I,1) = BF1(K,I,1) + BF_GI(I)
      IF (BF1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
        BF1(K,I,5) = (14.1-4.95*LOG10(BF1(K,I,1)))/100.0*BF1(K,I,1)
      END IF
    END DO
  END IF
END IF

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ELSE
  BF1(K,I,5) = 0.022*BF1(K,I,1)
END IF
END DO
END IF
IF(BMTPFXN) THEN
  DO K = KTI(I)-1,KBI(I)+1
    BF1(K,I,1) = BIM*EXP(BALP*(JDAY-BTI))
    IF(BF1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
      BF1(K,I,5) = (14.1-4.95*LOG10(BF1(K,I,1)))/100.0*BF1(K,I,1)
    ELSE
      BF1(K,I,5) = 0.022*BF1(K,I,1)
    END IF
  END DO
END IF
IF(BMTPFIXED) THEN
  CONTINUE
END IF
IF(BMTPUSER) THEN
  READ(FXNFN(2),'(2F8.0)') F1J,F1M
  BF1(:,I,1) = F1M
  IF(INT(JDAY).NE.INT(F1J)) THEN
    PRINT *, 'POSSIBLE PRESCRIBED MASS ERROR : ', F1J, JDAY
  END IF
END IF
IF(DIELCALC) THEN
  IF(DMTPSEG) THEN
    DO K = KTI(I),KBI(I)
      DF1(K,I,1) = DF1(K,I,1) + DF_GI(I)
      IF(DF1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
        DF1(K,I,5) = (14.1-4.95*LOG10(DF1(K,I,1)))/100.0*DF1(K,I,1)
      ELSE
        DF1(K,I,5) = 0.022*DF1(K,I,1)
      END IF
    END DO
  END IF
  IF(DMTPFXN) THEN
    DO K = KTI(I),KBI(I)
      DF1(K,I,1) = DIM*EXP(DALP*(JDAY-DTI))
      IF(DF1(K,I,1).LE.253.5) THEN ! UPDATE STOMACH CAPACITY (BRETT, 1971)
        DF1(K,I,5) = (14.1-4.95*LOG10(DF1(K,I,1)))/100.0*DF1(K,I,1)
      ELSE
        DF1(K,I,5) = 0.022*DF1(K,I,1)
      END IF
    END DO
  END IF
  IF(DMTPFIXED) THEN
    CONTINUE
  END IF
  IF(DMTPUSER) THEN
    READ(FXNFN(3),'(2F8.0)') F1J,F1M
    DF1(:,I,1) = F1M
    IF(INT(JDAY).NE.INT(F1J)) THEN
      PRINT *, 'POSSIBLE PRESCRIBED MASS ERROR : ', F1J, JDAY
    END IF
  END IF
END IF
END SUBROUTINE DAILY_GROWTH

! *****
! *****
! **
! **
! *****
! *****

SUBROUTINE FISHOUTPUT DAILY
**
! *****
! *****

SUBROUTINE FOUTPUT_DAILY
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE GROWTH_animation; USE DIAGNOSTIC; USE
ROOSEVELT; USE MOVEMENT

IF(FISHDIAG) THEN
  DO K = KTI(I),KBI(I)
    WRITE(BIOOUTFN(1),77771)
    JDAY,I,F_G(K,I),F1(K,I,1),CELL_PER(I),FULLSTO(K,I),VISIBLE(K,I),T1Z(K,I)
  END DO
  77771 FORMAT (F8.3,X,I8,X,F8.4,X,2(F8.2,X),I8,X,2(F8.2,X))
  77871 FORMAT (F8.3,X,I8,X,F8.4,X,2(F8.2,X),I8,X,2(F8.2,X),F8.5)
  IF(SURFDIAG) THEN

```

```

      K = KTI(I)
      WRITE(BIOOUTFN(16),77771)
JDAY,I,F_G(K,I),F1(K,I,1),CELL_PER(I),FULLSTO(K,I),VISIBLE(K,I),T1Z(K,I)
      END IF
      IF(BESTCALC) THEN
        K = KTI(I)
        WRITE(BIOOUTFN(2),77871)
JDAY,I,BF_GI(I),BF1(K,I,1),BCELL_PER(I),BFULLSTOI(I),BVISIBLE(I),T1BZ(I),GAMMAFDC(K,I)
      END IF
      IF(DIELCALC) THEN
        K = KTI(I)
        WRITE(BIOOUTFN(3),77771)
JDAY,I,DF_GI(I),DF1(K,I,1),DCELL_PER(I),DFULLSTOI(I),DVISIBLE(I),T1Z(K,I)
      END IF
      END IF ! FISHDIAG
      IF(BIOPARDIAG) THEN
        DO K = KTI(I),KBI(I)
          WRITE(BIOOUTFN(4),77772)
JDAY,I,F_G(K,I),F_D(K,I),F_R(K,I),F_S(K,I),F_W(K,I),F_U(K,I),F_F(K,I)
        END DO
        77772 FORMAT(F8.3,X,I8,X,7(F8.1,X))
        IF(SURFDIAG) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(17),77772) JDAY,I,F_G(K,I),F_D(K,I),F_R(K,I),F_S(K,I),F_W(K,I),F_U(K,I),F_F(K,I)
        END IF
        IF(BESTCALC) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(5),77772)
JDAY,I,BF_GI(I),BF_DI(I),BF_RI(I),BF_SI(I),BF_WI(I),BF_UI(I),BF_FI(I)
        END IF
        IF(DIELCALC) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(6),77772)
JDAY,I,DF_GI(I),DF_DI(I),DF_RI(I),DF_SI(I),DF_WI(I),DF_UI(I),DF_FI(I)
        END IF
      END IF ! BIOPARDIAG
      IF(CONSDIAG) THEN
        DO K = KTI(I),KBI(I)
          WRITE(BIOOUTFN(7),77773)
JDAY,I,CEFF(K),AVEC(K,I),MINC(K,I),MAXC(K,I),DAYC(K,I),DAYCM(K,I),DIET(K,I,1),DIET(K,I,2), &
          DIET(K,I,3),FCONMAXJ(K,I),FCONMAXGG(K,I),FCONJ(K,I),FCONGG(K,I),FCONP(K,I)
        END DO
        77773 FORMAT(F8.3,X,I8,X,5(F8.1,X),F8.2,X,3(F8.2,X),2(F8.1,X,F8.4,X),F8.3,X)
        77873 FORMAT(F8.3,X,I8,X,5(F8.1,X),F8.2,X,3(F8.2,X),2(F8.1,X,F8.4,X),2(F8.3,X))
        IF(SURFDIAG) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(18),77773)
JDAY,I,CEFF(K),AVEC(K,I),MINC(K,I),MAXC(K,I),DAYC(K,I),DAYCM(K,I),DIET(K,I,1),DIET(K,I,2), &
          DIET(K,I,3),FCONMAXJ(K,I),FCONMAXGG(K,I),FCONJ(K,I),FCONGG(K,I),FCONP(K,I)
        END IF
        IF(BESTCALC) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(8),77873)
JDAY,I,CEFF(K),BAVEC(I),BMINC(I),BMAXC(I),BDAYCI(I),BDAYCMI(I),BDIETI(I,1),BDIETI(I,2),BDIETI(I,3), &
          BFCONMAXJI(I),BFCONMAXGGI(I),BFCONJI(I),BFCONGGI(I),BFCONPI(I),T1BZ(I)
        END IF
        IF(DIELCALC) THEN ! NEED TO ADD TERMS
          K = KTI(I)
          WRITE(BIOOUTFN(9),77773)
JDAY,I,CEFF(K),DAVEC(I),DMINC(I),DMAXC(I),DDAYCI(I),DDAYCMI(I),DDIETI(I,1),DDIETI(I,2),DDIETI(I,3), &
          DFCONMAXJI(I),DFCONMAXGGI(I),DFCONJI(I),DFCONGGI(I),DFCONPI(I)
        END IF
      END IF ! CONSDIAG
      IF(DIGDIAG) THEN
        DO K = KTI(I),KBI(I)
          WRITE(BIOOUTFN(10),77774)
JDAY,I,F_D(K,I),F_DINI(K,I),F_DCON(K,I),F_DUNDIG(K,I),F1(K,I,3),F1(K,I,5),F1(K,I,4)
        END DO
        77774 FORMAT(F8.3,X,I8,X,4(F8.1X),3(F8.2,X))
        IF(SURFDIAG) THEN
          K = KTI(I)
          WRITE(BIOOUTFN(19),77774)
JDAY,I,F_D(K,I),F_DINI(K,I),F_DCON(K,I),F_DUNDIG(K,I),F1(K,I,3),F1(K,I,5),F1(K,I,4)
        END IF
        IF(BESTCALC) THEN ! ADD THE DIGESTIVE DIAGNOSTIC TERMS TO THE CODE
          K = KTI(I)
          WRITE(BIOOUTFN(11),77774)
JDAY,I,BF_DI(I),F_DINI(K,I),F_DCON(K,I),F_DUNDIG(K,I),BF1(K,I,3),BF1(K,I,5),BF1(K,I,4)
        END IF

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```

      IF(DIELCALC) THEN      ! NEED TO ADD TERMS
        K = KTI(I)
        WRITE(BIOOUTFN(12),77774)
JDAY,I,DF_DI(I),F_DINI(K,I),F_DCON(K,I),F_DUNDIG(K,I),DF1(K,I,3),DF1(K,I,5),DF1(K,I,4)
      END IF
      END IF ! DIGDIAG
      IF(RESPIAG) THEN
        DO K = KTI(I),KBI(I)
          WRITE(BIOOUTFN(13),77775) JDAY,I,F_R(K,I),FACTAVE(K,I),FVELAVE(K,I)
        END DO
        77775 FORMAT(F8.3,X,I8,X,F8.1,X,2(F8.3,X))
      IF(SURFDIAG) THEN
        K = KTI(I)
        WRITE(BIOOUTFN(20),77775) JDAY,I,F_R(K,I),FACTAVE(K,I),FVELAVE(K,I)
      END IF
      IF(BESTCALC) THEN
        K = KTI(I)
        WRITE(BIOOUTFN(14),77775) JDAY,I,BF_RI(I),BFACTAVE(I),BFVELAVE(I)
      END IF
      IF(DIELCALC) THEN
        K = KTI(I)
        WRITE(BIOOUTFN(15),77775) JDAY,I,DF_RI(I),DFACTAVE(I),DFVELAVE(I)
      END IF
      END IF ! RESPIAG
      GOTO 2121
      IF(SINGLEDIAG.AND.DEPTHCALC) THEN
        IF(I.EQ.SINIBIO) THEN
          DO II = 1, BESTSTEP
            WRITE(BIOOUTFN(21),'(4I8)') INT(JDAY-0.5), I, BESTK(I,II),DIELK(I,II)
          END DO
        END IF
      END IF
      2121 CONTINUE
      RETURN
      END SUBROUTINE FOUTPUT_DAILY

!*****
!*****
!**
!*****
!*****

! KTI,KBI ARE NOT W2 VALUES; NEED TO UPDATE TO INCORPORATE INTO W2
SUBROUTINE BIOEXPTRANSFORM
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE GROWTH_ANIMATION; USE DIAGNOSTIC; USE
ROOSEVELT; USE MOVEMENT
GOTO 5001
REWIND(BIOINFN(JI))
READ(BIOINFN(JI),'(A72)') FRED
FIRSTK = -1; LASTK = -1
DO K = 1,10000000
  READ(BIOINFN(JI),'(F8.0)') ZDAY1
  IF(ZDAY1.LT.FBIODAYLST) FIRSTK = K
  IF(ZDAY1.LT.FBIODAYNXT) LASTK = K
  IF(ZDAY1.GE.FBIODAYNXT) EXIT
END DO
! POSITION CURSOR TO READ THE INTENDED DAY
REWIND(BIOINFN(JI))
READ(BIOINFN(JI),'(A72)') FRED
DO K = 1, FIRSTK
  READ(BIOINFN(JI),'(F8.0)') ZDAY1
END DO
KTI(I) = 2; KBI(I) = LASTK-FIRSTK
IF(KBI(I).LT.KTI(I)) KBI(I) = KTI(I)
5001 CONTINUE
IF(FIRSTREAD(JI)) THEN
  REWIND(BIOINFN(JI))
  READ(BIOINFN(JI),'(A72)') FRED
  FIRSTREAD(JI) = .FALSE.
END IF
DO K = 2,10000000
  READ(BIOINFN(JI),'(F8.0)') ZDAY1
  IF(ZDAY1.LT.FBIODAYNXT) LASTK = K
  IF(ZDAY1.GE.FBIODAYNXT) EXIT
END DO
DO K = 2,LASTK+1
  BACKSPACE(BIOINFN(JI))
END DO

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```

KTI(I) = 2; KBI(I) = LASTK
DO K = KTI(I),KBI(I) ! WILL NEED TO CONVERT C2 (:,:,JZ) FROM NZP TO NZOOS,NZOOE FOR MAIN W2 PROGRAM
  READ(BIOINFN(JI), '(F8.0,8X,3F8.2,3F8.3,I8,2F8.0,A20)') ZDAY1,DEPTM(K,I),T1(K,I),GAMMA(K,I), &
    (C2(K,I,JZ),JZ=1,NZP),SEKG,BH(K,I),EL(K,I),GREGORY(GRCT)
  ! T1Z(K,I) = T1Z(K,I) - 1.0 !temperature sensitivity
  T1Z(K,I) = MAX(T1(K,I)-1,0.01) ! TEMPERATURES BELOW FREEZING
  DO JJZ = 1,NZP
    C1Z(K,I,JJZ)=C2(K,I,JJZ)/MZOO(JJZ)/1000.0 !C1Z HAS UNITS OF ORGANISMS PER M3 ! CONVERT FROM MG TO
G
  END DO
  ! AVAILABILITY COMPUTATION (MAZUR)
  IF(THRESHOLD) THEN
    DAP_IN = C2(K,I,3)*1000.0
    IF(DAP_IN.GE.THRESHV) THEN
      THRESHFEED(K) = .TRUE.
      CEFF(K) = C1Z(K,I,3)*ZAVAIL(3)
    ELSE
      THRESHFEED(K) = .FALSE.
      CEFF(K) = (C1Z(K,I,1)*ZAVAIL(1)+C1Z(K,I,2)*ZAVAIL(2)+C1Z(K,I,3)*ZAVAIL(3))
    END IF
  ELSE
    CEFF(K) = (C1Z(K,I,1)*ZAVAIL(1)+C1Z(K,I,2)*ZAVAIL(2)+C1Z(K,I,3)*ZAVAIL(3))
  END IF !THRESHOLD
END DO
END SUBROUTINE BIOEXPTRANSFORM

!*****
!***                                     S U B R O U T I N E   G E T   F I S H   D A T A
!***
!*****

SUBROUTINE GETFISHDATA
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE DIAGNOSTIC; USE ROOSEVELT; USE MOVEMENT
NUNIT = NUNIT+1; BIOCON = NUNIT
OPEN(BIOCON,FILE='W2_BIO_CON.NPT',STATUS='OLD')
DO II = 1,8
  READ(BIOCON,*)
END DO
  READ(BIOCON,'(/(8X,A8,I8,4A8))') FCALC,FUF,FDIAGC,BESTC,DIELC,CMAXC
  FISHCALC = FCALC == '      ' ON' ; FDIAG = FDIAGC == '      ' ON';BESTCALC = BESTC == '      ' ON' ;
  DIELCALC = DIELC == '      ' ON'
  CMAXCALC = CMAXC == '      ' ON'
  READ(BIOCON,'(/(8X,2F8.0))') JDAY, JEND
  READ(BIOCON,'(/(8X,8F8.0))') FISHT1,FISHT2,FISHT3,FISHT4,FISHK1,FISHK2,FISHK3,FISHK4
  FG1=(1/(FISHT2-FISHT1))*LOG((FISHK2*(1-FISHK1))/(FISHK1*(1-FISHK2)))
  FG2=(1/(FISHT4-FISHT3))*LOG((FISHK3*(1-FISHK4))/(FISHK4*(1-FISHK3)))
  READ(BIOCON,'(/(8X,F8.0))') FOXYCAL
  READ(BIOCON,'(/(8X,3F8.0))') (F1I(II),II=1,3)
  F1(:,1) = F1I(1); F1(:,2) = F1I(2); F1(:,3) = F1I(3)
  READ(BIOCON,'(//)')
  READ(BIOCON,'(:8X,9F8.0)') (LZOO(II),II = 1,3)
  READ(BIOCON,'(//)')
  READ(BIOCON,'(:8X,9F8.0)') (MZOO(II),II = 1,3)
  READ(BIOCON,'(//)')
  READ(BIOCON,'(:8X,9F8.0)') (EZOO(II),II = 1,3)
  READ(BIOCON,'(/(8X,4F8.0,A8,F8.0,I8,F8.0))')
HANDLE,FVELA,FVELB,FVELE,THRESHC,THRESHV,THRESHZ,DIELLUX
  THRESHOLD = THRESHC == '      ' ON'
  READ(BIOCON,'(/(8X,A8))') FGPC
  FGPPLOT = FGPC == '      ' ON'
  READ(BIOCON,'(/(8X,F8.0))') FGPD
  READ(BIOCON,'(/(8X,F8.0))') FGPF
  READ(BIOCON,'(/(8X,3A8))') GENMTP,BESTMTP,DIELMTP
  GMTPCELL = GENMTP == '      ' CELL';GMTPFIXN = GENMTP == '      ' FXN';GMTPUSER = GENMTP == '      '
  USER';GMTPFIXED = GENMTP == '      ' FIXED'
  BMTPSEG = BESTMTP == '      ' SEG';BMTPFIXN = BESTMTP == '      ' FXN';BMTPUSER = BESTMTP == '      '
  USER';DMTPFIXED = BESTMTP == '      ' FIXED'
  DMTPSEG = DIELMTP == '      ' SEG';DMTPFIXN = DIELMTP == '      ' FXN';DMTPUSER = DIELMTP == '      '
  USER';BMTPFIXED = DIELMTP == '      ' FIXED'
  IF (GMTPCELL.OR.GMTPFIXN.OR.GMTPUSER.OR.GMTPFIXED) GMTOK = .TRUE.
  IF (BMTPSEG.OR.BMTPFIXN.OR.BMTPUSER.OR.BMTPFIXED) BMTOK = .TRUE.
  IF (DMTPSEG.OR.DMTPFIXN.OR.DMTPUSER.OR.DMTPFIXED) DMTOK = .TRUE.
  IF(.NOT.GMTOK) THEN
    PRINT *, 'GENERAL FISH MASS TYPE NOT RECOGNIZED: ',GENMTP
    STOP
  END IF
  IF(.NOT.BMTOK) THEN

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        PRINT *, 'BEST FISH MASS TYPE NOT RECOGNIZED: ', BESTMTP
        STOP
    END IF
    IF (.NOT. DMTOK) THEN
        PRINT *, 'FORAGING FISH MASS TYPE NOT RECOGNIZED: ', DIELMTP
        STOP
    END IF
    READ (BIOCON, '(/(8X,9F8.0))') GIM, BIM, DIM, GALP, BALP, DALP, GTI, BTI, DTI
    READ (BIOCON, '(/(8X,7A8))') FISHC, BIOPARC, CONSC, DIGC, RESPC, SURFC, DEPTHC
    FISHDIAG = FISHC == '        ' ON'; BIOPARDIAG = BIOPARC == '        ' ON'; CONSDIAG = CONSC == '
ON'
    DIGDIAG = DIGC == '        ' ON'; RESPDIAG = RESPC == '        ' ON'; SURFDIAG = SURFC == '
ON'
    DEPTHCALC = DEPTHC == '        ' ON'
    READ (BIOCON, '(/(8X,A8,2I8,A8))') SINGLEC, SINGFN, SINIBIO, TLC
    SINGLEDIAG = SINGLEC == '        ' ON'
    IF (SINGLEDIAG) TLCALC = TLC == '        ' ON'
    IF (TLCALC) THEN
        NUNIT = NUNIT + 1; TLCALCFN = NUNIT
        OPEN (TLCALCFN, FILE='TLDIAG.DAT', STATUS='UNKNOWN')
        WRITE (TLCALCFN, '(2A8)') '    TEMP', '    TL'
    END IF
    READ (BIOCON, '(/(8X,A72))') ZAVFNAME
    FRED = ADJUSTL(ZAVFNAME)
    L = LEN_TRIM(FRED)
    ZAVFNAME = FRED(1:L)
    NUNIT = NUNIT + 1; ZAVFN = NUNIT
    READ (BIOCON, '(/)')
    DO II = 1, NWB
        NUNIT = NUNIT + 1; FGPFN = NUNIT
        READ (BIOCON, '(8X,A72)') FGPFNAME(II)
        FRED = ADJUSTL(FGPFNAME(II))
        L = LEN_TRIM(FRED)
        FGPFNAME(II) = FRED(1:L)
    END DO
    READ (BIOCON, '(/(8X,A72))') FXNFNAME(1)
    READ (BIOCON, '(/(8X,A72))') FXNFNAME(2)
    READ (BIOCON, '(/(8X,A72))') FXNFNAME(3)
    DO II = 1, 3
        FRED = ADJUSTL(FXNFNAME(II))
        L = LEN_TRIM(FRED)
        FXNFNAME(II) = FRED(1:L)
        NUNIT = NUNIT + 1; FXNFN(II) = NUNIT
    END DO
    IF (GMTPUSER) THEN
        OPEN (FXNFN(1), FILE=FXNFNAME(1), STATUS='OLD')
        READ (FXNFN(1), '(///)')
    END IF
    IF (BMTUSER) THEN
        OPEN (FXNFN(2), FILE=FXNFNAME(2), STATUS='OLD')
        READ (FXNFN(2), '(///)')
    END IF
    IF (DMTPUSER) THEN
        OPEN (FXNFN(3), FILE=FXNFNAME(3), STATUS='OLD')
        READ (FXNFN(3), '(///)')
    END IF
    CLOSE (BIOCON)
    RETURN
END SUBROUTINE GETFISHDATA

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! *****
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SUBROUTINE ANIMATION_DATA
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE GROWTH_ANIMATION; USE ROOSEVELT; USE
MOVEMENT

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NELEM = 0
DO JJI = 1, NIBIO
    IF (ANIMEXP(JJI)) THEN
        II = IBIO(JJI)
        DO K = KTI(II), KBI(II)
            NELEM = NELEM + 1
        END DO
    END IF

```

```

END DO
NNODE = NELEM*4
WRITE (ANIMFN,906) NNODE,NELEM
906 FORMAT('ZONE N=',i5,' E=',i6,' F=FEPOINT, ET=QUADRILATERAL')
LEFT = 0.0
DO JJI = 1,NIBIO
  IF (ANIMEXP(JJI)) THEN
    II = IBIO(JJI)
    DO K = KTI(II),KBI(II)
      IF (JJJ.EQ.1) THEN
        X1(K,II) = 0.0; X4(K,II) = 0.0
      ELSE
        X1(K,II) = LEFT(1); X4(K,II) = LEFT(1)
      END IF
      X2(K,II) = DISTR(II) ; X3(K,II) = DISTR(II)
    IF (K.EQ.KTI(II)) THEN
      Y1(K,II) = EL(K+1,II)+3 ; Y2(K,II) = EL(K+1,II)+3
      Y3(K,II) = EL(K+1,II)+1 ; Y4(K,II) = EL(K+1,II)+1
    ELSE
      Y1(K,II) = EL(K,II)+1 ; Y2(K,II) = EL(K,II)+1
      Y3(K,II) = EL(K,II)-1 ; Y4(K,II) = EL(K,II)-1
    END IF
    WRITE (ANIMFN, '(f8.1,X,f7.2,X,f7.3)') X1(K,II),Y1(K,II), F_G(K,II)
    WRITE (ANIMFN, '(f8.1,X,f7.2,X,f7.3)') X2(K,II),Y2(K,II), F_G(K,II)
    WRITE (ANIMFN, '(f8.1,X,f7.2,X,f7.3)') X3(K,II),Y3(K,II), F_G(K,II)
    WRITE (ANIMFN, '(f8.1,X,f7.2,X,f7.3)') X4(K,II),Y4(K,II), F_G(K,II)
  END DO
  LEFT(1) = DISTR(II)
END IF
END DO
DO IM=1,NELEM
  MPOS=IM*4
  WRITE (ANIMFN, '(4I6)') MPOS-3,MPOS-2,MPOS-1,MPOS
END DO
ZONECNT=ZONECNT+1
END SUBROUTINE ANIMATION_DATA

! *****
! *****
! **
! **
! *****
! *****

SUBROUTINE BY_SEG OUTPUT
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE GROWTH_ANIMATION; USE ROOSEVELT; USE
MOVEMENT; USE DIAGNOSTIC

WRITE (BYSEGFMN, '(F7.1,500(X,F6.2))') JDAY, (MAXM(IBIO(II)),II=1,NIBIO)
WRITE (BYSEGGMN, '(F7.1,500(X,F6.2))') JDAY, (MAXG(IBIO(II)),II=1,NIBIO)
IF (BESTCALC) THEN
  WRITE (BYSEGFMN2, '(F7.1,500(X,F6.2))') JDAY, (BF1(2,IBIO(II),1),II=1,NIBIO)
  WRITE (BYSEGGMN2, '(F7.1,500(X,F6.2))') JDAY, (BF_GI(IBIO(II)),II=1,NIBIO)
END IF
IF (DIELCALC) THEN
  WRITE (BYSEGFMN3, '(F7.1,500(X,F6.2))') JDAY, (DF1(2,IBIO(II),1),II=1,NIBIO)
  WRITE (BYSEGGMN3, '(F7.1,500(X,F6.2))') JDAY, (DF_GI(IBIO(II)),II=1,NIBIO)
END IF
WRITE (SURFSEGFMN, '(F7.1,500(X,F6.2))') JDAY, (F1(2,IBIO(II),1),II=1,NIBIO)
WRITE (SURFSEGGMN, '(F7.1,500(X,F6.2))') JDAY, (F_G(2,IBIO(II)),II=1,NIBIO)
END SUBROUTINE BY_SEG OUTPUT

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SUBROUTINE INITIALFILESETUP
USE MAINW2; USE FISH; USE FISH2; USE BIOEXPDATATransFORM; USE GROWTH_ANIMATION; USE ROOSEVELT; USE
MOVEMENT; USE DIAGNOSTIC

! *** ZOOPLANKTON AVAILABILITY ( REPLACE WITH INPUT FILE FORMAT (WILL NEED TIME CONTROL VARIABLES))
OPEN (ZAVFN, FILE=ZAVFNNAME, STATUS='OLD')
READ (ZAVFN, '(//)')
ZAVJD = -9999.99
DO WHILE (ZAVJD.LT.JDAY)
  READ (ZAVFN, '(:F8.0,9F8.0)') ZAVJD, (ZAVAIL(II),II=1,N2P)

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END DO
READ(ZAVFN, '(F8.0,9F8.0)') ZAVNX, (ZAVAILNX(II), II=1, NZP)
! *** ASSIGN BIOEXP DATA FILE NUMBERS AND FILENAMES
DO JI = 1, NIBIO
  IF (FIRST_BIO(JI)) THEN
    NUNIT = NUNIT + 1; BIOINFN(JI) = NUNIT
    WRITE (SEGNUM, '(I0)') JI
    SEGNUM = ADJUSTL(SEGNUM)
    L = LEN_TRIM(SEGNUM)
    OPEN (BIOINFN(JI), FILE='BIOEXP_'//SEGNUM(1:L)//'.opt', STATUS='OLD')
  END IF
END DO
IF (SINGLEDIAG) THEN
  NIBIO = 1.0
  BIOINFN(1) = BIOINFN(SINGFN)
  IBIO(1) = SINIBIO
END IF

! ***** RESULTS AND DIAGNOSTIC OUTPUT FILES *****
IF (FDIAG) THEN
  IF (FISHDIAG) THEN
    NUNIT = NUNIT + 1; BIOOUTFN(1) = NUNIT; OPEN(BIOOUTFN(1), FILE='BIO_FISH.DAT', STATUS='UNKNOWN')
    FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'GROWTH' ; FHEAD(4) = 'FMASS' ; FHEAD(5) =
'POS' ; &
    FHEAD(6) = 'FULLSTO'; FHEAD(7) = 'LIGHTMIN'; FHEAD(8) = 'TEMP'
    WRITE(BIOOUTFN(1), '(8(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 8)
    IF (SURFDIAG) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(16) = NUNIT;
      OPEN(BIOOUTFN(16), FILE='BIO_FISH_SURF.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(16), '(8(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 8)
    END IF
    IF (BESTCALC) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(2) = NUNIT;
      OPEN(BIOOUTFN(2), FILE='BIO_FISH_BEST.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(2), '(8(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 8)
    END IF
    IF (DIELCALC) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(3) = NUNIT;
      OPEN(BIOOUTFN(3), FILE='BIO_FISH_DIEL.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(3), '(8(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 8)
    END IF
  END IF ! FISHDIAG
  IF (BIOPARDIAG) THEN
    NUNIT = NUNIT + 1; BIOOUTFN(4) = NUNIT; OPEN(BIOOUTFN(4), FILE='BIO_PARA.DAT', STATUS='UNKNOWN')
    FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'GROWTH' ; FHEAD(4) = 'DIGEST' ; FHEAD(5) =
'RESP' ; &
    FHEAD(6) = 'SDA' ; FHEAD(7) = 'WASTE' ; FHEAD(8) = 'EXCRETE' ; FHEAD(9) = 'EGEST'
    WRITE(BIOOUTFN(4), '(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 9)
    IF (SURFDIAG) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(17) = NUNIT;
      OPEN(BIOOUTFN(17), FILE='BIO_PARA_SURF.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(17), '(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 9)
    END IF
    IF (BESTCALC) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(5) = NUNIT;
      OPEN(BIOOUTFN(5), FILE='BIO_PARA_BEST.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(5), '(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 9)
    END IF
    IF (DIELCALC) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(6) = NUNIT;
      OPEN(BIOOUTFN(6), FILE='BIO_PARA_DIEL.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(6), '(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 9)
    END IF
  END IF ! BIOPARDIAG
  IF (CONSDIAG) THEN
    NUNIT = NUNIT + 1; BIOOUTFN(7) = NUNIT; OPEN(BIOOUTFN(7), FILE='BIO_CONS.DAT', STATUS='UNKNOWN')
    FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'PREYDEN' ; FHEAD(4) = 'AVEC' ; FHEAD(5) =
'MINC' ; &
    FHEAD(6) = 'MAXC' ; FHEAD(7) = '#CON' ; FHEAD(8) = 'MASSCON' ; FHEAD(9) = 'DIET1'
    ; FHEAD(10) = 'DIET1' ; &
    FHEAD(10) = 'DIET2' ; FHEAD(11) = 'DIET3' ; FHEAD(12) = 'MAXC_J' ; FHEAD(13) = 'MAXC_G/G' ; FHEAD(14) =
'ACTC_J' ; &
    FHEAD(15) = 'ACTC_G/G' ; FHEAD(16) = 'P_VALUE'
    WRITE(BIOOUTFN(7), '(16(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 16)
    IF (SURFDIAG) THEN
      NUNIT = NUNIT + 1; BIOOUTFN(18) = NUNIT;
      OPEN(BIOOUTFN(18), FILE='BIO_CONS_SURF.DAT', STATUS='UNKNOWN')
      WRITE(BIOOUTFN(18), '(16(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1, 16)
    END IF
  END IF
END IF

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        IF(BESTCALC) THEN
            NUNIT = NUNIT+1; BIOOUTFN(8) = NUNIT;
            OPEN(BIOOUTFN(8),FILE='BIO_CONS_BEST.DAT',STATUS='UNKNOWN')
            WRITE(BIOOUTFN(8),'(16(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,16)
        END IF
        IF(DIELCALC) THEN
            NUNIT = NUNIT+1; BIOOUTFN(9) = NUNIT;
            OPEN(BIOOUTFN(9),FILE='BIO_CONS_DIEL.DAT',STATUS='UNKNOWN')
            WRITE(BIOOUTFN(9),'(16(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,16)
        END IF
    END IF ! CONSDIAG
    IF(DIGDIAG) THEN
        NUNIT = NUNIT+1; BIOOUTFN(10) = NUNIT; OPEN(BIOOUTFN(10),FILE='BIO_DIG.DAT',STATUS='UNKNOWN')
        FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'DIG_J' ; FHEAD(4) = 'INITIAL' ; FHEAD(5) =
        'CONSUMED';&
        FHEAD(6) = 'UNDIGEST'; FHEAD(7) = 'STOMCON'; FHEAD(8) = 'STOMCAP' ; FHEAD(9) = 'EDENSITY'
        FHEAD(16) = 'ACTC_G/G'; FHEAD(17) = 'P_VALUE'
        WRITE(BIOOUTFN(10),'(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,9)
    IF(SURFDIAG) THEN
        NUNIT = NUNIT+1; BIOOUTFN(19) = NUNIT;
        OPEN(BIOOUTFN(19),FILE='BIO_DIG_SURF.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(19),'(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,9)
    END IF
    IF(BESTCALC) THEN
        NUNIT = NUNIT+1; BIOOUTFN(11) = NUNIT;
        OPEN(BIOOUTFN(11),FILE='BIO_DIG_BEST.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(11),'(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,9)
    END IF
    IF(DIELCALC) THEN
        NUNIT = NUNIT+1; BIOOUTFN(12) = NUNIT;
        OPEN(BIOOUTFN(12),FILE='BIO_DIG_DIEL.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(12),'(9(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,9)
    END IF
    END IF ! DIGDIAG
    IF(RESPIAG) THEN
        NUNIT = NUNIT+1; BIOOUTFN(13) = NUNIT; OPEN(BIOOUTFN(13),FILE='BIO_RESP.DAT',STATUS='UNKNOWN')
        FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'RESP_J' ; FHEAD(4) = 'FACTAVE' ; FHEAD(5) =
        'FVELAVE'
        WRITE(BIOOUTFN(13),'(5(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,5)
    IF(SURFDIAG) THEN
        NUNIT = NUNIT+1; BIOOUTFN(20) = NUNIT;
        OPEN(BIOOUTFN(20),FILE='BIO_RESP_SURF.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(20),'(5(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,5)
    END IF
    IF(BESTCALC) THEN
        NUNIT = NUNIT+1; BIOOUTFN(14) = NUNIT;
        OPEN(BIOOUTFN(14),FILE='BIO_RESP_BEST.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(14),'(5(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,5)
    END IF
    IF(DIELCALC) THEN
        NUNIT = NUNIT+1; BIOOUTFN(15) = NUNIT;
        OPEN(BIOOUTFN(15),FILE='BIO_RESP_DIEL.DAT',STATUS='UNKNOWN')
        WRITE(BIOOUTFN(15),'(5(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,5)
    END IF
    END IF ! RESPIAG
    IF(SINGLEDIAG) THEN
        IF(DEPTHCALC) THEN
            NUNIT = NUNIT +1; BIOOUTFN(21) = NUNIT;
            OPEN(BIOOUTFN(21),FILE='FORAGING_DEPTHS.DAT',STATUS='UNKNOWN')
            FHEAD(1) = 'JDAY' ; FHEAD(2) = 'SEG' ; FHEAD(3) = 'BESTDTH' ; FHEAD(4) = 'DIELDTH'
            WRITE(BIOOUTFN(21),'(4(A8,1X))') (ADJUSTR(FHEAD(TT)), TT = 1,4)
        END IF
    END IF
END IF ! FDIAG

! ***** GROWTH ANIMATION OUTPUT FILE *****
NUNIT = NUNIT+1; ANIMFN = NUNIT
OPEN(ANIMFN,FILE='FGP_ANIM.DAT',STATUS='UNKNOWN') ! BASIC OUTPUT
WRITE(ANIMFN,'(A52)') HEADER1
WRITE(ANIMFN,'(A52)') HEADER2
IF(BESTCALC) THEN
    NUNIT = NUNIT+1; ANIMFN2 = NUNIT
    OPEN(ANIMFN2,FILE='FGP_ANIM_BEST.DAT',STATUS='UNKNOWN') ! BEST LOCATION OUTPUT
    WRITE(ANIMFN2,'(A52)') HEADER1
    WRITE(ANIMFN2,'(A52)') HEADER2
END IF
! PREP DISTANCE VALUES (TEMPORARY APPROACH)
NUNIT = NUNIT+1
OPEN(NUNIT,FILE='DLX.PRN',STATUS='OLD')

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READ(NUNIT,*)
DO J = 1,1000
  READ(NUNIT,'(I8,8X,2F8.0)',END=107) I,VLL,VLR
  DISTL(I) = VLL; DISTR(I) = VLR
END DO
107 CONTINUE
! REMOVE ZEROS
DO J = 2,IMX
  IF(DISTR(J).EQ.0.0) THEN
    DISTR(J) = DISTR(J-1)
  END IF
END DO
! FIX ERRORS
DO II = 2,NIBIO
  IF(DISTR(IBIO(II-1)).EQ.0.0) THEN
    PRINT *, 'ZERO ', II-1, IBIO(II-1)
    ! DISTR(IBIO(II-1)) = DISTR(IBIO(II))
  END IF
  DISTL(IBIO(II)) = DISTR(IBIO(II-1))
  IF(DISTL(IBIO(II)).NE.DISTR(IBIO(II-1))) THEN
    PRINT *, 'NE ', II, IBIO(II)
  END IF
END DO
CLOSE(NUNIT)

! ***** BYSEG FILE PREP *****
IF(BYSEG) THEN
  NUNIT = NUNIT+1; BYSEGMFN = NUNIT
  OPEN(BYSEGMFN,FILE='MASS.DAT',STATUS='UNKNOWN')
  NUNIT = NUNIT+1; BYSEGGFN = NUNIT
  OPEN(BYSEGGFN,FILE='GROWTH.DAT',STATUS='UNKNOWN')
  WRITE(BYSEGMFN,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
  WRITE(BYSEGGFN,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
  IF(BESTCALC) THEN
    NUNIT = NUNIT+1; BYSEGMFN2 = NUNIT
    OPEN(BYSEGMFN2,FILE='MASS_BEST.DAT',STATUS='UNKNOWN')
    NUNIT = NUNIT+1; BYSEGGFN2 = NUNIT
    OPEN(BYSEGGFN2,FILE='GROWTH_BEST.DAT',STATUS='UNKNOWN')
    WRITE(BYSEGMFN2,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
    WRITE(BYSEGGFN2,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
    NUNIT = NUNIT+1; BESTDIAGFN = NUNIT
    OPEN(BESTDIAGFN,FILE='BESTDIAG.DAT',STATUS='UNKNOWN')
  END IF
  IF(DIELCALC) THEN
    NUNIT = NUNIT+1; BYSEGMFN3 = NUNIT
    OPEN(BYSEGMFN3,FILE='MASS_DIEL.DAT',STATUS='UNKNOWN')
    NUNIT = NUNIT+1; BYSEGGFN3 = NUNIT
    OPEN(BYSEGGFN3,FILE='GROWTH_DIEL.DAT',STATUS='UNKNOWN')
    WRITE(BYSEGMFN3,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
    WRITE(BYSEGGFN3,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
  END IF
! SURFACE SEGMENT
  NUNIT = NUNIT+1; SURFSEGMFN = NUNIT
  OPEN(SURFSEGMFN,FILE='MASS_SURF.DAT',STATUS='UNKNOWN')
  NUNIT = NUNIT+1; SURFSEGGFN = NUNIT
  OPEN(SURFSEGGFN,FILE='GROWTH_SURF.DAT',STATUS='UNKNOWN')
  WRITE(SURFSEGMFN,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
  WRITE(SURFSEGGFN,'(A7,500(I6,A))') ' ' JDAY',((IBIO(II),'S'),II = 1,NIBIO)
END IF
! *** LIGHTOUT
  NUNIT = NUNIT+1; LIGHTNUM=NUNIT
  OPEN(LIGHTNUM,FILE='LIGHTOUT.PRN',STATUS='OLD')
  FIRSTLIGHT = .FALSE.
  READ(LIGHTNUM,'(10X,F10.0,20X,E10.2)') LJDAY1,LUX1
  READ(LIGHTNUM,'(10X,F10.0,20X,E10.2)') LJDAY2,LUX2
END SUBROUTINE INITIALFILESETUP

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