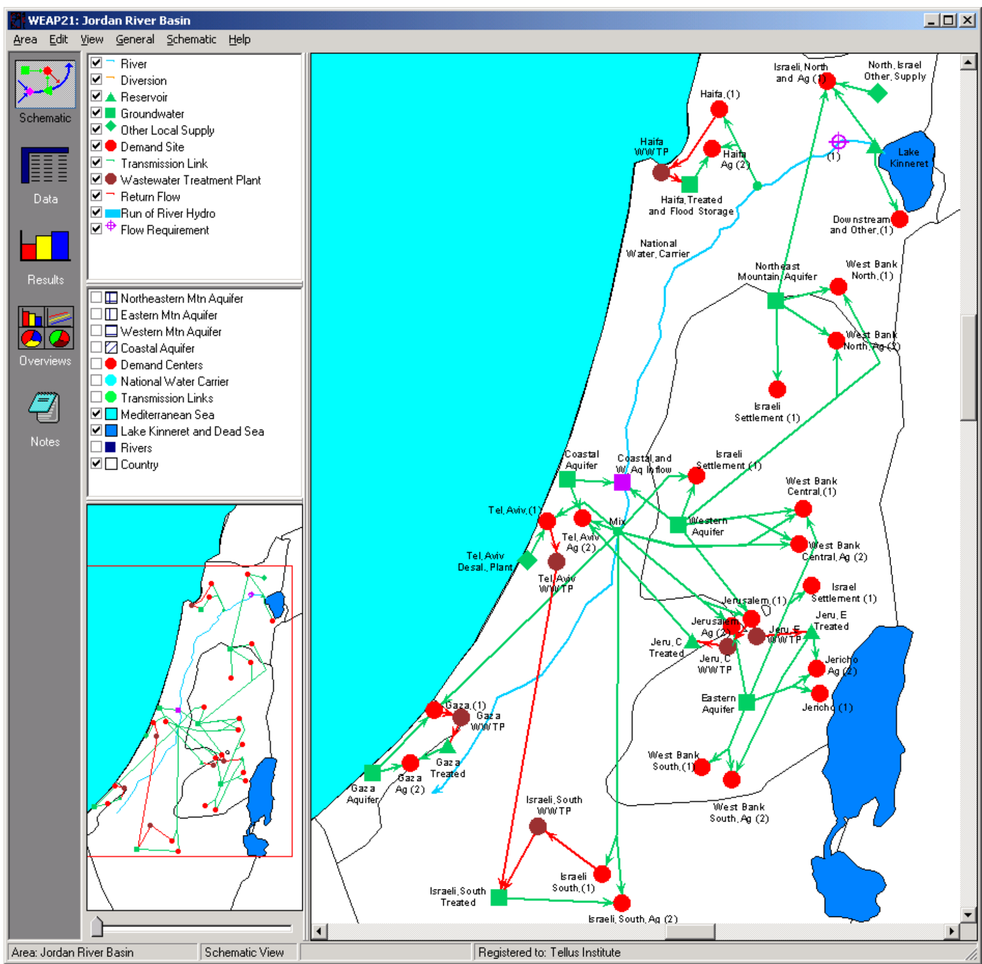
WEAP

Water Evaluation And Planning System

USER GUIDE

for WEAP21



TELLUS INSTITUTE
Resource and Environmental Strategies

SEI STOCKHOLM ENVIRONMENT INSTITUTE

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USER GUIDE

for WEAP21

Paul Raskin, Ph.D., Director
Jack Sieber, M.S., Water Systems Modeler
Annette Huber-Lee, Ph.D., Senior Scientist

Stockholm Environment Institute - Boston
Tellus Institute
11 Arlington Street
Boston, MA 02116-3411 USA

Telephone: (617) 266-5400
Fax: (617) 266-8303
Email: weap@tellus.org
Web: http://www.weap21.org
http://www.tellus.org

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1 Introduction

1.1 Background

Many regions are facing formidable freshwater management challenges. Allocation of limited water resources, environmental quality and policies for sustainable water use are issues of increasing concern. Conventional supply-oriented simulation models are not always adequate. Over the last decade, an integrated approach to water development has emerged which places water supply projects in the context of demand-side issues, as well as issues of water quality and ecosystem preservation.

The Water Evaluation and Planning System (WEAP) aims to incorporate these values into a practical tool for water resources planning. WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation—water use patterns, equipment efficiencies, re-use, prices and allocation—on an equal footing with the supply side—streamflow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies.

WEAP is comprehensive, straightforward and easy-to-use, and attempts to assist rather than substitute for the skilled planner. As a database, WEAP provides a system for maintaining water demand and supply information. As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. As a policy analysis tool, WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

1.2 Overview

Operating on the basic principle of water balance accounting, WEAP is applicable to municipal and agricultural systems, single subbasins or complex river systems. Moreover, WEAP can address an wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, and project benefit-cost analyses.

The analyst represents the system in terms of its various supply sources (e.g., rivers, creeks, groundwater, reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demand and pollution generation. The data structure and level of detail may be easily customized to meet the requirements of a particular analysis, and to reflect the limits imposed by restricted data.

WEAP applications generally include several steps. The study definition sets up the time frame, spatial boundary, system components and configuration of the problem. The Current Accounts provide a snapshot of actual water demands, pollution loads, resources and supplies for the system. Alternative sets of future assumptions are based on policies, costs, technological development and other factors that affect demand, pollution, supply and hydrology. Scenarios are constructed consisting of alternative sets of assumptions or policies. Finally, the scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables.

1.3 The WEAP Approach

Computer modeling in the field of water resources has a long history. Many sophisticated models have faltered by being mathematically obscure and overly ambitious in attempting to "optimize" solutions to real-life problems. Experience shows that the best approach is to build a straightforward and flexible tool to assist, but not substitute for, the user of the model. WEAP represents a new generation of water planning software that utilizes the powerful capability of today's personal computers to give water professionals everywhere access to appropriate tools.

The design of WEAP is guided by a number of methodological considerations: an integrated and comprehensive planning framework; use of scenario analyses in understanding the effects of different development choices; demand-management capability; environmental assessment capability; and ease of use. These are discussed in turn below.

1.3.1 Integrated and Comprehensive Planning Framework

WEAP places the evaluation of specific water problems in a comprehensive framework. The integration is over several dimensions: between demand and supply, between water quantity and quality, and between economic development objectives and environmental constraints.

1.3.2 Scenario Analysis

With WEAP, you first create a Current Accounts of the water system under study. Then, based on a variety of economic, demographic, hydrological, and technological trends, a "reference" or "business-as-usual" scenario projection is established, referred to as a Reference Scenario. You can then develop one or more policy scenarios with alternative assumptions about future developments.

The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water pollution are added? What if a water recycling program is implemented? What if a more efficient irrigation technique is implemented? What if the mix of agricultural crops changes? What if climate change alters the hydrology? These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

1.3.3 Demand Management Capability

WEAP is unique is its capability of representing the effects of demand management on water systems. Water requirements may be derived from a detailed set of final uses, or "water services" in different economic sectors. For example, the agricultural sector could be broken down by crop types, irrigation districts and irrigation techniques. An urban sector could be organized by county, city, and water district. Industrial demand can be broken down by industrial subsector and further into process water and cooling water. This approach places development objectives—providing end-use goods and services—at the foundation of water analysis, and allows an evaluation of effects of improved technologies on these uses, as well as effects of changing prices on quantities of water demanded. In addition, priorities for allocating water for particular demands or from particular sources may be specified by the user.

1.3.4 Environmental Effects

WEAP scenario analyses can take into account the requirements for aquatic ecosystems. They also can provide a summary of the pollution pressure different water uses impose on the overall system. Pollution is tracked from generation through treatment and outflow into surface and underground bodies of water.

1.3.5 Ease of Use

An intuitive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. The main functions—loading data, calculating and reviewing results—are handled through an interactive screen structure that prompts the user, catches errors and provides on-screen guidance. The expandable and adaptable data structures of WEAP accommodate the evolving needs of water analysts as better information becomes available and planning issues change. In addition, WEAP allows users to develop their own set of variables and equations to further refine and/or adapt the analysis to local constraints and conditions.

1.4 Getting Started

Each WEAP analysis is conducted in a single area. An area is typically a watershed, but could also be a larger or smaller geographic region. These help files contain comprehensive information on using the WEAP software. To get started, we suggest you familiarize yourself with some of the major concepts:

- **Help:** Use the Help menu to get access to WEAP's online documentation. Press the **F1** key to get context-sensitive help anywhere in WEAP.
- **Views:** WEAP is structured as a set of five different “views” onto your Area: Schematic, Data, Results, Overview and Notes. These views are listed as graphical icons on the View Bar, located on the left of the screen.
- **Current Accounts**: The Current Accounts represent the basic definition of the water system as it currently exists, and forms the foundation of all scenarios analysis.
- **Scenario analysis** is at the heart of using WEAP. Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. The comparison of these alternative scenarios proves to be a useful guide to development policy for water systems from local to regional scales.
- **User Interface:** This documentation assumes you are familiar with Windows-based programs. The main screen of the WEAP system consists of the View Bar on the left of the screen and a main menu at the top providing access to the most important functions of

the program, and a status bar a the bottom of the screen showing the current area name, current view, licensing information and other status information. The layout of the rest of the screen will depend on which view is selected.

- **Calculation Algorithms**: WEAP calculates a water and pollution mass balance for every node and link in the system on a monthly time step. Water is dispatched to meet instream and consumptive requirements, subject to supply priorities, demand site preferences, mass balance and other constraints.
- **Sample Data**: WEAP comes with a sample data set for a fictional area called the Weaping River Basin. The User Guide refers to this data set when describing data entry screens and reports. It is worthwhile exploring this data set, as it illustrates most of the features of WEAP and the types of analysis that WEAP facilitates. Essentially, the area depicts a river basin with growing problems of water shortages, groundwater depletion and environmental pressures. These problems of the Reference Scenario are addressed in a series of scenarios employing a variety of both demand- and supply-oriented measures.
- **Importing Monthly Inflow Data**: If you have a full sequence of monthly data on inflows to some or all of your rivers and local supplies, the Read From File Method allows you read it from an ASCII data file.
- **Additional Information** on the hardware and software requirements for using WEAP, and on how to license the system and obtain technical support is also available.

1.5 Acknowledgements

Many have contributed to the development and application of WEAP over the past ten years. We would like to acknowledge, in particular, Ken Strzepek, Bill Johnson, Zhongping Zhu, Dmitry Stavisky, Evan Hansen, Paul Kirshen, Tom Votta, David Purkey, Jimmy Henson, Alyssa Holt and David Yates.

2 WEAP Structure

2.1 Main Menu

The main menu in WEAP provides access to the most important functions of the program. There are seven sub-menus:

2.1.1 Area Menu

The area menu provides options for creating, opening, saving and managing areas (typically river basins), as well giving access to Area-wide operations such as managing scenarios, setting print options and exiting WEAP.

2.1.2 Edit Menu

The edit menu gives access to standard Windows editing operations: cut (Ctrl-X), copy (Ctrl-C), paste (Ctrl-V) and undo (Ctrl-Z). Note that the Undo feature is limited to a single undo operation and only within a given text editing box. WEAP does not currently support undoing of operations that affect data structures, nor does it support multi-level undo.

2.1.3 View Menu

The View menu allows you to switch between the five basic views in the WEAP system. It also lets you show or hide the View Bar, which by default is shown on the left of the screen. If the View Bar is hidden (to make more room on screen), use the View menu to switch views. See the View Bar help topic for a description of each view.

2.1.4 General Menu

The general menu gives access to basic parameters, such as the time horizon and units used for your analysis and the pollutants to be modeled. In addition, various formatting options are available for the Schematic View.

2.1.5 Tree Menu

The tree menu is used to edit and navigate through the Tree which appears in the Data View. Options on this menu allow you to add, rename, delete, move and organize branches. See “Editing the Tree” for more information. Many of these functions are also available by right-clicking on the Tree.

2.1.6 Favorites Menu

The Favorites menu, which is only displayed when in Results View, lets you save favorite charts including all settings for the axes, type of chart, and formatting. This feature is similar to the bookmark/favorites features found on popular Internet browsing software. In the Overviews View, you can group together favorite charts to create overviews of different results. Use the "Save Chart as Favorite" option to bookmark the current highlighted chart. You will be asked to give the favorite a name. Use the "Delete Favorite" option to delete a saved favorite. To switch to a favorite chart, select its name from the favorites menu.

2.1.7 Help Menu

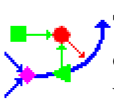
The Help menu gives access to the contents, index and search pages of WEAP's help system. You can also press the **F1** key at any time to access context-sensitive help appropriate to the screen you are working in.

The Help menu also gives access to the WEAP web site (this requires an Internet connection) and lets you send an email to SEI-Boston requesting technical assistance. This feature requires that you have a MAPI compliant email system installed on your PC, such as Microsoft Outlook or Netscape Navigator. An "About" screen gives you contact information should you wish to contact SEI-Boston by mail, phone or fax. This screen also gives you system information which can be useful in identifying problems you may encounter while running WEAP. An option labeled "**Check on Internet for Updates**" automatically checks for newer versions of WEAP over the Internet, and installs them onto your PC. This is the preferred method of updating the software as it requires a much smaller download compared to a full download and re-installation of the system. WEAP will automatically check for a newer version on startup, if there is an active Internet connection at the time.

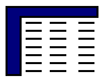
NB: the versions of WEAP available on the Internet work by default in "evaluation" mode (i.e., with the "Save" feature disabled). For those using this version, the "Register WEAP" option can be used to enter a user name and registration code to fully unlock the software. User names and registration codes are distributed by SEI-Boston to licensed users of the system. Visit the WEAP web site for more information on licensing WEAP.

2.2 View Bar

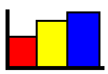
WEAP is structured as a set of five different "views" of your area. These views are listed as graphical icons on the "View Bar", located on the left of the screen. Click an icon in the View Bar to select one of the views. For the Results and Overviews view, WEAP will calculate scenarios before the view is displayed, if any changes have been made to the system or the scenarios.



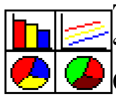
The Schematic View is the starting point for all activities in WEAP. A central feature of WEAP is its easy-to-use "drag and drop" graphical interface used to describe and visualize the physical features of the water supply and demand system. This spatial layout is called the **schematic**. You can create, edit and view it in the Schematic View. GIS layers can be added to add clarity and impact. The Schematic View provides you with one-click access to your entire analysis—right click on any element in the schematic to access its data or results.



The Data View is the place where you create your data structures, models and assumptions in WEAP. In the Data View, the screen is divided into four panes. On the top left, a hierarchical tree is used to create and organize data structures under six major categories Key Assumptions, Demand Sites, Hydrology, Supply and Resources, Environment, and Other Assumptions. The tree is also used to select the data to be edited, which is shown on the right of the screen. For example, clicking on the "Demand Sites" tree branch on the left of the screen, will display the data for all demand sites on the right of the screen. On the bottom left is a data inset schematic. Clicking on an element in the schematic will result in a jump to its place on the tree. On the top-right of the screen, a data entry table is used to edit data and create modeling relationships. The information you enter here is displayed graphically in the bottom right pane.



The Results View displays a wide variety of charts and tables covering each aspect of the system: demand, supply, costs, and environmental loadings. Customizable reports can be viewed for one or more scenarios. You can also use the "Favorites" option to bookmark the most useful charts for your analysis.



The Overviews View is used to group together "Favorite" charts (created earlier in the "Results" view) which can then be displayed on the screen simultaneously. With Overviews, you can get a birds-eye perspective on different important aspects of your system, such as demand, coverage, storage levels, environmental impacts and costs. You can create multiple Overviews, each of which can display up to 16 different Favorites.

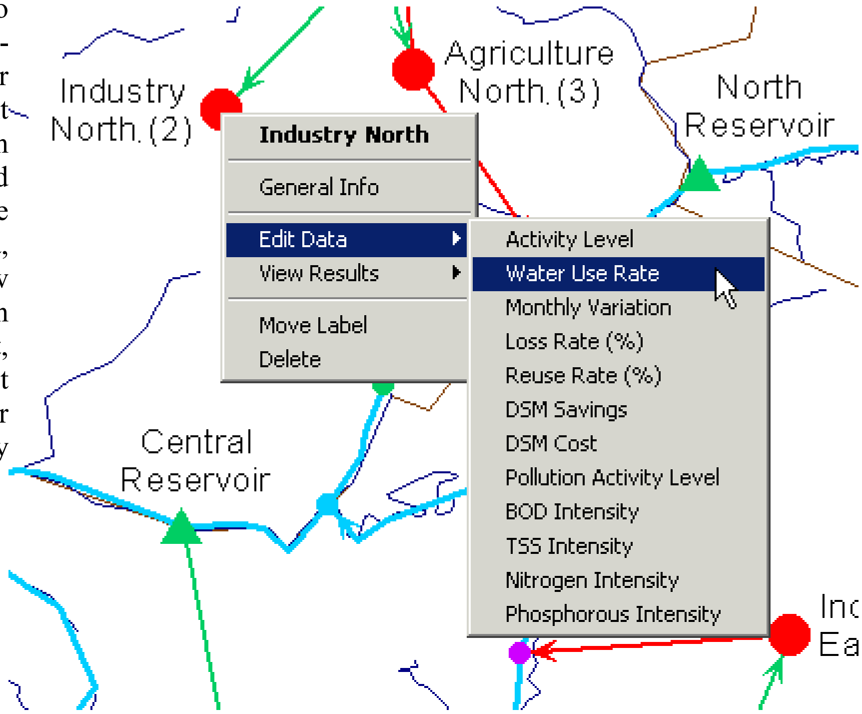
The Notes View is a simple word processing tool with which you can enter documentation and references for each branch of the tree. To edit the notes, either type directly into the Notes Window, or select **Edit** to display a larger window with additional word-processing features. Notes can include formatting (bold, underline, fonts, etc.) and can also include standard Windows "objects" such as spreadsheets. Use the **Print** and **Print All** buttons (🖨) to print one or all of the notes or the **Word** buttons to export one or all of the notes to Microsoft Word. We highly recommend extensive use of notes to document each scenario.

Tip: If you are working on a low-resolution screen, we suggest that you hide the View Bar to make more space on the screen. Use the menu option **View: View Bar** to do this. You will then need to use the **View** menu to select the different views.

2.3 Schematic View

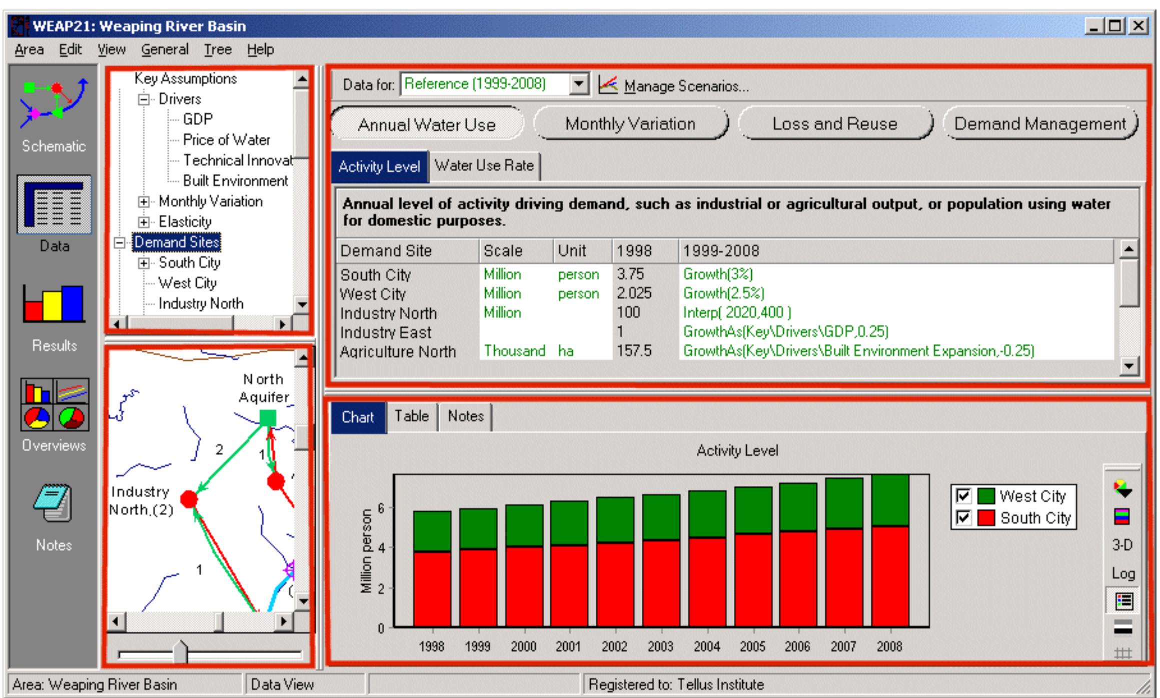
The Schematic View is the starting point for all activities in WEAP. A central feature of WEAP is its easy-to-use "drag and drop" graphical interface used to describe and visualize the physical features of the water supply and demand system. This spatial layout is called the **schematic**. You can create, edit and view it in the Schematic View. GIS layers can be added to add clarity and impact.

The schematic also provides you with one-click access to your entire analysis. Right-click on any element in the Main Schematic, and choose the data variable to edit under Edit Data, or the result table to view under View Results. In the example at the right, the user is about to edit Water Use Rate data for the demand site Industry North.



2.4 Data View

In the **Data View** you build the model of your system, entering the data structures, data, assumptions, modeling relationships and documentation for the Current Accounts and for each scenario. The screen is divided into four panes (marked by boxes in figure below):



2.4.1 Tree

On the top left, a hierarchical tree is used to create and organize data structures under six major categories Key Assumptions, Demand Sites, Hydrology, Supply and Resources, Environment, and Other Assumptions. The tree is also used to select the data to be edited, which is shown on the right of the screen. For example, clicking on the "Demand Sites" tree branch on the left of the screen, will display the data for all demand sites on the right of the screen. See Tree Overview for more information.

2.4.2 Inset Schematic

A small schematic of your area is located on the bottom left. When you click on an element, it will be highlighted in the tree (above) and its data will be displayed in the data entry tables to the right. Move the **zoom bar** (below the schematic) to zoom in or out. Alternatively, hold down the **Ctrl** key and click and drag to define a region to zoom in to. Hold down the **Shift** key and click and drag on the schematic to pan.

2.4.3 Data Entry Tables

The data entry tables on the top right are used to enter expressions that define Current Accounts and Scenario values of variables. Depending on which branches you click on the tree, different data entry tables will be available. For example, when editing groundwater sources you will see tabs giving access to "Storage Capacity", "Initial Storage" (only in Current Accounts), "Maximum Withdrawal" and "Natural Recharge". Select a table by clicking on the tab. The variables for some types are grouped into categories. For example, click on Demand Sites and you will see three category buttons labeled "Annual Water Use", "Monthly Variation", "Loss and Reuse" and "Demand Management". Click on one of these buttons to see the variables in that category. For example, "Annual Water Use" has two variables: "Activity Level" and "Water Use Rate". There are wizards to help you construct the expressions—see Expression Builder, Yearly Time-Series Wizard and Monthly Time-Series Wizard.

Immediately above the data entry tables is a toolbar containing a selection box and the Manage Scenarios button. Use the selection box to choose which data to edit—Current Accounts or one of the Scenarios. Click on Manage Scenarios to create, rename or delete scenarios, or to change their inheritance relationships.

2.4.4 Data Entry Results

The bottom right pane displays the data you entered in the top pane as either a chart or a table. These let you quickly examine the values generated by the expressions you have entered above. A toolbar on the right of the pane gives access to a range of options for formatting charts and tables (e.g. picking chart type and stacking options, colors, 3D effects, grids, number of decimal places, etc.) and for printing and copying charts and tables and exporting tables to Microsoft Excel.

The bottom pane also gives access to a notes screen: a word processing tool in which you can enter documentation and references for each branch of the tree. To edit the notes, right-click and select **Edit** to display the notes in a larger window, which includes a basic set of word processing controls. Notes can include formatting (bold, underline, fonts, etc.) and can also include standard Windows “objects” such as spreadsheets.

You may resize each of these four panels by dragging the dividing bars between them.

2.5 Results View

Once you have entered data for your area, WEAP can run its monthly simulation and report projections of all aspects of your system, including demand site requirements and coverage, streamflow, instream flow requirement satisfaction, reservoir and groundwater storage, hydropower generation, evaporation, transmission losses, wastewater treatment, pollution loads, and costs.

The Results View is a general purpose reporting tool for reviewing the results of your scenario calculations in either chart or table form. Monthly or yearly results can be displayed for any time period within the study horizon. The reports are available either as graphs or tables and can be saved as text, graphic or spreadsheet files. You may customize each report by changing: the list of nodes displayed (e.g., demand sites), scenarios, time period, graph type, unit, gridlines, color, or background image. (See Charts and Tables for more details.) Once you have customized a report, you can save it as a “favorite” for later retrieval. Up to sixteen “favorites” can be displayed side by side by grouping them into an “overview”. Using favorites and overviews, you can easily assemble a customized set of reports that highlight the key results of your analysis.

In addition to its role as WEAP's main reporting tool, the Results View is also important as the main place where you analyze your intermediate results to ensure that your data, assumptions and models are valid and consistent.

The reports are grouped into three categories: Demand, Supply and Resources, and Environment.

2.6 Overviews View

The Overviews View is used to group together multiple “Favorite” charts (created earlier in the Results View) on screen. With Overviews, you can simultaneously examine different important aspects of your system, such as demand, coverage, storage levels, environmental impacts and costs.

You can create multiple Overviews, each of which can display up to 16 different charts. The first time you access the system, WEAP will display a standard set of charts. After you define your own favorites, you can use the Overview Manager to select which favorite charts you want to include in your particular overview. You can also use the Overview manager to add, rename or delete overviews.

To zoom in to one of the charts shown in an Overview, double-click it or click the zoom button (). You will then switch to the Results View, with this chart displayed. If you change the formatting of the chart and want to save these customizations, choose the menu option Favorite, Save Chart as Favorite.

You can apply a couple of formatting options across all charts shown in the Overview: click on **3D** to set the 3D effect for all charts, or legend () to show or hide all legends.

2.7 Notes View

The notes screen is a simple word processing tool with which you can enter documentation and references for each branch of the tree. To edit the notes, either type directly into the Window, or right-click and select **Edit** to display a larger window with additional word-processing features.

Notes can include formatting (bold, underline, fonts, etc.) and can also include standard Windows "objects" such as spreadsheets. Use the Print and Print All buttons ( ) to print one or all of the notes or the **Word** buttons to export one or all of the notes to Microsoft Word.

3 Setting Up Your Analysis

To setup an area, the problem under study is characterized by defining physical elements comprising the water demand-supply system and their spatial relationships, the study time period, units, hydrologic pattern, and, when needed, pollutants and cost parameters. A central feature is an easy-to-use "drag and drop" graphical interface used to lay out and visualize the physical features of the water supply and demand system. This spatial layout represents the Schematic.

3.1 Creating an Area

An area in WEAP is defined as a self-contained set of data and assumptions. Its geographical extent is typically a river basin. The data is separated into Current Accounts and any number of alternative scenarios. An area is sometimes referred to as a data set.

A study area can be a set of demand sites defined by political or geographic boundaries. It can also be defined as a specific water supply system such as a river basin or a groundwater aquifer. In one case, the point of focus will be the demand sites, while in another, it will be the water supplies in a region of interest. In yet other cases, it may be necessary to conceive of both a set of demand sites and the specific river system together as the study area. Study area boundaries could be somewhat more flexible than the rigid definition of the hydrologic boundaries in order to include the adjacent demand areas served by water supplies from within the hydrologic supply system, or possibilities of importing or exporting water from or to sites outside the study area.

Whichever you choose, ultimately the study area in WEAP will contain a distinct set of information and assumptions about a system of linked demands and supplies. Several different study areas as defined in WEAP could actually be used to represent the same geographic area or watershed, each under alternative configurations or different sets of demand data or operating assumptions. In this way, study areas can be thought of as representing separate databases where different sets of water supply and demand data are stored, managed and analyzed.

To begin your analysis, you will first create a new area. To do so, choose Area, New Area… from the Main Menu. When creating a new area, you can begin with a copy of an existing area or start fresh with a blank area. If starting from a blank area, you will be prompted to Set Area Boundaries.

3.1.1 Set Area Boundaries

Here you can change the geographical extent of your study area. The Set Area Boundaries dialog shows an inset schematic on the lower left, which controls what is shown on the main schematic on the right. The main schematic has a green box that indicates the current area boundaries. To change, click and drag on the main schematic to specify the new boundaries.

Menu Option: Schematic: Set Area Boundaries

3.2 Schematic

The Schematic View is the starting point for all activities in WEAP. A central feature of WEAP is its easy-to-use “drag and drop” graphical interface used to describe and visualize the physical features of the water supply and demand system. This spatial layout is called the **schematic**. You can create, edit and view it in the Schematic View. GIS layers can be added to add clarity and impact.

3.2.1 Screen Layout

WEAP Legend

The **legend**, shown in the upper left corner of the Schematic View, lists the symbols used to represent each type of WEAP component. The checkbox next to each symbol can be used to hide or show all elements of that type on the schematic. To create a new element, simply click on its symbol in the legend and drag to the schematic on the right.

Background Maps

You may display GIS layers as overlays or backgrounds on your WEAP Schematic. These **background maps** are listed on the left side of the Schematic View, below the legend. The checkbox next to each layer can be used to hide or show it on the schematic.

To add a layer, right click on the list of background layers and choose Add Vector Layer (ArcView Shapefiles: *.SHP) or Add Raster Layer (ArcView GRID: hdr.adf). The right-click context menu also allows you to edit, delete or reorder the background maps.

Inset Schematic

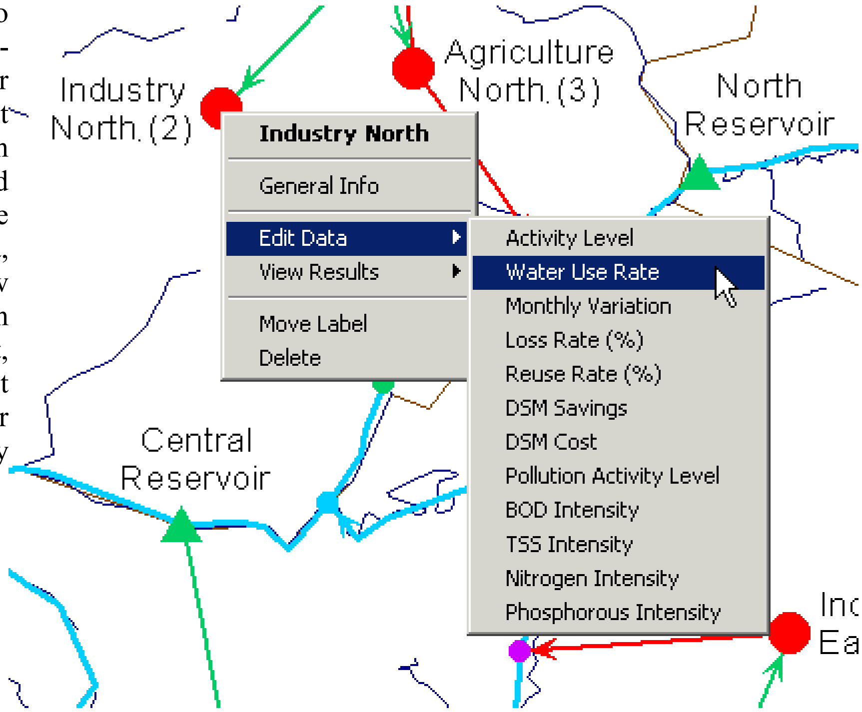
On the left side of the Schematic View, below the list of background maps, you will find the **inset schematic**. This small schematic always shows your complete area, and may be used to zoom in and out of the display on the main schematic. The area currently shown in the main schematic is indicated by a red box on the inset schematic. Click and drag on the inset schematic to change what is shown on the main schematic. You can also move the **zoom bar** (below the inset schematic) to zoom in or out.

Main Schematic

The large area on the right side of the Schematic View shows the **Main Schematic**. It is here that you will create and edit the schematic. Click and drag a symbol from the WEAP legend on the left and drop it on the main schematic on the right to create a new object. You can also click and drag an object on the main schematic to move it. Right click an object on the main schematic to edit general properties or data, view results, delete, or to move the label. These actions are described in more detail below.

The schematic has scroll bars for moving side to side. You may also hold down the **Shift** key and click and drag on the schematic to pan. To zoom in, hold down the **Ctrl** key and click and drag to define a region to zoom in to.

The schematic also provides you with one-click access to your entire analysis. Right click on any element in the Main Schematic, and choose the data variable to edit under Edit Data, or the result table to view under View Results. In the example at the right, the user is about to edit Water Use Rate data for the demand site Industry North.



3.2.2 Elements of a WEAP Schematic

A node represents a physical component such as a demand site, wastewater treatment plant, groundwater aquifer, reservoir or special location along a river. Nodes are linked by lines that represent the natural or man-made water conduits such as river channels, canals and pipelines. These lines include rivers, diversions, transmission links and return flow links. A river reach is defined as the section of a river or diversion between two river nodes, or following the last river node. WEAP refers to a reach by the node above it.

Each node (except demand sites and tributary nodes) may have a startup year, before which it is not active. With this feature you can include nodes in the analysis that may be built after the Current Accounts Year, or selectively exclude nodes from some scenarios. To exclude a node from a scenario entirely, set it to be not active in the Current Accounts, then enter 0 for the startup year. WEAP will ignore any nodes (not active in the Current Accounts) with startup year equal to 0.

To capture the features of most water systems, different types of components (or nodes) are incorporated in WEAP. Below we present detailed descriptions of each type of component. In Calculation Algorithms we present the set of rules defining system water allocation and storage in successive time periods.

Demand Sites

A demand site is best defined as a set of water users that share a physical distribution system, that are all within a defined region, or that share an important withdrawal supply point. You also must decide whether to lump demands together into aggregate demand sites (e.g., counties) or to separate key water uses into individual demand sites. The level of aggregation generally is determined by the level of detail of water use data available. Demand data may not be available for individual sites, but may only be available for a larger unit such as a city or county. In addition to data, your definition of demand sites may also depend on the level of detail desired for your analysis.

When defining demand sites, it is useful to inventory the actual physical infrastructure, such as pumping stations, withdrawal facilities, wastewater treatment plants and well fields. You should think carefully about the configuration of the entire demand and supply system, including the links between supplies and demands. You should also take into consideration the details of the water accounting picture you wish to present, any key water uses, and any key supply sources and river points that need to be tracked, described and evaluated. You might want to define demand sites according to the following groupings:

- major cities or counties
- individual user which manages a surface or groundwater withdrawal point, such as an industrial facility
- irrigation districts
- demands which return to a unique wastewater treatment plant
- water utilities

Each demand site needs a transmission link from its source, and where applicable, a return link either directly to a river, wastewater treatment plant or other location. The demand site cannot be placed directly on the river. The user-defined priority system determines the order of allocations to demand sites.

Local Supplies

Three types of Local Supplies (i.e., those not connected to a river) can be defined in WEAP:

- **groundwater** sources, with natural inflow, demand site and wastewater treatment plant returns, river interactions and storage capability between months.
- **local reservoir** sources, with predetermined monthly inflows, demand site and wastewater treatment plant returns, storage capability between months, and hydropower generation capability. In contrast to river reservoir nodes, they are managed independently of any river system.
- **other** sources, with predetermined water quantities available on a monthly basis, but with no storage capability between months (e.g., streams or other unconnected rivers, inter-basin transfers or other imports, and desalination plants

Local supplies can be linked to any number of demand sites. The user must assign a preference to each link to order withdrawals. Demand site and wastewater treatment plant return flows can be returned to groundwater sources and local reservoir sources, but since “other” sources do not have storage capability, WEAP does not capture the water returned to them.

Rivers, Diversions and River Nodes

Both rivers and diversions in WEAP are made up of river nodes connected by river reaches.

Other rivers may flow in (tributaries) or out (diversions) of a river. There are seven types of river nodes:

- **reservoir** nodes, which represent reservoir sites on a river. A river reservoir node can release water directly to demand sites or for use downstream, and can be used to simulate hydropower generation.
- **run-of-river hydropower** nodes, which define points on which run-of-river hydropower stations are located. Run-of-river stations generate hydropower based on varying streamflows but a fixed water head in the river.
- **flow requirement** nodes, which defines the minimum instream flow required at a point on a river or diversion to meet water quality, fish & wildlife, navigation, recreation, downstream or other requirements.
- **withdrawal** nodes, which represent points where any number of demand sites receive water directly from a river.
- **diversion** nodes, which divert water from a river or other diversion into a canal or pipeline called a diversion. This diversion is itself, like a river, composed of a series of reservoir, run-of-river hydropower, flow requirement, withdrawal, diversion, tributary and return flow nodes.
- **tributary** nodes define points where one river joins another. The inflow from a tributary node is the outflow from the tributary river.
- **return flow** nodes, which represent return flows from demand sites and wastewater treatment plants. (You may actually have return flows enter the river at any type of river node: reservoir, run-of-river, tributary, diversion, flow requirement, withdrawal, or return flow node.)

Transmission Links

Transmission links deliver water from local supplies, reservoir nodes, and withdrawal nodes to satisfy final demand at demand sites. WEAP uses two user-defined systems to determine the water allocation along each transmission link in each month, as described in Supply Priority, Demand Preferences and Allocation Order.

Return Flow Links

Water that is not consumed at a demand site can be directed to one or more wastewater treatment plants, river nodes or local supply sources. Return flows are specified as a percentage of satisfied demand.

Wastewater treatment plant return flow can be directed to one or more river nodes or local supply sources. Like demand site return flows, they are specified as a percentage of inflows.

Wastewater Treatment Plants

Wastewater treatment plants receive water from demand sites, remove pollutants, and then return treated effluent to one or more river nodes or local supply sources. A wastewater treatment plant can receive wastewater from multiple demand sites.

Priorities for Water Allocation

Two user-defined priority systems are used to determine monthly allocations from local supplies and river nodes to demand sites, and for instream flow requirements.

Competing demand sites and flow requirements are allocated water according to their **supply priorities**. The supply priority is attached to the demand site or flow requirement, and can be changed by right clicking on it and selecting General Info. Priorities can range from 1 to 99, with 1 being the highest priority and 99 the lowest. Many can share the same priority. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered. If priorities are the same, shortages will be equally shared. Typically, you would assign the highest priorities (lowest priority number) to critical demands that must be satisfied during a shortfall, such as a municipal water supply.

If a demand site is connected to more than one supply source, you may rank its choices for supply with **demand preferences**. The demand preferences are attached to transmission links, and can be changed by right clicking on a link and selecting General Info, or Edit Data, Demand Site Preference.

Using the supply priorities and demand preferences, WEAP determines the **allocation order** to follow when allocating the water. The allocation order represents the actual calculation order used by WEAP for allocating water. All transmission links and instream flow requirements with the same allocation order are handled at the same time. For example, flows through transmission links with allocation order 1 are computed, while temporarily holding the flows in other transmission links (with higher allocation order numbers) at zero flow. Then, after order 1 flows have been determined, compute flows in links with allocation order 2, while temporarily setting to zero flows in links ordered 3 and higher.

In general, if a source is connected to many demand sites with the same supply priority, WEAP attempts to allocate these flows simultaneously, regardless of the demand preferences on the links. For example, demand site DS1 is connected both a river and a groundwater source, with preference for the groundwater, while demand site DS2 is only connected to the river. Both demand sites have the same supply priority. The allocation orders would be 1 for DS1's link to the groundwater, and 2 for the demand sites' links to the river. In calculations, first DS1 is allocated water from groundwater, then both DS1 and DS2 are allocated water from the river. In this way, both demand sites have an equal chance to receive water from the river in the case of a water shortage. Note: in some unusual configurations, the demand preferences may be inconsistent with this rule. In those cases, a demand preference of 1 is used.

You may switch among viewing supply priorities, demand preferences or allocation orders on the schematic: from the Main Menu, select General, Change Priority View.

3.2.3 Creating and Editing WEAP Elements

Creating

To create a **new node** (demand site, local supply source, river node, wastewater treatment plant or flow requirement), merely click on the node's symbol in the WEAP legend and drag it anywhere inside the main schematic. To create a **new river** or diversion, click on the symbol (a line segment) in the legend and drag onto the main schematic, then release the mouse button to specify the headflow. Next, single click once for each intermediate point on the river, then double click to specify the endpoint of the river, as modeled in this particular system.

When you create a node or river, you will be prompted to enter the object's Name, a Schematic Label (used only for display on the schematic), and whether or not it is Active in the Current Accounts. The label can be displayed as multi-line text—use semicolons to indicate line breaks. The label will be displayed below the object. However, you can move the label anywhere you want to enhance the legibility of the Schematic. Right click on the object and choose the Move Label option. When you create a demand site or flow requirement, you will be prompted to enter its Supply Priority.

A river consists of a headflow point, an endpoint, and zero or more points in between. You may add as many bends in the river as you wish, to more closely approximate the actual shape of the river. To add a new bend in the river, just click on any straight section of the river and drag to create a bend.

To add a **new transmission (i.e., withdrawal) or return link**, click on the symbol (a line segment) in the legend for the desired type of link and drag onto the main schematic, releasing the mouse button on the node or river where the link originates. Next, single click once for each intermediate point on the link, then double click on the destination node. You will be prompted to enter the demand site's preference for the supply connected to this transmission link.

For instance, to create a transmission link from a local reservoir to a demand site, click on the transmission link symbol in the legend, drag it to the local reservoir and release, then double click on the demand site. When you create a transmission link, you will be prompted to enter the Demand Preference. To later add new bends in the link, just click on any straight section of the link and drag to create a bend.

River **withdrawal nodes** will automatically appear if you start a transmission link from a previously unused place along the river. Similarly, a **return flow node** will automatically appear if you end a return flow link on a previously unused place along the river.

Moving

To move an existing node in the schematic, merely click and drag the object to its new location. When you move a river node, the river underneath the node will not move with the node. For instructions on moving a river node along with the river underneath, see Moving Multiple Elements at Once below.

You may move a node from one river to another. Because reservoirs can exist both on (river reservoir) or off (local reservoir) a river, you may move a river reservoir off of a river, or a local reservoir onto a river.

Moving Multiple Elements at Once

For convenience, there is a way to move more than one object at a time. To select multiple objects, hold down the Alt key as you click and drag on the main schematic to draw a grouping box around the intended objects. After a moment, a red box will appear. Click inside this red box and drag to move all objects, including river points.

Deleting

To delete any object (node, link, river point), simply right click on it and select Delete. You will be prompted for confirmation before the object is deleted (except for river points). Transmission and return flow links to the deleted object will also be deleted. If you delete a river, all its river nodes will also be deleted.

Edit General Info

To edit information associated with a node, link or river (name, schematic label, active in Current Accounts, supply priority, demand preference), right click on the object and choose the General Info option. A dialog will pop up with the relevant information.

Connecting and Disconnecting Rivers and Diversions

To have one river flow into another (a tributary), move the endpoint from the first river onto a previously unused place along the second river. A tributary node will appear, connecting the two rivers. To disconnect a tributary, right click on it and choose Disconnect Endpoint.

To have one river flow out of another (a diversion), move the headflow point from the first river onto a previously unused place along the second river. A diversion node will appear, connecting the two rivers. To disconnect a diversion, right click on it and choose Disconnect Headflow.

3.2.4 Schematic Options

Set WEAP Node and Label Size

You may change the size of the WEAP symbols and labels. These options are available either from the **General** menu or by right clicking on the WEAP Legend. The dialog has a slider bar to make the nodes or labels either larger or smaller.

Menu Option: Schematic: Set WEAP Node Size or Set WEAP Node Label Size

Priority Views

You may view supply priorities (for demand sites and flow requirements), demand preferences (for transmission links) or allocation orders (for transmission links and flow requirements) on the schematic. See WEAP priority system for more information.

Menu Option: Schematic: Change Priority View

Show or Hide by Element Type

In some cases, you may wish to temporarily hide certain types of objects from display, such as all demand sites or wastewater treatment plants. Uncheck the box on the WEAP legend next to the type you want to hide. You may hide all objects at once: choose the **Hide All WEAP Objects** option from the General menu or from the right-click menu on the WEAP legend. Once some or all WEAP objects are hidden, an option to **Show All WEAP Objects** will be available.

3.3 General Area Parameters

3.3.1 Basic Parameters

The Basic Parameters screen is used to define the basic settings for your analysis.

Time Horizon

Enter the **Current Accounts Year** and **Last Year of Scenarios**. WEAP performs a monthly analysis from the first month of the Current Accounts Year through the last month of the Last Year. The Current Accounts Year is usually the most recent year for which reasonably reliable and complete data are available and from which future demand projections can be made. The Current Accounts year data comprise the **Current Accounts**, which all scenarios use as the basis for their projections.

Monetary

Select the Monetary **Unit** and **Discount Rate** for your study. The discount rate is used only in the Results view, to discount future costs.

Menu Option: General: Basic Parameters

3.3.2 Pollutants

WEAP tracks pollution loads, from their generation at demand sites to their processing at wastewater treatment plants and flows to the environment. On the pollutant setup screen, you may define up to 10 pollutants to track in your application. Set the **scale** and **unit** as appropriate for entering the annual production of the pollutant by the demand site, per unit of activity.

Menu Option: General: Pollutants

3.3.3 Units

Here you choose the units for data entry. The exception is the **Default Water Use Rate** set on the **Demand** tab. The Default Water Use Rate you set will be the default data entry unit, but you will be able to change the units individually for each branch.

Regardless of the unit used for data entry, you can view the results in any units.

Menu Option: General: Units

4 Data

4.1 Current Accounts

The Current Accounts represent the basic definition of the water system as it currently exists. Establishing Current Accounts requires the user to "calibrate" the system data and assumptions to a point that accurately reflects the observed operation of the system. The Current Accounts are also assumed to be the starting year for all scenarios. Note that the Current Accounts Year is not meant to be an "average" year, but the best available estimate of the current system in the present. The Current Accounts include the specification of supply and demand data (including definitions of reservoirs, pipelines, treatment plants, pollution generation, etc.) for the first year of the study on a monthly basis.

4.2 Scenarios

At the heart of WEAP is the concept of scenario analysis. Scenarios are self-consistent story lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. Using WEAP, scenarios can be built and then compared to assess their water requirements, costs and environmental impacts. All scenarios start from a common year, for which you establish your Current Accounts data.

The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water pollution are added? What if a water-recycling program is implemented? What if a more efficient irrigation technique is implemented? What if the mix of agricultural crops changes? What if climate change alters the hydrology?

Scenarios in WEAP encompass any factor that can change over time, including those factors that may change because of particular policy interventions, and those that reflect different socio-economic assumptions. Sensitivity analyses may also be done by varying uncertain factors through their range of plausible values and comparing the results.

4.2.1 Scenario Inheritance

An important concept in using scenarios is the idea of scenario inheritance. In WEAP's Data View, you create mathematical expressions that define the data values of each branch/variable combination in your analysis. Scenario inheritance allows you to create hierarchies of scenarios that inherit default expressions from their parent scenario. Initially, you create expressions for the Current Accounts. These can either be constant expressions, or expressions that generate a time-series of values. Then, you can create additional scenarios, with expressions that either simply inherit the Current Accounts expressions, or override these for particular branches and variables. So, for example, you might create a scenario that examines an irrigation efficiency program, that inherits most of its expression from a baseline "business as usual" scenario. Because the efficiency scenario inherits from the baseline scenario, when initially created it will contain exactly the same expressions as the baseline scenario, and hence will yield exactly the same results. To fully define the scenario you only need to type in expressions to reflect the branches and variables affected by the irrigation efficiency program. The inherited expressions for all other branches stay the same. You can define any number of levels of inheritance. So for example you could make a irrigation efficiency scenario that inherits from the first, with slightly revised assumptions. This approach makes it very easy to edit and organize scenarios, since a) they can be created with a minimum of data entry and b) common assumptions in families of scenarios can be edited by just editing the parent scenario. The ability to establish scenario inheritance is demonstrated in Manage Scenarios.

When editing scenario data in WEAP's Data View, the expression fields in data entry tables are **color coded** to show which expressions have been entered explicitly in the current scenario, and which are inherited either from a parent scenario or from the data specified for Current Accounts. Green text indicates a value entered explicitly in the current scenario, while black text indicates an inherited value (or data entered in Current Accounts).

4.2.2 Create and Manage Scenarios

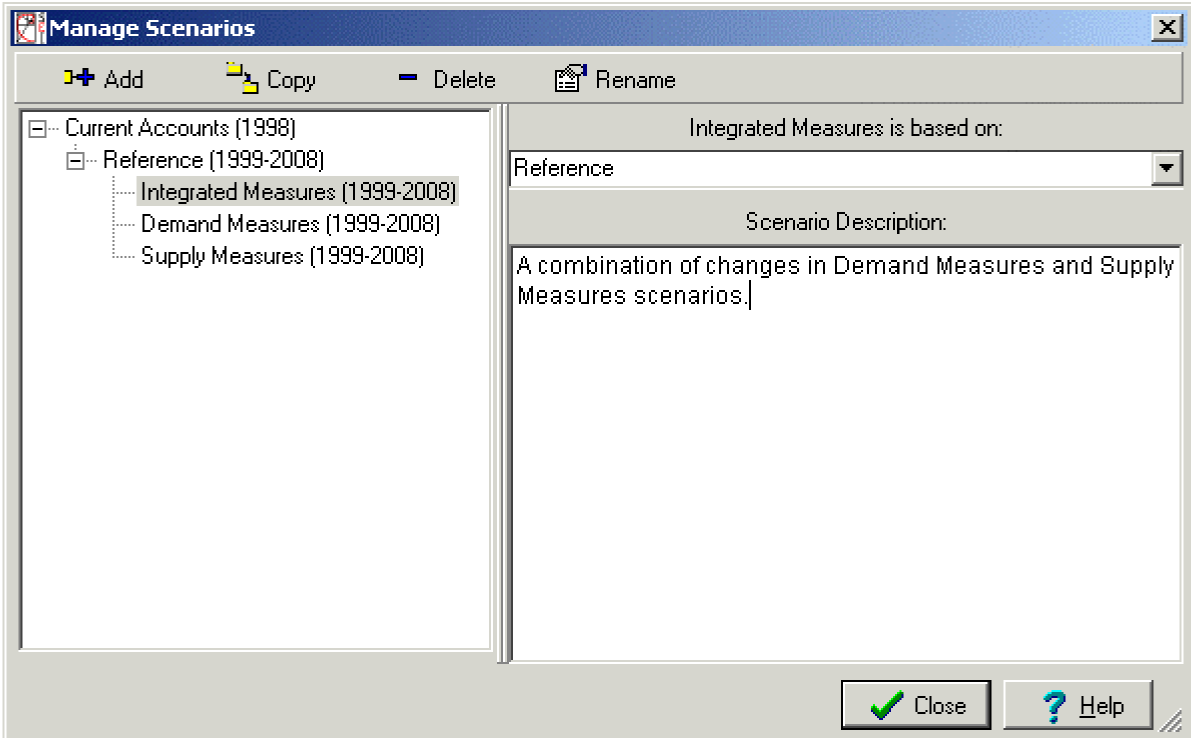
Use the Manage Scenarios screen, to create, delete, organize and set the properties of the scenarios in an Area.

The tool bar at the top of the Scenario Manager lets you add, copy, delete and rename scenarios. Click on **Add** (✚) to add a new scenario, immediately under the current scenario. Click on **Delete** (▬) to delete a scenario. Bear in mind that deleting a scenario will also delete all data associated with that scenario. Click on **Copy** ( ) to make a copy of a scenario with a different name, and click on **Rename** to rename the scenario.

On the left side of the screen, the Area's scenarios are listed in a hierarchical tree showing the main scenario inheritance structure. Scenario inheritance describes how each scenario inherits the expressions from the scenarios above it in the hierarchy. For more information, refer to Scenario Inheritance. Click on a scenario in the tree to edit it or to add a new scenario beneath it.

On the right of the screen, you can edit a scenario's inheritance and description. Use the **is based on** selection box to change the scenario's "parent." For those branch/variable combinations in the scenario for which no expression has been explicitly defined, a default expression is inherited from one of its ancestor scenarios. First the parent is checked for an expression. If none is found, then the parent's parent is searched. This continues until an expression is found, either in an ancestor scenario or in the Current Accounts.

In the example shown below, there are four scenarios defined—a Reference scenario, and three variants of the Reference scenario.

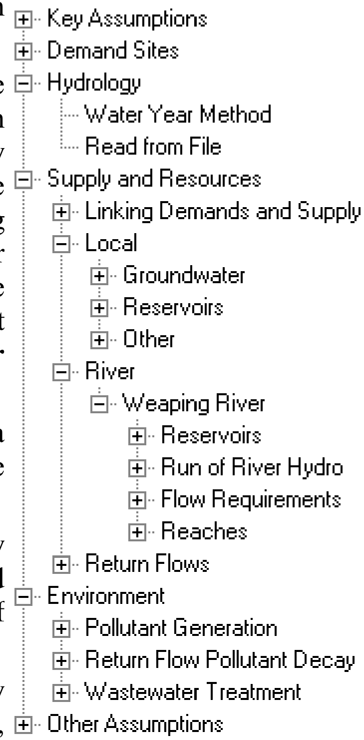


Menu Option: Area: Manage Scenarios (also on Data View toolbar)

4.3 Tree

The tree is a hierarchical outline used to organize and edit the main data structures in a WEAP analysis. You can edit the tree structure underneath the branches for Demand Sites, Key Assumptions, and Other Assumptions (by right-clicking with the mouse on a tree branch, or by using the Tree menu options), and you also click on the tree to select the data you want to view and edit. (See Editing the Tree for details.) You cannot add or remove schematic nodes (e.g., reservoirs, wastewater treatment plants) by editing the tree; all schematic changes must be done through the Schematic View

Data in the tree are organized under six major categories, which appear as the top level of branches in the tree:



- **Key Assumptions:** under which you create and organize independent variables used to "drive" the calculations in your analyses. Driver variables are not directly calculated in WEAP, but they are useful as intermediate variables that can be referenced in your modeling calculations. It is very useful to create variables here for all you major modeling assumptions, especially those that will vary from scenario to scenario. Less important intermediate variables should go under **Other Assumptions** (see below).
- **Demand Sites:** Demand analysis in WEAP is a disaggregated, end-use based approach for modeling the requirements for water consumption in an area.
- **Hydrology**: under which future inflows for each supply source are projected using either the Water Year Method or the Read From File Method. You specify the details of these two methods under the Hydrology section.
- **Supply and Resources:** given the monthly supply requirement from Demand and definitions of Hydrology, the Supply and resources section determines the amounts, availability and allocation of supplies, simulates monthly river flows, including surface/groundwater interactions and instream flow requirements, and tracks reservoir and groundwater storage.
- **Environment:** the Environment section tracks pollution from generation to treatment to its outflow and accumulation in surface and underground bodies of water.
- **Other Assumptions**: user-defined intermediate variables are created, similar to Key Assumptions (see above).

4.3.1 Editing the Tree

The branch structure underneath the top-level branches **Key Assumptions** and **Other Assumptions**, and under each demand site under the top-level branch **Demand Sites**, is edited directly from the tree, much like the tree in Windows Explorer. You can rename branches by clicking once on them and typing, and you can expand and collapse the outline by clicking on the +/- symbols to the left of each branch icon. Additional options to edit the tree are accessed by right-clicking on the tree and selecting an option from the pop-up menu that appears, or by using Tree menu.

Add is used to add a new branch as a "child" of the highlighted branch.

Rename allows you to rename a branch. Alternatively, you may click on the branch, wait a second, then click again to be put into edit mode.

Delete is used to delete the current highlighted branch and all branches underneath it You will be asked to confirm the operation before the branch is deleted, but bear in mind that a delete cannot be undone. Note however that you can exit WEAP without saving you data set to restore it to its status prior to the previous Save operation.

Cut Branches is used to mark a branch and all branches below it to be cut. Later when you select **Paste Branches (), **the marked branches will be moved to the new position selected in the tree. Notice unlike a conventional cut operation in a standard Windows program, the cut operation does not actually delete the branches, nor does it copy the branches to the Windows clipboard.

Copy Branches is similar to the Cut operation except that on the Paste operation, branches are subsequently copied not moved.

Auto-Expand specifies whether the branches in the tree automatically expand and collapse as you click on them.

Expand All fully expands the tree.

Collapse All fully collapses the tree.

Outline Level expands or collapses the tree to show all branches up to the selected level of depth.

Font is used to change the typeface and size of displayed tree.

Drag and Drop Editing of Branches

You can also move branch (and all branches below it) by dragging and dropping it onto another branch. To copy rather than move a branch, hold down the Ctrl key and then click and drag the branches. This approach allows you to rapidly create data sets, especially those containing many similar groups of branches (for example a household subsector with many similar disaggregated end-uses).

4.4 Demand

Demand analysis in WEAP is a disaggregated, end-use based approach for modeling the requirements for water consumption in an Area. Using WEAP you can apply economic, demographic and water-use information to construct alternative scenarios that examine how total and disaggregated consumption of water evolve over time in all sectors of the economy. Demand analysis in WEAP is also the starting point for conducting integrated water planning analysis, since all Supply and Resource calculations in WEAP are driven by the levels of final demand calculated in the demand analysis.

WEAP provides a lot of flexibility in how you structure your data. These can range from highly disaggregated end-use oriented structures to highly aggregate analyses. Typically a structure would consist of sectors including households, industry and agriculture, each of which might be broken down into different subsectors, end-uses and water-using devices. You can adapt the structure of the data to your purposes, based on the availability of data, the types of analyses you want to conduct, and your unit preferences. Note also that you can create different levels of disaggregation in each demand site and sector.

In each case, demand calculations are based on a disaggregated accounting for various measures of social and economic activity (number of households, hectares of irrigated agriculture, industrial and commercial value added, etc.) These activity levels are multiplied by the water use rates of each activity (water use per unit of activity). Each activity level and water use rate can be individually projected into the future using a variety of techniques, ranging from applying simple exponential growth rates and interpolation functions, to using sophisticated modeling techniques that take advantage of WEAP's powerful built-in modeling capabilities.

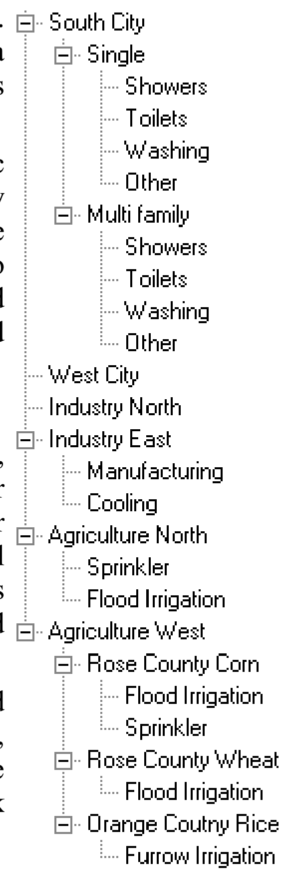
4.4.1 Getting Started

The following types of data are often useful:

- Basic water requirements data, categorized by sector and/or specific water users
- Existing water use studies for the study area, and data from national, state, county or municipal agencies
- Population projections for cities and towns, production activity level projections for industry and agriculture
- Water consumption (water consumed by a demand site that is lost to the system, lost to evaporation, embodied in products, or otherwise unaccounted for)

4.4.2 Demand Tree

WEAP uses a hierarchical structure to disaggregate water demand data. You can easily adapt this structure to the nature of your problem and data availability. A hypothetical example of a multilevel demand structure is shown on the right.



The first level corresponds to the demand sites (from the Schematic created on the Schematic View). Below this, you can create as many levels as you wish. For example, South City is broken down into single and multi family, and further by end use, while West City has no disaggregation. WEAP is flexible in allowing you to enter aggregated data initially, and to refine the demand projections later as more detailed data becomes available or necessary.

Types of disaggregation:

- **Sector**: A sample sectoral partition could include agriculture, industry, urban domestic and rural domestic. The sector categories can be used flexibly to correspond to the particular problem under analysis. The example at the right has no sectoral breakdown within a demand site—the demand sites themselves each represent one sector (two each for municipal, industry and agriculture).
- **Subsector**: For example, the industrial sector could be divided into industrial classifications, e.g., steel and iron, petroleum, chemistry, textile, pulp and paper, and food processing. The agriculture sector might be broken down by crop type, livestock or another appropriate subsector.
- **End-use**: For example, a crop end-use might be characterized by water requirements in different soil conditions or in different locations in the study area, or different irrigation techniques. Industrial end-uses might include processing, cooling and sanitary amenities.
- **Device**: For example, sprinkler, drip or flooding irrigation in agricultural sectors, or showers, toilets, and washing for domestic sectors.

You can organize the demand tree along the lines of the available data. For example, under the agricultural sector, the irrigation area for each crop can be identified at the subsector level. One level down, the percentage of each irrigation technique in each crop may be assigned at the end-use level. Another equally valid way to organize the agriculture sector would be to identify irrigation districts at the subsector level and the crops grown within the irrigation districts at the end-use level.

4.4.3 Annual Water Use

Activity Levels

The annual demand represents the amount of water required by each demand. Losses, reuse, and efficiency are accounted for separately. Water consumption is calculated by multiplying the overall level of activity by a water use rate. Activity Levels are used in WEAP's Demand analysis as a measure of social and economic activity.

Activity Level | Water Use Rate

Annual level of activity driving demand, such as industrial or agricultural output

Demand Site	Scale	Unit		1998	1999-2008
South City	Million	person		3.75	Growth(3%)
Single family	Percent	share	of people	42	Interp(2020,50)
Showers	Percent	saturati...	of people	90	Interp(2020,98)
Toilets	Percent	saturati...	of people	99	99
Washing	Percent	saturati...	of people	75	Interp(2020,85)
Other	Percent	saturati...	of people	80	Interp(2020,90)

Activity levels for one of the hierarchical levels are typically described in absolute terms (in this case, the number of people in South City is 3.75 million in the Current Accounts), while the other levels are described in proportionate (i.e., percentage share or percentage saturation) terms. In the example shown above, 42% of the population lives in single-family households in 1998 and of these, 90% have showers. Notice that at the top level, the user chooses an absolute unit for the activity level (person). At lower levels, WEAP keeps track of the units, and hence knows that the percentage number entered at the second level is the share "of people". In general, WEAP lets you choose the numerator units for activity levels, while automatically displaying the denominator unit. When selecting an activity level unit, you can choose from any of the standard units. WEAP multiplies activity levels down each chain of branches to get a total activity. (See Calculation Algorithms for details.) For example, the total number of single-family dwellers in South City with showers in 1998 = 3.75 million people * 42% * 90% = 1.42 million people. Multiply this value by the water use rate per person per shower per year to get the total annual demand for South City single-family showers.

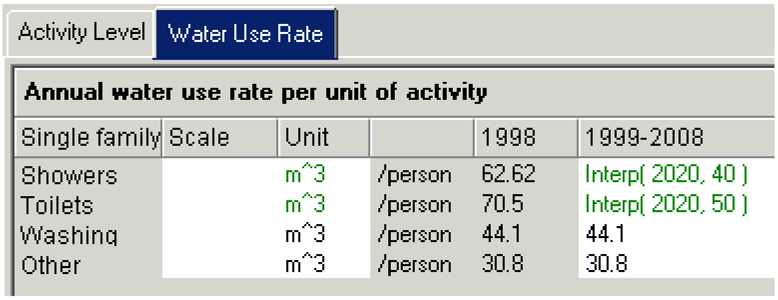
All values can be altered for future years in scenarios. This allows the planner to capture the combined effects of separate changes at many levels, such as, for example, the growth in the total population (shown above growing at 3%), the change in household structure, the growing penetration of washing machines (from 75% to 85%), and the market share of less efficient vs. more efficient washing machines. To project these data, you first use the Manage Scenarios option to create one or more scenarios. Then, in the Data View, you override the default (constant) expressions entered in Current Accounts for each branch, with new expressions that describe how each value changes over time. See Expressions for more information.

Entered on: Data View, Branch: Demand Sites, Category: Annual Water Use, Tab: Activity

Level

Water Use Rate

The Water Use Rate is the average annual water consumption per unit of activity. WEAP displays the denominator (person, in the example below) to emphasize that this is a rate per unit, not the total amount of water used by all showers.


Activity Level | Water Use Rate

Annual water use rate per unit of activity

Single family	Scale	Unit		1998	1999-2008
Showers		m^3	/person	62.62	Interp(2020, 40)
Toilets		m^3	/person	70.5	Interp(2020, 50)
Washing		m^3	/person	44.1	44.1
Other		m^3	/person	30.8	30.8

Entered on: Data View, Branch: Demand Sites, Category: Annual Water Use, Tab: Water Use Rate

4.4.4 Monthly Variation

In some demand sites, such as industrial sites, water use may remain constant throughout the year, while other demands may vary considerably from month to month. If the demand is constant throughout the year, leave this line blank. Otherwise, enter the percentage of annual water used in each month. The percentages will also be used to convert the annual pollution generated into monthly amounts. The variation should reflect the weighted effects of all users within the demand site. In estimating monthly variations for a demand site, historical patterns can be reviewed. If such records are unavailable, the user can reference demand sites with similar properties. Note that the twelve monthly coefficients entered on each screen must sum to one hundred percent. If demand does not vary, all months are assume to use the same amount. Note that the monthly variation is the same for all branches underneath a demand site.

Annual water demands are the requirements for final water services in industry, agriculture, domestic and other purposes. WEAP allows for three adjustments—demand site losses and reuse, and transmission link losses—to more accurately reflect the actual supply requirement needed to meet the demand for water services.

Entered on: Data View, Branch: Demand Sites, Category: Monthly Variation

4.4.5 Loss and Reuse

Loss Rate (%)

Loss Rate accounts for any distribution losses within each demand site. For example, in municipal systems, distribution losses could represent physical leaks, unmetered water use in public parks and buildings, clandestine connections, water used for line flushing, or water use for fire fighting. The effect of distribution losses is to increase the supply requirement by the factor

(1 + loss rate). NB: Do not include losses that are already accounted for as transmission link losses.

Reuse Rate (%)

Reuse Rate accounts for water recycling or reuse. This adjustment refers to processes by which water is used in more than one application before discharge. For example, irrigation water may be routed for reuse in more than one field. In industry, water may be recycled for multiple uses. The effect of reuse is to reduce the supply requirement by the factor (1 - reuse rate).

Entered on: Data View, Branch: Demand Sites, Category: Loss and Reuse, Tabs: Loss Rate, Reuse Rate

4.4.6 Demand Management

If you want to model the effects of various demand-side management (DSM) strategies for reducing demand, you can use either a **disaggregated** or **aggregated** approach. The disaggregate approach would make changes to the water use rates on individual branches. For example. to model a program to promote efficient washing machines, you would either decrease the water use rate for washing machines (if there was only one branch for washing machines), or increase the share of efficient washing machines (if there were two branches—one for traditional washing machines and one for more efficient ones).

The disaggregated approach works well if your demand data is already disaggregated to the level of end-uses or devices. However, most demand analyses will not be so disaggregated. With the aggregated approach for DSM, you estimate the fraction of total demand for a demand site that could be reduced by DSM programs, and enter that fraction under **DSM Savings**. For example, if efficient washing machines and toilets consume 60% less water than traditional ones, and those end uses accounts for 4% of overall water consumption for a demand site, enter 2.4% for the DSM Savings.

If there are costs associated with these DSM programs, enter the cost per unit of water saved on the **DSM Cost** tab.

Entered on: Data View, Branch: Demand Sites, Category: Demand Management, Tabs: DSM Savings, DSM Cost

4.5 Hydrology

An important aspect of modeling a water system is understanding how it operates under a variety of hydrologic conditions. Natural variations in hydrology—month to month and year to year—can have major effects on the results of your scenarios.

WEAP has three methods for projecting the surface water hydrology over the study period: the Water Year Method, Read From File Method and Expressions. These methods may be used to project the inflow to every surface and groundwater inflow point in the system for every month in the study period. This includes river and tributary headflows, surface water inflows to river reaches, groundwater, local reservoir and other local supply inflow. With Read From File, you specify the inflow for each month; with the Water Year Method, you specify the twelve months of inflow for the Current Accounts, and then specify the future sequence of wet and dry years; with Expressions, you specify the inflows via a mathematical expression.

WEAP allows you to mix these methods, using the Read From File method for some sources (e.g., one or two rivers for which you have historical streamflow data), the Water Year Method for others, and expressions for the rest. For example, the natural recharge for an aquifer might be relatively constant over time, so you would enter a constant for this value. As another example, you could use the Read From File method for the headflow and surface inflow of a major river, then use an expression for the minor rivers' inflows—perhaps a fraction of the flow in the main river. In this way, you could replicate the actual historical variation of the main river on the smaller rivers.

4.5.1 Water Year Method

The Water Year Method allows you to use historical data in a simplified form and to easily explore the effects of future changes in hydrological patterns. If you want to test a hypothetical event or set of events, or wish to approximate historic patterns, then you should probably select the Water Year Method. For example, you could use the Water Year Method to test the system under historic or hypothetical drought conditions. Hydrologic fluctuations are entered as variations from a Normal Water Year (the Current Accounts year is not necessarily a Normal water year). The Water Year Method requires data for defining standard types of water years (Water Year Definition), as well as defining the sequence of those years for a given set of scenarios (Water Year Sequence).

A **water year type** characterizes the hydrological conditions over the period of one year. The five types that WEAP uses—Normal, Very Wet, Wet, Dry, and Very Dry—divide the years into five broad categories based on relative amounts of surface water inflows.

Water Year Definition

To define each non-Normal water year type (Very Dry, Dry, Wet, Very Wet), specify how much more or less water flows into the system in that year relative to a Normal water year. For example, if a Wet year has 25% more inflow than a Normal year, enter 1.25 for the Wet year. Typically, you would derive these fractions from a statistical analysis of historical flows. First you would group the years into five bins (quintiles), then compute how they vary from the norm, perhaps by month. Note: the Current Accounts year is not necessarily a Normal water year.

You may specify a single variation fraction for an entire water year type, or you may specify a different fraction for each month. Your data might show, for example, that the winter months of a Dry year average 50% of a Normal winter, while the summer months are closer to 75% of Normal summer inflows.

A simple way to explore sensitivity to climate change would be to define two scenarios. The first would use the Water Year Method to reproduce the observed variation in hydrology from the historical record. The second scenario would use the first as a starting point, but alter each water year type according to predicted effects of climate change (e.g., wetter winters and dryer summers).

Entered on: Data View, Branch: Hydrology \ Water Year Method, Tab: Definitions (applies to scenarios only, not to the Current Accounts)

Water Year Sequence

Once you have given definitions for each water year type (Water Year Definition), specify the sequence of water year types (Very Dry, Dry, Normal, Wet, Very Wet) in your study. The defined sequence of water year types will set inflow values for future years by applying the appropriate fluctuation coefficients to the Current Accounts inflows. Note: the Current Accounts year is not necessarily a Normal water year.

When using the Water Year Method, your assignment of water year types can be based upon a variety of considerations:

- past hydrologic patterns, for a simplified historical analysis (a frequency analysis of an annual inflow record at a representative river point may be useful)
- a specific future hydrologic occurrence, such as a 3-year drought, in which 3 Very Dry years occur sequentially
- climate change scenarios

Entered on: Data View, Branch: Hydrology \ Water Year Method, Tab: Sequence

4.5.2 Read From File

If you have monthly data on inflows to some or all of your rivers and local supplies, the Read From File Method allows you to model the system using this sequence of inflows. The required file formats for these data files are given in ASCII Data File Format for Monthly Inflows. You can export gaged inflow data from many conventional hydrologic databases into ASCII files, and then edit these files into the required format. (USGS has extensive streamflow data for the United States available for download from the Web at http://water.usgs.gov) For ungaged locations, you will have to calculate streamflow estimates prior to entering them into WEAP.

The monthly inflow data is not restricted to historical values. Your detailed projected monthly surface water assumptions can be based on historical data, or on projections from some external model, or a mixture of both. For example, you might want to modify historical flows to account for projected changes due to climate change. Or you could use outputs from a climate model to project future inflows.

You can choose different time intervals from the historical data files to simulate the system over various historical time periods. For instance, if your study period is twenty years and you have sixty years of historical data, WEAP allows you to easily select any of the forty-one different twenty-year periods from the historical data, to explore the effects of various sequences of hydrologic conditions. Refer to ASCII Data File Format for Monthly Inflows for details.

Entered on: Data View, Branch: Hydrology \ Read from File

4.6 Supply and Resources

Given the monthly supply requirement established from the definitions of the system Demand, and the definitions of Hydrology, the Supply and Resources section determines the amounts, availability and allocation of supplies, simulates monthly river flows, including surface/groundwater interactions and instream flow requirements, and tracks reservoir and groundwater storage.

Supply and Resources include the following subsections:

- **Linking Demands and Supply**: transmission links carry water from local and river supplies to demand sites, subject to losses and physical capacity, contractual and other constraints.
- **Local Supplies**: non-river sources, including groundwater, reservoirs that are simulated as isolated facilities, and "other" sources (e.g., surface sources that are not modeled in your WEAP application, such as inter-basin transfers).
- **Rivers and Diversions**: surface inflows to rivers, properties and operation of reservoirs and run-of-river hydropower facilities, and instream flow requirements.
- **Return Flows**: wastewater from demand sites can be routed to one or more wastewater treatment plants, rivers or local supply sources; treated effluent from wastewater treatment plants can be routed to one or more rivers or local supply sources.

4.6.1 Getting Started

The following types of data are often useful:

- Streamflow gage records and their locations
- Estimates of streamflow for ungaged locations calculated using gage records, drainage area or other parameters
- Reservoir storage levels, volume-elevation relationships, net monthly evaporation rates, operating rules for fish and wildlife, recreation, hydropower, navigation, water supply and other conservation purposes
- Groundwater recharge rates, gains from and losses to rivers
- Instream flow requirements for recreation, water quality, fish and wildlife, navigation, other conservation purposes, and any downstream obligations
- Transmission link capacities and losses
- Wastewater and effluent routing
- Costs of delivered water

4.6.2 Specifying Inflow

There are several options for specifying the monthly inflow to rivers (both headflow and surface inflow to reaches), groundwater, local reservoirs and other local sources.

Water Year Method (available in Scenarios only)

The Water Year Method projects future inflows by varying the inflow data from the Current Accounts according to the Water Year Sequence and Definitions specified in the Hydrology section.

Read From File

If you have monthly inflow data for many years, WEAP can read these data from an ASCII data file. See Read From File for details.

Enter an Expression

Typical expressions include: constants (e.g, groundwater recharge that doesn't vary over time), a specified value for each month (this is usually how the Current Accounts inflow data is specified when you are using the Water Year Method to project future inflows—using the Monthly Time-Series Wizard can be helpful in establishing these data), or some other relationship (e.g., the headflow for an ungaged stream could be modelled as some fraction of the headflow in another river for which good data exists).

4.6.3 Linking Demands and Supply

Linking Rules

Transmission links carry water from local and river supplies to demand sites, subject to losses and physical capacity, contractual and other constraints. Primarily, WEAP allocates water according to the supply priority associated with each demand site. The sites with the highest priorities (lowest numbers) get water first, followed by sites with lower priorities (higher numbers), as availability allows. This system is useful in times of shortage to ensure that the highest priority water uses (e.g., municipal or minimum instream flows) are satisfied. When there is plenty of water to satisfy everyone, supply priorities are unnecessary.

A secondary concern, in cases where a demand site is connected to more than one supply source, is determining the mix of supply from various sources. Perhaps a city prefers groundwater to surface water because of its quality, or a farmer prefers surface water to groundwater because of the pumping expense, yet they are connected to both sources to ensure reliability of supply. However, in many cases, you may not know the underlying reasons to explain a particular observed mix (e.g., 20% from groundwater, 80% from surface water), but you want to reproduce it.

WEAP includes **linking rules** to specify the mix of supply from multiple sources. These rules enable the analyst to match observed allocation patterns in the Current Accounts and model future changes in the scenarios.

Demand Site Preference

Each demand site with multiple sources can specify its preference for a source, due to economic, environmental, historical, legal or political reasons. In the above example, the agricultural site would have a preference of 1 for the river source, and 2 for the groundwater source. With no other constraints, the site would pull everything it could from the river, falling back on the aquifer only if there was a shortage of river water.

If there is no preference for sources (or a demand site has only one source), set the preference to 1.

Maximum Flow: Volume

You can restrict the supply from a source, to model contractual or physical capacity limitations, or merely to match observations. For example, an agricultural site has a fixed allotment of river water, beyond which it must pump from groundwater. In this case, the demand site preference would be 1 for the river and 2 for the aquifer, and the allotment would be entered for the river source under Maximum Flow: Volume.

The rate of restriction can be entered for any time scale. For example, physical capacities would be entered as cubic meters per second, while contractual limitations might be entered as million cubic meters per month or per year. If the time scale is year, then the demand site's monthly variation will be used to distribute the allotment monthly.

Maximum Flow: % of Demand

You can also restrict the monthly flow along a transmission link by a percentage of the demand site's total monthly supply requirement. For instance, you might only know that a demand site got 20% of its yearly flow from one source and 80% from another. In this case, set the preferences for the sources to 1 and 2, respectively, then set the Maximum Flow: % of Demand for the preference 1 source to be its observed share (either 20% or 80%), and leave the preference 2 source unlimited. In general, you would choose the source more likely to experience shortages as the preference 1 source, in which cases the preference 2 source would meet the shortfall.

Another example for restricting flow as a percentage of demand would be for quality considerations. Perhaps one source is cheaper than another, but of inferior quality. You could estimate the maximum fraction of the poorer quality water you could use and still meet your water quality criteria. In this case, the cheaper source would have a higher preference than the more expensive one, and you would set its Maximum Flow: % of Demand accordingly.

In some cases, you might have restrictions both on Volume and % of Demand. For example, the volume constraint might represent a physical capacity, while the % of demand would model quality criteria (as mentioned above).

Entered on: Data View, Branch: Supply and Resources \ Linking Demands and Supply, Category: Linking Rules, Tabs: Demand Site Preference, Maximum Flow: Volume, Maximum Flow: % of Demand

Transmission Link Losses

The transmission losses refer to the evaporative and leakage losses as water is carried by canals and conduits to demand sites. This **Loss Rate** is specified as a percentage of the flow passing through a transmission link. NB: Do not include losses that are already accounted for as demand site losses.

Entered on: Data View, Branch: Supply and Resources \ Linking Demands and Supply, Category: Losses, Tab: Loss Rate

Cost of Delivered Water

All costs in WEAP are calculated based on the amount of water delivered to demand sites. The cost for a delivery to a demand site from a supply source is the unit cost multiplied by the volume of water delivered. Enter the unit cost of water here.

Tip: it is usually more convenient to create one or more variables (under the tree branch Key Assumptions) for unit cost, and then refer to those variables from the Cost of Delivered Water tab. For example, you could have one price of water that applies everywhere, or different prices for different sectors (municipal, industrial, agriculture). This makes it easy to keep the costs consistent for a scenario as you model their changes in the future. See Weaping River Basin for an example.

Entered on: Data View, Branch: Supply and Resources \ Linking Demands and Supply, Category: Cost, Tab: Cost of Delivered Water

4.6.4 Local Supplies

Groundwater

Initial and Total Groundwater Storage Capacity

The **Storage Capacity** represents the maximum theoretically accessible capacity of the aquifer, while the **Initial Storage** is the amount of water initially stored there at the beginning of the first month of the Current Accounts Year. Among other factors, these data will depend on pump depths. WEAP maintains a mass balance of monthly inflows and outflows in order to track the monthly groundwater storage volume.

Entered on: Data View, Branch: Supply and Resources \ Local \ Groundwater, Tabs: Initial Storage (Current Accounts only), Storage Capacity

Maximum Groundwater Withdrawal

The **Maximum Withdrawal** defines the maximum total amount that may be withdrawn from this aquifer in any month by all connected demand sites. In general, the maximum will be equal to the monthly pumping capacity of the well, although it may also depend on characteristics of the aquifer, such as hydraulic conductivity, aquifer specific yield, and hydraulic head (between the base and the rim of the pumping cone of depression).

If multiple demand sites are connected to a single aquifer each with their own wells (and thus their own individual constraints on pumping capacity), you could enter the individual pumping capacity limitations on the transmission links connecting the demand sites to the aquifer. In this case, the Maximum Withdrawal for the aquifer would be based on the above-mentioned hydraulic characteristics of the aquifer.

Entered on: Data View, Branch: Supply and Resources \ Local \ Groundwater, Tab: Maximum Withdrawal

Groundwater Recharge

The **recharge** represents inflow to the groundwater source—inflows that are not explicitly modeled in WEAP (e.g., return flows). You may specify the inflow using the Water Year Method, the Read from File Method, or with an expression. See Specifying Inflow for details.

Entered on: Data View, Branch: Supply and Resources \ Local \ Groundwater, Tab: Natural Recharge

Local Reservoirs

Physical

Local Reservoir Inflow

Local reservoirs by definition are modeled independently of river streamflow. For this reason, you must explicitly enter monthly inflows to local reservoir sources. The monthly inflows you enter should not include return flows from demand sites and wastewater treatment plants—WEAP will calculate the inflows from return flows separately. You may specify the inflow using the Water Year Method, the Read from File method, or with an expression. See Specifying Inflow for details.

Entered on: Data View, Branch: Supply and Resources \ Local \ Reservoir, Tabs: Inflow

Reservoir Initial and Total Storage Capacity

The **Storage Capacity** represents the total capacity of the reservoir, while the **Initial Storage** is the amount of water initially stored there at the beginning of the first month of the Current Accounts year. WEAP maintains a mass balance of monthly inflows and outflows in order to track the monthly storage volume.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tabs: Initial Storage (Current Accounts only), Storage Capacity

Reservoir Volume Elevation Curve

In order to calculate the amount of evaporation and/or the amount of energy production from hydropower, WEAP must have a function to convert between volume and elevation. This function is defined by the points on the **Volume Elevation Curve**. Values between the points are interpolated. You must enter at least one point, corresponding to the total storage capacity of the reservoir. If you choose to model the reservoir as a box with straight sides, you do not need to enter any other point.

Click on **Add** ( ) to add a new point. After you have at least one point (other than 0, 0), you can create or move points by clicking on the graph.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tab: Volume Elevation Curve (Current Accounts only)

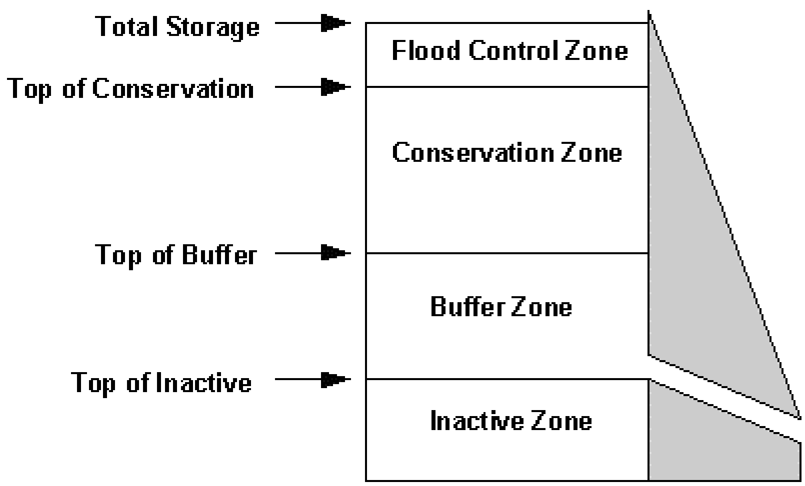
Reservoir Evaporation

The monthly evaporation rate can be positive or negative to account for the difference between evaporation and precipitation on the reservoir surface. A positive (negative) net evaporation represents a net loss from (gain to) the reservoir.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tabs: Net Evaporation

Reservoir Zones and Operation

Reservoir storage is divided into four zones, or pools. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone. The conservation and buffer pools, together, constitute the reservoir's active storage. WEAP will ensure that the flood-control zone is always kept vacant, i.e., the volume of water in the reservoir cannot exceed the top of the conservation pool.



WEAP allows the reservoir to freely release water from the conservation pool to fully meet withdrawal and other downstream requirements. Once the storage level drops into the buffer pool, the release will be restricted according to the buffer coefficient, to conserve the reservoir's dwindling supplies. Water in the inactive pool is not available for allocation, although under extreme conditions evaporation may draw the reservoir into the inactive pool.

To define the zones, you enter the volumes corresponding to the top of each zone (**Top of Conservation**, **Top of Buffer** and **Top of Inactive**). WEAP uses the **Buffer Coefficient** to slow releases when the storage level falls into the buffer zone. When this occurs, the monthly release cannot exceed the volume of water in the buffer zone multiplied by this coefficient. In other words, the buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully while rapidly emptying the buffer zone, while a coefficient close to 0 will leave demands unmet while preserving the storage in the buffer zone. Essentially, the top of buffer should represent the volume at which releases are to be cut back, and the buffer coefficient determines the amount of the cut back.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Operation, Tabs: Top of Conservation, Top of Buffer, Top of Inactive, Buffer Coefficient

Hydropower Generation

Maximum and **Minimum Turbine Flows** define the upper and lower capacity limits. When turbine flow exceeds the maximum, hydropower will only be generated up to the maximum flow. When turbine flow falls below the minimum, no hydropower will be generated. **Tailwater Elevation** defines the working water head on the turbine. The power generated in a given month depends on the head available, which is computed as the drop from the reservoir elevation (as computed by WEAP, using the Volume Elevation Curve and the current storage volume) to the tailwater elevation. The **Plant Factor** specifies the percentage of each month that the plant is running. The plant **Generating Efficiency** defines the generator's overall operation effectiveness (electricity generated dived by hydropower input).

If the reservoir does not generate hydropower, simply leave this section blank.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Hydropower, Tabs: Min. Turbine Flow, Max. Turbine Flow, Tailwater Elevation, Plant Factor, Generating Efficiency

Other Local Supplies

Other Local Supply Monthly Inflow

"Other" local supplies represent non-river supplies that have no storage capacity. Examples include streams or other unconnected rivers, inter-basin transfers or other imports, and desalination plants. Since these sources have no carry-over storage, unused supply from one month cannot be stored for next month's use.

You may specify the inflow using the Water Year Method, the Read from File Method, or with an expression. See Specifying Inflow for details.

Entered on: Data View, Branch: Supply and Resources \ Local \ Other, Tab: Inflow

4.6.5 Rivers and Diversions

River Headflow

Headflow represents the average inflow to the first node on a river. The monthly inflows you enter should not include return flows from demand sites and wastewater treatment plants—WEAP will calculate the inflows from return flows separately. You may specify the inflow using the Water Year Method, the Read from File Method, or with an expression. See Specifying Inflow for details.

Entered on: Data View, Branch: Supply and Resources \ River \ <River Name>, Tab: Inflow

Maximum Diversion

Diversion nodes withdraw water from a river (or another diversion), and this diverted flow becomes the headflow for a diversion. A diversion is modeled in WEAP as a separate river, complete with river nodes, demands and return flows. WEAP will divert only as much water as needed to satisfy the demand sites connected to the diversion, and its instream flow requirements.

Typically, a diversion is an artificial conduit, such as a canal or pipeline. The **Maximum Diversion** represents the maximum amount that can be diverted, due to physical capacity, contractual or other constraints.

Entered on: Data View, Branch: Supply and Resources \ River \ <Diversion Name>, Tab: Maximum Diversion

Reservoirs

River reservoirs provide storage of river water, provide a source of water for demand sites and downstream requirements, and generate hydropower. The reservoir simulation in WEAP takes into account net evaporation on the reservoir, priorities of downstream requirements, and the reservoir's operating rules.

Physical

Reservoir Initial and Total Storage Capacity

The **Storage Capacity** represents the total capacity of the reservoir, while the **Initial Storage** is the amount of water initially stored there at the beginning of the first month of the Current Accounts year. WEAP maintains a mass balance of monthly inflows and outflows in order to track the monthly storage volume.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tabs: Initial Storage (Current Accounts only), Storage Capacity

Reservoir Volume Elevation Curve

In order to calculate the amount of evaporation and/or the amount of energy production from hydropower, WEAP must have a function to convert between volume and elevation. This function is defined by the points on the **Volume Elevation Curve**. Values between the points are interpolated. You must enter at least one point, corresponding to the total storage capacity of the reservoir. If you choose to model the reservoir as a box with straight sides, you do not need to enter any other point.

Click on **Add** ( ) to add a new point. After you have at least one point (other than 0, 0), you can create or move points by clicking on the graph.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tab: Volume Elevation Curve (Current Accounts only)

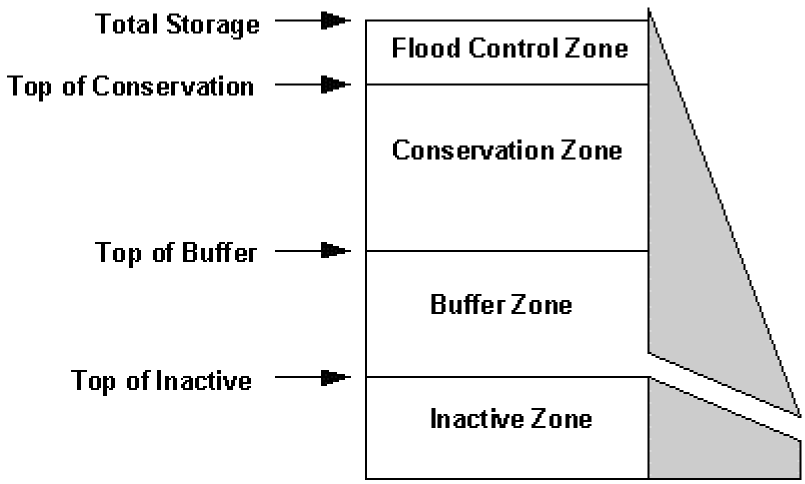
Reservoir Evaporation

The monthly evaporation rate can be positive or negative to account for the difference between evaporation and precipitation on the reservoir surface. A positive (negative) net evaporation represents a net loss from (gain to) the reservoir.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Physical, Tabs: Net Evaporation

Reservoir Zones and Operation

Reservoir storage is divided into four zones, or pools. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone. The conservation and buffer pools, together, constitute the reservoir's active storage. WEAP will ensure that the flood-control zone is always kept vacant, i.e., the volume of water in the reservoir cannot exceed the top of the conservation pool.



WEAP allows the reservoir to freely release water from the conservation pool to fully meet withdrawal and other downstream requirements. Once the storage level drops into the buffer pool, the release will be restricted according to the buffer coefficient, to conserve the reservoir's dwindling supplies. Water in the inactive pool is not available for allocation, although under extreme conditions evaporation may draw the reservoir into the inactive pool.

To define the zones, you enter the volumes corresponding to the top of each zone (**Top of Conservation**, **Top of Buffer** and **Top of Inactive**). WEAP uses the **Buffer Coefficient** to slow releases when the storage level falls into the buffer zone. When this occurs, the monthly release cannot exceed the volume of water in the buffer zone multiplied by this coefficient. In other words, the buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully while rapidly emptying the buffer zone, while a coefficient close to 0 will leave demands unmet while preserving the storage in the buffer zone. Essentially, the top of buffer should represent the volume at which releases are to be cut back, and the buffer coefficient determines the amount of the cut back.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Operation, Tabs: Top of Conservation, Top of Buffer, Top of Inactive, Buffer Coefficient

Hydropower Generation

Maximum and **Minimum Turbine Flows** define the upper and lower capacity limits. When turbine flow exceeds the maximum, hydropower will only be generated up to the maximum flow. When turbine flow falls below the minimum, no hydropower will be generated. **Tailwater Elevation** defines the working water head on the turbine. The power generated in a given month depends on the head available, which is computed as the drop from the reservoir elevation (as computed by WEAP, using the Volume Elevation Curve and the current storage volume) to the tailwater elevation. The **Plant Factor** specifies the percentage of each month that the plant is running. The plant **Generating Efficiency** defines the generator's overall operation effectiveness (electricity generated dived by hydropower input).

If the reservoir does not generate hydropower, simply leave this section blank.

Entered on: Data View, Branch: Supply and Resources \ Local or River \ Reservoir, Category: Hydropower, Tabs: Min. Turbine Flow, Max. Turbine Flow, Tailwater Elevation, Plant Factor, Generating Efficiency

Run of River Hydropower

Maximum and **Minimum Turbine Flows** define the upper and lower capacity limits. When turbine flow exceeds the maximum, hydropower will only be generated up to the maximum flow. When turbine flow falls below the minimum, no hydropower will be generated. The **Fixed Head** defines the working water head on the turbine—the distance the water falls. The **Plant Factor** specifies the percentage of each month that the plant is running. The plant **Generating Efficiency** defines the generator's overall operation effectiveness (electricity generated divided by hydropower input).

Entered on: Data View, Branch: Supply and Resources \ River \ <River Name> \ Run of River Hydro, Tabs: Min. Turbine Flow, Max. Turbine Flow, Plant Factor, Generating Efficiency, Fixed Head

Minimum Flow Requirement

A flow requirement defines the minimum monthly flow required along a river to meet water quality, fish & wildlife, navigation, recreation, downstream or other requirements. Depending on its supply priority, a flow requirement will be satisfied either before or after other demands on the river.

Entered on: Data View, Branch: Supply and Resources \ River \ <River Name> \ Flow Requirements, Tab: Minimum Flow Requirement

Inflow to and Outflows from River Reaches

On river reaches, flow can be reduced by **Evaporation** or **Groundwater Outflow**, and increased by **Surface Water Inflow** or **Groundwater Inflow**.

Both evaporation losses and groundwater outflow are specified as percentages of streamflow, while surface water inflow and groundwater inflow as entered as volumes. For groundwater interactions, you must specify to which Groundwater Source each reach is connected. Surface water inflow represents either non-point runoff into the river, or the confluence of streams or rivers not otherwise modeled. You may specify this inflow using the Water Year Method, the Read from File Method, or with an expression. See Specifying Inflow for details.

Entered on: Data View, Branch: Supply and Resources \ River \ <River Name> \ Reaches, Tabs: Surface Water Inflow, Groundwater Inflow, Groundwater Outflow, Evaporation

Other River Nodes

The following river nodes have no data associated with them—they serve to mark the points of inflow and outflow from a river.

Withdrawal nodes, which represent points where any number of demand sites receive water directly from a river.

Diversion nodes, which divert water from a river or other diversion into a canal or pipeline called a diversion. This diversion is itself, like a river, composed of a series of reservoir, run-of-river hydropower, flow requirement, withdrawal, diversion, tributary and return flow nodes.

Tributary nodes define points where one river joins another. The inflow from a tributary node is the outflow from the tributary river.

Return flow nodes, which represent return flows from demand sites and wastewater treatment plants. (You may actually have return flows enter the river at any type of river node: reservoir, run-of-river, tributary, diversion, flow requirement, withdrawal, or return flow node.)

4.6.6 Return Flows

Return Flow Routing

Wastewater from demand sites can be routed to one or more wastewater treatment plants, rivers or local supply sources; treated effluent from wastewater treatment plants can be routed to one or more rivers or local supply sources.

The **Return Flow Routing** specifies the fraction of inflow (water supplied to the demand site or treated by the wastewater treatment plant) that is sent to each return flow destination. Normally, the percentages will not sum to 100%. The unrouted fraction constitute consumptive losses—lost to evaporation or treatment, embodied in products, or otherwise unaccounted for. These amounts are lost from the system. Note: the routing fractions do not include any losses along the return flow link—these are specified below in Return Flow Losses.

Entered on: Data View, Branch: Supply and Resources \ Return Flows \ <Demand Site Name>, Tab: Return Flow Routing

Losses in Return Links

The **Losses in Return Links** refer to the evaporative and leakage losses as wastewater is carried by canals and/or conduits from demand sites and wastewater treatment plants. This loss rate is specified as a percentage of the flow passing through the link.

Entered on: Data View, Branch: Supply and Resources \ Return Flows \ <Demand Site Name>, Tab: Losses in Return Flows

4.7 Environment

4.7.1 Getting Started

The Environment section tracks pollution from generation to treatment to its accumulation in surface and underground bodies of water.

The following types of data are often useful:

- Population projections for cities and towns, production activity level projections for industry and agriculture
- Production activity level projections for industry and agriculture.
- Pollution discharges, their locations and quantities.
- Wastewater treatment plant ratings for pollutant removal

4.7.2 Pollution Generation

Demand Sites may generate pollution, which is carried in its wastewater return flows to treatment plants and local and river sources. The manner in which pollution data is entered and calculated is similar to that of water demands. The data is broken down into **activity level** and pollution **intensity** (amount of production) per activity. WEAP computes the annual wastewater pollution generated over time by multiplying activity levels with unit pollution intensities. Projected activities and unit pollution intensities can be based on several methods. Annual pollution generated is converted to monthly values, using the Monthly Variation entered under Annual Water Use.

To edit the list of pollutants, go to the menu option General: Pollutants.

Entered on: Data View, Branch: Environment \ Pollutant Generation, Tabs: Pollutant Activity Level, <Pollutant Name> Intensity

4.7.3 Pollutant Decrease in Return Flows

Some pollutants decay or are otherwise lost en route from the demand site or wastewater treatment plants to their destinations. For each return flow link, enter the % decrease of each pollutant while flowing through the link. If no change, enter 0 or leave blank.

Entered on: Data View, Branch: Environment \ Pollutant Decrease in Return Flows, Tabs: <Pollutant Name> Decrease

4.7.4 Wastewater Treatment

In WEAP, a wastewater treatment plant accepts wastewater from demand sites and treats it to remove pollutants. The removal rates will typically vary among wastewater treatment plants and among the different types of pollutants. Enter the % of each pollutant that is removed by treatment.

Entered on: Data View, Branch: Environment \ Wastewater Treatment, Tabs: <Pollutant Name> Removal

4.8 Key Assumptions and Other Assumptions

Key Assumptions and Other Assumptions are user-defined variables that you can reference in expressions elsewhere in WEAP. It is very useful to create variables here for all your major modeling assumptions, especially those that will vary from scenario to scenario. Less important intermediate variables should go under **Other Assumptions** (see below). For example, you could create variables that contain your projections of the unit cost of water by sector (municipal, agricultural, industrial). This would provide a convenient, consistent and transparent method for varying costs by scenario.

Another class of useful variables is macroeconomic drivers, such as population and GDP. For example, in Weaping River Basin, the expression for Industry East's Activity Level in the Reference scenario is "GrowthAs(Key\Drivers\GDP,0.25)". This means that the activity level will change as GDP changes, with an elasticity of 0.25. (When referenced in an expression Key

"Assumptions\Drivers\GDP" is shortened to "Key\Drivers\GDP".)

Entered on: Data View, Branches: Key Assumptions, Other Assumptions

4.9 Expressions

WEAP borrows an approach made popular in spreadsheets: the ability for users to enter data and construct models using mathematical expressions. Expressions are standard mathematical formulae used to specify the values of variables in WEAP's Data View. In the Current Accounts an expression defines the initial value for a given variable at a branch, while in scenarios, the expression defines how that variable changes over time (from one year after the Current Accounts to the end of the study period). Expressions can range from simple numeric values to complex mathematical formulae. Each formula can optionally reference one of WEAP's many built-in functions, as well as referencing the values of other branches and variables entered elsewhere in the WEAP analysis. Expressions can even create dynamic links to the values stored in an external Microsoft Excel spreadsheet.

WEAP provides a number of ways of editing expressions. The most common are:

- Typing directly into the expression field in one of the data entry table's in WEAP's Data View.
- Selecting one of the most commonly used functions (Interpolation, Growth, Remainder) using the pop-up selection box attached to each expression field.
- Using the Yearly Time-Series Wizard: a tool for easily entering time-series functions (Interpolation, Step, and Smooth Curve functions)
- Using the Expression Builder tool: a tool for creating expressions by dragging-and-dropping functions and WEAP variables.

Note: Expressions are not case-sensitive. You can enter variable and function names in any combination of upper and lower-case letters. When you have finished entering the formula, WEAP will put the names in a standard format-capitalizing the function names.

4.9.1 Expression Builder

The Expression **Builder** is a general purpose tool that helps you construct WEAP's expressions by dragging and dropping the functions and WEAP Branches into an editing box. To access the wizard, either right-click on the data table or click on the down arrow on the right side of the expression box, and choose Expression Builder from the menu.

The screen of the Expression Builder is divided into two resizable panes. At the top are a set of tabs that are used to access the names of the mathematical, logical and modeling functions built-in to WEAP, as well as to access the names of all branches in WEAP. At the bottom of the screen is an editing box, into which you can directly type to edit an expression, or into which you can add an item from the top pane, either by dragging-and-dropping or by double-clicking on an item. At the right of the editing box is a set of buttons that give quick access to the most common mathematical operators (+, -, *, /, ^, etc.).

A toolbar at the top of the expression builder gives quick access to the most common editing options such as **Cut** ( ), **Copy** (), **Paste** (), etc. When constructing an expression, you can check whether the expression is valid by clicking on the **Verify** button. Finally, when you have finished with the expression, click on **Finish** to put the expression back into the data entry table you came from, or click on **Cancel** to abandon the edit.

There are two tabbed pages in the Expression Builder:

- **Functions** contain the list of functions built in to WEAP. You can see a list of ALL functions or filter the list to show the modeling, mathematical and logical functions. On the right of the tab, each function is fully documented with notes describing syntax and usage, as well as examples of how to apply each function. The modeling functions are the main functions used for defining and calculating variables in WEAP. The mathematical functions are standard mathematical functions (log, exp, max, min, etc.). Wherever possible the names and syntax of these functions are the same as equivalent functions in Microsoft Excel. The logical functions are standard logical operators (IF, AND, NOT, OR, LessThan, etc.) used to construct conditional expressions that yield different results depending on the values of variables.
- **Branches** contain a tree outline listing all WEAP branches. When you drag and drop, or double-click on a branch to add it to the expression, a pop-up box will appear prompting you to pick a variable from the branch to which you wish to refer (only if there are more than one variable associated with that branch).

4.9.2 Reserved Words

The following words are reserved for use in WEAP's expressions and cannot be included as part of a WEAP branch name:

%
Abs
And
CurrentAccountsYear
CurrentAccountsValue
Billion
Ceil
Equal
Exp
ExpForecast
Floor
Frac
GreaterThan
GreaterThanOrEqual
Growth
GrowthAs
GrowthFrom
Hundred
If
Int
Interp

LastYear
LessThan
LessThanOrEqual
LinForecast
Ln
Log
Log10
LogisticForecast
Max
Million
Min
MonthlyValues
Not
NotEqual
Or
Parent
PrevYear
PrevYearValue
ReadFromFile Remainder
Round
Smooth

- Sqr
- Sqrt
- Step
- Thousand
- TotalChildren
- Trillion
- Trunc
- VolumeElevation
- WaterYearMethod
- WaterYearSequence
- Year

In addition, branch names are limited to no more than 50 characters, and no less than 2 characters, and may only contain alphabetic and numeric characters as well as the following additional characters: _ . ? $ # [ ] { } All branch names must begin with an alphabetic character.

5 Results

5.1 Available Reports

5.1.1 Demand Results

Demand results cover requirements by and allocations to demand sites. The following reports are available:

Annual Water Demand

The annual requirement at each demand site, **before** distribution losses, reuse and demand-side management savings are taken into account.

Monthly Supply Requirement

The monthly requirement at each demand site, **after** distribution losses, reuse and demand-side management savings are taken into account.

Supply Delivered

The amount of water supplied to demand sites, listed either by source (supplies) or by destination (demand sites). When listed by destination, the amounts reported are the actual amounts reaching the demand sites, after subtracting any transmission losses.

Unmet Demand

The amount of each demand site's requirement that is not met. When some demand sites are not getting full coverage, this report is useful in understanding the magnitude of the shortage.

Coverage

The percent of each demand site's requirement (adjusting for distribution losses, reuse and demand-side management savings) that is met, from 0% (no water delivered) to 100% (delivery of full requirement). The coverage report gives a quick assessment of how well demands are being met.

Cost of Delivered Water

The cost of delivering water to demand sites, listed either by source (supplies) or by destination (demand sites).

Demand Site Inflow and Outflow

The mass balance of all water entering and leaving one or more demand sites. Inflows (from local and river supplies) are represented as positive amounts, outflows (either consumed or routed to wastewater treatment plants, rivers and local supplies) as negative amounts.

5.1.2 Supply and Resources Results

Area

Inflows: Water entering the area (river headflows, surface water inflows to reaches, groundwater recharge, local reservoir inflows, other local supply inflows).

Outflows: Water leaving the area (consumption at demand sites, evaporation on river reaches and reservoirs, losses in transmission links, losses in wastewater treatment, and outflows from the end of rivers and diversions).

Note: Inflows to area may not equal total outflows from area due to changes in storage.

River

Streamflow: The streamflow at selected nodes and reaches along a river. You can plot a line for each point on the river over time (choose Year for the X Axis), or a line for each month plotted along the river (choose River Nodes and Reaches for the X Axis).

Flow Requirement Coverage: The percent of each flow requirement that is met, from 0% (no water flowing) to 100% (flow requirement met or exceeded).

Groundwater

Storage: The aquifer storage levels at the end of each month.

Inflows and Outflows: A mass balance of all water entering and leaving a specified aquifer. Inflows (from recharge, inflow from river reaches, and return flows from demand sites and wastewater treatment plants) are represented as positive amounts, outflows (withdrawals by demand sites and outflows to river reaches) as negative amounts.

Overflow: Groundwater overflow occurs when the aquifer storage is at its maximum, and there is net inflow.

Reservoir

Storage: The reservoir storage levels at the end of each month.

Inflows and Outflows: All water entering and leaving a specified reservoir. Inflows (either from upstream (river reservoirs) or monthly inflow (local reservoirs) or return flows from demand sites and wastewater treatment plants) are represented as positive amounts, outflows (to downstream, evaporation, or withdrawals by demand sites) as negative amounts.

Hydropower: The power generated by reservoirs and hydropower nodes.

Transmission Link

Inflows and Outflows: Includes amounts lost to evaporation and leakage.

Other Local Supply

Inflows and Outflows: A mass balance of all water entering and leaving a specified other local supply source. Inflows are represented as positive amounts, outflows as negative amounts.

Return Link

Inflows and Outflows: Includes amounts lost to evaporation and leakage.

5.1.3 Environment Results

Environment results cover pollution generation by demand sites, pollution loads at receptors, and wastewater treatment.

Pollution Generation

Pollution generated by each demand site.

Pollution Loads

Pollutant loads carried by return flow links from demand sites and wastewater treatments (sources) into rivers and local supplies (receptors).

Pollution Inflow to Treatment Plants

Total pollution flowing in to wastewater treatment plants.

5.2 Options

5.2.1 Charts and Tables

Two tabs at the top of the Results View let you switch between **Charts** and **Tables**: both formats contain the same basic information. You can change any of the selection boxes that any time, but typically you will follow these steps to create a new chart:

1. First, use the selection box at the top of the screen (the chart title) to choose a particular report, such as Monthly Supply Requirement, Groundwater Storage or Streamflow.

2. Next, use the selection boxes attached to the chart's X axis and legend to pick the data dimensions you want to see on each axis of the chart. Different categories of results will have different data dimensions. For example, the Supply Delivered report has the following dimensions: years, demand sites, sources and scenarios, so you can therefore create a chart that has any two of these dimensions on the X axis and legend of a chart. Examples of charts you can create include: demand site by year (for a one or more sources and a given scenario), source by year (for a one or more demand sites and a given scenario), demand site by source (for a given year and scenario), demand site by scenario (for one or more sources and a given year), etc. Some restrictions do apply. For example, the years dimension cannot be plotted on the legend axis. Those dimensions not placed on the X axis or legend are listed in combo boxes the subtitle (just below the title), allowing you to pick one item (or where appropriate the total of all items) in that dimension. So for example, if you chose to view a demand site by year chart for Supply Delivered, you will choose from the subtitle the source (or sources) and scenario to display. When picking a dimension for the X axis or legend you will also be able to specify whether you want to show all items in the dimension or only selected items. If you choose “selected” you will be shown a dialog box in which you can check off the items to be displayed.
3. Next, you can use the various additional on-screen controls to further customize your chart.
   - Use the **Units** selection box to pick the unit for the chart. The class of the unit (volume, flow, energy, monetary, etc.) is determined by the category of result you are examining. WEAP handles scaling and units conversion automatically.
   - When viewing cost results, an additional **Costs** selection box appears, letting you choose either real (i.e. constant value) costs or discounted costs.
4. Finally, you can use the Toolbar on the right of the screen (or right-click on a chart) to customize the appearance of the chart or the table, to copy results to the Windows clipboard, and to print or export results to Microsoft Excel. Options on the toolbar let you select the type of chart, type of stacking, and formatting options such as 3D effects, log scales, grid lines, and the number of decimal places reported in numeric values. For charts that show results for just one year (i.e., the X axis dimension is not time), the animate button will play a movie showing the results for each year.

Saving Favorite Charts

If you want to save a particular chart, with all your formatting choices, for later retrieval, you can save it as a “favorite.” See Favorites for details.

5.2.2 Chart Toolbar

The chart toolbar is used to customize and print the charts and tables displayed in WEAP. It consists of the following buttons:

Chart Type selects the type of chart (pie, bar, horizontal bar, area, line, and point). Some restrictions apply to the types of charts you can choose. In particular, you can only pick pie charts when the there is a single set of summable values, and you can only pick area charts when values are summable.

Stack Type is used in area, bar and horizontal bar charts to pick how series are formatted. The options are: stacked, not stacked, grouped, percent stacked, and not stacked - 3D. This last option displays series behind one another in a 3D effect. Note that stacking of charts is only available when it makes to stack the variable or dimension. So for example, a variable such as water use rate cannot be stacked, and nor can different scenario values of any variable.

3D toggles whether charts are shown with a 3 dimensional effect. Note that due to software limitations, any charts with negative values cannot currently be shown with 3D effects.

Log toggles the use of a logarithmic scale on the chart. Note that log scales do not work well if the chart contains negative values.

Legend toggles whether a legend is displayed on the chart. Legends are always displayed in the Results View.

Shading toggles between colored charts and shaded charts. Depending on your type of printer, you may find that shaded charts work best in printed reports, while color charts work best while working with WEAP and for use in on-screen presentations.

Gridlines toggles the display of gridlines on a chart.

Increase Decimals increases the number of decimal places displayed in a table.

Decrease Decimals decreases the number of decimal places displayed in a table.

Copy copies the chart to the Windows clipboard in metafile format. Chart images can be pasted into any Windows program that supports image objects.

Print prints the chart or table. When printing tables you will be given the chance to set printer options such as print layout (landscape or portrait), print margins and how you want the table to be scaled to fit the page.

Print Preview lets you preview a chart and set basic printer options before printing.

Select Background Image lets you insert a background image behind your chart. You will be prompted to select a JPG, GIF or BMP file, and given the chance to preview the image before selecting it. Several water-related pictures come with WEAP, located in the _Pictures subdirectory. Background image settings are saved along with your other settings when you save a “Favorite” chart, and can then be displayed when you use WEAP's Overview feature.

Clear Background Image removes the background image from the current chart.

5.2.3 Favorites

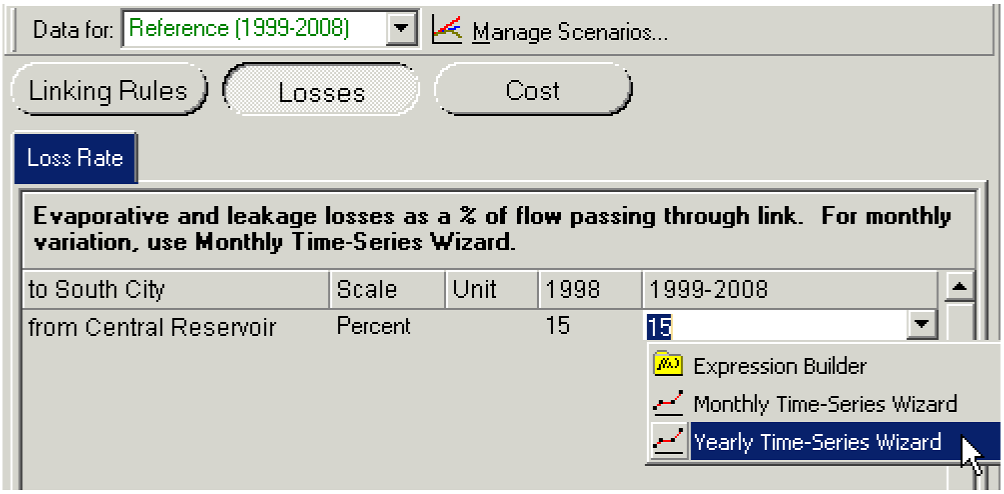
You can save your favorite charts including all settings for the axes, type of chart, and formatting, using the Favorites menu. This feature is similar to the bookmark/favorites features found on popular Internet browsing software. Later, in the Overviews View, you can group together favorite charts to create overviews of different results. Use the **Save Chart as Favorite** menu option to bookmark the current highlighted chart. You will be asked to give the favorite a name. Use the **Delete Favorite** menu option to delete a saved favorite. To switch to a favorite chart, select its name from the favorites menu.

6 Supporting Screens

6.1 Yearly Time-Series Wizard

The Yearly Time-Series Wizard is a tool that helps you construct the various time-series expressions supported by WEAP's Data View. These expressions include functions for interpolation, step functions, smooth curves and linear, exponential and logistic projections.

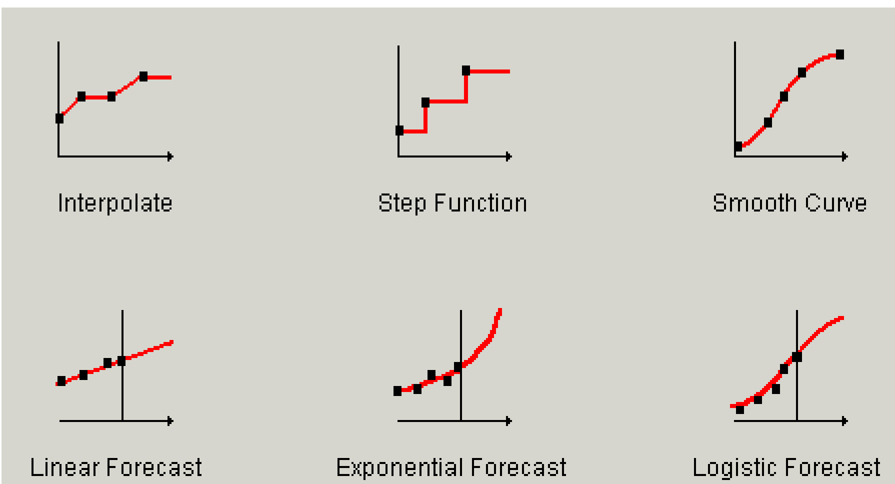
To access the wizard, either right-click on the data table or click on the down arrow on the right side of the expression box, and choose Yearly Time-Series Wizard from the menu.



The wizard is divided into three pages, which you step through using the **Next** ( ) and **Previous** ( ) buttons.

6.1.1 Page 1: Projection Method

Use this page to select the type of function you want to create. The functions are summarized in graph form on screen as shown below, and are grouped into two main types.



The three functions on the top row allow you to specify data points for various future years, and the function then calculates the values for intervening years:

- The **interpolation** function calculates values based on a linear (straight line) interpolation between the values you specify.
- The **step** function assumes that values change discretely at the specified data years. In other words, values stay constant after a specified data year, until the next specified data year.
- The **smooth curve** function calculates a best-fit smooth curve based on a polynomial least-squares fit of the specified data points. To achieve a good fit, the smooth curve function requires at least 3 data points.

The interpolation and smooth curve functions are most useful when you expect data to change gradually (for example when modeling the gradual penetration of some common device such as refrigerators or vehicles). The step function is most useful for specifying "lumpy" changes to your system, such as the construction of new transmission links.

The last three functions allow you to specify historic data values (i.e., values before the Current Accounts). The different functions are then used to extrapolate data forward to calculate future values. Extrapolations are based on **linear**, **exponential** or **logistic** least-squares curve fits. Use these functions with care. The onus is on you to ensure that the projections are reasonable, both in terms of how a) well the estimated curve fits the historical data, and b) how policies and other structural factors may change in the future. In other words, **be sure to consider how well you can identify past trends, but also if it is reasonable to expect these past trends to continue into the future.** WEAP helps you with task a) by providing various statistics describing the curve-fit: the R^2 value, the standard error, and the number of observations. If you need to do a more detailed analysis, we suggest you use the data analysis features built-in to Microsoft Excel, and then link your results to your WEAP analysis (see below).

6.1.2 Page 2: Data Source

On page 2, you select the source of the data for the expression. Select whether you want to enter the data directly (*i.e.*, type it in) or whether you want to link to the values in an external Excel spreadsheet.

6.1.3 Page 3: Data Entry

Depending on you choice on page 2, in page 3 you either enter the data used by the function or select an Excel spreadsheet and range from which to extract the data for the selected time-series function.

- When entering data directly, use the **Add** (+) and **Delete** (−) buttons to add or delete new year/value pairs, or click and drag data points on the adjoining graph to enter values graphically. For the Interpolation function, an additional data field is shown allowing you to specify a percentage growth rate, which is applied after the last specified data year. By default this value is zero. In other words, by default values are not extrapolated past the last interpolation data year. The data you entered will be shown as the points on the adjoining chart, while the line drawn on the chart will reflect the projection method you chose on page one.

- When linking to a Microsoft Excel sheet, first enter the name of the worksheet file (.XLS or .XLW) or use "**...**" button to browse your PC and local area network for the file. Next enter the range name from which the data will be extracted, or click the button attached to the field to select from the named ranges in the worksheet. Ranges can be specified either as names, or as Excel range formulae (e.g. Sheet1!A1:B16). NB: ranges must contain only two columns of data. The first column must contain years, arranged in chronological order (with the earliest at the top), and the second must contain data values. Click on the **Get Excel Data** button to extract the data from Excel and preview the values in the adjoining graph. Notice that the points on the chart will be the values in the Excel spreadsheet, while the line drawn on the chart will reflect the projection method you chose on page one.

6.2 Manage Areas

Use the Manage Areas screen, to create, delete, and organize the data sets (Areas) on your computer. The Area Manager screen is divided into two panes. At the top a table shows the names of areas installed on your computer, with checkmarks indicating which areas are currently "zipped" (i.e., compressed into a single "zip" file). At the bottom you can view and edit Notes associated with each area.

On the right of the screen a set of buttons provide a variety of options for managing areas:

- **New:** Use this option to create a new Area data set. The new area can either be blank or a copy of an existing Area.
- **Delete:** Use this option to delete an area. NB: deleted areas are permanently deleted from your hard disk, and unless previously backed up, cannot be restored.
- **Rename:** Use this option to change the name of an area (and the subdirectory in which it is stored).
- **Backup:** Use this option to make a backup copy of an area. The area will first be archived into a single zip file. You can backup to any drive or folder on your PC or on a local area network.
- **Restore:** Use this option to restore a previously backed up data set, or to load an area sent to you by another person. You will be prompted to select the name of a zip file. WEAP will check the zip file to ensure that it is a valid WEAP Area data set.
- **Zip:** Use this option to compress an unused area in order to save disk space (it will automatically expand to normal size when next selected from the Main Menu: Area, Open).
- **Unzip:** Use this option to uncompress an area. Since a compressed area is automatically uncompressed when it is next selected (Main Menu: Area, Open), you do not normally need to unzip it here in Manage Areas.
- **Email to...** Use this option to send a data set as an email attachment. WEAP will automatically archive the data set into a single zip file and then attach the file to an email message. The contents of the email will include a summary of the system information for your PC. This option can be very useful if you are encountering any problems in your analysis and want to be able to send the data set to the staff of SEI-Boston for their review. The default email address is weap@tellus.org. Note: this feature requires that you have a MAPI compliant email system installed on your PC, such as Microsoft Outlook or

Netscape Navigator.

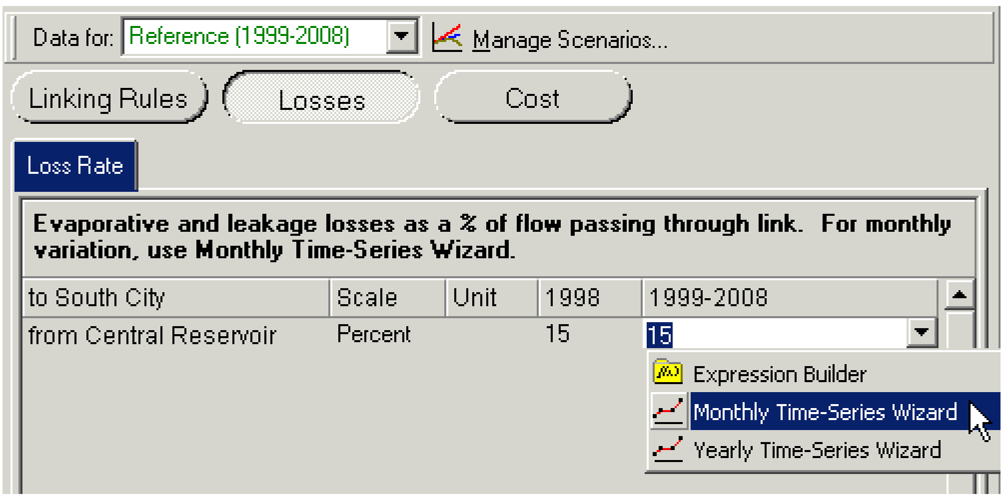
- **Repair:** Use this option to check an area data set for errors, including corrupted data files and orphaned data. Where possible, WEAP will attempt to fix these errors. If it cannot it will report the problem to you. If errors cannot be fixed, contact the staff of SEI-Boston for assistance. This option will also “pack” the data files of your area, removing unused space and compacting the data files. (this is different from the Zip option)

Menu Option: Area: Manage Areas

6.3 Monthly Time-Series Wizard

The Monthly Time-Series Wizard helps you enter values that vary monthly but not yearly, e.g., monthly variation of demand. Enter monthly values in the table on the left and they will be graphed on the right. If you leave some months blank, WEAP will interpolate using adjacent points.

To access the wizard, either right-click on the data table or click on the down arrow on the right side of the expression box, and choose Monthly Time-Series Wizard from the menu.



6.4 Overview Manager

Use the Overview Manager (accessed from the Overviews Toolbar) to

- Add ( ), delete ( ) and rename ( ) overviews, and to
- quickly select which favorite charts are to be included in an overview.

Use the selection box to select which overview you wish to manage, and then click the check boxes next to the list of favorite charts to include or exclude charts. When you click the close button, the edited overviews will be displayed on screen.

See Also Overviews View

7 Calculation Algorithms

WEAP calculates a water and pollution mass balance for every node and link in the system on a monthly time step. Water is dispatched to meet instream and consumptive requirements, subject to supply priorities, demand site preferences, mass balance and other constraints. Point loads of pollution into receiving bodies of water are computed, but no in-stream water quality concentrations are calculated.

WEAP operates on a monthly time step, from the first month of the Current Accounts year through the last month of the last scenario year. Each month is independent of the previous month, except for reservoir and aquifer storage. Thus, all of the water entering the system in a month (e.g., headflow, groundwater recharge, or runoff into reaches) is either stored in an aquifer or reservoir, or leaves the system by the end of the month (e.g., outflow from end of river, demand site consumption, reservoir or river reach evaporation, transmission and return flow link losses). Because the time scale is relatively long (monthly), all flows are assumed to occur instantaneously. Thus, a demand site can withdraw water from the river, consume some, return the rest to a wastewater treatment plant that treats it and returns it to the river. This return flow is available for use in the same month to downstream demands.

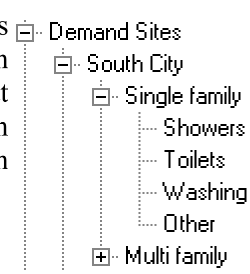
Each month the calculations follow this order:

1. Annual demand and monthly supply requirements for each demand site and flow requirement.
2. Inflows and outflows of water for every node and link in the system. This includes calculating withdrawals from supply sources to meet demand, and dispatching reservoirs. This step is solved by a linear program (LP), which attempts to optimize coverage of demand site and instream flow requirements, subject to supply priorities, demand site preferences, mass balance and other constraints.
3. Pollution generation by demand sites, flows and treatment of pollutants, and loadings on receiving bodies.
4. Hydropower generation.
5. Costs of delivered water.

7.1 Annual Demand and Monthly Supply Requirement Calculations

7.1.1 Annual Demand

A demand site's (*DS*) demand for water is calculated as sum of the demands for all the demand site's bottom-level branches (*Br*). A bottom-level branch is one that has no branches below it. For example, in the structure shown at the right, Showers, Toilets, Washing and Other (and four others underneath Multi family that are not shown) are the bottom-level branches for South City.



$$AnnualDemand_{DS} = \sum_{Br} (TotalActivityLevel_{Br} \text{ x } WaterUseRate_{Br})$$

The total activity level for a bottom-level branch is the product of the activity levels in all branches from the bottom branch back up to the demand site branch (where Br is the bottom-level branch, Br' is the parent of Br, Br" is the grandparent of Br, etc.).

$$TotalActivityLevel_{Br} = ActivityLevel_{Br} \times ActivityLevel_{Br'} \times ActivityLevel_{Br''} \times ...$$

For the example above, this becomes

$$TotalActivityLevel_{Showers} = ActivityLevel_{Showers} \times ActivityLevel_{SingleFamily} \times ActivityLevel_{SouthCity}$$

= percent of people in single family homes who have showers x percent of people who live in single family homes x number of people in South City

The activity level for a branch, and the water use rate for a bottom-level branch, are entered as data. (See Demand\Annual Water Use\Activity Level and Demand\Annual Water Use\Water Use Rate.) Note that those branches marked as having “No data” (unit = N/A) are treated as having an activity level of 1.

7.1.2 Monthly Demand

The demand for a month (*m*) equals that month's fraction (specified as data under Demand\Monthly Variation) of the adjusted annual demand.

$$MonthlyDemand_{DS,m} = MonthlyVariationFraction_{DS,m} \times AdjustedAnnualDemand_{DS}$$

7.1.3 Monthly Supply Requirement

The monthly demand represents the amount of water needed each month by the demand site for its use, while the **supply requirement** is the actual amount needed from the supply sources. The supply requirement takes the demand and adjusts it to account for internal reuse, demand side management strategies for reducing demand, and internal losses. These three adjustment fractions are entered as data—see Demand\Loss and Reuse and Demand\Demand Side Management.

$$MonthlySupplyRequirement_{DS,m} = (MonthlyDemand_{DS,m} \times (1 - ReuseRate_{DS}) \times (1 - DSMSavings_{DS})) / (1 - LossRate_{DS})$$

7.2 Inflows and Outflows of Water

This step computes water inflows to and outflows from every node and link in the system for a given month. This includes calculating withdrawals from supply sources to meet demand. A linear program (LP) is used to maximize satisfaction of demand site and user-specified instream flow requirements, subject to supply priorities, demand site preferences, mass balance and other constraints. The LP solves the set of simultaneous equations explained below. For details of how supply priorities and demand site preferences affect calculations, see Supply Priority, Demand Preferences and Allocation Order.

Mass balance equations are the foundation of WEAP's monthly water accounting: total inflows equal total outflows, net of any change in storage (in reservoirs and aquifers). Every node and link in WEAP has a mass balance equation, and some have additional equations which constrain their flows (e.g., inflow to a demand site cannot exceed its supply requirement, outflows from an aquifer cannot exceed its maximum withdrawal, link losses are a fraction of flow, etc.).

7.2.1 Demand Site Flows

The amount supplied to a demand site (*DS*) is the sum of the inflows from its transmission links. (The inflow to the demand site from a supply source (*Src*) is defined as the outflow from the transmission link connecting them, i.e., net of any leakage along the transmission link).

$$DemandSiteInflow_{DS} = \sum_{Src} TransLinkOutflow_{Src,DS}$$

Every demand site has a monthly supply requirement for water, as computed in Demand Calculations. The inflow to the demand site equals this requirement, unless there are water shortages due to hydrological, physical, contractual or other constraints.

$$DemandSiteInflow_{DS} \leq SupplyRequirement_{DS}$$

Some fraction of the water received by a demand site will be unavailable for use elsewhere in the system (i.e., because the water is consumed—lost to evaporation, embodied in products, or otherwise unaccounted for—it disappears from the system.) The remainder of the water received by a demand site is available downstream in the system, and is called the return flow (which is directed to one or more specified destinations (Dest). (These return flow routing fractions are entered as data—see Supply and Resources\Return Flows\Routing.)

$$Consumption_{DS} = DemandSiteInflow_{DS} - \sum_{Dest} DSReturnLinkInflow_{DS,Dest}$$

7.2.2 Transmission Link Flows

In a transmission link from a supply source (*Src*) to a demand site (*DS*), the amount delivered to the demand site (i.e., the outflow from the transmission link) equals the amount withdrawn from the source (i.e., the inflow to the transmission link) minus any losses along the link.

$$TransLinkOutflow_{Src,DS} = TransLinkInflow_{Src,DS} - TransLinkLoss_{Src,DS}$$

The losses in the transmission link are a fraction of its inflow, where the loss rate is entered as data (see Supply and Resources\Linking Demand and Supply\Transmission Losses).

$$TransLinkLoss_{Src,DS} = TransLinkLossRate_{Src,DS} \times TransLinkInflow_{Src,DS}$$

You may set constraints to model the physical, contractual or other limits on the flow from a source to a demand site, using one of two types of constraints. One type of constraint is a fixed upper bound (*MaximumFlowVolume*) on the amount of water flowing into the link. For example, this might represent a pipeline capacity, or a contractually limited allotment.

$$TransLinkInflow_{Src,DS} \leq MaximumFlowVolume_{Src,DS}$$

The other type of constraint allow you to set the maximum fraction (*MaximumFlowPercent*) of the demand site's supply requirement that can be satisfied from a particular source. Both of these constraints are entered as data (see Supply and Resources\Linking Demand and Supply\Linking Rules).

$$TransLinkOutflow_{Src,DS} \leq MaximumFlowPercent_{Src,DS} \times SupplyRequirement_{DS}$$

7.2.3 Demand Site Return Link Flows

Demand site return flow links transmit wastewater from demand sites (*DS*) to destinations (*Dest*), which may be either wastewater treatment plants or receiving bodies of water. The amount that flows into the link is a fraction of demand site inflow. (This return flow routing fraction is entered as data—see Supply and Resources\Return Flows\Routing.)

$$DSReturnLinkInflow_{DS,Dest} = DSReturnFlowRoutingFraction_{DS,Dest} \times DemandSiteInflow_{DS}$$

The amount that reaches the destination (i.e., the outflow from the link) equals the outflow from the demand site (i.e., the inflow to the link) minus any losses along the link.

$$DSReturnLinkOutflow_{DS,Dest} = DSReturnLinkInflow_{DS,Dest} - DSReturnLinkLoss_{DS,Dest}$$

The losses along the link are a fraction of its inflow, where the loss rate is entered as data (see Supply and Resources\Return Flows\Losses).

$$DSReturnLinkLoss_{DS,Dest} = DSReturnLinkLossRate_{DS,Dest} \times DSReturnLinkInflow_{DS,Dest}$$

7.2.4 Wastewater Treatment Plant Flows

A wastewater treatment plant (*TP*) receives wastewater inflows from one or more demand sites (*DS*). (The inflow to the treatment plant from a demand site is defined as the outflow from the return flow link connecting them.)

$$TreatmentPlantInflow_{TP} = \sum_{DS} DSReturnLinkOutflow_{DS,TP}$$

The treatment plant treats wastewater inflows, removes a fraction of the pollution, then returns the treated effluent to one or more receiving bodies of water (*Dest*), less any water lost in processing. (See Pollution Calculations for details on the generation, treatment and flow of pollution.)

$$\sum_{Dest} TPReturnLinkInflow_{TP,Dest} = TreatmentPlantInflow_{TP} - TreatmentLoss_{TP}$$

The amount lost in processing, which disappears from the system, is assumed to be a fraction of the water received by the treatment plant. This loss is defined as the treatment plant inflow not routed to a destination. (These return flow routing fractions are entered as data—see Supply and Resources\Return Flows\Routing.)

$$TreatmentLoss_{TP} = TreatmentPlantInflow_{TP} - \sum_{Dest} TPReturnLinkInflow_{TP,Dest}$$

7.2.5 Wastewater Treatment Plant Return Link Flows

The treatment plant return link transmit treated wastewater from treatment plants (*TP*) to receiving bodies of water (*Dest*). The amount that flows into the link is a fraction of treatment plant inflow. (This outflow routing fraction is entered as data—see Supply and Resources\Return Flows\Outflow Routing.)

$$TPReturnLinkInflow_{TP,Dest} = TPOutflowRoutingFraction_{TP,Dest} \times TreatmentPlantInflow_{TP}$$

The amount that reaches the destination (i.e., the outflow from the link) equals the outflow from the treatment plant (i.e., the inflow to the link) minus any losses along the link.

$TPReturnLinkOutflow_{TP,Dest} = TPReturnLinkInflow_{TP,Dest} - TPReturnLinkLoss_{TP,Dest}$

The losses along the link are a fraction of its inflow, where the loss rate is entered as data (see Supply and Resources\Return Flows\Losses).

$TPReturnLinkLoss_{TP,Dest} = TPReturnLinkInflow_{TP,Dest} \times TPReturnLinkLossRate_{TP,Dest}$

7.2.6 River

River Headflow

Headflow is defined as the flow into the first reach (*Rch*) of a river (*River*), and is entered as data (see Supply and Resources\River\Headflow).

$UpstreamInflow_{Rch} = RiverHeadflow_{River}$

Reach Flows

The inflow to a reach (*Rch*) from upstream (other than the first reach) is defined as the amount flowing downstream from the node (*Node*) immediately above the reach.

$UpstreamInflow_{Rch} = DownstreamOutflow_{Node}$

The flow out of a reach into the downstream node equals the flow into the reach from upstream plus surface water runoff and groundwater inflows to the reach minus evaporation and outflow to groundwater (inflows from runoff and groundwater are entered directly—see Supply and Resources\River\Reaches). This downstream outflow from the reach will become the upstream inflow to the node immediately below the reach (or the outflow from the river as a whole if there are no more nodes downstream of the reach).

$$DownstreamOutflow_{Rch} = UpstreamInflow_{Rch} + SurfaceWaterInflow_{Rch} + GroundwaterFlowToReach_{GW,Rch} - ReachFlowToGroundwater_{GW,Rch} - Evaporation_{Rch}$$

Outflows to groundwater are a fraction (entered as data—see Supply and Resources\River\Reaches) of upstream inflows to the reach.

$ReachFlowToGroundwater_{,Rch} = ReachFlowToGroundwaterFraction_{Rch} \times UpstreamInflow_{Rch}$

Evaporation is calculated as a fraction (entered as data—see Supply and Resources\River\Reaches) of upstream inflow to the reach.

$Evaporation_{Rch} = EvaporationFraction_{Rch} \times UpstreamInflow_{Rch}$

River Reservoir Flows

A reservoir's (*Res*) storage in the first month (*m*) of the simulation is specified as data (see Supply and Resources\River\Reservoir\Storage).

$BeginMonthStorage_{Res,m} = InitialStorage_{Res}$ for $m = 1$

Thereafter, it begins each month with the storage from the end of the previous month.

$BeginMonthStorage_{Res,m} = EndMonthStorage_{Res,m-1}$ for $m > 1$

This beginning storage level is adjusted for evaporation. Since the evaporation rate is specified as a change in elevation (see Supply and Resources\River\Reservoir\Physical\Net Evaporation), the storage level must be converted from a volume to an elevation. This is done using the volume-elevation curve (specified as data—see Supply and Resources\River\Reservoir\Physical\Volume Elevation Curve).

$$BeginMonthElevation_{Res} = VolumeToElevation(BeginMonthStorage_{Res})$$

The elevation is reduced by the evaporation rate.

$$AdjustedBeginMonthElevation_{Res} = BeginMonthElevation_{Res} - EvaporationRate_{Res}$$

Then the adjusted elevation is converted back to a volume.

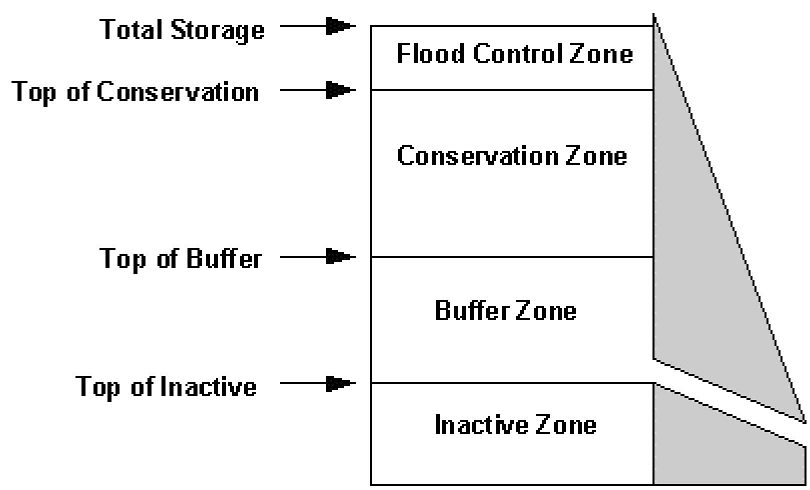
$$AdjustedBeginMonthStorage_{Res} = ElevationToVolume(AdjustedBeginMonthElevation_{Res})$$

A reservoir's operating rules determine how much water is available in a given month for release, to satisfy demand and instream flow requirements, and for flood control. These rules operate on the available resource for the month. This “storage level for operation” is the adjusted amount at the beginning of the month, plus inflow from upstream and return flows from demand sites (*DS*) and treatment plants (*TP*).

$$StorageForOperation_{Res} = AdjustedBeginMonthStorage_{Res} + UpstreamInflow_{Res} + \sum_{DS} DSReturnFlow_{DS,Res} + \sum_{TP} TPReturnFlow_{TP,Res}$$

The amount available to be released from the reservoir is the full amount in the conservation and flood control zones and a fraction (the buffer coefficient fraction is entered as data—see Supply and Resources\River\Reservoir\Operation) of the amount in the buffer zone. Each of these zones is given in terms of volume (i.e. not elevation). The water in the inactive zone is not available for release.

$$StorageAvailableForRelease_{Res} = FloodControlAndConservationZoneStorage_{Res} + BufferCoefficient_{Res} \times BufferZoneStorage_{Res}$$



All of the water in the flood control and conservation zones is available for release, and equals the amount above Top Of Buffer (TOB and other reservoir zones levels are entered as data—see Supply and Resources\River\Reservoir\Operation),

$$FloodControlAndConservationZoneStorage_{Res} = StorageForOperation_{Res} - TopOfBuffer_{Res}$$

or zero if the level is below Top Of Buffer.

$$FloodControlAndConservationZoneStorage_{Res} = 0$$

Buffer zone storage equals the total volume of the buffer zone if the level is above Top Of Buffer,

$BufferZoneStorage_{Res} = TopOfBufferZone_{Res} - TopOfInactiveZone_{Res}$

or the amount above Top Of Inactive if the level is below Top of Buffer,

$BufferZoneStorage_{Res} = StorageForOperation_{Res} - TopOfInactiveZone_{Res}$

or zero if the level is below Top Of Inactive.

$BufferZoneStorage_{Res} = 0$

WEAP will release only as much of the storage available for release as is needed to satisfy demand and instream flow requirements, in the context of releases from other reservoirs and withdrawals from rivers and other sources. (As much as possible, the releases from multiple reservoirs are adjusted so that each will have the same fraction of their conservation zone filled. For example, the conservation zone in a downstream reservoir will not be drained while an upstream reservoir remains full. Instead, each reservoir's conservation zone would be drained halfway.)

$$Outflow_{Res} = DownstreamOutflow_{Res} + \sum_{DS} TransLinkInflow_{Res,DS}$$

where

$$Outflow_{Res} \leq StorageAvailableForRelease_{Res}$$

The storage at the end of the month is the storage for operation minus the outflow.

$EndMonthStorage_{Res} = StorageForOperation_{Res} - Outflow_{Res}$

The change in storage is the difference between the storage at the beginning and the end of the month. This is an increase if the ending storage is larger than the beginning, a decrease if the reverse is true.

$IncreaseInStorage_{Res} = EndMonthStorage_{Res} - BeginMonthStorage_{Res}$

Run-of-River Hydropower Flows

A run-of-river hydropower facility (*ROR*) generates hydropower from a fixed head on the river (see Hydropower Calculations for details). It does not have any storage nor does it remove water from the river. The flow out of the facility equals the flow in from upstream, plus demand site (*DS*) and treatment plant (*TP*) returns. (See Hydropower Calculations for details of hydropower generation.)

$$DownstreamOutflow_{ROR} = UpstreamInflow_{ROR} + \sum_{DS} DSReturnFlow_{DS,ROR} + \sum_{TP} TPReturnFlow_{TP,ROR}$$

Minimum Flow Requirement Node Flows

A minimum instream flow requirement (*FR*), which is entered as data (see Supply and Resources\River\Flow Requirement), specifies a minimum flow required at a point on the river, to meet water quality, fish & wildlife, navigation, recreation, downstream or other requirements. Depending on its supply priority, a flow requirement will be satisfied either before or after other requirements in the system. (The minimum flow is achieved either by restricting withdrawals from the river or by releasing water from reservoirs.) The flow out of the node equals the flow in from upstream, plus demand site (*DS*) and treatment plant (*TP*) returns flows that come in at that point.

$$DownstreamOutflow_{FR} = UpstreamInflow_{FR} + \sum_{DS} DSReturnFlow_{DS,FR} + \sum_{TP} TPReturnFlow_{TP,FR}$$

River Withdrawal Nodes Flows

Water is withdrawn from withdrawal nodes (*WN*) and delivered via transmission links to satisfy supply requirements at demand sites. The amount to withdraw, from zero up to the full supply requirement, is computed within the context of all demand and instream flow requirements, available supplies, supply priorities, demand preferences and other constraints. The downstream outflow from the withdrawal node equals the inflows from upstream plus demand site (*DS*) and treatment plant (*TP*) returns, minus the withdrawal to all connected demand sites.

$$DownstreamOutflow_{WN} = UpstreamInflow_{WN} + \sum_{DS} DSReturnFlow_{DS,WN} + \sum_{TP} TPReturnFlow_{TP,WN} - \sum_{DS} TransLinkInflow_{WN,DS}$$

Diversion Node Flows

Diversion nodes (*DN*) withdraw water from a river (or another diversion), and this diverted flow becomes the headflow for a diversion. A diversion is modeled in WEAP as a separate river, complete with river nodes, demands and return flows. WEAP will divert only as much water as needed to satisfy the demand sites connected to the diversion, and its instream flow requirements. The downstream outflow from the diversion node equals the inflows from upstream plus demand site (*DS*) and treatment plant (*TP*) returns, minus the amount diverted.

$$DownstreamOutflow_{DN} = UpstreamInflow_{DN} + \sum_{DS} DSReturnFlow_{DS,DN} + \sum_{TP} TPReturnFlow_{TP,DN} - AmountDiverted_{DN}$$

Return Flow Node Flows

Return flow nodes (*RFN*) are a point at which demand sites (*DS*) and treatment plants (*TP*) returns enter the river. The downstream outflow from the return flow node equals the inflows from upstream plus demand site (*DS*) and treatment plant (*TP*) return flows.

$$DownstreamOutflow_{RFN} = UpstreamInflow_{RFN} + \sum_{DS} DSReturnFlow_{DS,RFN} + \sum_{TP} TPReturnFlow_{TP,RFN}$$

Tributary Inflow Node Flows

A tributary inflow node (*TN*) is the point at which one or more rivers or diversions flow into another river or diversion. The downstream outflow from the tributary inflow node equals the inflows from upstream of the node on the main river plus the outflow from the last reach (*Rch*) on the tributary.

$DownstreamOutflow_{TN} = UpstreamInflow_{TN} + DownstreamOutflow_{Rch}$

7.2.7 Local Supply

Groundwater Flows

A groundwater node's (*GW*) storage in the first month (*m*) of the simulation is specified as data (see Supply and Resources\Local\Groundwater\Storage).

$BeginMonthStorage_{GW,m} = InitialStorage_{GW} \text{ for } m = 1$

Thereafter, it begins each month with the storage from the end of the previous month.

$BeginMonthStorage_{GW,m} = EndMonthStorage_{GW,m-1} \text{ for } m > 1$

The storage at the end of the month equals the storage at the beginning plus inflows from natural recharge (entered as data: Supply and Resources\Local\Groundwater\Natural Recharge), demand site (*DS*) and treatment plant (*TP*) return flows, and subsurface flow from river reaches (*Rch*), minus withdrawals by demand sites and subsurface flow to river reaches. (For a description of groundwater/surface water interactions, see River Reach Flows.)

$$EndMonthStorage_{GW} = BeginMonthStorage_{GW} + NaturalRecharge_{GW} + \sum_{DS} DSReturnFlow_{DS,GW} + \sum_{TP} TPReturnFlow_{TP,GW} + ReachFlowToGroundwater_{GW,Rch} - \sum_{DS} TransLinkInflow_{GW,DS} - GroundwaterFlowToReach_{GW,Rch}$$

The amount withdrawn from the aquifer to satisfy demand requirements is determined in the context of all other demands and supplies in the system. The maximum withdrawals from an aquifer can be set (see Supply and Resources\Local\Groundwater\Maximum Withdrawal), to model the monthly pumping capacity of the well or other characteristics of the aquifer that could limit withdrawals.

$$\sum_{DS} TransLinkInflow_{GW,DS} \leq MaximumGroundwaterWithdrawal_{GW}$$

Local Reservoir Flows

Local reservoirs are identical to river reservoirs, except that they are not located along a river, tributary or diversion and therefore do not have inflow from these sources. All other properties of the local reservoir calculations are the same as river reservoirs. In detail, a local reservoir's (*Res*) storage in the first month (*m*) of the simulation is specified as data (see Supply and Resources\Local\Reservoir\Storage).

$BeginMonthStorage_{Res,m} = InitialStorage_{Res} \text{ for } m = 1$

Thereafter, it begins each month with the storage from the end of the previous month.

$BeginMonthStorage_{Res,m} = EndMonthStorage_{Res,m-1} \text{ for } m > 1$

This beginning storage level is adjusted for evaporation. Since the evaporation rate is specified as a change in elevation (see Supply and Resources\Local\Reservoir\Physical\Net Evaporation), the storage level must be converted from a volume to an elevation. This is done using the volume-elevation curve (specified as data—see Supply and Resources\Local\Reservoir\Physical\Volume Elevation Curve).

$$BeginMonthElevation_{Res} = VolumeToElevation(\ BeginMonthStorage_{Res}\ )$$

The elevation is reduced by the evaporation rate.

$$AdjustedBeginMonthElevation_{Res} = BeginMonthElevation_{Res} - EvaporationRate_{Res}$$

Then the adjusted elevation is converted back to a volume.

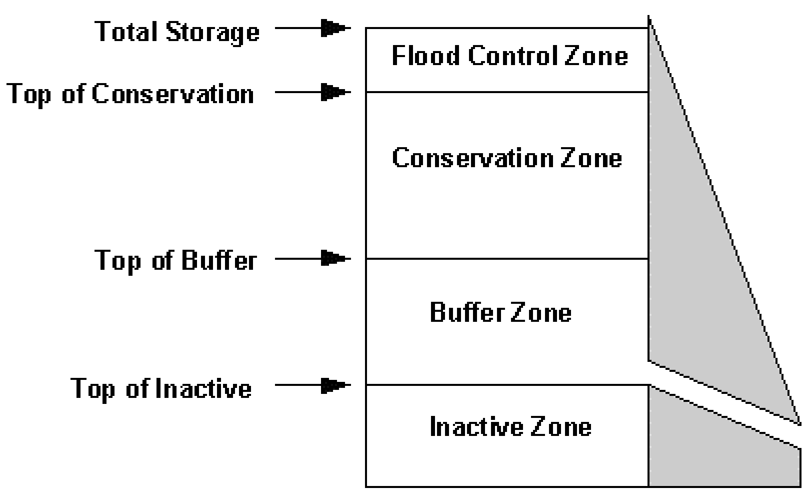
$$AdjustedBeginMonthStorage_{Res} = ElevationToVolume(\ AdjustedBeginMonthElevation_{Res}\ )$$

A reservoir's operating rules determine how much water is available in a given month for release, to satisfy demand requirements and for flood control. These rules operate on the available resource for the month. This "storage level for operation" is the adjusted amount at the beginning of the month, plus inflow from return flows from demand sites (*DS*) and treatment plants (*TP*).

$$StorageForOperation_{Res} = AdjustedBeginMonthStorage_{Res} + \sum_{DS} DSReturnFlow_{DS,Res} + \sum_{TP} TPReturnFlow_{TP,Res}$$

The amount available to be released from the reservoir is the full amount in the conservation and flood control zones and a fraction (the buffer coefficient fraction is entered as data—see Supply and Resources\Local\Reservoir\Operation) of the amount in the buffer zone. Each of these zones is given in terms of volume (i.e. not elevation). The water in the inactive zone is not available for release.

$$StorageAvailableForRelease_{Res} = FloodControlAndConservationZoneStorage_{Res} + BufferCoefficient_{Res} \times BufferZoneStorage_{Res}$$



All of the water in the flood control and conservation zones is available for release, and equals the amount above Top Of Buffer (TOB and other reservoir zones levels are entered as data—see Supply and Resources\Local\Reservoir\Operation),

$$FloodControlAndConservationZoneStorage_{Res} = StorageForOperation_{Res} - TopOfBuffer_{Res}$$

or zero if the level is below Top Of Buffer.

$$FloodControlAndConservationZoneStorage_{Res} = 0$$

Buffer zone storage equals the total volume of the buffer zone if the level is above Top Of Buffer,

$BufferZoneStorage_{Res} = TopOfBufferZone_{Res} - TopOfInactiveZone_{Res}$

or the amount above Top Of Inactive if the level is below Top of Buffer,

$BufferZoneStorage_{Res} = StorageForOperation_{Res} - TopOfInactiveZone_{Res}$

or zero if the level is below Top Of Inactive.

$BufferZoneStorage_{Res} = 0$

WEAP will release only as much of the storage available for release as is needed to satisfy demand requirements, in the context of releases from other reservoirs and withdrawals from rivers and other sources.

$$Outflow_{Res} = \sum_{DS} TransLinkInflow_{Res,DS}$$

where

$$Outflow_{Res} \leq StorageAvailableForRelease_{Res}$$

The storage at the end of the month is the storage for operation minus the outflow.

$$EndMonthStorage_{Res} = StorageForOperation_{Res} - Outflow_{Res}$$

The change in storage is the difference between the storage at the beginning and the end of the month. This is an increase if the ending storage is larger than the beginning, a decrease if the reverse is true.

$$IncreaseInStorage_{Res} = EndMonthStorage_{Res} - BeginMonthStorage_{Res}$$

Other Local Supply Flows

“Other” local supplies (*OLS*) have no storage capacity. The full amount of the monthly inflow (entered as data—see Supply and Resources\Local\Other\Inflow) is available for withdrawal by demand sites. What is not withdrawn is assumed to flow out of the system, and therefore is not available for use in the system.

$$Outflow_{OLS} = Inflow_{OLS} - \sum_{DS} TransLinkInflow_{OLS,DS}$$

7.3 Pollution Calculations

7.3.1 Annual Generation

The amount of a pollutant (*p*) generated by a demand site (*DS*) is the product of the level of activity producing pollution and the annual pollution rate per activity. (The activity level and pollution intensity are entered as data—see Environment\Pollution Generation.)

$$AnnualPollutionGenerated_{DS,p} = PollutionActivityLevel_{DS} \times PollutionRate_{DS,p}$$

7.3.2 Monthly Generation

The pollution generated in a month (*m*) equals that month's fraction of the annual generation, which is assumed to follow the volume of demand, and therefore the demand site's monthly variation in demand. This fraction is specified as data under Demand\Monthly Variation.

$$MonthlyPollutionGenerated_{DS,p,m} = MonthlyVariationFraction_{DS,m} \times AnnualPollutionGenerated_{DS,p}$$

7.3.3 Pollution Routing from Demand Sites

The pollution generated by a demand site is carried in the wastewater return flows to wastewater treatment plants and receiving bodies of water. Wastewater flows from a given demand site to multiple destinations are assumed to have approximately the same concentrations. Therefore, the pollution streams flowing from a single source are proportional to the volume of flow. Thus, the amount of pollution that flows out of a demand site into a return flow link is a fraction of the pollution generated.

$$DSReturnLinkPollInflow_{DS,Dest,p} = (DSOutflowRoutingFraction_{DS,Dest}1 / \sum_{Dest} DSOutflowRoutingFraction_{DS,Dest}) \times MonthlyPollGenerated_{DS,p}$$

For example, if the routing fraction from Demand Site North Agriculture to North Aquifer was 35%, and the routing fraction from Agriculture North to the Weaping River was 25% (with 40% of water consumed by the demand site), the fraction of Agriculture North's pollution that flow towards North Aquifer would be 0.35 / (0.35 + 0.25) = 0.58.

Some of the pollutant might decay or otherwise be lost as it passes through the return flow link. The pollution that flows out of the return flow link is a fraction (entered as data—see Environment\Pollutant Decrease in Return Flows) of the inflow.

$$DSReturnLinkPollOutflow_{DS,Dest,p} = (1 - DSReturnLinkPollDecreaseRate_{DS,Dest,p}) \times DSReturnLinkPollInflow_{DS,Dest,p}$$

7.3.4 Wastewater Treatment

The pollution that flows into a wastewater treatment plant (*TP*) is the sum of the flows from all connected demand site return flow links.

$$TreatmentPlantPollInflow_{TP} = \sum_{DS} DSReturnLinkPollOutflow_{DS,TP}$$

Some fraction of the pollution will be removed by the plant (entered as data—see Environment\Wastewater Treatment), and the rest will flow out.

$$TreatmentPlantPollOutflow_{TP,p} = (1 - RemovalRate_{TP,p}) \times TreatmentPlantPollInflow_{TP,p}$$

7.3.5 Pollution Routing from Treatment Plants

The pollution remaining in the treatment plant effluent is carried by the treatment plant return flow links to receiving bodies of water. Flows from a given plant to multiple destinations are assumed to have approximately the same concentrations. Therefore, the pollution streams flowing from a single source are proportional to the volume of flow. Thus, the amount of pollution that flows out of a treatment plant into a return flow link is a fraction of the pollution remaining in the effluent.

$$TPReturnLinkPollInflow_{TP,Dest,p} = (TPOutflowRoutingFraction_{TP,Dest} /$$

$$\sum_{Dest} TPOutflowRoutingFraction_{TP,Dest} \text{) x } TreatmentPlantPollOutflow_{TP}$$

Some of the pollutant might decay or otherwise be lost as it passes through the return flow link. The pollution that flows out of the return flow link is a fraction (entered as data—see Environment\Pollutant Decrease in Return Flows) of the inflow.

$$TPReturnLinkPollOutflow_{TP,Dest,p} = (1 - TPReturnLinkPollDecreaseRate_{TP,Dest,p}) \times TPReturnLinkPollInflow_{TP,Dest,p}$$

7.3.6 Pollutant Loads

The pollutant load to a receiving body of water (*Node*) is the sum of all the pollution from all connected demand site and treatment plant return flow links.

$$PollutionLoad_{Node,p} = \sum_{DS} DSReturnLinkPollOutflow_{DS,Node,p} + \sum_{TP} TPReturnLinkPollOutflow_{TP,Node,p}$$

7.4 Hydropower Calculations

Hydropower generation is computed from the flow passing through the turbine, based on the reservoir release or run-of-river streamflow, and constrained by the turbine's flow capacity. Note that the amount of water that flows through the turbine is calculated differently for local reservoirs, river reservoirs and run-of-river hydropower. For river reservoirs, all water released downstream is sent through the turbines, but water pumped from the reservoir to satisfy direct reservoir withdrawals is not sent through the turbines.

$$Release_{Node} = DownstreamOutflow_{Node}$$

For local reservoirs, all linked demand sites are assumed to be downstream of the reservoir, so all reservoir releases are sent through the turbines.

$$Release_{Node} = \sum_{DS} TransLinkInflow_{Node,DS}$$

For run-of-river hydropower nodes, the “release” is equal to the downstream outflow from the node.

$$Release_{Node} = DownstreamOutflow_{Node}$$

The volume of water that passes through the turbines is bounded by the minimum and maximum turbine flow (entered as data—see Supply and Resources\Reservoir\Hydropower). Note that if there is too much water, extra water is assumed to be released through spillways which do not generate electricity. If the release is less than the minimum turbine flow, then no electricity is generated.

$$VolumeThroughTurbine_{Node} = 0 \quad \text{for } Release_{Node} < MinTurbineFlow_{Node}$$

Otherwise, the turbine flow is the smaller of the reservoir release and the maximum turbine flow.

$$VolumeThroughTurbine_{Node} = Min(Release_{Node}, MaxTurbineFlow_{Node}) \quad \text{for } Release_{Node} \geq MinTurbineFlow_{Node}$$

The volume (in m^3) is converted to mass (in kg).

$$MassThroughTurbineKG_{Node} = VolumeThroughTurbine_{Node} \times 1000$$

The gigajoules (GJ) of energy produced in a month is a function of the mass of water through the turbines multiplied by the drop in elevation, the plant factor (fraction of time on-line), the generating efficiency, and a conversion factor (9.806 kN/m^3 is the specific weight of water, and from joules to gigajoules). The plant factor and efficiency are entered as data (see Supply and Resources\Reservoir\Hydropower).

$$EnergyFullMonthGJ_{Node} = MassThroughTurbineKG_{Node} * DropElevation_{Node} \times PlantFactor_{Node} \times PlantEfficiency_{Node} * 9.806 / 1{,}000{,}000{,}000$$

For reservoirs, the height that the water falls in the turbines is equal to the average elevation of the reservoir during the month minus the tailwater elevation (entered as data—see Supply and Resources\Reservoir\Hydropower).

$$DropElevation_{Node} = AverageElevation_{Node} - TailwaterElevation_{Node}$$

where

$$AverageElevation_{Node} = (BeginMonthStorage_{Node} + EndMonthStorage_{Node}) / 2$$

For run-of-river hydropower nodes, the drop in elevation is entered as data (see Run of River Hydropower).

$$DropElevation_{Node} = FixedHead_{Node}$$

7.5 Cost Calculations

Costs are calculated based on the amount of water delivered to a demand site. The cost for a delivery to a demand site (DS) from a supply source (Src) is the unit cost multiplied by the volume of water delivered.

$$CostOfDeliveredWater_{Src,DS} = UnitCost_{Src,DS} \times TransLinkOutflow_{Src,DS}$$

The total cost for a demand site is the sum of all its individual costs.

$$CostOfDeliveredWater_{DS} = \sum_{Src} CostOfDeliveredWater_{Src,DS}$$

The total cost in the system is the sum of all the demand site's costs.

$$CostOfDeliveredWater = \sum_{DS} CostOfDeliveredWater_{DS}$$

7.6 Functions

WEAP borrows an approach made popular in spreadsheets—the ability for users to enter data and construct models using mathematical expressions. Expressions are standard mathematical formulae used to specify the values of variables in WEAP's Data View. WEAP supports a comprehensive set of functions that you can include in your expressions to create your models. For more information, see Expressions for an introduction to expressions. Functions are divided into three groups:

- **Modeling functions**: the major functions used to help you model data.
- **Mathematical functions**: standard mathematical functions, similar in syntax to the ones used in Microsoft Excel.
- **Logical functions**: which can be used to create complex conditional modeling

expressions.

7.6.1 Modeling Functions

CurrentAccountsYear

Syntax

CurrentAccountsYear or CAY

Description

The Current Accounts year as a numeric value.

Example

Year - CurrentAccountsYear

Evaluated for a Current Accounts year of 1995

2000 = 5.0
2020 = 25.0

CurrentAccountsValue

Syntax

CurrentAccountsValue or

CurrentAccountsValue(BranchName)

Description

Calculates the Current Accounts value of either the current branch, or of another branch referred to as a parameter to the function.

Examples

10+CurrentAccountsValue for a Current Accounts value of 100

Evaluated in any year = 110

10+CurrentAccountsValue(Households\Urban)

for branch "Household\Urban" with a Current Accounts value of 1000.

Evaluated in any year = 1010

ExpForecast

Syntax

ExpForecast(Year1, Value1, Year2, Value2,... YearN, ValueN) or ExpForecast(XLRange(Filename, Rangename))

Description

Exponential forecasting is used to estimate future values based on a time series of historical data.

The new values are predicted using linear regression to an exponential growth model (Y = m + X^c) where the Y terms corresponds to the variable to be forecast and the X term is years. Exponential forecasting is most useful in cases where certain values can be expected to grow at constant growth rates over the period in question (e.g. population levels).

Use this function with caution. You may need to first use a spreadsheet or some other package to test the statistical validity of the forecast (i.e. test how well the regression "fits" the historical data). Moreover, bear in mind that future trends may be markedly different from historical ones, particularly if structural or policy shifts in the economy are likely to have an impact on future trends.

Using the above two alternatives syntaxes the time-series data required by the function can either be entered explicitly in WEAP as year/value pairs or it can be specified as a range in an Excel spreadsheet. Use the yearly time-series wizard to input these values or to link to the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1990-2200.

When linking to a range in Excel, you must specify the directory and filename of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. "Import") or a range address (e.g. "Sheet1!A1:B5"). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the WEAP Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: The result of this function will be overridden by any value calculated for the Current Accounts. In some cases this may lead to a marked "jump" from the Current Accounts value to the succeeding year's value. This may reflect the fact that the Current Accounts year you have chosen is not a good match of the long-term trends in your scenario, or it may reflect a poor fit between the regression and the historical data.

Tip

Use the Yearly Time-Series Wizard to enter the data for this function.

Growth

Syntax

Growth(Expression)

Description

Calculates a value in any given year using a growth rate from the base year value. Because it references the Current Accounts value, this function is only available when editing scenarios.

Example

Growth(0.05) or Growth(5%)

Evaluated from a Current Accounts value of 100 in 2000

2001 = 105.00
2002 = 110.25

Tip for users of older versions of WEAP: This function is equivalent to the old "Growth Rate" method for projecting data.

GrowthAs

Syntax

GrowthAs(BranchName) or
GrowthAs(BranchName, Elasticity) or

Description

Calculates a value in any given year using the previous value of the current branch and the rate of growth in another named branch. This is equivalent to the formula:

Current Value(t) = Current Value(t-1) * NamedBranchValue(t)
NamedBranchValue(t-1)

In the second form of the function, the calculated growth rate is adjusted to reflect an elasticity. More precisely, the change in the current (dependent) branch is related to the change in the named branch raised to the power of the elasticity. This is a common approach in econometric modeling, in which the growth in one variable is estimated as a function of the growth in another (independent) variable.

Tip for users of older versions of WEAP: This second form is equivalent to the old "Drivers and Elasticities" method for projecting data.

Examples

Growth(Household\Rural)

Growth(GDP, 1)

In this example (elasticity = 1), the current branch grows at the same rate as the named branch (GNP).

Growth(GDP, 0.9)

In this example (elasticity = 0.9), the current branch grows more slowly than GDP.

Growth(GDP, 1.2)

In this example (elasticity = 1.2), the current branch grows more rapidly than GDP.

Growth(GDP, 0)

In this example (elasticity = 0), the current branch is constant (i.e. independent of GDP).

GrowthFrom

Syntax

GrowthFrom(GrowthRate, StartYear, StartValue)

Description

Calculates a value in any given year using a growth rate from the StartValue in the StartYear. The StartYear can be any year, past, present or future.

Example

GrowthFrom(5%, 1990, 100)

2000 = 162.89
2002 = 171.03

GrowthFrom(5%, 2010, 100)

2001 = 61.39
2002 = 64.46

Interp

Syntax

Interp(Year1, Value1, Year2, Value2,... YearN, ValueN, [Growthrate]) or Interp(ExcelFilename, ExcelRangeName, [Growthrate])

Description

Calculates a value in any given year by linear interpolation of a time-series of year/value pairs.

Using the above two alternatives syntaxes year/value pairs can either be entered explicitly or linked to a range in an Excel spreadsheet. Use the WEAP Yearly Time-series Wizard to input these values or specify the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1990-2200. The final optional parameter to the function is a growth rate that is applied after the last specified year. If no growth rate is specified zero growth is assumed (i.e. values are not extrapolated).

When linking to a range in Excel, you specify the full path name of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. “Import”) or a range address (e.g. “Sheet1!A1:B5”). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: the Current Accounts value is always implicit in the above function, and will override any value explicitly entered for that year by the user. So for example, if the Current Accounts year is 1998 and the Current Accounts value (entered in Current Accounts) is 6.0 then the above function will result in the value 8.0 1999.

Example

Interp(2000, 10.0, 2010, 16.0, 2020, 30.0, 2%)

2000 = 10.0
2005 = 13.0
2020 = 30.0
2021 = 30.6

Tips

- For users of older versions of WEAP: this function is similar to the old “Interpolation” method for projecting data.
- Use the Yearly Time-Series Wizard to enter the data for this function.

LastYear

Syntax

LastYear

Description

The last year of the analysis as a numeric value (as specified in the Areas: General Parameters screen).

Example

LastYear - Year

Evaluated for an last year of 2020

2000 = 20.0
2018 = 2.0

LinForecast

Syntax

LinForecast(Year1, Value1, Year2, Value2,... YearN, ValueN) or LinForecast(XLRange(Filename, Rangename))

Description

Linear forecasting is used to estimate future values based on a time-series of historical data. The new values are predicted using linear regression assuming a linear trend (y = mx +c) where the Y term corresponds to the variable to be forecast and the X term is years. Linear forecasting is most suitable in cases where exponential growth in values is not expected: for example when forecasting how market shares or technology penetration rates might change over time.

Use this function with caution. You may need to first use a spreadsheet or some other package to test the statistical validity of the forecast (i.e. test how well the regression “fits” the historical data). Moreover, bear in mind that future trends may be markedly different from historical ones, particularly if structural or policy shifts in the economy are likely to have an impact on future trends.

Using the above two alternatives syntaxes the time-series data required by the function can either be entered explicitly in WEAP as year/value pairs or it can be specified as a range in an Excel spreadsheet. Use the yearly time-series wizard to input these values or to link to the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1900-2200.

When linking to a range in Excel, you must specify the directory and filename of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. “Import”) or a range address (e.g. “Sheet1!A1:B5”). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the WEAP Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: The result of this function will be overridden by any value calculated for the Current Accounts. In some cases this may lead to a marked “jump” from the Current Accounts value to the succeeding year's value. This may reflect the fact that the Current Accounts year you have chosen is not a good match of the long-term trends in your scenario, or it may reflect a poor fit between the regression and the historical data.

Tip

Use the Yearly Time-Series Wizard to enter the data for this function.

LogisticForecast

Syntax

LogisticForecast(Year1, Value1, Year2, Value2,... YearN, ValueN) or

LogisticForecast(XLRange(Filename, Rangename))

Description

Logistic forecasting is used to estimate future values based on a time series of historical data. The new values are predicted using an approximate fit of a logistic function by linear regression.

A logistic function takes the general form:

$$Y = A + \frac{B - A}{1 + e^{(-a.X + b)}}$$

where the Y terms corresponds to the variable to be forecast and the X term is years. A, B, a, b are constants and e is the base of the natural logarithm (2.718…). A logistic forecast is most appropriate when a variable is expected to show an "S "shaped curve over time. This makes it useful for forecasting shares, populations and other variables that are expected to grow slowly at first, then rapidly and finally more slowly, approaching some final value (the "B" term in the above equation).

Use this function with caution. You may need to first use some other package to test the statistical validity of the forecast (i.e. test how well the regression "fits" the historical data).

Using the above two alternatives syntaxes the time-series data required by the function can either be entered explicitly in WEAP as year/value pairs or they can be specified as a range in an Excel spreadsheet. Use the yearly time-series wizard to input these values or to link to the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1990-2200.

When linking to a range in Excel, you must specify the directory and filename of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. "Import") or a range address (e.g. "Sheet1!A1:B5"). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the WEAP Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: The result of this function will be overridden by any value calculated for the Current Accounts. In some cases this may lead to a marked "jump" from the Current Accounts value to the succeeding year's value. This may reflect the fact that the Current Accounts year you have chosen is not a good match of the long-term trends in your scenario, or it may reflect a poor fit between the regression and the historical data.

Tip

Use the Yearly Time-Series Wizard to enter the data for this function.

MonthlyValues

Syntax

MonthlyValues(Month1, Value1, Month2, Value2,... MonthN, ValueN)

Description

Specify values for each month. If some months are not specified, their values will be calculated by interpolating the values before and after.

Example

MonthlyValues(Jan, 10, Feb, 15, Mar, 17, Apr, 20, May, 21, Jun, 22, ...)

Values are specified for each month.

MonthlyValues(Jan, 10.0, July, 40.0)

Values are specified for two months—the others are interpolated.

Jan = 10
Feb = 15
Mar = 20
Apr = 25
May = 30
Jun = 35
Jul = 40
Aug = 35
Sep = 30
Oct = 25
Nov = 20
Dec = 15

MonthlyValues(Jan, 8.3333)

The values do not change month to month, so only need to be specified for one month. (You could also just enter the constant 8.3333 without the MonthlyValues function.)

Jan = 8.3333
Feb = 8.3333
Mar = 8.3333
Apr = 8.3333
May = 8.3333
Jun = 8.3333
Jul = 8.3333
Aug = 8.3333
Sep = 8.3333
Oct = 8.3333
Nov = 8.3333
Dec = 8.3333

Tip: the WEAP Monthly Time-Series Wizard makes it easy to enter these values.

Parent

Syntax

Parent
Parent(BranchName)
Parent(VariableName)
Parent(BranchName, VariableName)

Description

The current value of the specified variable in the parent branch of named branch. Both BranchName and VariableName are optional parameters so that, when used without any parameters, the function returns the value of the current variable in the parent branch of the current branch.

Tip

Because the simple form of this function points, not to a named branch, but to a relative branch address (the parent), it can be safely used in cases where you want to write a model for a particular set of subsectoral branches, and then copy branches for use elsewhere in the tree. See also: the "TotalChildren" function.

PrevYear

Syntax

PrevYear

Description

The year previous to the one being evaluated as a numeric value. This function is not available when entering Current Accounts.

Examples

Evaluated in 2000 = 1999.0
Evaluated in 2020 = 2019.0

PrevYearValue

Syntax

PrevYearValue or
PrevYearValue(BranchName)

Description

Calculates the previous year's value of either the current branch or of another branch referred to as a parameter to the function. This function is not available when entering Current Accounts.

Examples

10+PrevYearValue

Evaluated for a value of 100 in 2000

2001 = 110
2002 = 120
2003 = 130

0.3+PrevYearValue(Households\Urban\Cooking)

Evaluated for a value of 30 in 2000 in a branch named "Household\Urban\Cooking".

2001 = 30.3
2002 = 30.6
2003 = 30.9

Remainder

Syntax

Remainder(Expression)

Description

Calculates the remainder between an Expression and the sum of the values of neighboring (sibling) branches.

Example

Consider two neighboring branches in a demand tree in which you are specifying the split between urban and rural households (in percent):

Branch	Expression
Urban	Interpolate(2000, 50, 2020, 30)
Rural	Remainder(100)

Remainder(100) is evaluated as follows:

2000 = 50.0
2010 = 60.0
2020 = 70.0

Smooth

Syntax

Smooth (Year1, Value1, Year2, Value2,... YearN, ValueN) or
Smooth (ExcelFilename, ExcelRangeName)

Description

Estimates a value in any given intermediate year based on the year/value pairs specified in the function and a smooth curve polynomial function of the form

Y = a + b.X + c. X2 + d. X3 + e.X4 + …

When more points are available, a higher degree polynomial is used to give a more accurate fit.

NB: A minimum of 4 year/value pairs are required in order for the curve to be estimated.

Using the above two alternatives syntaxes year/value pairs can either be entered explicitly or linked to a range in an Excel spreadsheet. Use the Yearly Time-series Wizard to input these values or to specify the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1990-2200.

When linking to a range in Excel, you specify the full pathname of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. “Import”) or a range address (e.g. “Sheet1!A1:B5”). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the WEAP Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: The Current Accounts value is always implicit in the function, and will override any value explicitly entered for that year by the user. So for example, if the Current Accounts year is 1997 and the Current Accounts value (entered in Current Accounts) is 200.0 then the above function will results in the value 200.0 for both 1998 and 1999.

Tip

Use the Yearly Time-Series Wizard to enter the data for this function.

Step

Syntax

Step(Year1, Value1, Year2, Value2,... YearN, ValueN) or
Step(ExcelFilename, ExcelRangeName)

Description

Calculates a value in any given year using a step function between a time-series of year/value pairs.

Using the above two alternatives syntaxes year/value pairs can either be entered explicitly or linked to a range in an Excel spreadsheet. Use the Yearly Time-series Wizard to input these values or to specify the Excel data. In either case, years do not need to be in any particular order, but duplicate years are not allowed, and must be in the range 1990-2200.

When linking to a range in Excel, you specify the full path name of a valid Excel worksheet or spreadsheet (an XLS or XLW) file, followed by a valid Excel range. A range can be either a valid named range (e.g. "Import") or a range address (e.g. "Sheet1!A1:B5"). The Excel range must contain pairs of years and values in its cells arranged into 2 columns. Use the WEAP Yearly Time-series Wizard to select a worksheet, to choose among the valid named ranges in the worksheet, and to preview the data that will be imported.

NB: The Current Accounts value is always implicit in the function, and will override any value explicitly entered for that year by the user. So for example, if the Current Accounts year is 1997 and the Current Accounts value (entered in Current Accounts) is 200.0 then the above function will results in the value 200.0 for both 1998 and 1999.

Example

Step (2000, 300.0, 2010, 500.0, 2020, 900.0)

2000 = 300.0
2012 = 500.0
2022 = 900.0

Tip

Use the Yearly Time-Series Wizard to enter the data for this function.

TotalChildren

Syntax

TotalChildren
TotalChildren(BranchName)
TotalChildren (VariableName)
TotalChildren (BranchName, VariableName)

Description

The sum of the specified variable across all children of the named branch. Both BranchName and VariableName are optional parameters so that, when used without any parameters, the function returns the sum of the current variable across the children of the current branch.

Tip: Because the simple form of this function points, not to a named branch, but to a relative branch address (all children), it can be safely used in cases where you want to write a model for a particular set of subsectoral branches, and then copy branches for use elsewhere in the tree. See also: the “Parent” function

Year

Syntax

Year or Y

Description

The year being evaluated as a numeric value.

Example

Evaluated in 2000 = 2000.0
Evaluated in 2020 = 2020.0

7.6.2 Mathematical Functions

Abs

Syntax

Abs(Expression)

Description

The absolute value of the expression.

Example

Abs(-2.8) = 2.8
Abs(2.8) = 2.8

Ceil

Syntax

Ceil(Expression)

Description

The expression rounded up toward positive infinity. Use Ceil to obtain the lowest integer greater than or equal to X.

Example

Ceil(-2.8) = -2
Ceil(2.8) = 3
Ceil(-1.0) = -1

Exp

Syntax

Exp(Expression)

Description

The constant e raised to the power of Expression. The constant e equals 2.71828182845904, the base of the natural logarithm. EXP is the inverse of LN, the natural logarithm of number.

Examples

EXP(1) = 2.718282 (the approximate value of e)
EXP(2) = 7.389056
EXP(LN(3)) = 3

Tip

To calculate the powers of other bases, use the exponentiation operator (^).

Floor

Syntax

Floor(Expression)

Description

The expression rounded toward negative infinity. Use Floor to obtain the highest integer less than or equal to X.

Example

Floor(-2.8) = -3
Floor(2.8) = 2
Floor(-1.0) = -1

Frac

Syntax

Frac(Expression)

Description

The fractional part of Expression. Frac(Expression) = Expression - Int(Expression).

Examples

Frac(2.3) = 0.3
Frac(-2.5) = -0.5

Int

Syntax

Int(Expression)

Description

The integer part of the expression (the expression rounded toward zero).

Example

Int(25.5) = 25

Int(-2.3) = -2

Ln

Syntax

Ln(Expression)

Description

The natural logarithm of the expression

Example

Ln(2.7182) = 1
Ln(10) = 2.3026

Log

Syntax

Log(Expression)

Description

The base 10 logarithm of the expression

Example

Log(10) = 1
Log(100) = 2

LogN

Syntax

LogN(Base, Expression)

Description

The logarithm of the expression with a specified base

Example

LogN(10, 100) = 2
LogN(2.7182, 100) = 4.605

Max

Syntax

Max(Expression1, Expression2) or
Max(Expression1, Expression2, Expression3)

Description

Returns the maximum value of the list of parameters. Accepts up to 3 parameters.

Example

Max(3,4,5) = 5

Min

Syntax

Min(Expression1, Expression2) or
Min(Expression1, Expression2)

Description

Returns the minimum value of the list of parameters. Accepts up to 3 parameters.

Example

Min(3,4,5) = 3

Round

Syntax

Round(Expression)

Description

Round returns the nearest whole number to the expression. If expression is exactly halfway between two whole numbers, the result is always the even number.

Example

Round(25.4) = 25
Round(25.5) = 26
Round(25.6) = 26
Round(26.5) = 26

Sqr

Syntax

Sqr(Expression)

Description

The square of the expression, equivalent to Expression * Expression or (expression ^2).

Example

Sqr(3) = 9
Sqr(10) = 100

Sqrt

Syntax

Sqrt(Expression)

Description

The square root of the expression.

Example

Sqrt(9) = 3
Sqrt(100) = 10

7.6.3 Logical Functions

And

Syntax

AND(Expression1, Expression2) or
AND(Expression1, Expression2, Expression3)

Description

Performs a logical "AND" operation. Returns a value of 1 (true) if all of the parameters are non-zero. Otherwise returns a value of zero (false).

Example

AND(1,2,4) = 1
AND(1,0,4) = 0

Equal

Syntax

Equal(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is equal to parameter 2. Otherwise returns a value of zero.

Example

Equal(-1,3) = 0
Equal(3,3) = 1

GreaterThan

Syntax

GreaterThan(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is greater than parameter 2. Otherwise returns a value of zero.

Example

GreaterThan(-1,3) = 0
GreaterThan(3,1) = 1
GreaterThan(1,1) = 0

GreaterThanOrEqual

Syntax

GreaterThanOrEqual(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is greater than or equal to parameter 2. Otherwise returns a value of zero.

Example

GreaterThanOrEqual(-1,3) = 0
GreaterThanOrEqual(3,1) = 1
GreaterThanOrEqual(1,1) = 1

If

Syntax

If(TestExpression, ResultIfTrue, ResultIfFalse)

Description

Use the If function to return one value if a condition is TRUE (<> 0) and another value if it is FALSE (=0)

TestExpression is any value or expression that can be evaluated to TRUE or FALSE. Test expressions are generally made up of two or more statements which are compared using WEAP's logical functions (and, or, lessthan, greaterthan, equal, etc.).

ResultIfTrue is an expression that is evaluated if TestExpression is TRUE (<>0).

ResultIfFalse is an expression that is evaluated if TestExpression is FALSE (=0).

IF functions can be nested to construct more elaborate tests.

Examples

If(GreaterThan(Income,1000), 10, 20)

If the branch named Income has a value equal to 2000 then the function evaluates to value 20.

LessThan

Syntax

LessThan(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is less than parameter 2. Otherwise returns a value of zero.

Example

LessThan(-1,3) = 1
LessThan(3,1) = 0
LessThan(1,1) = 0

LessThanOrEqual

Syntax

LessThanOrEqual(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is less than or equal to parameter 2. Otherwise returns a value of zero.

Example

LessThanOrEqual (-1,3) = 1
LessThanOrEqual (3,1) = 0
LessThanOrEqual (1,1) = 1

Not

Syntax

NOT(Expression)

Description

Reverses the logic of the parameter. Returns a 1 (true) if the parameter is zero (false). Returns a zero (false) if the parameter is non-zero (true).

Example

NOT(1) = 0
NOT(-1) = 0
NOT(0) = 1

NotEqual

Syntax

NotEqual(Expression1, Expression2)

Description

Returns a value of 1 if parameter 1 is not equal to parameter 2. Otherwise returns a value of zero.

Example

NotEqual(-1,3) = 1
NotEqual(3,3) = 0

Or

Syntax

OR(Expression1, Expression2) or
OR(Expression1, Expression2, Expression3)

Description

Performs a logical “OR” operation. Returns a value of 1 (true) if one or more of the parameters are non-zero. Otherwise returns a value of zero (false).

Example

OR (1,2,-1) = 1
OR(1,0,4) = 1
OR(0,0) = 0

8 ASCII Data File Format for Monthly Inflows

If you have monthly data on inflows to some or all of your rivers and local supplies, the Read From File Method allows you to model the system using this sequence of inflows. You can export gaged inflow data from many conventional hydrologic databases into ASCII files, and then edit these files into the required format described below. (USGS has extensive streamflow data for the United States available for download from the Web at http://water.usgs.gov.)

These data may come from a historical record, or they may be outputs from some other model, such as a physically-based hydrologic model. A single ASCII file is meant to be a consistent set of data, both spatially and temporally. You may have many different ASCII import files, but each WEAP scenario can reference only one. For example, if you were investigating the sensitivity to climate change, you could have a different file for each of your climate scenarios.

You may include in these files data for years and supplies not included in a particular WEAP area. Thus, you could use one set of data files for several different WEAP areas, which might include different sets of rivers and supplies. Or you can easily run the WEAP calculations using different historical time periods to test a scenario's sensitivity to a particular hydrological sequence. WEAP will ignore any data extraneous to its current analysis. In this way, the file can comprise a master database of historic flow data that you will use for all your analyses.

The files should be named with the extension .FLO, and placed in the subdirectory corresponding to the WEAP area (e.g., WEAP\Weaping River Basin\ ).

8.1 Sections

The ASCII file is divided into six sections.

Section Name	Description
`[OPTIONS]`	Set water flow unit and first year
`[HEADFLOW]`	River headflows
`[REACH]`	Surface water runoff to reaches
`[RESERVOIR]`	Local Reservoir inflows
`[GROUNDWATER]`	Groundwater inflows
`[OTHER]`	Other Local Supply inflows

In the options section you specify the first year of data to use and the units.

8.2 First Year

When using historical datasets, you need to specify which historical year to use. If your analysis is longer than the entered dataset, WEAP will loop through the historical sequence up to the number of years specified in the model time horizon. For example, if the historical dataset spanned 1950-1959, and your WEAP time horizon was 1998-2017, you would specify 1950 as the first year. In this case, the ten years of data from the file would be used twice—for 1998-2007 and for 2008-2017. You can choose different time intervals to simulate the system over various historical time periods. For instance, if your study period is twenty years and you have sixty years of historical data, WEAP allows you to easily select any of the forty-one different twenty-year periods from the historical data, to explore the effects of various sequences of hydrologic conditions.

The first year is specified in the `[OPTIONS]` section, in the following format:

`FIRST YEAR =` <year>

If you do not specify the first year, WEAP will assume the Current Accounts year is the first year to use.

8.3 Units

You may use any unit for your data and WEAP will automatically convert it. To set the unit to be used in reading the file, include the optional first section `[OPTIONS]` in your data file. If you do not specify the unit, WEAP will assume cubic meters per second. However, to avoid any potential confusion, we recommend that you always include the specification of unit in the file.

The unit is specified in the `[OPTIONS]` section, in the following format:

`UNIT` = [optional scale] <volume unit> `per` <time unit>

The scale is optional and can be either a word (thousand, million, etc.) or a number. For volume unit and time unit, select from the tables below. You may use either the word '`per`' or a slash (`/`) to separate them. You may also use the following flow unit abbreviations: `CFS, CMS, CFM` and `MGD`. If you use month as the time unit, WEAP will take into account the variable number of seconds in each of the twelve months when converting into its per second flow rate. You may use a mixture of upper or lower case.

The following are examples of valid units:

```
CUB. METERS/SECOND
1000 M^3/min
MGD
CFS
million acre-inch per day
```

Time Unit	**Abbreviation**
second	sec
minute	min
hour	hr
day	day
month	mon

Volume Unit	Abbreviation
cubic meters	m^3
cubic feet	ft^3
liter	ltr
gallon	gal
acre-inch	AI
acre-foot	AF

Flow Unit	Abbreviation
cubic feet per second	CFS
cubic feet per minute	CFM
cubic meters per second	CMS
million gallons per day	MGD

8.4 Data Sections

The other five sections contain monthly flow data for river headflow, river reach inflow, local reservoir inflow, groundwater and other-type local supply inflow. Enter the section name in square brackets to define a section, i.e., `[HEADFLOW]`, `[REACH]`, `[RESERVOIR]`, `[GROUNDWATER] AND [OTHER]`. To specify the flows for a particular element, first give its name on a line by itself. The name must match exactly the name given in the WEAP schematic (except for differences in upper or lower case). Because the name is used to match the Schematic element to its data, all supply elements in the Schematic must have unique names. Note: the name of an element is not its Schematic label, but its "name", as specified on General Info for the node.

On the lines following the name, enter the monthly inflows to this element, one year per line. Each line of data must contain thirteen pieces of data: the year, followed by data for each of the twelve months.

The years must be listed in increasing order, although there may be gaps in the years. During calculations, the flows for the Current Accounts Year will be taken from the data year specified with the First Year option (or the Current Account year if not specified). Inflows for each subsequent year will be taken from the next sequential year in the data file. If there is no data for the next year, WEAP will cycle back to the first year of the contiguous block of yearly data, which might be before the First Year. In this way, you can use a subset of historical data as a cycle. For example, if the time horizon is 2000 to 2020, the First Year is 1930, and there is historical data for years 1925 through 1934, the sequence of historical data used will be: 1930, 1931, 1932, 1933, 1934, 1925, 1926, 1927, 1928, 1929, 1930, 1931, 1932, 1933, 1934, 1925, 1926, 1927, 1928, 1929, 1930.

8.5 Numeric Format

Numbers can be entered in either floating point or fixed point notation or a mixture of the two. Floating point format is as follows: <mantissa>E<exponent>, with no spaces before or after the E. The following numbers are all equivalent:

```
3421.032
```

```
3.421032E+3
0.3421032E+4
3421032E-3
```

8.6 Data Delimiters

Numbers can be separated by commas, tabs or spaces. Names of rivers and nodes can be enclosed in quotes or not, although you must use quotes if a name itself includes a comma.

Tip: It may be convenient to collect and format your data in Excel, then export them as tab-delimited or comma separated value (CSV) files. WEAP will be able to read these exported files without any further reformatting.

8.7 Comments

Any line that begins with a semicolon (;) will be treated as a comment line and ignored. Comments can be very useful for documenting your historical data. Blank lines are also ignored and can be used to enhance readability.

8.8 Example

The following example comes from the file HIST.FLO in Weaping River Basin. (To save space, ellipses are shown in place of data for months 4-11.)

```
; Sample historical data file for 1950-59
 ; All flows are in cubic meters per second
 [OPTIONS]
 Unit = CMS
 FirstYear = 1950

[GROUNDWATER]

 “West Aquifer”
   1950, 8.606448, 7.03752, 21.57701, ..., 3.302112
   1951, 2.659248, 7.360368, 4.820064, ..., 4.77192
   1952, 11.20906, 14.1515, 8.38272,..., 11.22038
   1953, 7.921104, 11.92838, 10.63699, ..., 13.91928
   1954, 9.116208, 11.15242, 10.50389, ..., 5.22504
   1955, 4.684128, 9.413568, 5.468592, ..., 5.32416
   1956, 3.981792, 3.86568, 4.664304, ..., 8.546976
   1957, 8.173152, 9.484368, 11.54606, ..., 4.004448
   1958, 7.402848, 5.151408, 4.075248, ..., 2.832
   1959, 5.669664, 5.641344, 8.532816, ..., 7.836144


[HEADFLOW]

 “Blue River”
   1950, 17.22706, 10.33397, 41.10081, ..., 3.22848
```

```
   1951, 2.982096, 17.88408, 8.844336, ..., 6.125616
   1952, 16.66632, 38.58034, 11.5489, ..., 22.04995
   1953, 13.7437, 20.48669, 19.41619, ..., 33.88488
   1954, 15.88469, 15.91584, 17.83027, ..., 7.252752
   1955, 6.68352, 21.81206, 7.921104, ..., 9.031248
   1956, 5.06928, 6.105792, 8.207136, ..., 8.051376
   1957, 20.75856, 10.43592, 16.96085, ..., 4.505712
   1958, 10.50955, 9.184176, 4.910688, ..., 2.560128
   1959, 5.740464, 6.842112, 11.5489, ..., 12.37584

[REACH]

 "Blue River","Below Industry East With."
   1950, 3.205824, 1.948416, 7.765344, ..., .620208
   1951, .555072, 3.188832, 1.523616, ..., 1.229088
   1952, 2.928288, 6.366336, 1.945584, ..., 3.664608
   1953, 2.319408, 3.460704, 3.726912, ..., 6.493776
   1954, 2.829168, 3.007584, 3.29928, ..., 1.57176
   1955, 1.365024, 3.234144, 1.416, ..., 1.67088
   1956, 1.050672, 1.084656, 1.6992, ..., 2.248608
   1957, 3.404064, 2.741376, 3.474864, ..., .674016
   1958, 1.951248, 2.118336, .982704, ..., .75048
   1959, 1.07616, 1.333872, 1.710528, ..., 2.509152

[RESERVOIR]

; No local reservoirs exist

[OTHER]

; No other local supplies exist
```

9 Sample Data Set

The **Weaping River Basin** is the sample data set associated with WEAP. The goal of the data set is to give the user the opportunity to explore some of WEAP's capabilities, and to illustrate the problems and solutions that WEAP can help identify.

The Weaping River Basin is a river basin consisting of rivers, aquifers, reservoirs, demand sites, flow requirements, wastewater treatment facilities and the links among them. The data are compiled for a 11-year (1998-2008) monthly time series. There are four scenarios presented in this data set: Reference, Demand Measures, Supply Measures, and Integrated Measures (a combination of the Demand and Supply scenarios).

9.1 Reference

Demands increase steadily over time, while the supply infrastructure remains static—no improvements are made that might increase availability of supply. As demands increase and groundwater sources are depleted, there are increasing shortfalls in meeting demand and instream flow requirements. Pollution generation and loads follow demand trend, increasing over time. Identification of problems guides creation of scenarios to alleviate them. The following three scenarios implement measures designed to reduce demand or increase available supply.

9.2 Demand Measures

The Demand Measures Scenario slows the increasing rate of the demands by decreasing water use rates in the future. Supply coverage is improved in all areas because the supply requirement is decreased, although still less than 100%. This scenario also slows, but does not halt, the depletion rate of the groundwater. Costs increase due to demand efficiency measures.

9.3 Supply Measures

The Supply Measures Scenario consists of building the North Reservoir in 2003. This reservoir allows the storage of surplus surface water from winter and spring, to be made available in the drier summer and fall. Supply coverage is improved due to the increased supply available, although still less than 100%. This scenario slows the depletion of groundwater and allows all flow requirements to be met. Costs increase due to construction of a new reservoir.

9.4 Integrated Measures

The Integrated Measures Scenario combines measures from Demand Measures and Supply Measures Scenarios. This scenario decreases demand and provides excellent supply coverage. Combining Demand and Supply Scenarios increases groundwater storage and fulfills all flow requirements. Costs increase due to demand efficiency measures and construction of new reservoir.

10 Technical Support

Technical support is provided at no charge to licensed users of the system. Various options are available for obtaining support, but we suggest you first make use of the WEAP technical support web site at http://groups.yahoo.com/group/WEAP. This site provides a moderated forum for users to share their experiences in using WEAP and to see how other users managed to solve their problems.

When requesting technical support by email, we strongly suggest that you send your data set as an attachment and include the system information from the Help: About WEAP screen. To do this easily using the Email option on the Manage Areas screen on the Area menu.

Finally, before requesting help, be sure to check to see if a more recent version of the system is available. Use the "**Check on Internet for Updates**" on the Help menu to check for a newer version over the Internet, and then install it onto your PC. Note that this is the preferred method of updating the software as it requires a much smaller download compared to a full download and installation of the system.

The full set of technical support options are as follows:

- **WEAP Web Site:** http://www.seib.org/weap
- **WEAP Technical Support Web Site:** http://groups.yahoo.com/group/WEAP
- **Mail:** Stockholm Environment Institute-Boston, Tellus Institute, 11 Arlington Street, Boston, MA 02116, USA
- **Email:** weap@tellus.org
- **Phone:** (617) 266 5400
- **Fax:** (617) 266 8303

10.1 Hardware and Software Requirements

WEAP requires a 200 MHz or faster Pentium class PC with Microsoft Windows 95 or later (a 400 MHz PC with Windows 98 or later is recommended). A minimum of 32 MB of RAM and 50 MB of free hard disk space is also required (64 MB of RAM recommended). In addition Microsoft Internet Explorer version 4.0 is required for viewing WEAP's HTML Help. If you do not have it you can download it for free from the Microsoft web site. It is OK to install Internet Explorer after installing WEAP.

Your computer screen should be set to a minimum resolution of 800x600, but preferably even higher (e.g., 1024x768 or 1280x1024), to maximize the presentation of data and results.

An Internet connection is not required, but is useful for tasks such as emailing data sets and receiving automatic updates to the software.

WEAP can also communicate with Microsoft Excel and Microsoft Word, but they are not required.

NB: WEAP is designed as a single-user system. It is not intended as a multi-user system and we do not recommend running it from a shared network drive.

10.1.1 Installation on Early Version of Windows

Some users of the very earliest versions of Windows 95 and NT have experienced problems in using WEAP. WEAP requires that you have version 4.00 or higher of the Windows component “SHELL32.DLL” installed on your system. If you have an earlier version, you will need to update your system for WEAP to work correctly. This file CANNOT be updated manually. According to Microsoft, to update the file you need to install a full copy of Internet Explorer 4.0 including its desktop shell extensions (i.e., “Active Desktop”). Just installing the default version of IE 4.0 will not do the trick. Also, installing version 5.0 or higher of Internet Explorer will not update these files. You have to install 4 first, then install 5. NB: this problem does not apply to newer versions of Windows including Windows 98, Windows ME or Windows 2000.

For more information, see this page at Microsoft's web site:

http://msdn.microsoft.com/library/psdk/shellcc/shell/versions.htm

NB: WEAP is a 32-bit program and as such, cannot be run on earlier 16-bit versions of Windows, including Windows 3.1 or Windows for Workgroups.

10.2 Notes For Users of WEAP 99

The latest version of WEAP (WEAP21) builds upon the bottom-up, needs-oriented, accounting framework approach used in earlier DOS versions of the software (WEAP 99).

While the latest version is very different from older versions, the fundamental design approach embodied in the older version remains intact. In particular the tool remains focused on providing a user-friendly accounting framework for those conducting integrated water resources analysis.

10.2.1 New Features Compared to WEAP 99

- **Expression-based modeling:** WEAP borrows an approach made popular in spreadsheets: the ability for users to enter data and construct models using mathematical expressions. This greatly enhances the modeling capability of the tool. For more information, see Expressions.
- **Visual Interface:** WEAP 99 was a menu-driven, form-based modeling tool. WEAP21 takes a more visual approach to modeling, for example, letting you edit demand data structures using the tree.
- **Windows-Based Tool:** WEAP21 is designed to work on 32-bit version of Windows (Windows 95 or later). WEAP 99 was a DOS-based tool.
- **Internet Enabled:** The new tool takes advantage of (but does not require) Internet connections. It includes Internet features such as automatic software updates, web-based technical support and emailing of data sets.
- **Improved Reporting:** including visual design of charts and tables, multi-scenario comparisons, etc. See Results View
- **Enhanced Scenario Management:** including dynamic scenario inheritance. See Scenarios.
- **Tracking of Activity Level Units in Demand Analyses:** A common problem for users of the older version of WEAP was keeping track of the units associated with Demand

activity levels. WEAP21 provides smarter tracking of activity level units, including automatic canceling of units where appropriate. See Activity Levels.

- **Documentation Capabilities:** WEAP21 includes word processing tools to let you include.

10.2.2 Installing WEAP21 and WEAP 99 on a Single Computer

WEAP 99 and WEAP21 will happily reside together on a single PC. In fact, this is the easiest solution for those who want to import a data set from WEAP 99 into WEAP21. (WEAP21 is not able to read or convert data from previous versions.) The only thing to be careful of is that you do not install WEAP21 in the C:\WEAP directory, which is reserved for WEAP 99.

For more information on WEAP 99, refer to the WEAP 99 User Guide (available on the Internet in PDF format).

11 Glossary

Activity Level

A measure of social and economic activity. When used in WEAP's Demand analysis, activity levels are multiplied by water use rates to yield overall levels of annual water demand. See Water Use Rate.

Aggregate

To summarize by grouping together. See Disaggregate

Allocation Order

The actual calculation order, assigned to transmission links and instream flow requirements, used by WEAP for allocating water. WEAP automatically determines the allocation order based on the supply priorities and demand preferences. See Supply Priority, Demand Preference.

Area

The water system being studied, often a river basin.

Branch

An item on the tree, e.g., “Supply and Resources” or “Key Assumptions”.

Current Accounts

The Current Accounts represent the basic definition of the water system as it currently exists. Establishing Current Accounts requires the user to “calibrate” the system data and assumptions to a point that accurately reflects the observed operation of the system. The Current Accounts are also assumed to be the starting year for all scenarios. Note that the Current Accounts Year is not meant to be an “average” year, but the best available estimate of the current system in the present. The Current Accounts include the specification of supply and demand data (including definitions of reservoirs, pipelines, treatment plants, pollution generation, etc.) for the first year of the study on a monthly basis.

Current Accounts Year

The first year of the analysis period, and the year for which the system is 'calibrated.'

Demand Preference

The preference a demand site has for a particular source. Each transmission link has a preference number, ranging from 1 (highest preference) to 99 (lowest). See Supply Priority, Allocation Order.

Demand Site

A set of water users that share a physical distribution system, that are all within a defined region, or that share an important withdrawal supply point.

Disaggregate

To break something down into sub-categories (e.g. breaking a municipal demand site into urban and rural sectors). See Aggregate, Sector, Subsector.

Diversion

A canal or pipeline that is supplied by water diverted from a river. A diversion is represented as a river in WEAP—composed of a series of reservoirs, run-of-river hydropowers, flow requirements, withdrawals, diversions, tributaries and return flow nodes. See Diversion Node.

Diversion Node

A point at which water is diverted from a river or other diversion into a canal or pipeline called a diversion. See Diversion.

DSM

Demand-Side Mangement—strategies for reducing demand for water, such as a program to reduce leakage or unauthorized withdrawals from the system, a program to encourage reuse or more efficient use of water, or programs that use price as an incentive to reduce demands.

Endogenous

Something calculated internally in a model.

Exogenous

A value explicitly specified (i.e., not calculated internally by the model).

Expression

A mathematical formula used to specify how the values of a variable changes over time.

Favorite

A result chart saved by the user, complete with all formatting, for later retrieval, or inclusion in an Overview. See Overview.

Flow Requirement

Minimum instream flow required at a point on a river or diversion to meet water quality, fish & wildlife, navigation, recreation, downstream or other requirements.

GIS

Geographic Information System. WEAP allows you to load GIS maps, in standard ArcView Shape and Grid format, as background layers for the Schematic.

Head

Hydropower is generated when water falls from a height into a turbine. This height is called the head, or head difference.

Hydrology

The time-series of monthly inflows to the system, specified using either the Water Year Method or the Read from File Method. See Inflow, Water Year Method, Read from File.

Inflow

Flows into the WEAP system: Groundwater recharge, River Headflow, and Inflow to River Reaches, Local Reservoirs and Other Local Supplies. See Hydrology.

Key Assumptions

Independent user-defined variables used to "drive" the calculations in your analyses. See Tree.

Local Supply

Supply sources not connected (or not modeled as connected) to a river, i.e., Groundwater, Local Reservoirs, and Other Local Supplies.

Normal Water Year Type

A water year type that represents an average hydrological conditions. Note: the Current Accounts Year is not necessarily a Normal Water Year Type. See Water Year Type.

Other Local Supply

Sources with predetermined water quantities available on a monthly basis, but with no storage capability between months (e.g., streams or other unconnected rivers, inter-basin transfers or other imports, and desalination plants).

Overview

Side-by-side display of multiple result charts, constructed from user-defined “Favorites.” See Favorite.

Pool

Synonym for Reservoir Zone. See Zone.

Read from File

A detailed means for projecting inflows in the future. Inflow values for every month for one or more supply sources are read in from an ASCII file. Typically, this file contains either historical data or outputs from another model (e.g., a climate change model). See Inflow.

Recharge

The natural inflow to a groundwater source. This does not include return flows and inflows from a river.

Reference Scenario

A scenario that represents the changes that are likely to occur in the future, in the absence of any new policy measure. Sometimes called a “business as usual” scenario.

Return Flow

Wastewater flows from demand sites and wastewater treatment plants, to treatment plants and receiving bodies of water. See Return Flow Node.

Return Flow Node

Point at which a return flow enters a river. (You may actually have return flows enter the river at any type of river node: Reservoir, Run-of-River Hydropower, Tributary, Diversion, Flow Requirement, Withdrawal Node, or Return Flow Node.) See Return Flow.

River Node

A point on a river, of the following types: Reservoir, Run-of-River Hydropower, Withdrawal Node, Return Flow Node, Tributary Node, Diversion Node, Flow Requirement.

River Reach

The portion of a river between two river nodes. See River Node.

Run-of-River Hydro

Points on which run-of-river hydropower stations are located. Run-of-river stations generate hydropower based on varying streamflows but a fixed water head in the river. They have no storage.

Scenario

A self-consistent storyline of how a future system might evolve over time in a particular socio-economic setting, for an assumed hydrologic sequence, and under a particular set of policy and technology conditions.

Schematic

A user-created spatial layout that encompasses the physical features of the water supply and demand system. The schematic is the starting point for all activities in WEAP—from here you have one-click access to all data and results.

Sector

A water-using sector of society, e.g., Agricultural, Municipal or Industrial. See Subsector, Disaggregate, Aggregate.

Sensitivity

Changes that occur in a scenario because of different socio-economic, hydrologic or technology assumptions, rather than because of different policies.

Subsector

Detailed breakdown of a sector, e.g., urban and rural subsectors represent the municipal sector, or crop types, which represent subsectors for the agricultural sector. See Sector, Disaggregate, Aggregate.

Supply Priority

A demand site's or instream flow requirement's area-wide priority for receiving water, ranging from 1 (highest preference) to 99 (lowest). These priorities represent the user's priorities for delivery of water for each demand site and instream flow requirement. See Demand Preference, Allocation Order.

Surface Runoff

Surface water inflow to river reaches represents either non-point runoff into the river, or the confluence of streams or rivers not otherwise modeled.

Transmission Link

Transmission links deliver water from local supplies, reservoir nodes, and withdrawal nodes to satisfy final demand at demand sites.

Tree

A hierarchical structure for organizing data, under six major categories: Key Assumptions, Demand Sites, Hydrology, Supply and Resources, Environment, and Other Assumptions.

Tributary Node

Points where one river joins another.

Variable

Data that can change over time.

Wastewater Treatment Plant

Treats wastewater from demand sites to remove pollutants, then returns treated effluent to one or more river nodes or local supply sources.

Water Use Rate

The average water consumption of some device or end-use per unit of activity. See Activity Level.

Water Year Method

A simplified means for projecting inflows in the future. Enter Current Accounts inflow data, then define the fluctuations of each water year type from the norm, and specify the sequence of water year types in the future. See Water Year Type, Inflow.

Water Year Type

A water year type characterizes the hydrological conditions over the period of one year. The five types that WEAP uses—Normal, Very Wet, Wet, Dry, and Very Dry—divide the years into five broad categories based on relative amounts of surface water inflows. See Water Year Method.

Withdrawal Node

Point where any number of demand sites receive water directly from a river.

Zone

Reservoir storage is divided into four zones, or pools. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone. The conservation and buffer pools, together, constitute the reservoir's active storage.

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