Water Evaluation and Planning (WEAP) Lab Exercise
Lower Bear River, Utah

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Summary

This document provides directions and prompts to get started using the Water Evaluation and Planning (WEAP) system to simulate water supply, demands, and allocations in the Lower Bear River, Utah. Students are given a nearly complete WEAP Area for the Lower Bear River and Excel Workbooks containing flow, demand, and reservoir data to add to the model. Students will (i) add the required data, (ii) simulate water deliveries under historical flow conditions and existing infrastructure, and (iii) compare results to alternative scenarios that reduce urban water demands by 10% or build a new reservoir.

Introduction

The Bear River covers an area of about 7,600 square miles in Utah, Idaho and Wyoming (Figure 1). There are numerous reservoirs in the Bear River basin including upstream storage reservoirs like Woodruff, Bear Lake, and Oneida Narrows. On the Little Bear River which is a tributary to the Bear River, there is also Hyrum Reservoir. Cutler Reservoir is located on the Bear River but has very little active storage capacity. Additionally, there are several proposed on- and off-stream storage reservoirs including Barrens, Above Cutler, Honeyville, and a site above Honeyville that could supply water to either Cache or Box Elder Counties or the Wasatch Front.

The most senior (highest priority) water rights holder in the basin is the Bear River Canal Company which is located in Box Elder county downstream of Cutler Reservoir. The lower Bear River study area starts in southern Idaho and has its outlet at the Great Salt Lake. The major tributaries to the Lower Bear River include the Blacksmith Fork, Little Bear, and Malad Rivers. There are major demand urban and agricultural demand sites both in Cache Valley and Box Elder County.The Utah Division of Water Resources (UDWR) developed the GenRes (FORTRAN) model to simulate the monthly historical (1966-2006) water allocation within the basin. Here, we will finish the UDWR model in WEAP and use the WEAP model to compare the existing system to alternatives that re-prioritize water use among users or build a new reservoir.

Original UDWR Model

The UDWR GenRes model (Figure 2) considers inflows along the Bear River, 3 tributaries (Blacksmith Fork, Little Bear, Malad), and 2 reach gains and losses (at the Bear-Little Bear

confluence and the Bear-Malad confluence). Additionally, the UDWR model includes flows down the Weber Basin (to help determine future out-of-basin transfers from the Bear River to the Watasch Front).

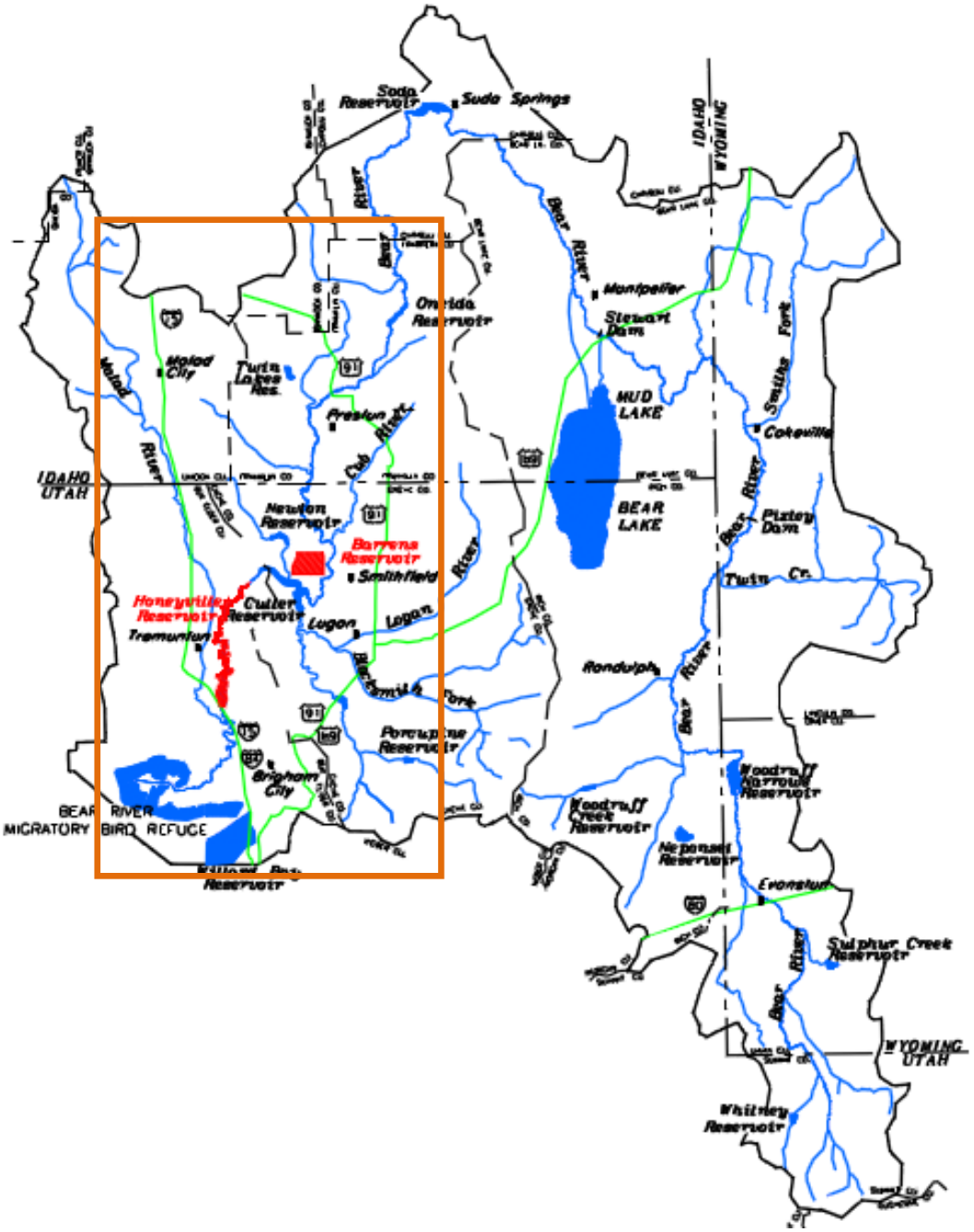

Figure 1. Bear River Basin with Lower Bear River study area highlighted in orange (adapted from UDWR, 2000).

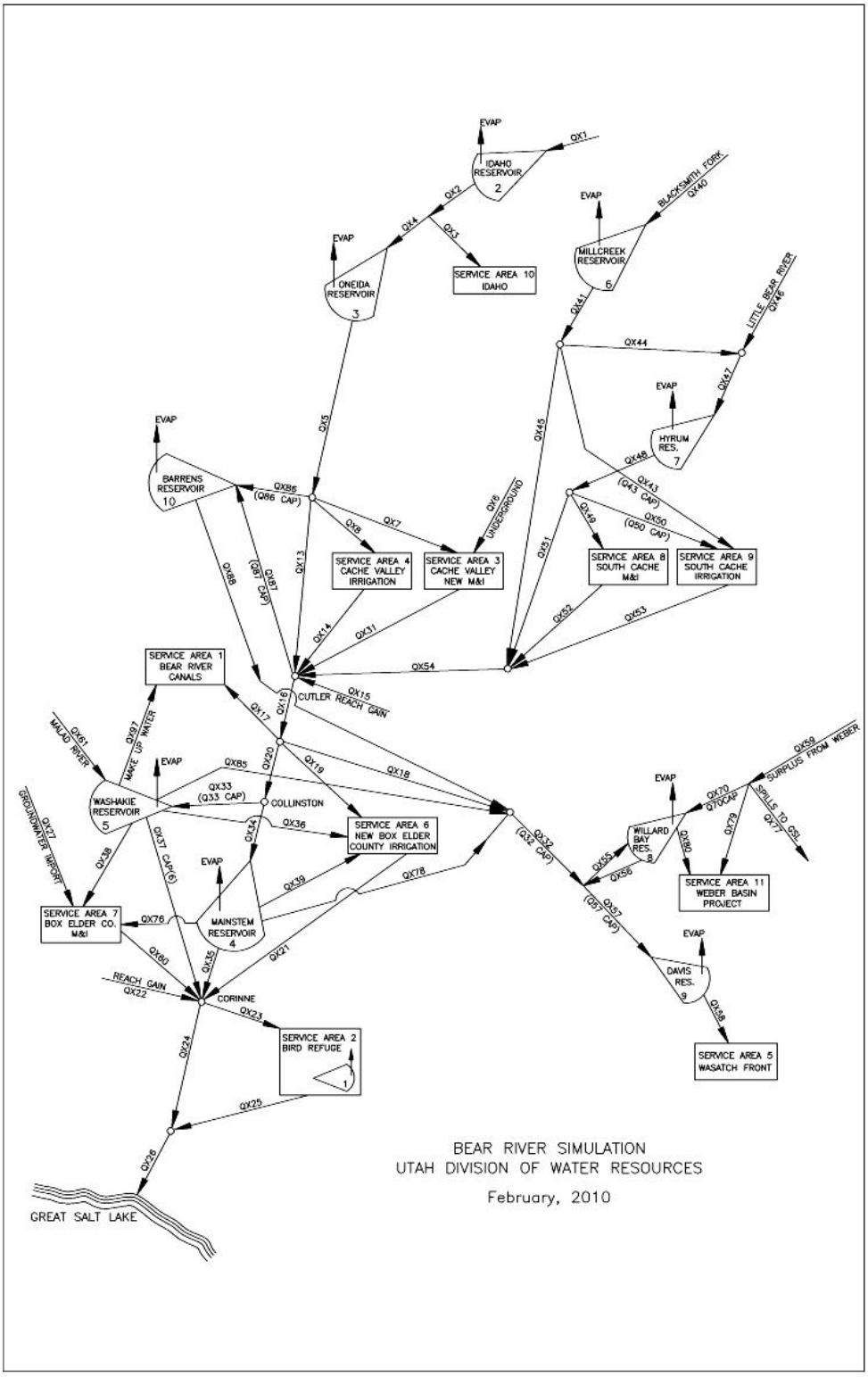

Figure 2. UDWR Bear River simulation model schematic

The UDWR model specificies 11 service areas (including the Bird Refuge). A service area is a group of canals or diversions that serve agricultural, urban, or environmental users and is alternatively refered to as a "demand site" in WEAP. The UDWR model allocates water among service areas based on priorities (Table 1). Demand sites that have the high priorities (numbers closest to 1) are allocated their full deliverty targets first before sites with lower priorities are allocated any water. Note, that at present, only 4 sites have quantified demands; the remaining sites are placeholders for future demands.

Table 1. Bear River Basin Demand Site Priorities

Priority	Service Area No.	Name	Use Type	Demand Quantified
Included in WEAP Model				
2	1	Bear River Canal (Company)	Irrigation	Yes
3	2	Bird Refuge	Environmental	Yes
4	8	South Cache Existing	Irrigation	Yes
4	9	South Cache New	Municipal	No
8	3	Cache Valley New	Municipal	No
5	4	Cache Valley Irrigation	Irrigation	No
6	6	New Box Elder County	Irrigation	No
7	7	Box Elder County	Municipal	No
21	5	Wasatch Front	Municipal	No
20	11	Weber Basin	Municipal	Yes
Excluded from WEAP Model				
NA	10	Idaho	Irrigation	No

The UDWR model also includes 4 existing reservoirs (Idaho, Oneida, Hyrum, and Willard Bay) and 5 proposed reservoirs (Barrens, Washaskie, Mainstem, Davis, and Millcreek). A 6th reservoir now under consideration is termed "Above Cutler" and would be located on the Bear River above Cutler reservoir along the reach labeled QX13 in Figure 2. The Above Cutler reservoir could also supply water to Cache Valley users.

The WEAP Model

WEAP was developed by the Stockholm Environemntal Institute in 1988 and is a software package to help plan and manage water supply. WEAP operates on the principle of mass-balance, and allocates water based on the priorities specified for the system components such as the demand sites, reservoirs, environmental flows (SEI, 2007). WEAP has been used in numerous water resources studies throughout the world, including the Aral Sea (Raskin et al., 1992); Upper Chattahoochee River Basin, Georgia (Johnson, 1994); South Africa (Levite et al., 2003); Sacramento River, California (Purkey et al., 2008); Austin, Texas; Portland, Oregon; and Philadelphia, Pennsylvania (Huber-Lee et al., 2005). Here, you will use WEAP to represent inflows, demand sites, reservoirs, transmission links (diversions), return flows, reach gains and

losses, and to simulate the effects of these system components on deliveries to demand sites (Figure 3).

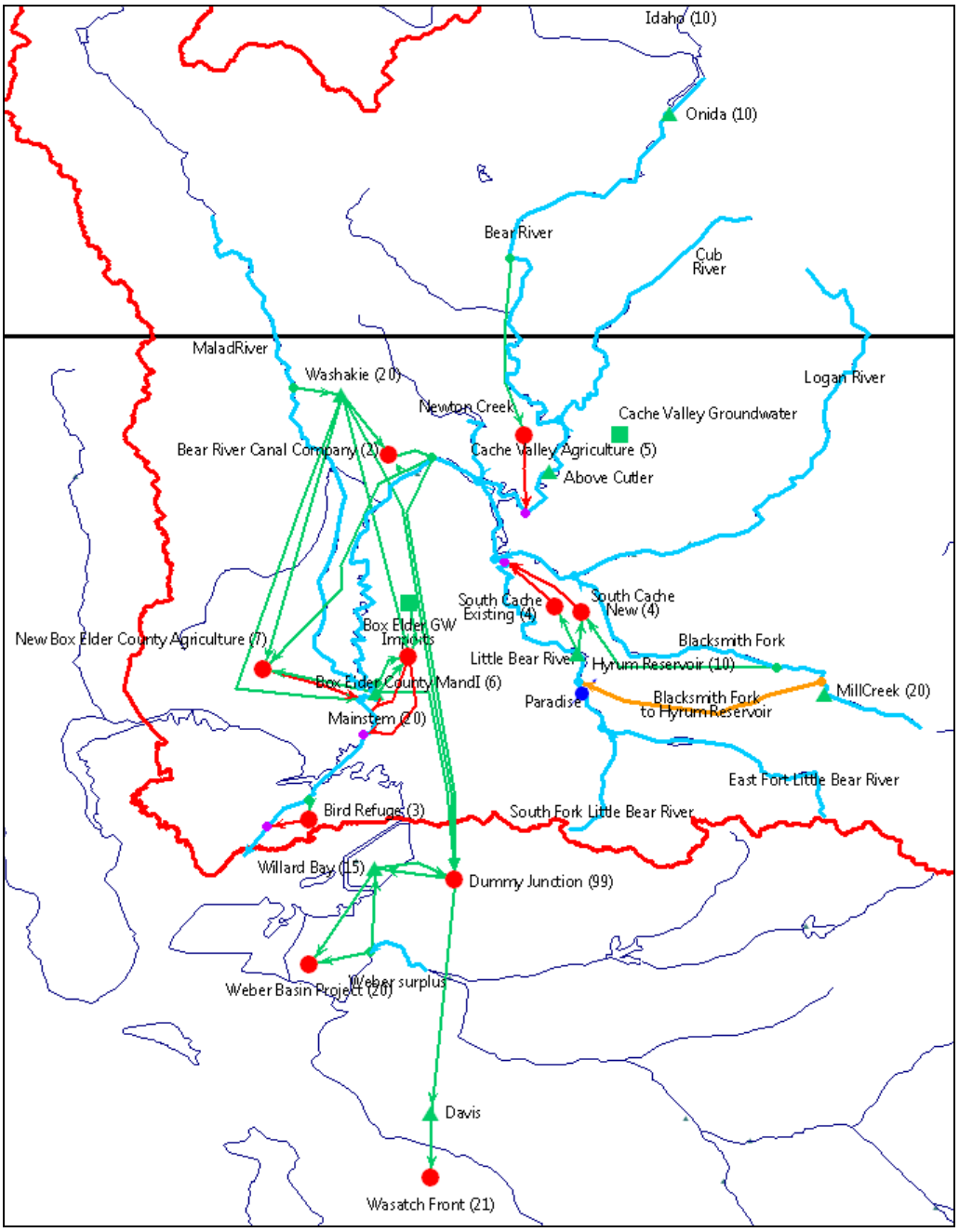

Figure 3. Schematic for the Lower Bear River Basin WEAP Model

This document will guide you through completing a WEAP model for the Lower Bear River. You are given a mostly-complete WEAP area for the Lower Bear River (LowerBearRiver-Spring2016-Start.zip) as well as the required data (Excel File LowerBearRiverModelData.xlsx

within the zip folder; some data overlap from ILO-4). You will complete the WEAP model for the Lower Bear River, then, you will specify three scenarios. The first scenario will represent past historical conditions (1966-2007); the second scenario will re-prioritize water use among agricultural and urban users; and the third scenario will add a new reservoir in Cache County Above Cutler. Finally, you will simulate each scenario to determine the effects on deliveries and unmet demand to the Bear River Canal company and new urban users in Cache County.

Directed Activity

Below are the steps to follow to enter the inflows and reach gains for the Lower Bear River in WEAP. Instructions in **Bold** or *Italic* refer to WEAP program items (windows, menus, tabs, input items, etc.). *Include short answers to italicized, underlined questions as an appendix to your ILO write-up.* There are also numerous resources—User Guide, forums, etc.—available to help you use WEAP which we will introduce you to in the next section.

WEAP Resources, Installation, and Sample River Basins

1. Go to the WEAP home page (http://www.weap21.org/) and overview the resources available for you. These resources include a demonstration, user guide, tutorials, and user forums.

2. Download and install WEAP (skip Step 2 if you are working on a computer where the program is already installed).

   a. On the left side of the WEAP home page under **Using WEAP**, click **Download**, join the WEAP forum, login with your newly assigned password, and follow the directions from there. Also, read the box "Download WEAP" (below) and start downloading.

> Download WEAP
>
> The free, **evaluation** version of WEAP (53 MB) is a fully working version of the software--only the Save Data feature is disabled. To enable, you will need a license number (see step 2b below). This download can also be used to upgrade any existing versions of WEAP.
>
> WEAP requires Windows 2000, XP, Vista or 7, and at least 256 MB of RAM. To install WEAP, right click on the setup program (WEAP_Install.exe) and choose Run as Administrator. The WEAP program (weap.exe) will install under Program Files; WEAP data files will be stored under My Documents.
>
> In some cases, when WEAP is first run the following error message appears: 'Unable to merge new configuration, use BDE Administrator to merge your new configuration'. This is not a problem--click OK to continue. It may also suggest that you should restart your computer, but this is not necessary.

   b. The free version of WEAP you downloaded is an evaluation version and therefore has limited use. Opening the program will prompt you to register the program. To register, enter the **User Name** and **Registration Code** (provided by your professor). After registering, enter your initials and click "End user information" in the window provided.

3. Open the program and explore the *Weaping River Basin* sample model.

    a. In the **Schematic** mode (click top icon at left), explore the system spatial configuration. *How many headflows, reach gains, reservoirs, and aquifers are in the sample model?*

    b. In the **Data** mode (click second icon at left), explore the types of data entered. The data is organized into a tree of *Key Assumptions*, *Demand Sites*, *Hydrology*, *Supply and Resources*, *Water Quality and Other Assumptions*. *What is the data source for headflows for each river?* Note this specification is different from demand data in the Weber River Basin case study.

    c. In the **Results** mode, explore the numerous available results for one or multiple model runs (scenarios); four scenarios are defined in the model (*Demand Measures*, *Integrated Measures*, *Reference*, and *Supply Measures*). In the **Chart** view, use the drop-down menu to select results to view. *What menu options did you select to view water supplied to a demand site and shortages at a demand site (i.e., the difference between the actual delivery and the delivery target)?*

    d. Click the **Scenario** icon to view, define, and compare results from the various scenarios created.

The Lower Bear River Basin

Area Setup

4. Unzip the zip file named LowerBearRiver-Spring2016-Start.zip available on the class website which contains a mostly-complete WEAP watershed for the Lower Bear River basin. Unzip the folder into *C:\Documents and Settings\...\My Documents\WEAP Areas*. Keep the area name *LowerBearRiver-Spring2016-Start*. If WEAP is already open, close and then reopen it.

    a. From the **Area** menu, select **Open** and select the area *LowerBearRiver-Spring2016-Start* from the list. The model should load, and you should see the Lower Bear River Basin schematic.

Model Schematic

5. The **Schematic** mode has three tool boxes arranged in a column just to the right of the *Schematic*, *Data*, *Results*, etc. icons at the far left. The top box provides tools to add elements to the model. The middle box shows GIS files which can be layered onto the schematic. And the lower box shows a wide-angle zoom of the schematic.

6. Note that this project includes most of the schematic elements for the Lower Bear River Basin but a few are missing! Compare the WEAP schematic to Figure 2.

    a. *What reservoirs, demand sites, and other elements need to be added in WEAP?* (hint: look in the Cache Valley area of the model)

7. Now, add the elements you identified as missing in Step 6a.

    a. To add a Demand Site (Service Area in Figure 2), go to the top box and check *Demand Site*.

        i. Click the *Demand Site* label in the box, drag it, and drop it at the desired location. Note that you need place Demand Sites only approximately on the WEAP schematic since the background shape layers are only to provide visual cues (do not affect WEAP calculations).

        ii. After dropping, a **General Info** window will open. Enter a *Name* and *Optional Label* (to display on the schematic).

        iii. Use Table 1 to decide the *Demand Priority*. Recall this priority (similar to appropriative water rights) determines the order in which scarce water is allocated and delivered to demand sites. Higher priority (lower numbered) sites receive their full demands before lower priority (higher numbered) sites receive any water.

        iv. Keep all other options to default values and click **OK**.

    b. Repeat Step 7a for other Demand Sites that need to be added to the schematic.

    c. Add *Transmission Links* by dragging the transmission link tool, clicking on the starting point, and dragging to an ending point at a desired *Demand Site*. Keep all other options to default values. You can also add a *Return Flow* from a *Demand Site* back to the river using a similar procedure.

    d. Place *reservoirs* in their target locations. Again, click and drag the reservoir icon to the appropriate location on the schematic. In the **General Info** window that opens, enter a *Name*. Leave the *Demand Priority* at the default setting of *99*. Since the reservoir is new, it will have the lowest priority to fill should there be surplus water in a year.

    e. All the other river and groundwater components should be present on the schematic. But check!

8. After adding all the missing elements, save your work!

Data Entry

9. Now enter data for the model elements present on the schematic by selecting the **Data** icon. When entering data, make sure to press Enter after each data entry. Also, information on inflows, demand sites, and reservoirs that you can use for inputs is organized in the file LowerBearRiverModelData.xlsx available in the WEAP area folder. You will need to enter data for headflows, demand sites, transmission links, return flows, and reservoirs.

10. First, on the **Data For** dropdown list, make sure to select *Current Accounts*.

11. *Headflows.* **Headflows** are the most upstream flow inputs to river elements in the WEAP model and are indicated by the corresponding most-upstream arrows in Figure 2 on each river. Each arrow is also labeled with a name. To assign headflow data:

    a. In the data tree, select **Supply and Resources**=>**River**. A data window will open with the **Headflow** tab highlighted. You will be prompted to enter average monthly inflow at the head of the river. Below, you will see a table for the rivers (Bear River, Little Bear River, etc.). *For what rivers has headflow data already been specified?* The original headflow data is located in the LowerBearRiverModelData.xlsx Excel file on the worksheets whose names begin with "QX" (e.g., QX46-LittleBearInflow" for the headflow for the Little Bear River). Look at the worksheets in the Excel Workbook. You can also find comma separated values (CSV) files with the same data in the WEAP area folder. *What headflows need to be added to the WEAP model?* Note: not all rivers in the WEAP model will have head flows. *Why?* (hint: skip down to Step 12).

    b. In the WEAP **Headflow** tab, click inside the cell in the **1966** column for the river. A drop-down list icon will appear. Click it and select *ReadFromFile Wizard*. A file window will open. Navigate to and select the corresponding CSV file mentioned in Step 11a. A new window will show you a graph of the time-series you just selected. Click **Finish** to return to the Data window.

    c. Repeat step b to define headflows for other rivers that require it. Note, you will not enter water quality or cost data for rivers.

12. *Reach inflows*. **Reach inflows** are local or tributary inflows (sometimes called reach gains) that flow into a river at downstream locations. These reach inflows are also indicated by arrows in Figure 2 and labeled by source (QX15-Reach Gain; QX22-Reach Gain). These inflows have already been entered in the WEAP model. *To which reaches are the gains assigned?*

13. *Demand Sites*. Demand sites are locations where water is desired to be used and are represented by boxes in Figure 2. In the schematic, right click one of the Demand Sites you added in Step 7a. Select **Edit Data**=>**Method**. A data window will open.

    a. Select the **Advanced** button at the far right. In the **Method** table, click the Demand Site name, select *Specify monthly demand,* and press enter.

    b. Select the **Water Use** button. On the *Annual Activity Level* tab, change **Unit** to *AF* (acre foot). Click in the cell 1967-2006, select *Monthly timeseries wizard,* and enter montly demands in the new window using the demand site data provided in the LowerBearRiverModelData.xlsx Excel file.

    c. On the **Consumption** tab, enter the appropriate *Consumption* rate for the site based on the return flow fraction data provided in the same Excel file.

    d. Ignore the **Loss and Reuse**, **Demand Management**, **Water Quality**, and **Cost** buttons. Verify that the **Priority** setting is correct.

    e. Repeat steps a to d for each Demand Site you created in Step 7a. Verify the other demand sites have the correct data.

14. *Transmission Links*. In the schematic, right click on a *Transmission Link* you added in Step 7c and select **Edit Data**=>**Maximum Flow Volume**. Leave nearly all settings at their default values (i.e., unlimited capacity, no losses, and no costs). On the Supply Preference tab, verify for the New Cache M&I demand site that transmissions from the groundwater have the highest priority (1), and transmission from other sources (e.g., the Bear River) have lower priority (2). For other demand sites, verify all sources have equal priority.

15. *Return Flows*. Right click on a Return Flow you created in Step 7c and select **Edit Data**=>**Return Flow Routing**. Again, leave all settings at their default values (i.e., 100% return flow routing, zero loss from system, zero groundwater loss, zero gain from groundwater, and no costs). *What does a setting of 100% return flow routing mean?*

16. *Reservoir Data*. On the schematic, right click on Above Cutler Reservoir and select **Edit Data**=>**Storage Capacity**. A data window will open. Note that there is no data entered for Above Cutler Reservoir. Enter the **Physical**, **Operation**, and **Priority** data for the reservoir as though it exists by clicking the various buttons. Use Above Cutler Reservoir data provided in the Excel file.

    a. **Physical** Data: On the *Storage Capacity* and *Initial Storage* tabs, enter data using the appropriate units. On the *Volume Elevation Curve* tab, use the two column table provided to enter data for the Volume-Elevation Curve. On the *Net*

Evaporation tab, *chose Monthly Time-Series Wizard* under the year 1966. Then enter the monthly values provided. Leave *Loss to Groundwater* at the default setting of zero.

b. **Operation** Data defines the reservoir zones (pools) and releases from them. Enter storage volumes that correspond to the *Top of Conservation*, *Top of Buffer*, and *Top of Inactive* pools (if not provided, you will need to use your judgement to determine appropriate values). Enter the *Buffer Coefficient* value as 1. This coefficient takes values between 0 and 1 and indicates the fraction of water in the buffer pool available for release each month (should the storage level drop into the buffer pool). The buffer pool represents the storage level at which deliveries to demand sites are cut back (by the buffer coefficient). *What type of operation (that you examined in ILO-4) does a buffer coefficient value of 1 represent? What was your reason for entering the Top of Inactive, Buffer, and Conservation Pool values that you did?*

c. Note, you will not enter hydropower, water quality, or cost data for reservoirs.

d. Now, since the reservoir is proposed (does not yet exist), make it inactive for the base case. To do this, click the **Physical Button** again and in the **Storage Capacity** tab, set the reservoir capacity to a number very close to zero.

e. Look at all the other reservoirs. *Which reservoirs are in-active (or proposed)?*

17. Congratulations! You have now (hopefully) entered all the model data.

Model Results

18. With the system schematic represented and all pertinent data entered, you can now run the model and generate results for the base case that represents current conditions.

19. Click the **Results** icon. When asked to recalculate results, select **Yes**.

20. There are numerous results to view and explore in WEAP. To view results for an element, right-click the element and select **View Results** and the result type. For example:

    a. *Which demand site(s) have unmet demand (i.e., experience shortage(s))?*

    b. *What is the reliability of annual deliveries to the Bear River Canal Company and New Urban Users in Cache County? What is the reliability of annual deliveries to the stakeholder your group is studying for the group project (if the stakeholder is already included in the Lower Bear River model)?*

c. Note that a variety of tools are available at the right-hand-side of plots to reformat and export results, including exporting to Excel.

Scenario Explorer

21. Scenarios allow you to test the effects of new infrastructure, operations, demand forecasts, climate projections, or other changes to model inputs. In this exercise, you will create a second scenario to represent reducing urban water demands by 10% and a third scenario to represent building and operating the Above Cutler reservoir.

22. Create the second scenario and modify some input data to represent reducing urban water demands by 10% from base case demands.

    a. In WEAP, click the **Data** icon. On the top row of the data page, click the **Manage Scenarios** button. In the **Manage Scenarios** window select *Current Accounts(1966)* and click the **Add** button at the top left corner of the window. Finally, **Name** the new scenario something meaningful like *Reduced Urban Use*. Click OK and close the windows to return to the **Data** page.

    b. Now change some/all of the demand site data you entered in Step 7a. Again, *what data did you change?*

    c. Run the new scenario (see Steps 18-20). *What are the answers to questions 20a,b above? How do results for this scenario change from the base case scenario?*

23. Create the third scenario. This scenario will represent building and operating the Above Cutler reservoir. Change some/all of the reservoir data you entered in Step 16a-d, run the new scenario, and again answer the questions: *What data did you change?* *What are the answers to questions 20a,b above?*

Next Steps

24. *What changes will you need to make to the WEAP model for the Lower Bear River basin to represent the stakeholder you are studying for your semester group project?*

Remember to write up your answers to the *italicized, underlined questions* and include as an appendix in your ILO-5 report.

References

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