

# THE W2 ANIMATOR – USER MANUAL

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# GENERAL INFORMATION AND INSTALLATION

## ABOUT THE W2 ANIMATOR

The W2 Animator, or W2Anim for short, is an interactive Perl script that allows the user to explore and visualize output from the [CE-QUAL-W2](#) two-dimensional flow and water-quality model as well as measured data from limnological profiles and time series. Several W2Anim visualizations can be animated to view data and model results over time. All graphs are created on a “drawing canvas” that can be annotated with text, shapes, lines, and images. Everything on the canvas can be exported as encapsulated PostScript, and optionally in PDF or raster image formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF) or as a video file (AVI, FLV, GIF, MOV, MP4).

A number of different graph types are supported, including:

- Vertical profiles of measured parameters over time,
- Vertical profiles of model results over time,
- Longitudinal slices of model results through the model domain over time,
- Time/distance maps of model results,
- Vertical withdrawal zones at dam outlets, computed from measured data,
- Vertical withdrawal zones from model output,
- Measured time series, and
- Modeled time series.

More graph types and features will continue to be added with future releases.

### Latest Version

The most recent version of The W2 Animator can be found on its GitHub page at  
<https://github.com/sarounds/w2anim/releases/latest>.

### License

The W2 Animator is free software; you may redistribute it and/or modify it under the terms of the [GNU General Public License](#) as published by the Free Software Foundation, either version 3 of the License or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

## INSTALLATION

The W2 Animator is written in Perl with the Tcl/Tk toolkit, and therefore requires the user to have both Perl and Tcl installed with the proper modules. Detailed instructions for installing Perl and Tcl on a Windows machine are given below. Once Perl and Tcl are installed and any [helper programs](#) also are installed, the [W2Anim package](#) may be downloaded from its home on GitHub and unzipped to any appropriate location on the user's computer. Running The W2 Animator is as simple as starting the `w2anim.pl` script. Windows users may double-click on that script file from the Windows File Explorer, or a Perl command window may be started and the `w2anim.pl` script initiated from there.

### Installation of Perl and Tcl

Both Perl and Tcl must be installed, along with several required modules of those interpreters. Tcl is needed because the Tk module in Perl is not up to date, whereas the Tcl/Tk module *is* up to date. The W2 Animator

requires version 8.6 of Tk to build and use all of the features of its user interface, and the Tcl/Tk module utilizes version 8.6 or later of Tk.

These instructions describe how to install the Strawberry Perl and ActiveTcl distributions of Perl and Tcl, respectively, on a 64-bit Windows system. If you wish to install different distributions of these languages, feel free, but the instructions here are specific to Strawberry Perl and ActiveTcl. The W2 Animator should work on multiple operating systems, but you may need different source distributions of Perl and Tcl to make it work on each operating system.

### **Step 1. Install Strawberry Perl**

Strawberry Perl is a free distribution of Perl for Windows that is designed to be as close as possible to the Perl environments on unix systems. Strawberry Perl is free and available at <https://strawberryperl.com/>. Download the installer for your system and install it as you would normally install any Windows program. I installed version 5.32.1.1 (64-bit) to my system at C:\Perl\Strawberry.

### **Step 2. Install ActiveTcl**

ActiveState provides packages for several useful languages. I signed up for a free account at ActiveState, which you can find at <https://www.activestate.com/products/tcl/>. I downloaded the standard Tcl package for Windows, which at the time was version 8.6.12.0000 (64-bit). Install it as you would any Windows program. I installed my package to C:\Tcl\ActiveTcl.

Depending on whether ActiveState has modified their standard Tcl distribution package, you may need to make a few edits. I had to modify one file in the Tcl package after installation. In the file:

C:\Tcl\ActiveTcl\lib\tclConfig.sh

I found six lines that the installer did not properly complete in that file. Here are the 6 lines, where I commented out the first line in the pair (with a leading #), copied it to the second line and edited the second line to have the correct path and syntax:

```
#TCL_PREFIX='C:\TEMP\ActiveState'-----please-run-the-install-script-----'  
TCL_PREFIX='C:\Tcl\ActiveTcl'  
  
#TCL_EXEC_PREFIX='C:\TEMP\ActiveState'-----please-run-the-install-script-----\bin'  
TCL_EXEC_PREFIX='C:\Tcl\ActiveTcl\bin'  
  
#TCL_LIB_SPEC='C:\TEMP\ActiveState'-----please-run-the-install-script-----\lib\tcl86t.lib'  
TCL_LIB_SPEC='LC:\Tcl\ActiveTcl\lib\tcl86t.lib'  
  
#TCL_INCLUDE_SPEC='IC:\TEMP\ActiveState'-----please-run-the-install-script-----\include'  
TCL_INCLUDE_SPEC='IC:\Tcl\ActiveTcl\include'  
  
#TCL_STUB_LIB_SPEC='LC:\TEMP\ActiveState'-----please-run-the-install-script-----\lib\tclstub86.lib'  
TCL_STUB_LIB_SPEC='LC:\Tcl\ActiveTcl\lib\tclstub86.lib'  
  
#TCL_STUB_LIB_PATH='C:\TEMP\ActiveState'-----please-run-the-install-script-----\lib\tclstub86.lib'  
TCL_STUB_LIB_PATH='C:\Tcl\ActiveTcl\lib\tclstub86.lib'
```

With these modifications to the tclConfig.sh file, Strawberry Perl will be able to download and properly compile the Perl Tkx module, which is an interface to the Tcl/Tk package. Without these modifications, the Tkx interface in Perl to Tcl/Tk will not be available and The W2 Animator program will not run properly.

### **Step 3. Modify the System PATH (optional)**

I found it useful to modify the Windows system PATH. The installer for ActiveTcl unnecessarily puts its folder at the top of the PATH list, whereas Strawberry Perl puts its entries at the bottom of the system PATH. To modify your Windows system PATH, click the Start menu and select Settings. Then type “system path” into the search bar. On Windows, you need to be Administrator to modify the system PATH. You may need to enlist the assistance of your system administrator to complete some of these instructions.

I moved the three entries for Strawberry Perl up to the top, before the Tcl path, as follows:

```
C:\Perl\Strawberry\c\bin  
C:\Perl\Strawberry\perl\site\bin  
C:\Perl\Strawberry\perl\bin  
C:\Tcl\ActiveTcl\bin
```

#### Step 4. Install Required Perl Modules

The W2 Animator requires several additional Perl modules to be installed. This is a common task and is simple to carry out. Start by opening Strawberry Perl's text interface. Check the Start menu for a new item—it is probably labelled “Perl (command line).” I added a shortcut to my tray for future use.

New modules can be installed in Strawberry Perl, and indeed in most Perl distributions, by using the “cpanm” command. It's really simple, but pay attention to the messages it prints to the screen. If you have problems, you should be able to find a “build.log” file in C:\Users\your\_user\_name\.cpanm\ that will be more verbose. You will also find more build logs under C:\Users\your\_user\_name\.cpanm\work\.

Running as Administrator (I don't know if this is necessary), I started by installing the Perl Tkx module with:

```
cpanm Tkx
```

This module is small and quick to install, but it requires the Tcl module as a dependency, and so will install the Tcl module as well. The Tcl/Tk module is used for creating user interfaces. As a result, you will see many different windows popping up as various tests are generated and run. Do not be alarmed, as this is normal.

Other Perl modules that you will need, and their installation commands:

```
cpanm Tkx::ROText  
cpanm Tkx::Scrolled  
cpanm Proc::Background  
cpanm File::Find::Object  
cpanm Win32::GUI
```

All of the other modules required by The W2 Animator were already part of the standard distribution of Strawberry Perl. For example, the Math::Trig and Imager modules were already installed.

Finally, I found one error in my older version the Strawberry Perl Tcl module, but newer versions do not have this error. You should probably check it out, and you may need to edit the file at:

```
C:\Perl\Strawberry\perl\site\lib\Tcl.pm
```

In that file, find the line that looks like:

```
print "TCL::TRACE_DELETECOMMAND: $interp -> ($tclname )\n" if TRACE_DELETECOMMAND();
```

This line may be missing a “Tcl::” in front of the final TRACE\_DELETECOMMAND. The fixed line should look like:

```
print "TCL::TRACE_DELETECOMMAND: $interp -> ( $tclname )\n" if Tcl::TRACE_DELETECOMMAND();
```

Doing this little edit may be tricky, as the default file permissions for the Tcl.pm file don't include write permissions, even for the owner. I worked around it by changing the file's user write permission while logged in as Administrator in my Cygwin environment and editing the file with vi there. Another user reported that you can open the file in Notepad++, right-click on the file-name tab, and choose the option to clear the ReadOnly flag. You may find another solution.

That's all. You should now have a functioning Strawberry Perl environment with ActiveTcl available to assist.

## **Starting The W2 Animator**

Put the W2Anim scripts in a location that makes sense to you. Optionally, you may put that folder on the system PATH. Once copied into place, W2Anim can be started in several ways:

- Type “w2anim.pl” in a Perl command line window. You may need to be in the directory where the W2anim scripts reside if that folder is not on the system PATH.
- Type “perl w2anim.pl” in any command window. You may need to be in the directory where the W2Anim scripts reside if that folder is not on the system PATH.
- Double-click any W2Anim project file in the File Explorer. See the section [Opening a W2Anim Project File with a Double-Click](#) for more information.

## **Helper Programs**

Visualizations from The W2 Animator can be exported natively in encapsulated PostScript format. To export visualizations in PDF format or in several types of raster image formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF), an independent helper program such as Ghostscript must also be installed. Similarly, to export video files in several formats (AVI, FLV, GIF, MOV, MP4), an independent helper program such as FFmpeg must be available. Detailed instructions for obtaining and installing these independent helper programs on a 64-bit Windows machine are given below. Alternate methods are discussed in this manual under [Alternate Export Methods](#).

### **Ghostscript**

Ghostscript is a powerful and commonly used interpreter for the PostScript language and for Portable Document Files (PDFs). Artifex Software maintains and develops the Ghostscript software and has ported it to a number of operating systems including Windows and Linux. As of this writing, the current version is 10.04.0.

I am using version 10.0.0. The source code as well as pre-compiled binaries are available at:

- <https://www.ghostscript.com/>
- <https://www.ghostscript.com/releases/gsdnld.html>

Ghostscript is available as open source software under the [GNU Affero General Public License](#).

The important point is that Open Source Ghostscript is free to use. None of the source code has been modified for use with W2Anim, none of the source code has been incorporated into W2Anim, and Ghostscript is not distributed with W2Anim. It is up to the user to decide whether to use Ghostscript in conjunction with W2Anim. If the user wishes to export screenshots or animations from W2Anim, then the user may find it useful to install and use Ghostscript as a helper application to W2Anim. See the Help/Configure menu option in The W2 Animator to ensure that W2Anim knows where Ghostscript is located on your computer.

In Windows, you can install Ghostscript by running the installation executable program as Administrator. I suggest that you install the program under

C:\Program Files\gs\gsxx.xx.xx

where the xx stuff refers to the version number. For example, my installation location is

C:\Program Files\gs\gs10.00.0\

### **FFmpeg**

FFmpeg is a powerful set of tools and libraries for decoding, encoding, translating, and reformatting almost every type of audio and video file. It is free to use and is covered under the GNU General Public License (GPL), version 2 or later. See <https://ffmpeg.org/legal.html> for more information.

FFmpeg may be used with W2Anim as a helper program to make AVI, FLV, MOV, and MP4 video output files from a series of PNG images. FFmpeg is not needed in order to run or use W2Anim, and it is up to the user to decide whether (or not) to download and install FFmpeg as a helper program. None of the source code of FFmpeg has been incorporated into W2Anim, and FFmpeg is not distributed with W2Anim. If the user wishes

to create certain video output files, then the user may wish to download and install FFmpeg or some other video software to accomplish that task.

FFmpeg tools include:

- `ffmpeg` -- a command line tool to convert multimedia files between various formats
- `ffplay` -- a simple media player
- `ffprobe` -- a simple multimedia stream analyzer

More information and free downloads of the FFmpeg software can be found online at the following URLs:

- <https://ffmpeg.org/>
- <https://ffmpeg.org/about.html>
- <https://ffmpeg.org/download.html>

Compiled packages of FFmpeg are available for Windows at:

- <https://www.gyan.dev/ffmpeg/builds/>
- <https://www.gyan.dev/ffmpeg/builds/ffmpeg-git-full.7z>

The compiled package for Windows mentioned above does not come with an installer. To install FFmpeg on your Windows system, create the following directory:

C:\Program Files\FFmpeg\

and then unzip the package so that the following folders exist:

C:\Program Files\FFmpeg\bin  
C:\Program Files\FFmpeg\doc  
C:\Program Files\FFmpeg\presets

Lastly, you may wish to put the C:\Program Files\FFmpeg\bin folder on the system PATH so that the programs are more easily accessible, but this is not strictly necessary if you use the folders as suggested above and/or provide the appropriate path to the FFmpeg programs to The W2 Animator program under the Help/Configure menu.

## **Video Files**

### **Video Formats**

When used with Ghostscript and FFmpeg, W2Anim can create several types of video output files. Although the smoothest and possibly fastest way to view W2Anim animations is probably within W2Anim itself, you may find it useful to export video files to share with your colleagues or partners. The following video formats are available for export from W2Anim. You can research their advantages and disadvantages yourself, but here is my take:

- **AVI**—Audio Video Interleave format. This is an older video format that is still in use and is compatible with a wide range of video players. Quality is high, but the file size will be larger than MOV or MP4 formats.
- **FLV**—Flash Video format. This format was developed for use with the Adobe Flash player, and often was used for showing videos in web pages. It is provided in case compatibility for older web pages is needed.
- **GIF**—Animated Graphics Interchange Format. Animated GIFs have enjoyed somewhat of a resurgence in popularity for small animations, but this format is not recommended unless you have no other options. W2Anim can create animated GIFs without FFmpeg, but Ghostscript or a similar PostScript interpreter is still needed. This video format restricts the color palette to 256 colors, and compression of the final file is poor compared to other video formats.
- **MOV**—QuickTime movie format. The MOV format was developed by Apple and is compatible with Windows and Mac OS systems. It uses the MPEG-4 encoding algorithms and results in smaller file sizes compared to AVI, FLV, and GIF formats.

- **MP4**—MPEG-4 format. The latest MPEG-4 format was derived at one time from the QuickTime movie format. MP4 files are commonly used for modern videos, and file sizes are small compared to the AVI, FLV, and GIF formats. File sizes for MP4 and MOV files created by FFmpeg through W2Anim will be the same.

## Video Codecs

Your computer probably already has most of the video codecs required to encode, decode, compress, and decompress the data in video files. If a video player on your system cannot play a particular video file, it may or may not be due to not having the proper codecs installed. Many video players rely on codecs that are compiled into their code, but some rely on libraries installed with the operating system. If you wish to update the codecs on a Windows computer, you may wish to download and install the codecs contained in the “K-Lite Codec Pack Standard” available at [https://www.codecguide.com/download\\_k-lite\\_codec\\_pack\\_standard.htm](https://www.codecguide.com/download_k-lite_codec_pack_standard.htm).

## Video Players

Many video players are available, but not all of them can open and play the video files that may be exported by W2Anim with or without FFmpeg as a helper program. Here is a limited list of some video players that may be useful:

- **MPC-HC**: The K-Lite Codec Pack includes a video player program called MPC-HC that can be used to view just about any video file and has some decent user controls.
- **VLC Media Player**: The VLC Media Player also can be used to view just about any video file and comes with its own codecs compiled into the program. This is a very useful video viewer, but I personally don't like the user controls as much as those in some other programs.
- **MPV**: The MPV player works well, but personally I find the user controls of some other players to be more useful.
- **IrfanView**: IrfanView is a powerful image editor program that also can play certain types of video files, depending on the codecs that are installed and known by that program. Give it a try to see if you like it, but recognize that it won't work in all instances, and the user controls are limited.
- **Windows Media Player**: The Windows Media Player still exists, but is no longer under development and has been superceded with other tools in Windows 11. Some types of video files will not play in this older viewer.
- **Woldo's MCI Video File Player**: Despite the fact that this is the oldest and most out-of-date video file player in this list, it can still be made to view the AVI files created by W2Anim in conjunction with FFmpeg. I like the user controls and the fact that the video can be viewed one frame at a time at superspeed in both forward and reverse directions. It's a useful program to have, despite its age and incompatibility with more modern video formats.

## SUPPORT

### Documentation

This User Manual is the only official documentation for The W2 Animator. It will be continuously updated as time allows and as new features are added.

### Updates

The most recent version of The W2 Animator can be found on its GitHub page at <https://github.com/sarounds/w2anim/releases/latest>.

## **Questions and Bug Reports**

If you have questions or wish to report a problem with The W2 Animator, please send me an email at [roundsstewart@gmail.com](mailto:roundsstewart@gmail.com). I will try to respond in a timely manner. Alternatively, you can ask questions or report problems directly on the GitHub page for The W2 Animator at <https://github.com/sarounds/w2anim>.

## **Supporting W2 Tool Development**

Developing The W2 Animator as a data visualization tool has been a hobby and obsession, and I am happy to make it available for free to the W2 user community. Although this software is absolutely free of charge, it is my hope that some users of The W2 Animator, perhaps particularly those who may be using it as part of a business, will choose to independently support higher education in some fashion. Two worthy funds that might be considered are:

- *The CE-QUAL-W2 Model Development Fund (#8610011)* at the [Portland State University Foundation](#), and
- *The Stewart Rounds & Bernadine Bonn Scholarship Fund* at the [Oregon State University Foundation](#).

## **AUTHORS AND ACKNOWLEDGMENTS**

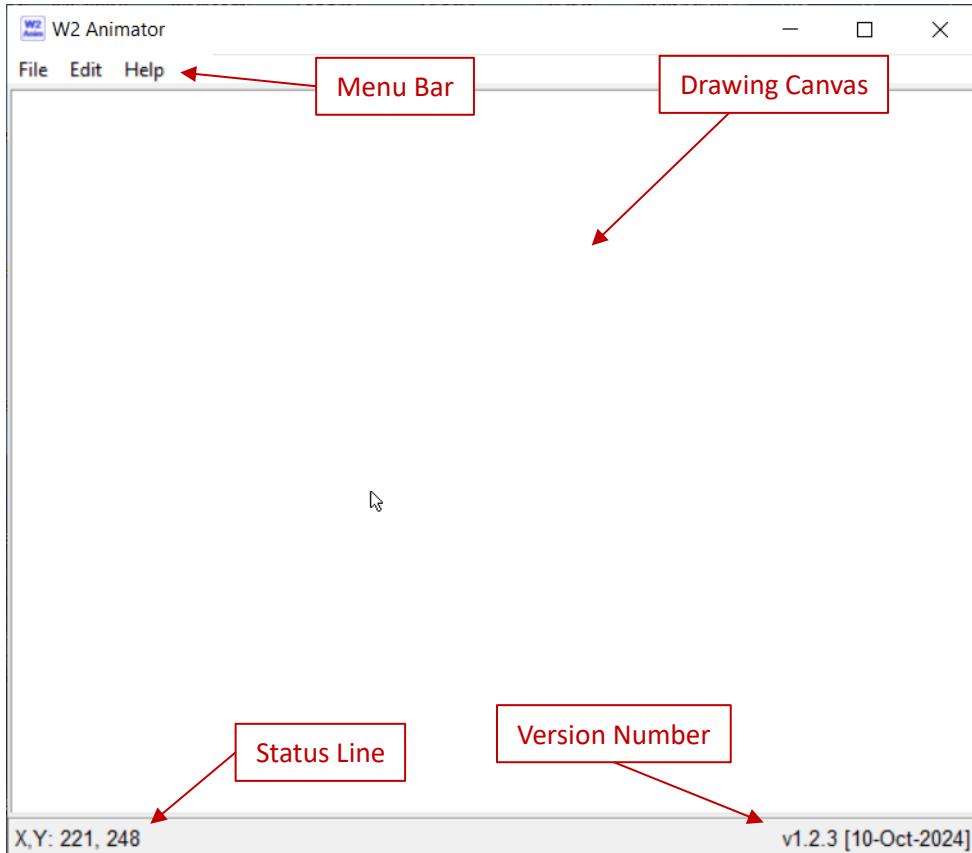
All development on The W2 Animator up to this point has been done by the primary author, Stewart Rounds. The author appreciates all of the work on the Perl base code and various Perl modules by the Perl community. The author also appreciates the pre-release testing done on W2Anim by Laurel Stratton Garvin (Oregon Water Resources Department), Annett Sullivan (U.S. Geological Survey), Scott Wells and Zhonglong Zhang (Portland State University), and Bernadel Garstecki (City of Portland), as well as suggestions submitted by users later.

The author also acknowledges and is thankful to those who have developed useful color schemes that are applied in this program. Several of the color schemes used in The W2 Animator were developed by, or [described by](#), Kenneth Moreland. Seven of the perceptually uniform color schemes are part of the [Scientific Colour Maps](#) package produced by Fabio Crameri. All color schemes used in The W2 Animator are free for use and redistribution, and their known developers or copyright holders and licenses are listed here:

- **CoolWarm**: Developed by Kenneth Moreland ([public domain; CC0 creative commons](#))
- **Viridis**: Developed by Eric Firing ([public domain; CC0 creative commons](#))
- **Plasma**: Developed by Stefan van der Walt and Nathaniel Smith ([public domain; CC0 creative commons](#))
- **Inferno**: Developed by Stefan van der Walt and Nathaniel Smith ([public domain; CC0 creative commons](#))
- **BlackBody**: Developer unknown; scheme has been in use for decades (no known claims of intellectual property)
- **Batlow**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Bam**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Cork**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Roma**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Vik**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Oslo**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **GrayC**: Developed and copyrighted by Fabio Crameri ([MIT license](#))
- **Kindlmann**: Developed by Kindlmann, Reinhard, and Creem (no known claims of intellectual property)
- **Extended Kindlmann**: Based on scheme developed by Kindlmann, Reinhard, and Creem (no known claims of intellectual property)
- **Turbo**: Copyrighted by Google, LLC. ([Apache license, version 2.0](#))
- **Jet**: Developer unknown. Used in matplotlib. ([matplotlib BSD-compatible license](#))
- **CubeYF**: Developed by Matteo Niccoli ([free use and redistribution](#))
- **Cube1**: Developed by Matteo Niccoli ([free use and redistribution](#))

## THE DRAWING CANVAS AND OBJECT DEFAULTS

All graphs and annotations in The W2 Animator are drawn or placed on a “drawing canvas” where the location, size, and characteristics of each object are controlled by the user. This approach allows for interactive and efficient generation of visualizations. When first initialized, the W2Anim screen looks something like this:



The status line is used by W2Anim to provide status messages, instructional prompts, and location and size information. In the example above, the status line is showing the X and Y location of the mouse cursor on the drawing canvas in units of pixels, where the upper left of the drawing canvas is the (0,0) point. A canvas that is 600 pixels wide has X pixel coordinates that range from 0 to 599.

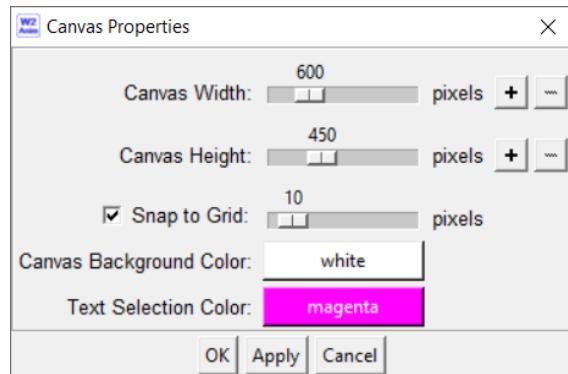
The main W2Anim window containing the drawing canvas can be resized by grabbing a window edge or corner with the mouse (hold down the left mouse button) and dragging that edge or corner. Making the window smaller will cause scroll bars to appear. The main window cannot be made larger than the drawing canvas. The size of the drawing canvas is not altered by changing the size of the main window; rather, resizing the window in some cases just makes it easier to fit a visualization on the screen, or makes it easier to work on a large visualization when the user is, for example, using a smaller screen temporarily. The main window cannot be larger than the current screen size, but the drawing canvas can be large (thousands of pixels) in either width or height. A maximum of 20,000 pixels in width or height is imposed by W2Anim, but hopefully no user will ever need so large a canvas.

## CANVAS PROPERTIES

The properties of the drawing canvas can be changed by the user. A Canvas Properties menu (seen at right) is accessed either through the menu bar (Edit/Preferences/Canvas Props) or by right-clicking (or typing Alt-p) while hovering over the canvas and selecting Canvas Props from the pop-up menu.

The maximum canvas width and height are derived from the size of the user's screen. To allow canvas sizes that exceed the screen size, click the + button to expand the scale of the slider. The *Snap to Grid* option is useful because it can facilitate the alignment of objects and graphs when they are first placed on the canvas, or when aligning objects later. By default, the canvas background is white.

When the mouse cursor is hovered over an object on the drawing canvas, W2Anim displays not only the X,Y position of the mouse cursor in the status line, but also the object type. To show that the object under the mouse cursor is ready for selection or editing, the object will be highlighted in some fashion using the "Text Selection Color." For a text object, the text temporarily assumes the selection color. For graph objects, the graph frame temporarily assumes the selection color and its thickness is temporarily incremented by one unit. For shape objects (lines, circles, etc.), the outline of the shape is incremented but no color change occurs. For images, a bounding box is shown.



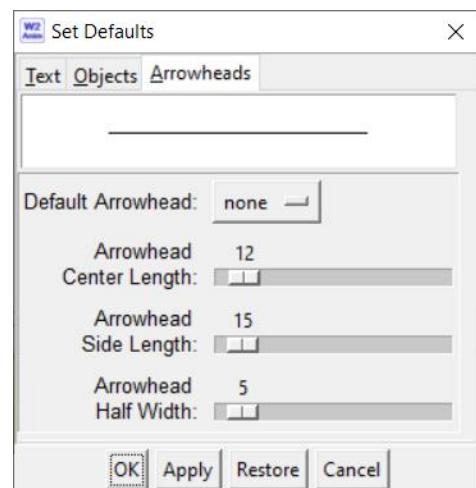
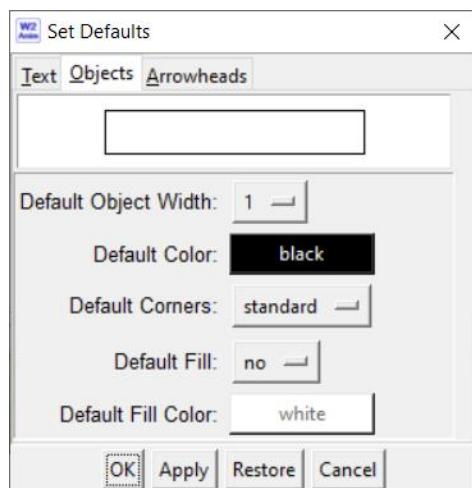
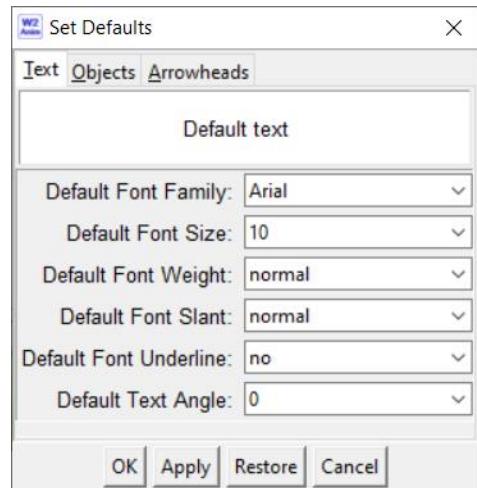
## PROGRAM DEFAULTS

Default properties for text annotations and drawing objects may be set by the user through the menu bar (Edit/Preferences/Defaults) or by right-clicking on the drawing canvas and selecting Defaults.

The default properties of several types of objects may be set through this menu. The user may select any of the Text, Objects, or Arrowheads tabs at the top of the menu, and then set their defaults as desired.

For text, any font that is installed on the user's computer should be available in the drop-down list of the default font family. The preview area at the top of the menu will display the results of the user's choices. Existing text objects will not be affected by a change in the default text properties, but new text objects and the text in new graph objects will use the default font. Choosing "Restore" will reset the defaults back to those used by W2Anim at startup.

For drawing objects such as lines, circles, rectangles, and so forth, some of their default properties may be set from the Objects tab of the Defaults menu. A preview of the object properties is provided at the top of the menu. Line width is an integer value in pixels. Corners for rectangles and diamonds can be standard or rounded; the exact shape of the rounded corner is fixed by the toolkit and cannot be changed. For lines, arrowheads can be set by default for neither, both, or the start or end of the line. The exact shape of the arrowhead is set through a combination of the center length, side length, and half width. Play with those parameters to see what is possible. Note that these are simply system defaults for the next drawing objects that are created. Each object also offers an independent means of editing its properties.



## W2ANIM INITIALIZATION FILE

By default, The W2 Animator will begin with canvas dimensions of 600x450 pixels (width x height), a white canvas background, a magenta text selection color, a grid spacing of 10 pixels, and *Snap to Grid* disabled. These program defaults can be overridden through the use of an initialization file named w2anim.ini. Place this file either in the directory where the W2Anim scripts are located, or in the folder from which the W2Anim program is started. If a w2anim.ini file exists in the folder from which W2Anim is started, the program will read that file. Lacking an initialization file there, W2Anim will look for a w2anim.ini file in the directory where the W2Anim scripts are located. If no initialization file exists in those two locations, the program will fall back to its defaults.

A sample w2anim.ini file should exist in the directory where the W2Anim scripts are located, and that file can be copied and/or edited. The format of the key words and values must be followed if the initialization is to work properly. The proper format for a w2anim.ini file is shown below.

In this case, canvas dimensions of 1200x600 pixels are specified, the canvas background color is white, the text selection color is magenta, the grid spacing is 10 pixels, and *Snap to Grid* is enabled (1=enabled, 0=disabled). The canvas width must be a minimum of 200 pixels, and the canvas height must be at least 150 pixels. Colors may be specified with the format #RRGGBB, where RR, GG, and BB are hex codes for red, green, and blue; for example, the color magenta is identical to #FF00FF. Unrecognized color names will be ignored.

Defaults for text objects are in the next section. The font family entry will be ignored if it does not exist. The default font family will be used as the initial font for text in graph objects. The font size for text objects is restricted to a range of 5-32. The font weight must be “normal” or “bold”. The font slant must be “normal” or “italic”. The font underline must be “yes” or “no”. The font angle must be in the range 0-359.

For object defaults, the width must be in the range 1-10. The corner entry must be “standard” or “rounded”. The object fill must be “yes” or “no”.

The arrow setting must be “none” or “start” or “end” or “both”. The arrowhead center length must be in the range 6-100. The arrowhead side length must be in the range 10-100. The arrowhead half width must be in the range 3-40.

The default temporary space in this example is located in a “tmp” folder off of the directory where the W2Anim scripts reside. An absolute or relative path may be used.

You can specify the path to the helper programs with the gr\_path and ffmp\_path entries. If the Ghostscript program resides at “C:\Program Files\gs\gs10.00.0\bin\gswin64c.exe” then that is the entry that should be in the w2anim.ini file after the “gr\_path:” key word. Similarly, if the FFmpeg program resides on the local system at “C:\Program Files\FFmpeg\bin\ffmpeg.exe” then that is the entry that should follow the “ffmp\_path:” key word in the w2anim.ini file. Do not include any quotation marks.

To turn off the use of Ghostscript or FFmpeg, simply enter the word “off” (without the quotation marks) in the w2anim.ini file instead of specifying the path to either of these programs. If no path is specified and the entry is left blank as in the example above, then W2Anim will do its best to find the helper programs upon initialization, and will notify the user if the helper programs are not found.

```
# W2 Animator initialization file, version 1.2.3 [10-Oct-2024]

===== CANVAS =====
width: 1200
height: 600
color: white
text_sltc: magenta
snap2grid: 1
grid_spac: 10
===== END CANVAS =====

===== FONT DEFAULTS =====
family: Arial Narrow
f_size: 10
f_weight: normal
f_slant: normal
f_under: no
f_angle: 0
===== END FONT DEFAULTS =====

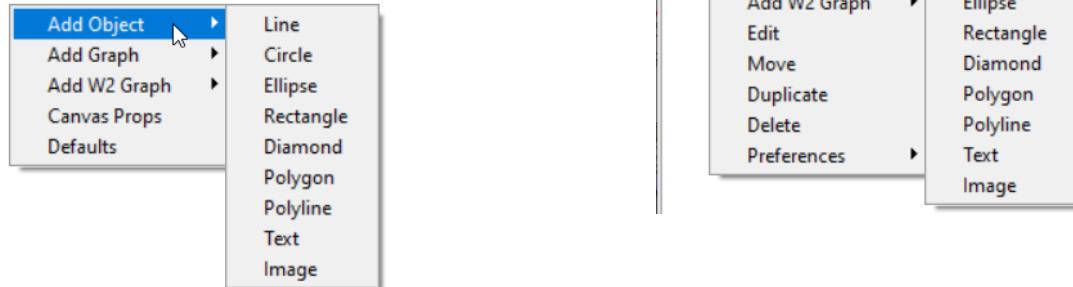
===== OBJECT DEFAULTS =====
ob_width: 1
ob_color: black
ob_corner: standard
ob_fill: no
ob_fcolor: white
===== END OBJECT DEFAULTS =====

===== ARROW DEFAULTS =====
arrow: none
center: 12
side: 15
halfwidth: 5
===== END ARROW DEFAULTS =====

===== CONFIG =====
tmp_path: .\tmp
gr_path:
ffmp_path:
===== END CONFIG =====
```

# DRAWING OBJECTS

New text annotations, drawing objects, and images may be added to the drawing canvas either through the Edit entry of the menu bar (Edit/Add Object), or by right-clicking (or typing Alt-p) while hovering on the canvas, and then selecting the Add Object option.



## ADDING NEW OBJECTS

### Lines

When adding a new line, the mouse cursor will change to a crosshair and wait for the user to designate the starting point of the line via a left mouse click. Note that the user can monitor the X,Y location of the mouse cursor on the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After the first click, the status line will show the coordinates of both the starting and potential ending points of the line. A strictly horizontal or vertical line can be forced by holding down the Shift key. A second left click of the mouse ends the line, whereas a right click will abort the creation of the line. If the default line properties include an arrowhead, that feature will be present in the new line.

### Circles and Ellipses

When adding a new circle or ellipse, the mouse cursor will change to a crosshair and wait for the user to designate an anchor point for its bounding box. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a circle or ellipse being drawn within a bounding box covered by the anchor point and the mouse cursor position at the opposite corner. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. An ellipse can be forced to be a circle by holding down the Shift key. As the mouse is moved, the status line shows the X,Y position of the mouse as well as the width and height of the object being created. Clicking the left mouse button sets the final shape of the circle or ellipse, whereas a right click will abort the creation of the object. New circles and ellipses will have the default line width, outline color, and fill properties, all of which may be edited later.

### Rectangles and Diamonds

When adding a rectangle or diamond, the mouse cursor will change to a crosshair and wait for the user to designate an anchor point for its bounding box. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a rectangle or diamond being drawn within a bounding box covered by the anchor point and the mouse cursor position at the opposite corner. Of course, the bounding box for a rectangle is the rectangle itself. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. A rectangle can be forced to be a square by holding down the Shift key; similarly, a diamond will be forced to

have equal-length sides if the Shift key is depressed. As the mouse is moved, the status line shows the X,Y position of the mouse as well as the width and height of the object being created. Clicking the left mouse button sets the final shape of the rectangle or diamond, whereas a right click will abort the creation of the object. New rectangles and diamonds will have the default line width, outline color, corners, and fill properties, all of which may be edited later.

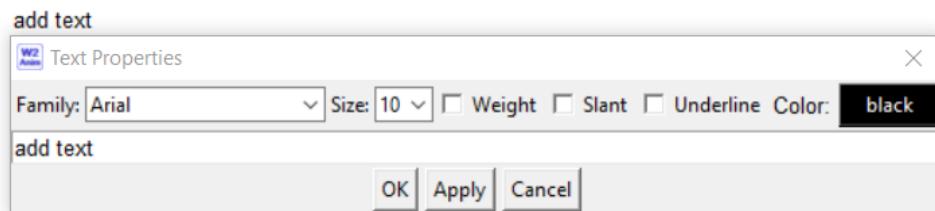
### **Polygons and Polylines**

A polygon is a closed shape with at least three sides, whereas a polyline is simply a line with more than one segment and at least three points. Both polygons and polylines are created in a similar way. When adding a polygon or a polyline, the mouse cursor will change to a crosshair and wait for the user to designate the first point of the object. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a line connected between the anchor point and the mouse cursor location. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. Holding down the Shift key will force the current line segment of the polygon or polyline to be exactly horizontal or vertical. The status line will continue to show the X,Y position of the mouse cursor, as influenced by the *Snap to Grid* setting.

Points are added to the polygon or polyline by clicking the left mouse button. For a polyline with an arrowhead at its end, the arrowhead will be transferred to the end of the line as new points are added. When the user wishes to add the final point of the polygon or polyline, the left mouse button should be double-clicked to complete the object. Clicking the right mouse button at any point in the process will abort the creation of the object. The new object will have the default line width and line color. Polygons will be given the default fill and fill color, whereas polylines will be given the default arrowhead properties.

### **Text**

When adding a text object, the mouse cursor changes to the text cursor and waits for the user to choose an anchor point. By default, the anchor for text objects will be at the left side, midway between top and bottom (this is called west, or "w"). The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the text anchor point with a left mouse click, the text "add text" will be displayed on the drawing canvas in the default font, size, color, weight, slant, underline, and angle.



At this point, the text may be changed in the Text Properties window and its attributes can be changed. Multi-line text is not allowed at this time. Clicking OK or Apply will apply the changes to the text object. The OK button will also remove the menu, whereas the Apply button will retain the menu. Clicking Cancel will abort the creation of the new text object.

### **Images**

When adding an image, W2Anim first asks the user to choose an image file. Many image formats are valid, including PNG, GIF, JPG, BMP, PPM, TGA, and TIFF. After the image file is chosen, the image will be imported to the center of the drawing canvas and any mouse movement will move the image on the canvas. The status line shows the X,Y location of the anchor point (the upper left corner, by default) and the image's bounding box

coordinates. A single left click will place the image at the current coordinates, whereas a right click of the mouse will abort the import of the image.

If the image is too large for the drawing canvas, such as might be the case for an imported photograph, the image will be scaled down until it fits on the canvas before showing its initial placement. The image may be resized and cropped after it is imported and placed on the canvas.

## OBJECT ANCHORS

Every object on the drawing canvas has an X,Y anchor position in pixels, where the (0,0) position is at the upper left corner of the canvas. The anchor position is used during move, resize, and rotate operations, and can be used in alignment requests. The current anchor position can be found by hovering the mouse over the object of interest, then right-clicking the mouse and selecting the Info option. Remember that the status line will show the type of object that the mouse is over, and that object will reveal that it is the “selected” object by increasing its outline width, changing its text color, showing a bounding box, or changing the color of its graph frame.

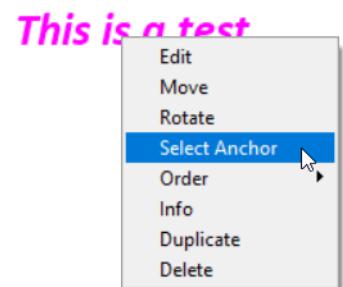
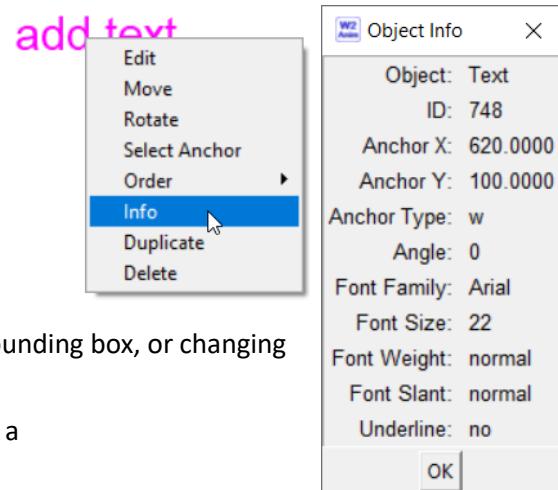
Anchor types for text and image objects are named according to a compass-like naming system:

- w = west (left side, midpoint vertically)
- n = north (top side, midpoint horizontally)
- e = east (right side, midpoint vertically)
- s = south (bottom side, midpoint horizontally)
- nw = northwest (upper left corner)
- ne = northeast (upper right corner)
- se = southeast (lower right corner)
- sw = southwest (lower left corner)
- c = center (midpoint horizontally and vertically)

Object anchors can be chosen from a selection of possible anchors by right-clicking on the object of interest and choosing the Select Anchor option, as shown at the right.

The text object example shown at the right has a “w” or west anchor, as designated by the magenta-filled square at the west position. That example shows what is displayed on the screen when the user chooses the Select Anchor option for this unrotated text object. The user may choose a new anchor by hovering the mouse cursor over any of the cyan-colored anchor points and clicking the left mouse button. Alternatively, the user may exit “select anchor mode” by right-clicking on the mouse.

Lines have potential anchor points only at either end and at their midpoint. Circles, ellipses, rectangles, diamonds, polygons, and polylines have potential anchor points at the corners and midpoints of their bounding box as well as in their geometric center. The bounding box used for potential anchor points includes any rotation angle that has been applied to the object. Polygons and polylines also allow anchor points to be chosen at the location of any vertex/point and also at the center point of the smallest circle that bounds all of the points of the object. These various anchor points may be called “point” or “midpoint” or “corner” or “center” or “center\_rot” (center of rotation). The exact coordinates are available from the Info option.



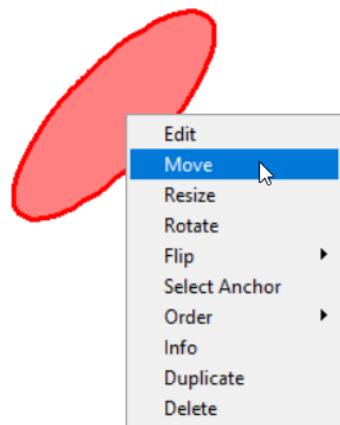
## MANIPULATING DRAWING OBJECTS

### Moving Objects

Any object on the drawing canvas can be moved by hovering over it so that it is the “current” object, then right-clicking the mouse (or typing Alt-p) and selecting the Move option. Alternatively, select Edit/Move from the menu bar and then select the item of interest. Once the Move option is selected, the object will move on the canvas as the mouse is moved. If *Snap to Grid* is turned on, the anchor point of the object will be shown with a magenta point. The status line will display the X,Y location of the anchor as well as the coordinates of the object’s bounding box. Clicking the left mouse button will confirm the move, whereas clicking the right mouse button will cancel the move.

Note that W2Anim does not allow objects to be moved off of the drawing canvas. Valid moves are only those that cause the entire object to remain on the canvas, even if part of the object was initially not on the canvas. The anchor point is allowed to be moved off of the canvas, as long as the object itself remains on the canvas.

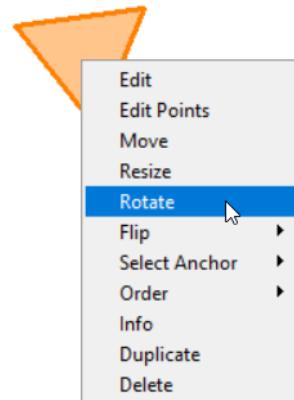
An object also can be moved by selecting it with a left mouse click and then moving it with the arrow keys.



### Rotating Objects

Most drawing objects (ellipses, rectangles, diamonds, polygons, polylines, text, and images) can be rotated in W2Anim. It is pointless to try to rotate a circle. W2Anim does not allow single lines to be rotated, but they can be resized, which essentially allows for a different orientation. Graphs in W2Anim are objects, but not included in the list of drawing objects, and are not allowed to be rotated.

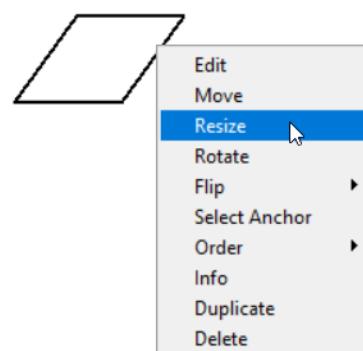
To rotate an object, hover the mouse over it, then right click (or type Alt-p) and select the Rotate option. Images provide three choices under the Rotate option: Clockwise 90, Counterclockwise 90, and Free Rotate. If the current rotation angle for an image is nonzero, then a fourth option is presented: To Zero. All rotations are implemented around the object’s current anchor point, which will be highlighted with a magenta point when the rotation option is chosen.



In free-rotation mode, as the user moves the mouse on the canvas, the object is rotated to correspond to the angle between the anchor point and the mouse cursor location. The rotation angle is shown in the status line, and is restricted to integer values. Clicking the left mouse button confirms the current rotation, whereas clicking the right mouse button will cancel the current rotation and revert to the previous rotation.

### Resizing Objects

All objects on the drawing canvas in W2Anim, including graphs, can be resized. For text objects, resizing is just a matter of changing the font size, which is implemented under its Edit option. Resizing a line is accomplished by moving the non-anchor point of the line, which redraws the entire line. Resizing an object will always retain the existing anchor point. Resizing an image will retain its existing aspect ratio, after accounting for any cropping. Resizing an object also retains its existing angle of rotation, unless the user removes that rotation.



To resize an object, hover the mouse over it, then right click (or type Alt-p) and select the Resize option. Moving the mouse will cause the object or its bounding box (or the graph frame) to be temporarily resized on the canvas. Holding the Shift key down while moving the mouse will cause the same sort of result as it would when creating a new object of that type. For a line, holding down the Shift key causes a line to be exactly horizontal or vertical. The Shift key causes a rectangle to be a square or an ellipse to be a circle—generally causing the adjacent sides of an object's bounding box (other than images) to have equal lengths. The Shift key has no effect on images, whose aspect ratios (after any cropping) are preserved.

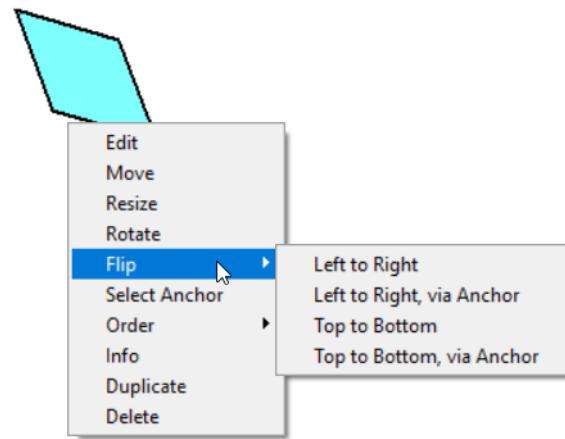
Holding the Ctrl key down while moving the mouse will cause any original nonzero rotation angle to revert to zero. The user may also combine the Shift and Ctrl keys, and the effects combine as one would expect.

If an image object has been resized or cropped or flipped or rotated, a Revert option will become available from the pop-up menu. Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point.

### ***Flipping Objects***

W2Anim allows lines, ellipses, rectangles, diamonds, polygons, polylines, and images to be flipped vertically or horizontally. The action can be centered on the object's center (Left to Right, Top to Bottom) or relative to its anchor point (Left to Right, via Anchor; Top to Bottom, via Anchor). It is pointless to flip a circle, and W2Anim does not allow text or graphs to be flipped. Note that flipping an object may affect its rotation angle and anchor point designation.

If an image object has been flipped, a Revert option will become available from the pop-up menu (right-click or Alt-p while hovering on the object). Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point.

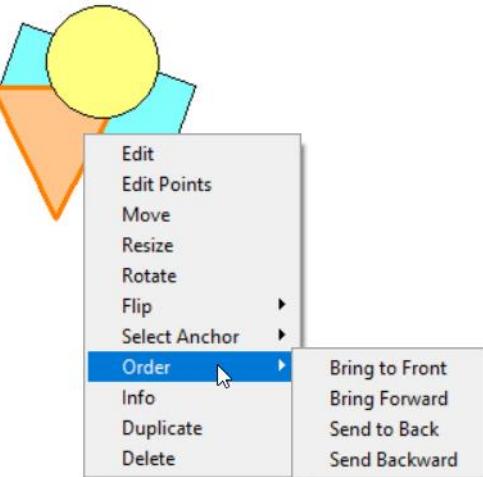


### ***Changing the Drawing Order***

Each object on the drawing canvas is drawn in a specific order, such that objects drawn later in the list are placed in front of earlier objects if the objects overlap. The user can move objects forward and backward in the list. Simply hover the mouse over the object of interest, then right click (or type Alt-p), select the Order option, then the desired order-change option:

- Bring to Front – puts object in front of all other objects
- Bring Forward – move object up one place in drawing order
- Send to Back – pushes object behind all other objects
- Send Backward – move object back one spot in drawing order

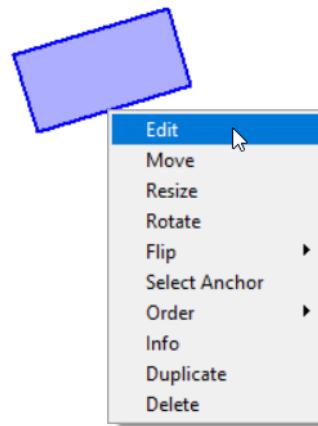
If an object is already being drawn last, then the Bring to Front and Bring Forward options will be inactivated. Similarly, if an object is first in the drawing list, the Send to Back and Send Backward options will be inactivated.



## Editing Object Properties

The appearance of objects other than images on the canvas can be modified by editing their properties. Start by hovering over the object of interest so that it is the “current” object, then right-click the mouse (or type Alt-p) and select the Edit option. Alternatively, select Edit/Edit from the menu bar and then left-click on the object of interest. Each object type will present a different Object Properties pop-up menu. The following properties may be edited for each object type:

Object Type	Line Width	Line Color	Arrowheads	Arrowhead Center Length	Arrowhead Side Length	Arrowhead Half Width	Fill	Fill Color	Corners	Font Family	Font Size	Font Weight	Font Slant	Font Underline	Font Color
Line	✓	✓	✓	✓	✓	✓									
Circle	✓	✓						✓	✓						
Ellipse	✓	✓						✓	✓						
Rectangle	✓	✓						✓	✓	✓					
Diamond	✓	✓						✓	✓	✓					
Polygon	✓	✓						✓	✓						
Polyline	✓	✓	✓	✓	✓	✓								✓	✓
Text										✓	✓	✓	✓	✓	✓

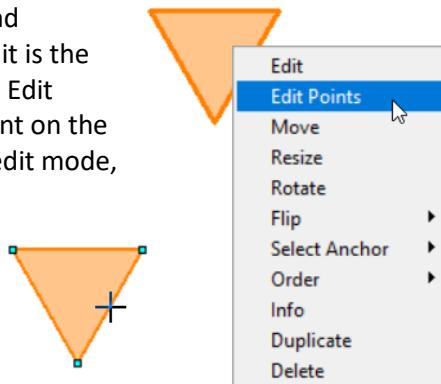


Graph objects have entirely different properties that can be edited, such as those for axes, titles, color schemes, and legends. These properties are described later, in the section on Graph Types.

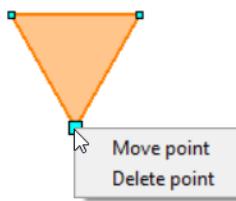
## Adding, Moving, and Deleting Points of Polygons and Polylines

W2Anim allows the user to add, move, or delete points from polygons and polylines. To begin that process, hover over the object of interest so that it is the “current” object, then right-click the mouse (or type Alt-p) and select the Edit Points option. In point-edit mode, each vertex of the polygon or each point on the polyline will be highlighted with a small cyan-filled square. To exit point-edit mode, click the right mouse button on the canvas.

When in point-edit mode, hovering the mouse cursor over any part of the polyline or any part of the outline of the polygon changes the mouse cursor to a crosshair, which then allows a new point to be added via a click of the left mouse button. The status line at that point also prompts the user to “Click to add point...”. A left click adds a point, which then is positioned by moving the mouse and left-clicking again to denote the final position of the new point.

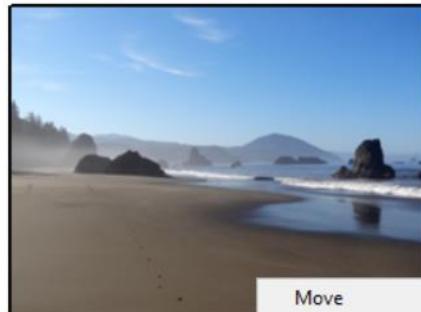


Moving or deleting an existing point begins by hovering the mouse cursor over an existing point. The status bar prompts the user to “Right click to move or delete...”. Clicking the right mouse button brings up a small menu with the options “Move point” and “Delete point.” Left-clicking on “Delete point” will delete the point, whereas left-clicking on “Move point” allows the user to move the point. Right-click on the canvas to exit point-edit mode.



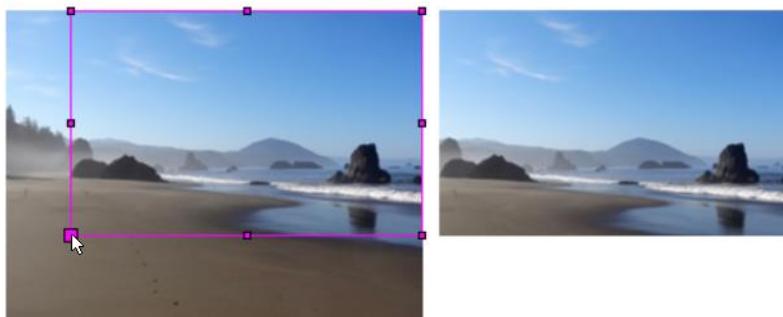
## Cropping Images

W2Anim allows users to interactively crop imported images. Hover over the image of interest so that it is the “current” object, then right-click the mouse (or type Alt-p) and select the Crop option. In image-crop mode, the current cropping frame will be drawn on the image with a magenta rectangle, with magenta control points at each corner and at the midpoints of each side:



- Move
- Resize
- Revert
- Rotate
- Flip
- Crop**
- Select Anchor
- Order
- Info
- Duplicate
- Delete

The cropping frame can be altered by clicking the left mouse button while hovering over one of the control points and dragging that control point to the desired location. While the control point is selected and being moved, its size is enlarged. Drag any of the other control points to finalize the desired cropping, then double-click the left mouse button to implement that cropping frame on the selected image. The cropping frame and control points are removed.



Exit image-crop mode without altering the cropping frame by clicking the right mouse button.

If an image has already been cropped, the Crop option will include two sub-options: Modify and Uncrop. The Modify option will allow the current cropping frame to be altered, whereas the Uncrop option will directly remove any cropping.

An image can be cropped, or its cropping modified, while at any size or rotation angle or after being flipped. Any image that has been resized, cropped, flipped, or rotated will include a Revert option in its pop-up menu (right-click or Alt-p while hovering on the object). Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point. Large images that were automatically resized to fit the canvas will include the Revert option, but possibly only because W2Anim had to resize the image because it was larger than the canvas.

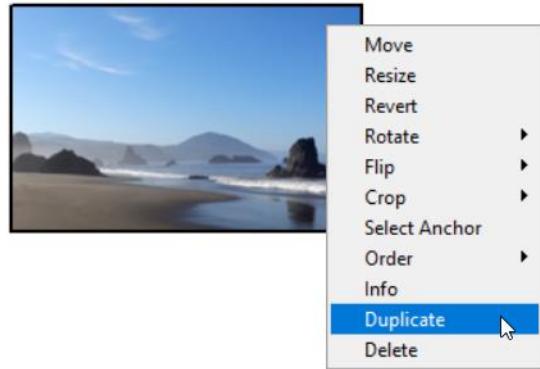


- Move
- Resize
- Revert
- Rotate
- Flip
- Crop**
- Modify**
- Uncrop**
- Select Anchor
- Order
- Info
- Duplicate
- Delete

## Duplicating Objects

Any object on the W2Anim drawing canvas, including graphs, can be duplicated. To duplicate an object, hover over the object of interest so that it is the “current” object, then right-click the mouse (or type Alt-p) and select the Duplicate option.

Alternatively, select the Edit/Duplicate option from the menu bar and then left-click on the object to be duplicated. The duplicated object may now be moved to a new location by moving the mouse. The status line shows the X,Y location of the anchor point along with the duplicated object’s bounding box coordinates. A single left click will place the new object at its moved coordinates, whereas a right click of the mouse will abort the move, but not the duplication, of the object.



## Deleting Objects

Any object on the drawing canvas can be deleted by hovering over the object of interest so that it is the “current” object, then right-clicking the mouse (or typing Alt-p) and selecting the Delete option. Alternatively, select the Edit/Delete option from the menu bar and then left-click on the object to be deleted. When initiating object deletion from the menu bar, the mouse cursor is changed to a skull and cross-bones; that mode can be aborted through a click of the right mouse button. Take care when deleting, as W2Anim has no “undo” feature.

## GROUPING OBJECTS

More than one object on the drawing canvas can be selected, and those multiple objects may be moved, aligned, and/or grouped.

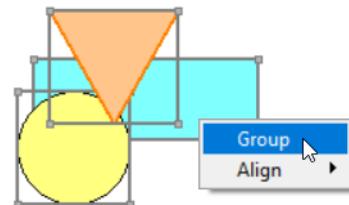
### Selecting Multiple Objects

Objects may be selected in two different ways:

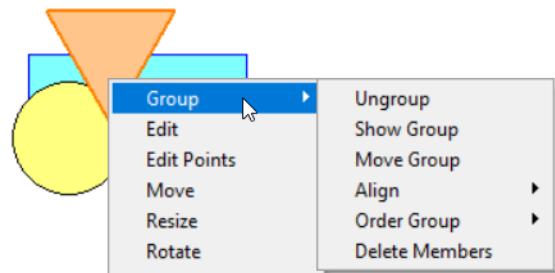
- The user can draw a selection rectangle on the canvas by holding down the left mouse button and dragging it so that the selection rectangle fully encloses the objects of interest. After releasing the left mouse button, selected objects will display their bounding boxes in gray, along with small gray squares at the corners of each bounding box.
- Alternatively, or in addition, individual objects may be selected with a click of the left mouse button. After one or more objects are selected, objects can be added or removed from the selection by clicking the left mouse button while holding down the Shift key.

### Grouping Objects

Objects may be assigned to a group by first selecting multiple objects, and then hovering over one of the selected objects and clicking the right mouse button or typing Alt-p and then selecting the Group option. Objects need not be grouped for them to be moved or aligned as a group. It can be useful, however, for certain items in a visualization to be grouped so that they can be moved later as a grouped object.



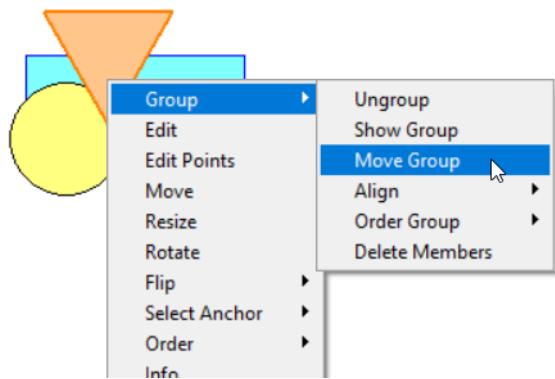
Once a group is assigned, a Group menu option is added to the pop-up menu for each object in the group, as seen at the right. From this menu, the objects may be ungrouped, shown with selection boxes, moved as a group with the mouse, deleted, and aligned in certain ways. In addition, the members of the group may be moved up or down in the drawing order list from the Order Group submenu options.



### **Moving Multiple Objects**

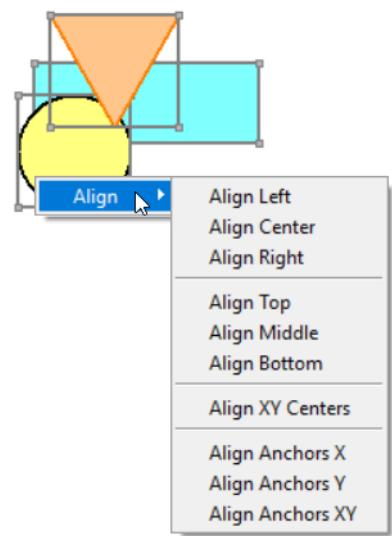
When multiple objects are selected, the only way to move those multiple objects without assigning them to a group is by using the arrow keys on the keyboard. Each use of an arrow key will move the group by only one pixel, unless the *Snap to Grid* option is turned on. With *Snap to Grid* enabled, each depression of an arrow key moves the group's anchor point to the next closest grid node in the direction of movement, where the anchor point for the group is set at the upper left corner of the bounding box for the group.

When objects are assigned to a group, a grouped move can be initiated by hovering over one of the grouped items (it need not be selected), right-clicking the mouse or typing Alt-p, then selecting the Group/Move Group option. At that point, the items in the group will be moved together when the mouse is moved. If *Snap to Grid* is enabled, the group's anchor point at the upper left corner of the group's bounding box will be shown with a small magenta square, and movement of the group will be tied to moves that snap the group's anchor point to the grid. The group move is finalized with a left mouse click, or aborted with a right mouse click.



### **Aligning Objects**

Multiple objects may be aligned in a number of different ways, either by selecting two or more objects and bringing up the Align menu, or by assigning a group and accessing the Align menu through the Group menu. The example at the right shows three selected objects. The Align pop-up menu was activated by hovering over one of the selected objects and clicking the right mouse button (or typing Alt-p).



Alignment is always performed relative to the object that was used to bring up the Align menu. In the example to the right, the Align menu was activated by right-clicking while hovering over the yellow circle. Therefore, alignment actions will be relative to the left, top, center, right, bottom, or the anchor of the yellow circle. The options should be self-explanatory.

If the user wishes to align to an anchor point but has forgotten its location, the position of the anchor point of the reference object may be determined in two different ways. First, the user could right click on the object and choose the Select Anchor option and look for the magenta-highlighted anchor position (left click on a point to select; right click to abort). This may require some iteration for a polygon or polyline, as two different methods of setting anchor points are available for such objects. The second way to determine the location of the anchor point is to right-click on the reference object, select the Info option, and take note of the X,Y anchor position.

Alignment is a great way to ensure that annotations on a visualization are properly placed, or to align graphs or to draw dam schematics and outlet structures and align them to their proper elevations relative to a graph.

## GRAPH TYPES

The W2 Animator supports a number of different graph types, including:

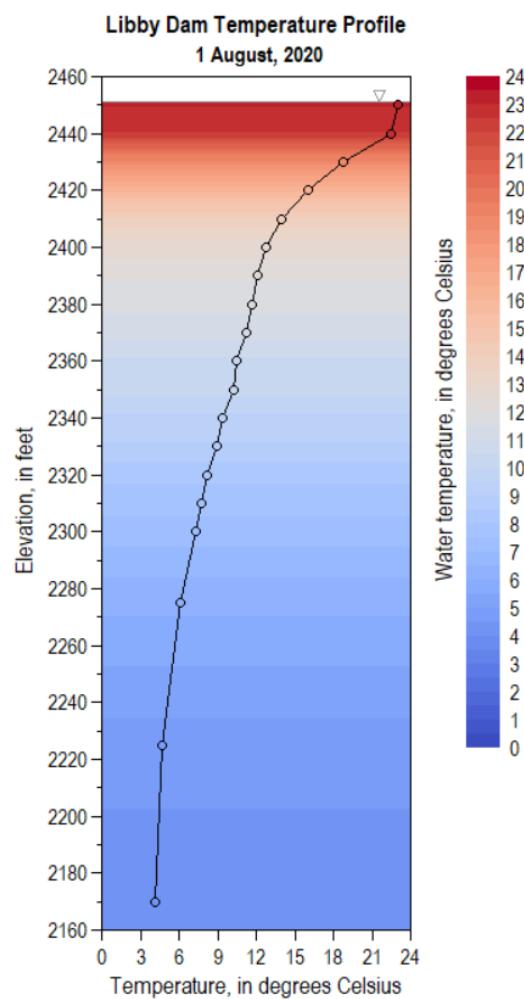
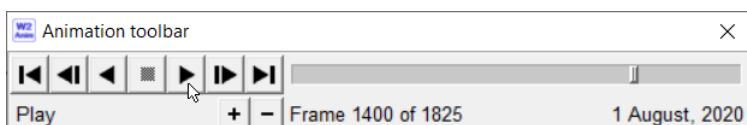
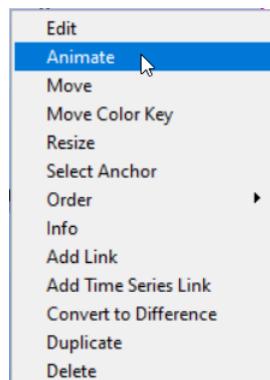
- Vertical profiles of measured parameters over time,
- Vertical profiles of model results over time,
- Longitudinal slices of model results through the model domain over time,
- Time/distance maps of model results,
- Vertical withdrawal zones at dam outlets, computed from measured data,
- Vertical withdrawal zones from model output,
- Measured time series, and
- Modeled time series.

More graph types will continue to be added with future releases. This section describes how each of the graph types is created and used in The W2 Animator.

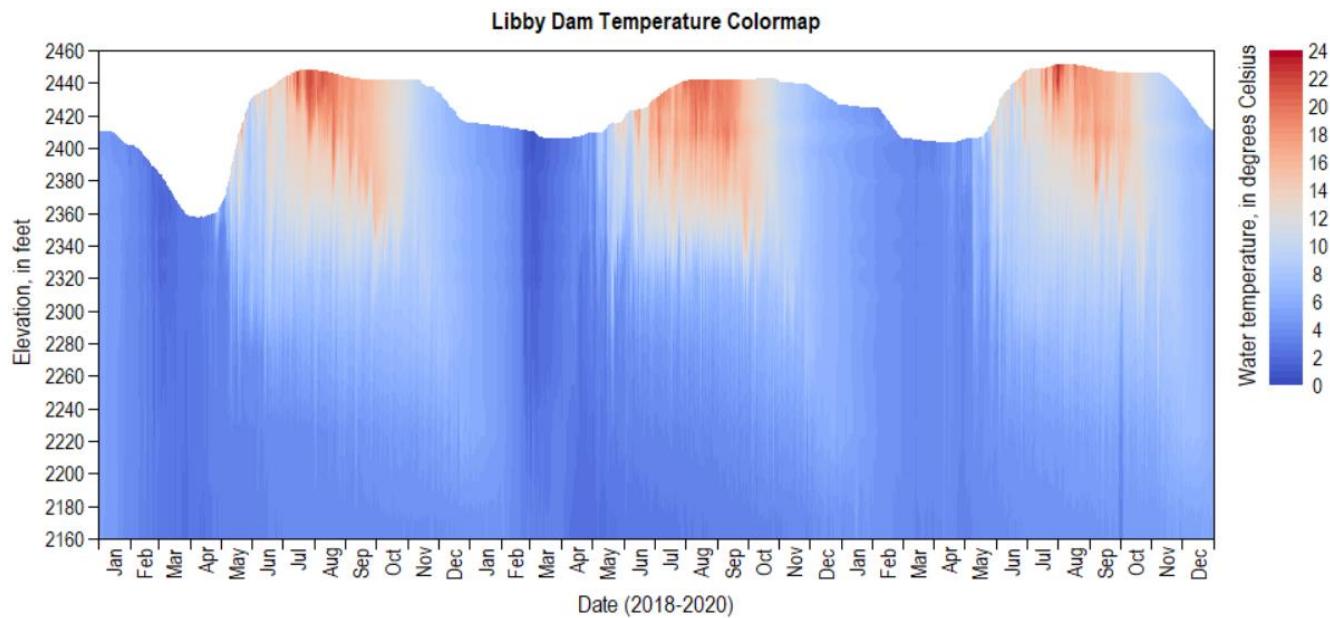
### MEASURED VERTICAL PROFILES

Measured vertical profiles of any parameter can be graphed in two different ways—either as a time-indexed profile that can be animated for the available dates, or as a colormap over time. The data can be provided at any time interval, such as daily or hourly, but a more consistent visualization is obtained if the measurement frequency is constant over time. An example of a measured vertical profile graph of water temperature using daily measurements from the U.S. Army Corps of Engineers at Libby Dam in Montana is shown below. In that graph, the vertical profile is shown for one date or date/time, with elevation or depth on the Y axis and a scale for the measured parameter on the X axis. The vertical profile is shown with circles plotted at the measurement elevation or depth and at the measurement values, and with the points connected with lines to show the profile. An optional color-highlighting scheme can be added to emphasize the variation in the parameter value with depth. In this case, a CoolWarm [color scheme](#) is used to display temperatures between 0 and 24°C. The measurements are interpolated to vertical increments of 1 ft or less, depending on the number of pixels in the vertical range of the graph.

W2Anim can animate this type of vertical profile. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical profiles change over time.



The W2 Animator can also represent vertical profiles of a measured parameter as a colormap over time. In this type of graph, the X axis is a date/time or Julian Date axis, and the measured vertical profiles are represented as colors according to a chosen color scheme. In the example below, several years of measured vertical temperature profiles at Libby Dam are represented using the CoolWarm color scheme, based on daily data from the U.S. Army Corps of Engineers.

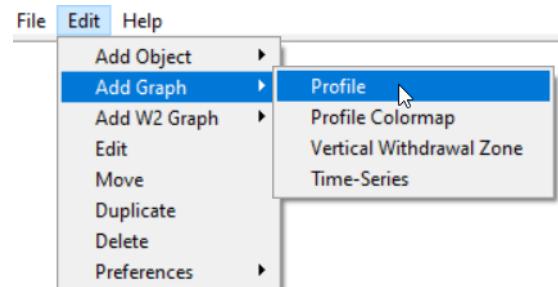


### Creating a New Graph

To create a Measured Vertical Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

The Measured Vertical Profile graph can be started by choosing the Edit/Add Graph/Profile option from the menu bar, or by right-clicking on the canvas and choosing Add Graph/Profile. If the measured vertical profile colormap is the graph of interest, choose the Profile Colormap option instead. When either of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair also will be highlighted with a magenta point.

Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen on the next page.



The only difference in the Profile Setup menu between the vertical profile and the vertical profile colormap graph is that the colormap menu will not ask for a Parameter Major entry. The first step is to browse your file system for a [measured vertical profile data file](#). Find and set that file by clicking on the Browse button and selecting the file from your file system. W2Anim will scan that file for the parameter it contains as well as some initial values for many of the fields in this menu.

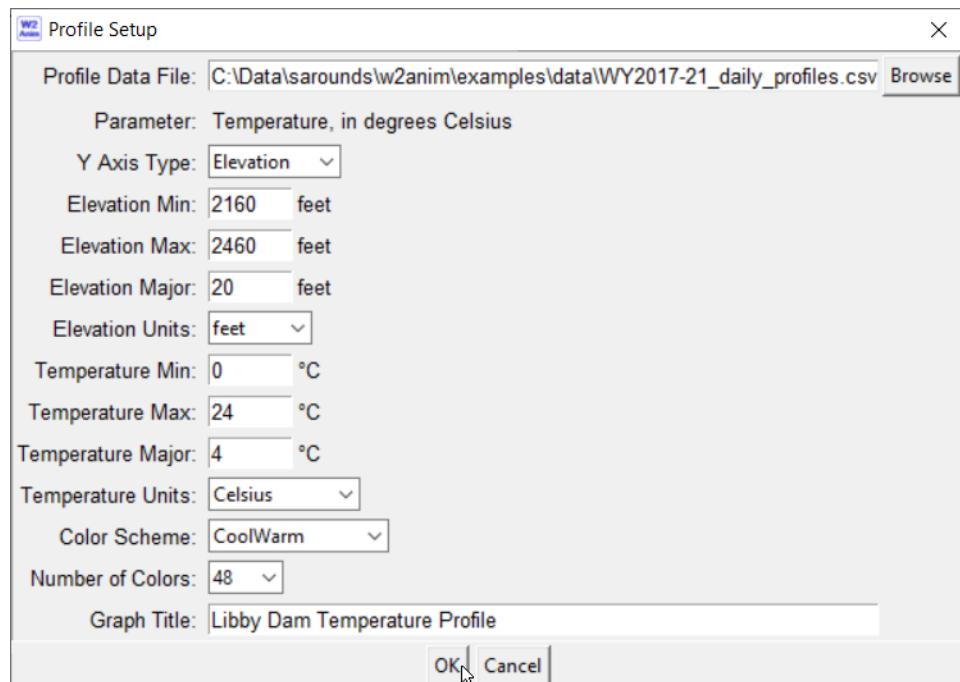
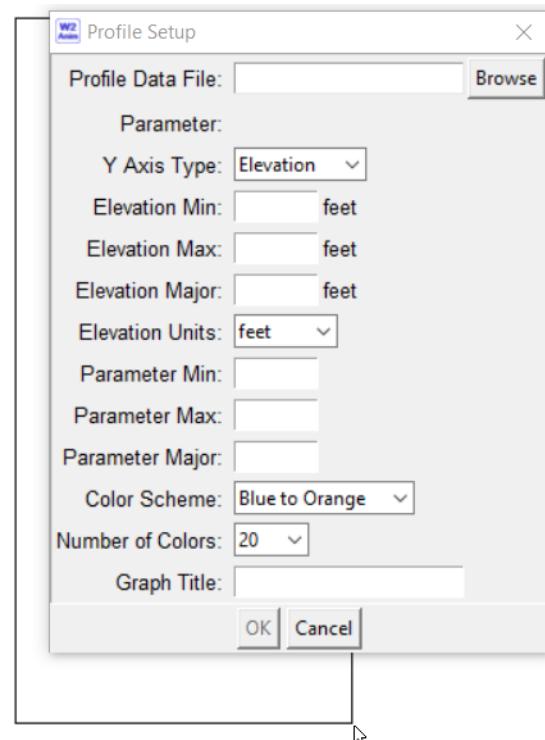
At this point, the user may change any of the menu options and select an initial color scheme for highlighting the profile. All of the inputs to this menu can be changed later, with the exception of the profile data file and the parameter. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero.

The color scheme input for this menu offers a limited range of options; other choices become available after the graph has been created, and more information on [color schemes](#) is available elsewhere in this user manual. For this example, the CoolWarm scheme was chosen with 48 colors because 48 is an even multiple of the parameter value range when a minimum and maximum of 0 and 24, respectively, are chosen. The resulting filled-out menu is shown below.

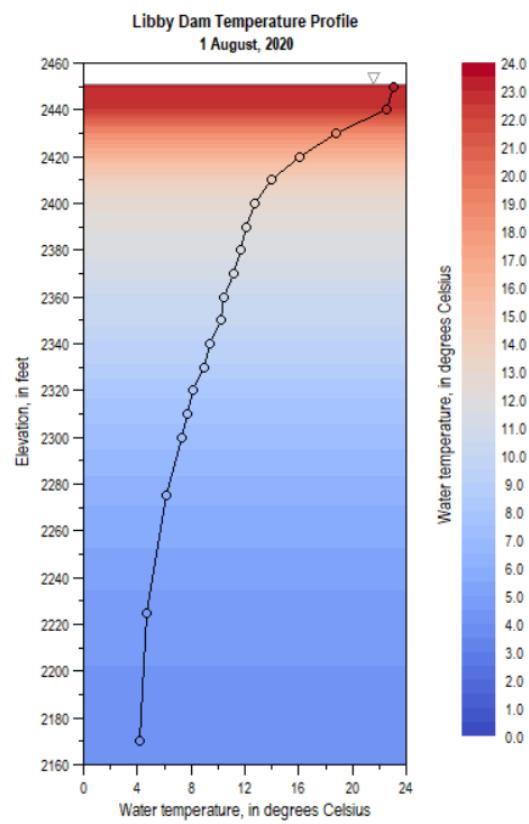
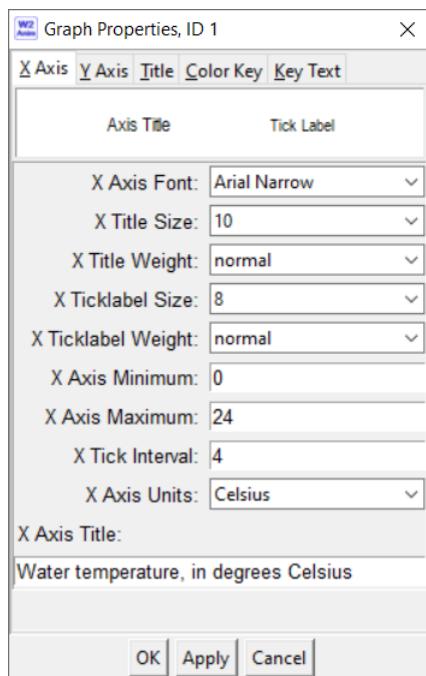
Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The vertical profile graph created from this example looks similar to the first measured vertical profile graph shown in this section, and is also shown on the next page.

The default font family is set by W2Anim and is likely Helvetica, Arial, or Times, as most computer systems are guaranteed to have one of those. The initial font size for new graphs is scaled

according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles. The default font family for graph text can be set by the user in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#).



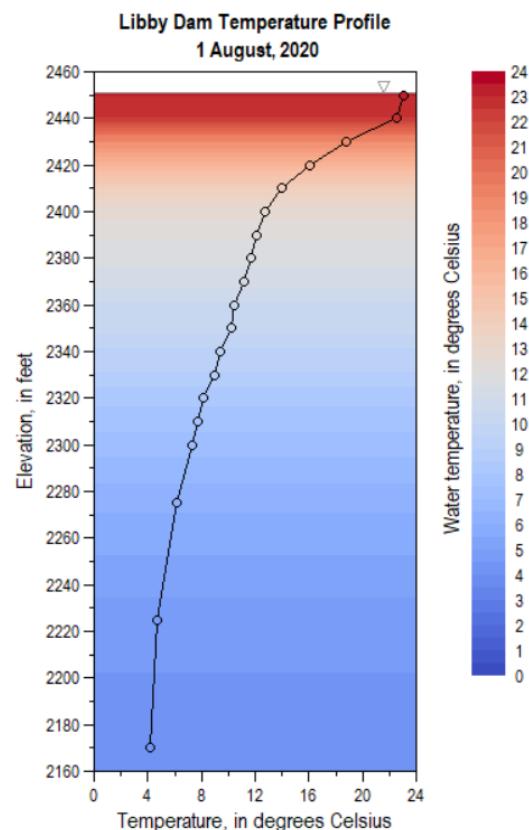
To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.



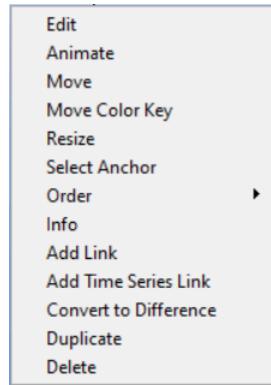
The various options of the Graph Properties menu should be fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked.

Under the Color Key tab, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same source data file.

For vertical profile colormaps, the X Axis tab of the Graph Properties menu has different options relating to the date axis. The X Axis can be plotted as a Date/Time axis or as a Julian Date axis; to translate between them, a base year must be set. In Date/Time mode, the X Axis tick labels can be set just to the Year or Month or to a Mon-DD or Mon-DD-YYYY format. In Month mode, the labels will adjust themselves according to how much space is available. After changing font sizes, the X Axis title, and the number of digits after the decimal for the color key, the updated vertical profile graph is shown at the right.



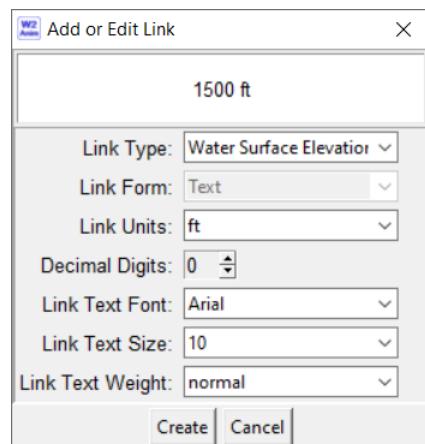
Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, extract a link or add a linked time-series graph, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.



### Adding a Link

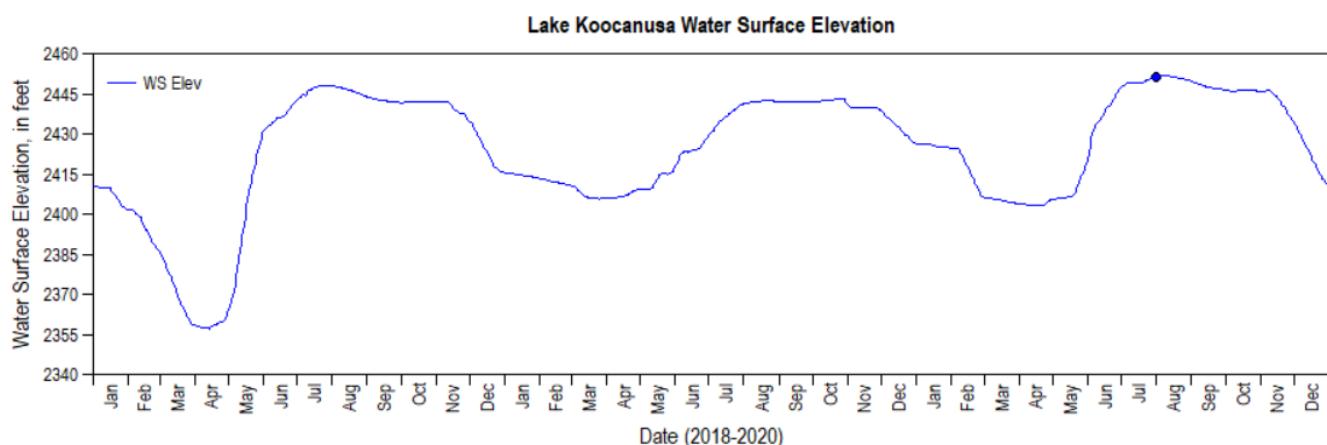
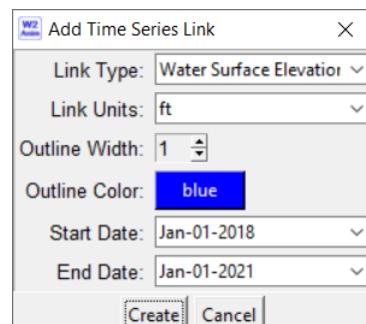
The Measured Vertical Profile graph allows a user to create a linked text object that is tied to the water-surface elevation for the date/time of the profile being depicted. In this way, a linked text object can be placed on or near the graph that shows the current water-surface elevation, and which is continually updated when the graph is animated to show the water-surface elevation on the date tied to the profile being graphed.

After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be changed later by choosing the Edit Link option from the linked text object's menu.



### Adding a Time Series Link

The entire time series of water-surface elevation data associated with the Measured Vertical Profile graph can be linked to a separate time-series graph. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the right will pop up. Choose the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, a circle showing the date of the animation moves along the graph.



## Creating a Difference Plot

If a user wishes to visualize the parameter profile values as a difference relative to a constant or relative to a user-supplied time series, the Convert to Difference option can be applied to either the measured Profile or Profile Colormap graph. Choosing this option will bring up a new menu asking for the type of difference, where the menu on the left is for the choice of a difference relative to a constant value, and the menu on the right is for computing differences relative to a time series.

W2 Animator Convert to Difference

Please provide a constant or time-series as the basis for a difference.

Reference Type: Constant

Reference Value: 12

Data Parameter: Temperature Difference, in degrees Celsius

Difference Min: -12 °C

Difference Max: 12 °C

Difference Major: 4 °C

Axis Title: Temperature Difference, in degrees Celsius

W2 Animator Convert to Difference

Please provide a constant or time-series as the basis for a difference.

Reference Type: Time-Series

Data Parameter: Temperature, in degrees Celsius

Reference Data File:

Ref. Parameter:

Conversion: None

Match Tolerance: 10 minutes

Difference Min: -12 °C

Difference Max: 12 °C

Difference Major: 4 °C

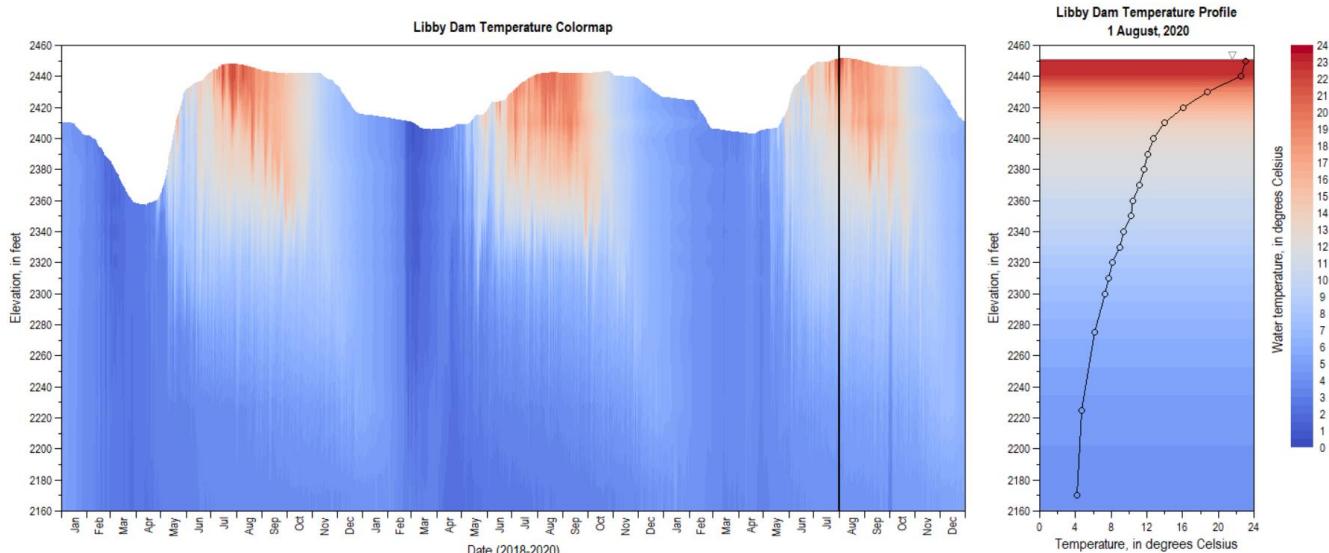
Axis Title: Temperature Difference, in degrees Celsius

For example, if the goal is to determine how much of the profile might provide more-optimal conditions for a particular aquatic species and a threshold temperature exists to denote the limits of that range, then the profile data could be plotted as a difference relative to that threshold. On the other hand, if the goal is to visualize the heat content of a lake profile relative to the heat content of a stream entering the same reservoir at that time, then a difference relative to a temperature time series of the incoming stream might be of interest. (Thanks to Laurel Stratton Garvin for that idea!)

To compute the difference plot, fill out the fields in the Convert to Difference menu and press the OK button. The user can revert back to the measured parameter profiles later by choosing the Undo Differences option that is available when the profile plot is in difference mode.

## Pairing Profiles and Colormaps

Often it is useful to pair a Measured Vertical Profile graph with a Measured Vertical Profile Colormap because the profile graph is specific to a particular date/time whereas the colormap provides a time-series context. When the profile is animated, a vertical black line is shown on the colormap to denote the current date/time.

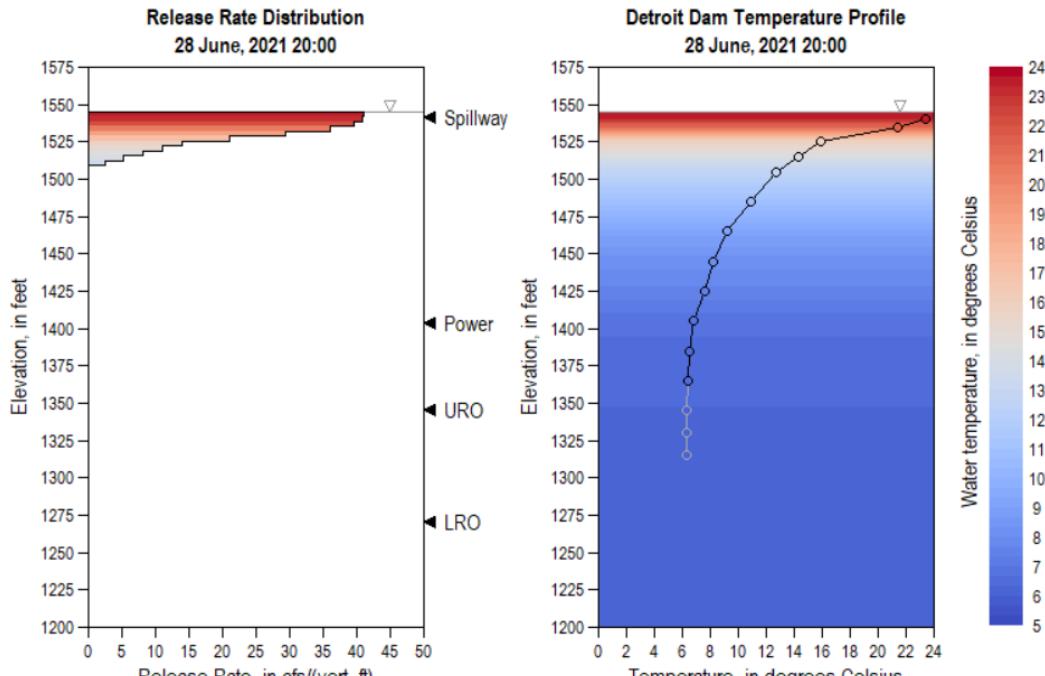


## VERTICAL WITHDRAWAL ZONES FROM MEASURED DATA

The characteristics of releases from dam outlets depends on many factors, including the elevation or depth and dimensions of the outlet, the release rate, the density profile of the water in the reservoir next to the dam, and the temperature and quality of the water in that profile. When a reservoir is strongly stratified, a release from an outlet located above the thermocline generally draws water from depths above the thermocline. Similarly, a release from an outlet located below the thermocline typically draws water from a range of depths below the thermocline. The range of depths from which water is drawn to the outlet and the amount of water that is drawn from each depth in that range can be calculated based on the factors mentioned above. This release of water from a specific vertical depth range or zone is known as selective withdrawal. The CE-QUAL-W2 model includes algorithms to compute selective withdrawal, and those algorithms have been incorporated into The W2 Animator so that vertical withdrawal zones and the vertical distribution of flows toward dam outlets can be calculated and visualized. The Vertical Withdrawal Zones from Measured Data graph type is a visualization of such withdrawal zones.

To compute vertical withdrawal zones, information about dam outlets and their release rates is needed, along with the vertical density profile in the reservoir. Water density in fresh water is controlled mainly by water temperature, so it is sufficient to provide vertical profiles of water temperature. Finally, to convert horizontal velocities toward dam outlets into flow rates, the width of the reservoir as a function of depth also is needed.

An example of a computed vertical withdrawal zone graph for releases from Detroit Dam's spillway is given at the right, along with a corresponding measured vertical temperature profile at the far right to illustrate the degree of stratification. The vertical distribution of release rates is shown in the graph, in units of  $\text{ft}^3/\text{s}$  per vertical foot, and the temperature of the water being drawn to

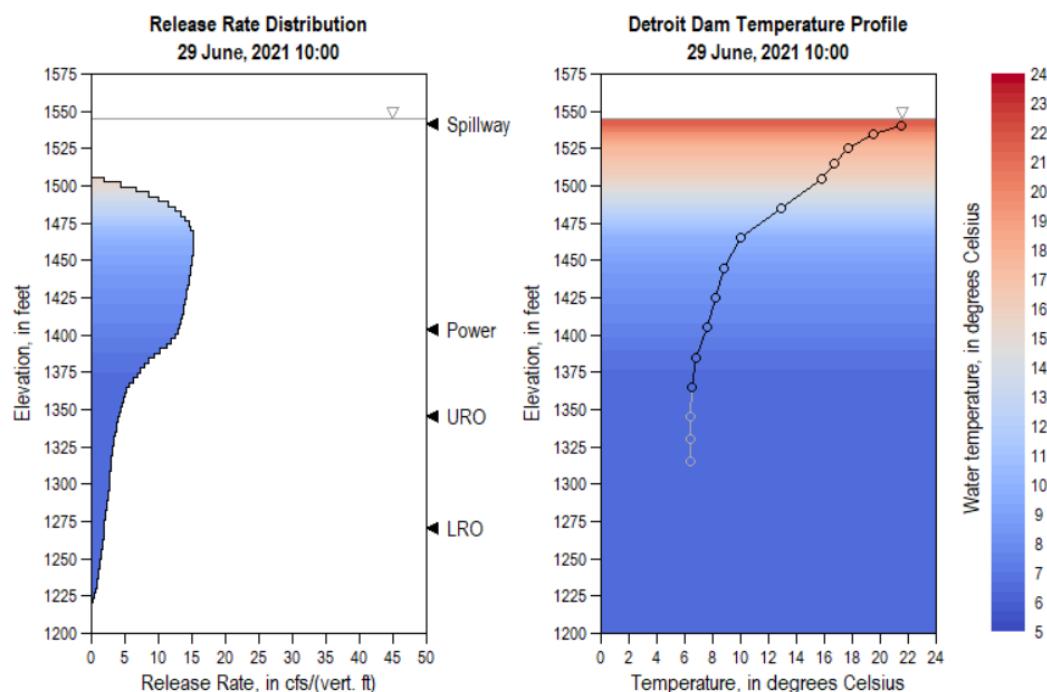


the spillway is illustrated with the color highlighting. In this example, the spillway release rate was  $810 \text{ ft}^3/\text{s}$  and stratification was strong near the lake surface, resulting in a relatively shallow withdrawal zone and releases that were fairly warm. (Detroit Dam is located on the North Santiam River in western Oregon.)

The user can choose whether to plot the release rate per unit depth ( $\text{ft}^3/\text{s}/\text{ft}$  or  $\text{m}^3/\text{s}/\text{m}$ ) or the horizontal velocity ( $\text{ft}/\text{s}$  or  $\text{m}/\text{s}$ ) on the X axis. Knowing how much water is drawn from each depth and knowing the water temperature as a function of depth allows W2Anim to also compute the overall temperature of the release through each outlet. Each of the release rates and computed release temperatures can also be linked to objects on the canvas to provide an information-rich visualization.

The annotations for the vertical locations of the outlets on the right side of the withdrawal zone graph were manually added using text and polygon objects.

As a contrast to the previous graph in which releases were over the spillway, another example is shown at the right using data from just a few hours later when releases were solely through the power penstocks at Detroit Dam. In this case, the release rate was more than twice as large ( $2,040 \text{ ft}^3/\text{s}$ ) and the release was from below the thermocline, which caused the vertical withdrawal zone to

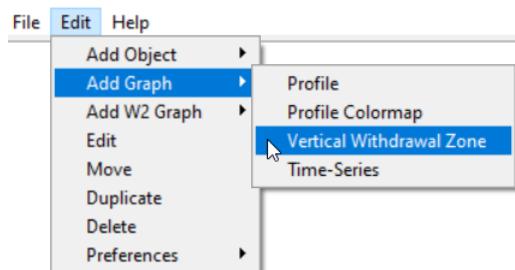


be much wider, vertically, than in the previous example. Releases from below the thermocline in this instance would be far cooler than those over the spillway. This example also illustrates that with a large enough release rate and a zone of water densities that are not all that different, releases from a single discrete outlet can draw water from a very large range of depths.

### Creating a New Graph

To create a Vertical Withdrawal Zone from Measured Data graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by right-clicking on the canvas and choosing the *Canvas Props* option or by choosing the *Edit/Preferences/Canvas Props* option from the menu bar. See also the information in this user manual at [Canvas Properties](#).

The Vertical Withdrawal Zone from Measured Data graph can be started by choosing the *Edit/Add Graph/Vertical Withdrawal Zone* option from the menu bar, or by right-clicking on the canvas and choosing *Add Graph/Vertical Withdrawal Zone*. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen on the next page.



The first step is to determine whether all of the dam outlets may be treated with the original CE-QUAL-W2 selective withdrawal algorithm, or whether one or more has a variable bulkhead configuration such as what is found at Libby Dam. If a Libby-Dam-like outlet is present, the user must choose the Libby Dam option for the Withdrawal Algorithm. More details on that option are provided [later](#).

Next, browse your file system for a [measured temperature profile data file](#). Click on the Browse button and select the file from your file system. W2Anim will scan that file for the parameter it contains (Temperature, in this case) as well as suggested initial values for some of the fields in this menu. Similarly, an [outlet flow file](#) must be provided; use the Browse button to select that file from your file system. Finally, a CE-QUAL-W2 bathymetry file is required; use the Browse button to find and set that file name. To help W2Anim use the information in the bathymetry file, the user must provide the model segment number that is adjacent to the dam, as well as the elevation of the top of the bottom-most layer in that bathymetry file.

At this point, the rest of the menu inputs and options may be changed or set. An initial color scheme for highlighting the profile should be selected. All of the inputs to this menu can be changed later, with the exception of the withdrawal algorithm and the file names.

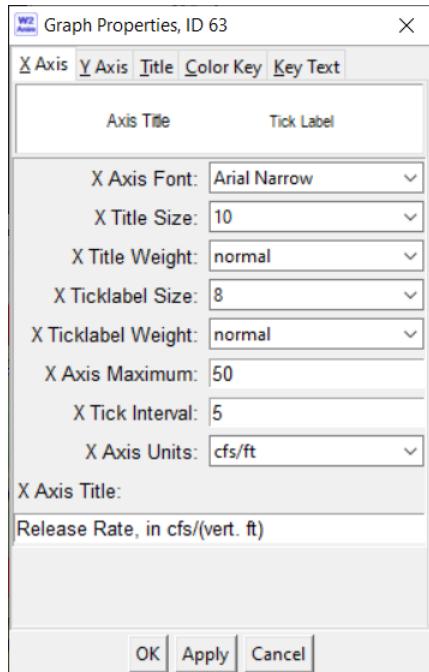
The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth is zero.

The [color scheme](#) input for this menu offers just a few options; other choices are available after the graph has been created. For this example, the CoolWarm scheme was chosen with 57 colors because 57 is an even multiple of the temperature range when a minimum and maximum of 5 and 24, respectively, are chosen. The resulting filled-out menu is shown to the right.

Click the OK button to remove the menu and create the graph. Click the Cancel button to remove both the menu and the graph. The Vertical Withdrawal Zone graph created from this example looks similar to the first example graph shown in this section, and is shown here to the right.

The default font family for graph text can be set in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#). The initial font size for new graphs is scaled according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.



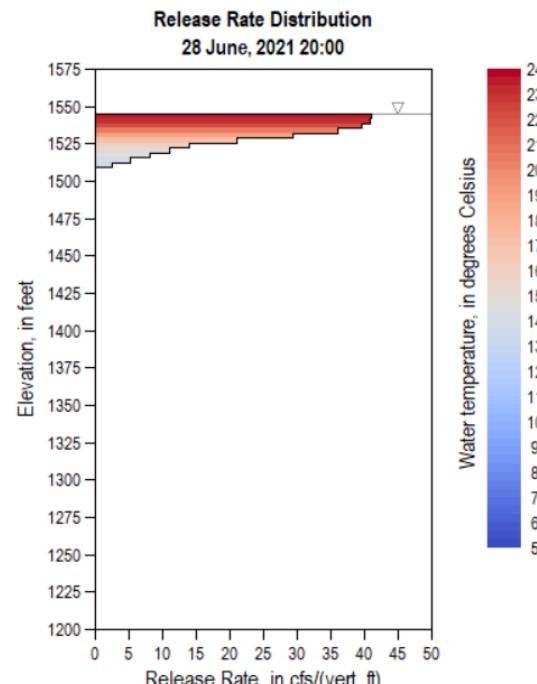
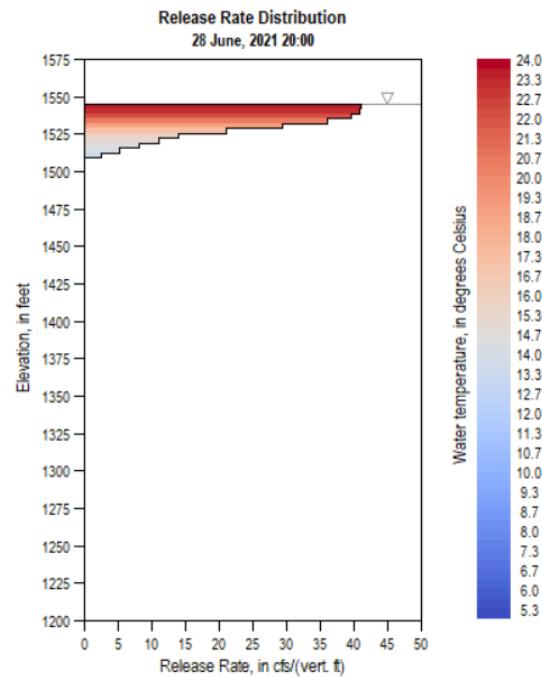
Setting the X axis maximum value can be a challenge for the vertical withdrawal graph type, but the limits of the data are available from the Object Info box. Just right-click over the

graph, select the Info option, look at the values given for the Layer Flow Range or the Velocity Range, and adjust the X axis maximum value accordingly. Click on Calculate if needed.

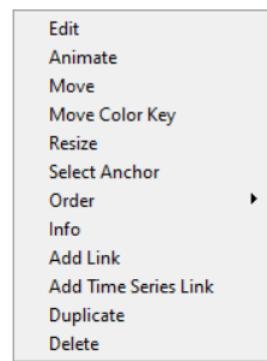
Most options in the Graph Properties menu should be fairly self-explanatory, and therefore are not discussed in detail here. The user is advised to play with the various options and observe the results when the Apply button is clicked.

Under the Color Key tab, the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs, either for the same parameter or for the same source data file.

After changing font sizes, the color key cell height, and the number of digits after the decimal for the color key, the updated graph is shown at the right.



Now that the graph has been created and edited, the user has a number of options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, extract a link or add a linked time-series graph, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.



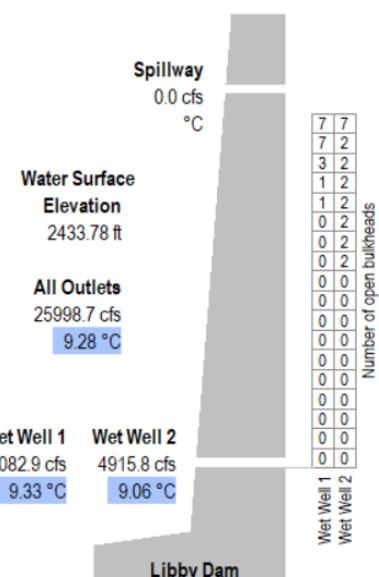
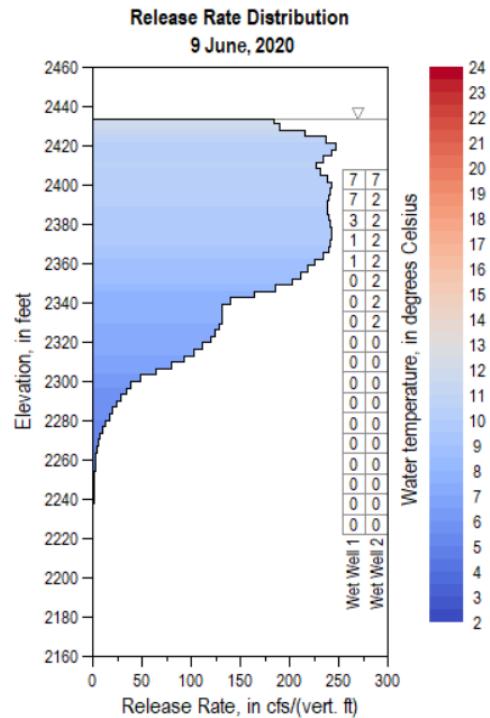
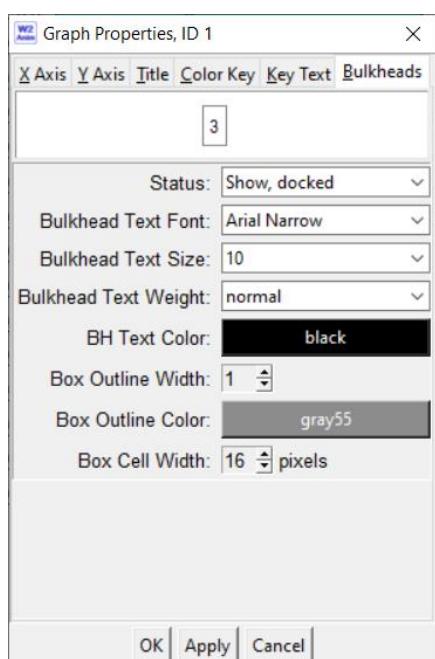
### Libby-Dam-Type Outlets

If one or more of the dam outlets has a time-varying bulkhead configuration such as what is used at Libby Dam, then the user must choose the Libby Dam option for the Withdrawal Algorithm and specify the name of a [Libby Dam Bulkhead Configuration file](#). At Libby Dam, flow to the power penstocks is from two different wet wells that are fronted by an array of bulkheads that can be installed or removed to modify the vertical withdrawal zone and thereby the release temperature. Each wet well has 7 vertical slots of up to 18 rows of removable bulkheads. The example at the right shows a vertical withdrawal zone for Libby Dam and also shows the configuration of bulkheads, where the numbers in the diagram are the number of open bulkhead positions in each row for each wet well. The “Wet Well” text at the bottom was added as an annotation.

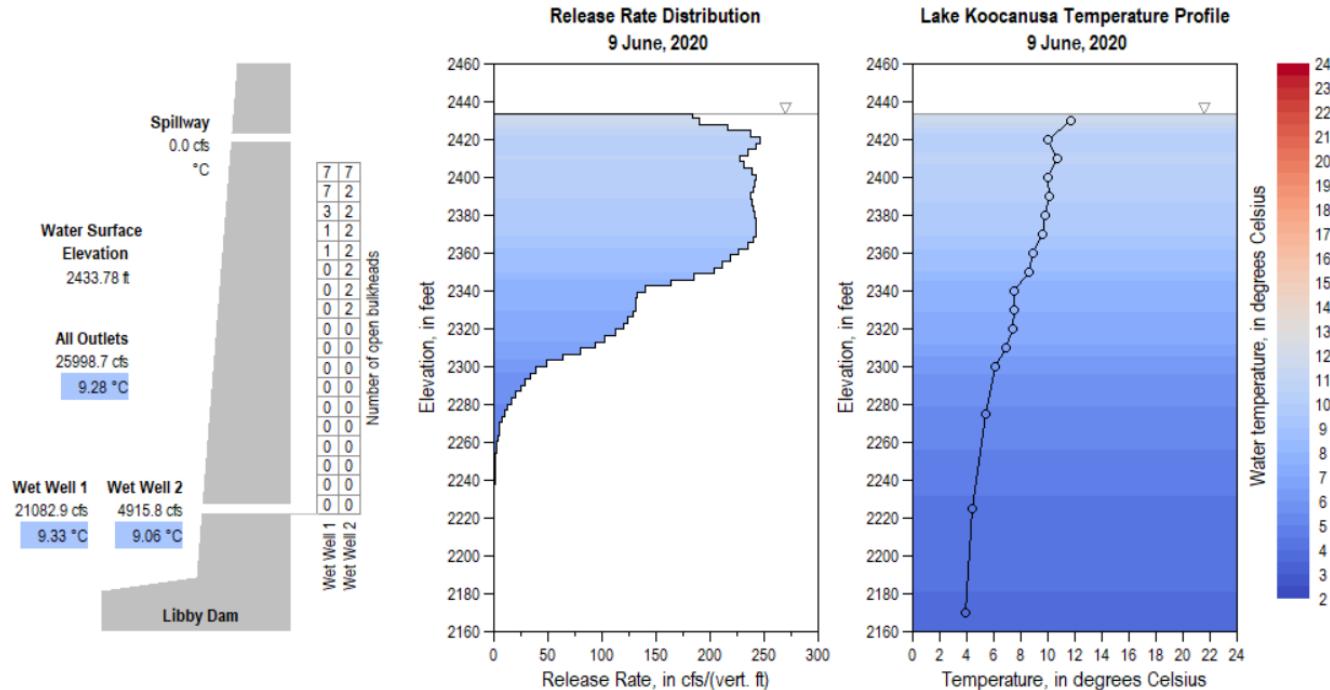
The Graph Properties menu for a Libby-Dam-type withdrawal zone graph includes a Bulkheads tab, which allows the user to show or hide the time-varying bulkhead diagram. When “docked” to the

graph, the diagram is pinned to the inner right side of the graph and the rows are shown at their exact depth or elevation. When “undocked” from the graph, the bulkhead diagram may be moved elsewhere on the canvas, perhaps next to a drawing of the dam itself, such as the example shown to the right.

Many of the text objects showing release rates and release temperatures, as well as the filled rectangles showing the release temperature according to a color scale, were added as linked objects. See the next section on [Adding a Link](#).



The example below combines the sketch of the dam, the undocked bulkhead diagram, a Vertical Withdrawal Zone from Measured Data graph, and a Measured Vertical Profile graph for Libby Dam, where both of the graphs have color highlighting based on the measured temperature profile.

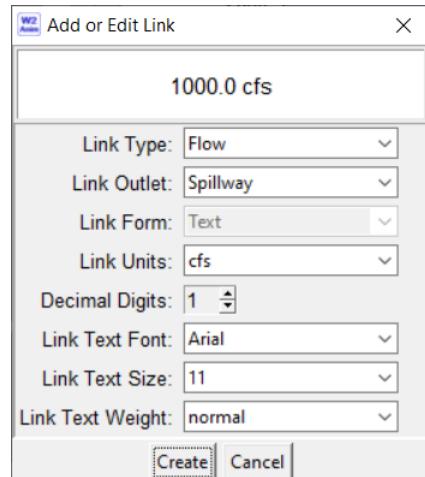
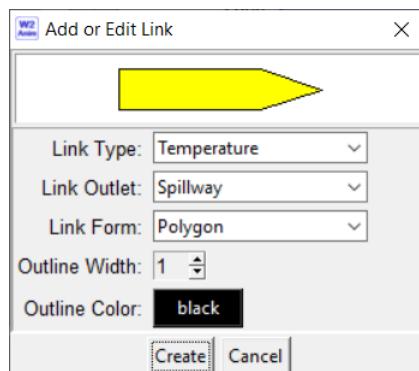


### Adding a Link

The Vertical Withdrawal Zone from Measured Data graph allows a user to create linked text or graphical objects that are tied to the water-surface elevation or the release rate or release temperature for any or all of the outlets at the date/time of the withdrawal zone being depicted. In this way, linked text objects and color-filled shapes can be placed on or near the graph that show the current water-surface elevation, release rates, and release temperatures, and the text or fill colors would be continually updated when the graph is animated.

After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be changed later by choosing the Edit Link option from the linked text object's menu.

For example, the combination of linked text objects and a linked shape shown at the right can be used to annotate results on the canvas in a dynamic manner as the visualization is animated.

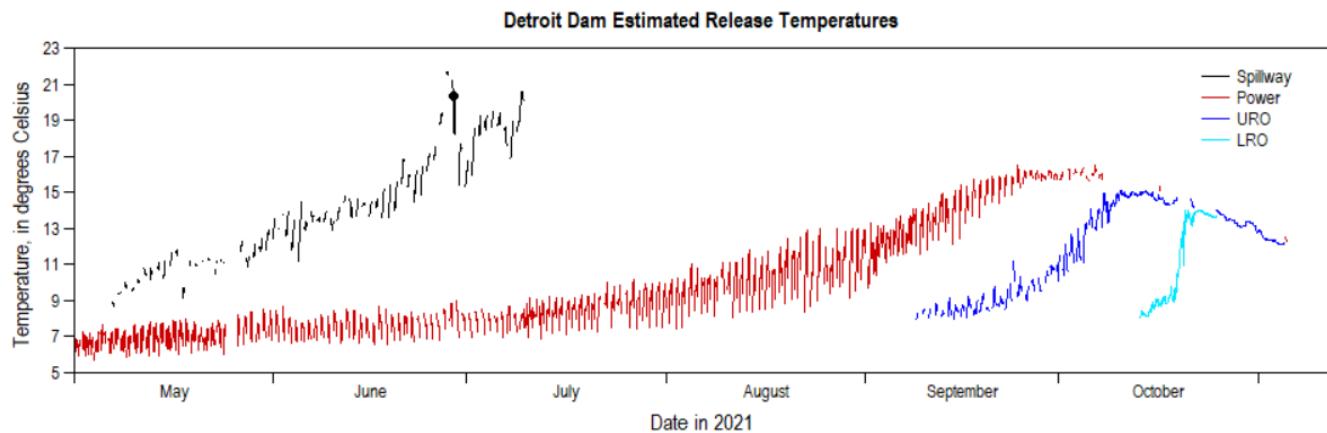
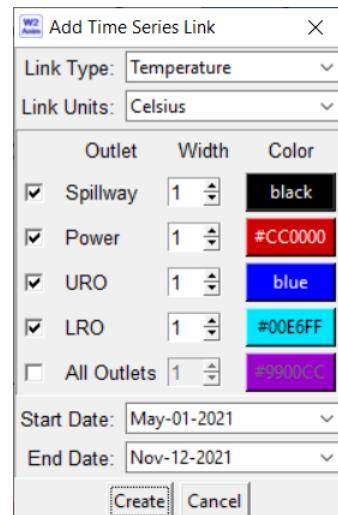


810.0 cfs  
20.33 °C

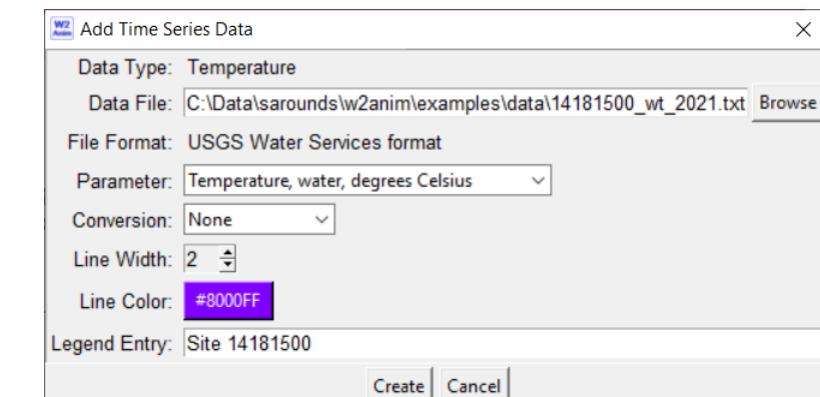
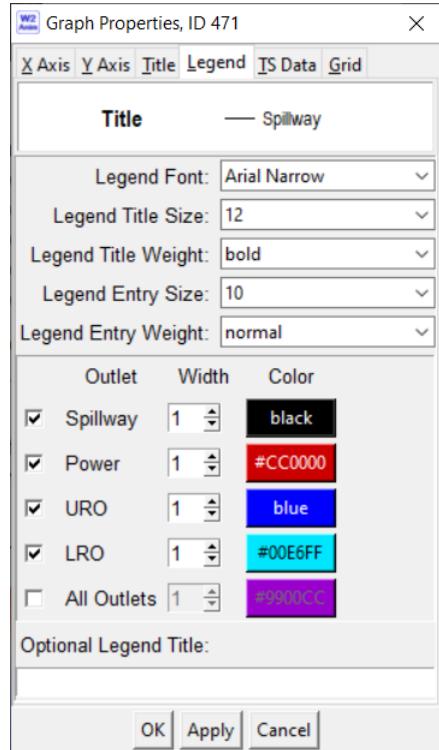
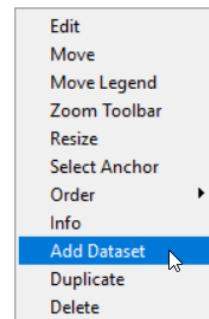
## Adding a Time Series Link

Entire time series of water-surface elevations, release rates, and release temperatures associated with the Vertical Withdrawal Zone graph can be linked to separate time-series graphs. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the right will pop up. Choose the Link Type (Flow, Temperature, or Water-Surface Elevation), the desired units, the outlets of interest, the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a rectangular frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, circles highlighting the linked datasets on the date of the animation will move along the graph for each of the graphed datasets.

For temperature, W2Anim will need a few moments to pre-calculate the release temperatures prior to creating the linked time-series graph.

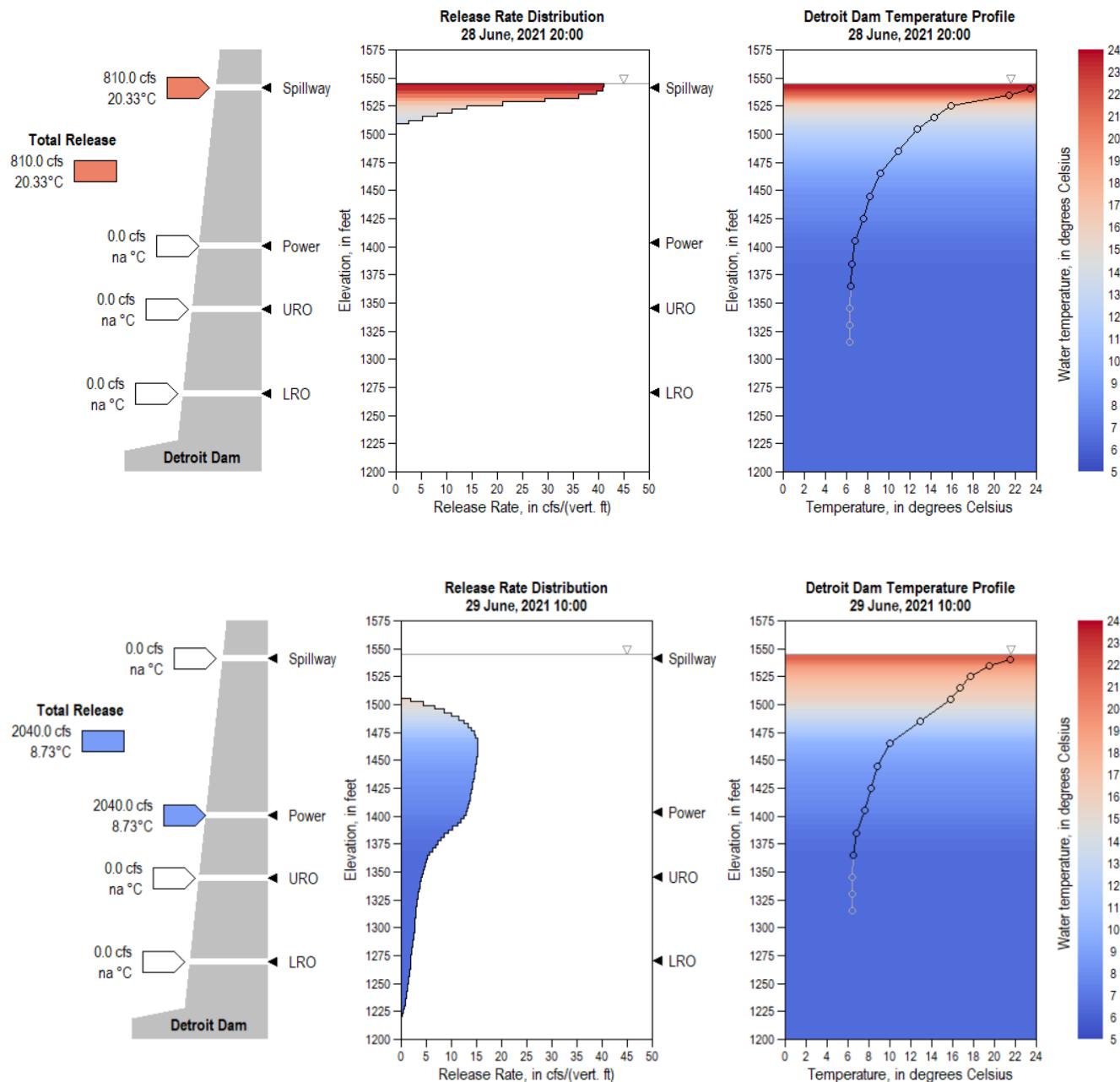


The Graph Properties menu (Edit option) for the linked time-series graph has a Legend tab, and may have a TS Data tab if additional datasets have been added to the graph. These tabs allow the user to change line widths and line colors, show or hide each dataset, change the legend font and so forth. Additional datasets may be added to a linked time-series graph by hovering the mouse over the graph and right-clicking (or typing Alt-p) and selecting the Add Dataset option. This brings up the Add Time Series Data menu.



## Pairing Multiple Graphs and Drawings

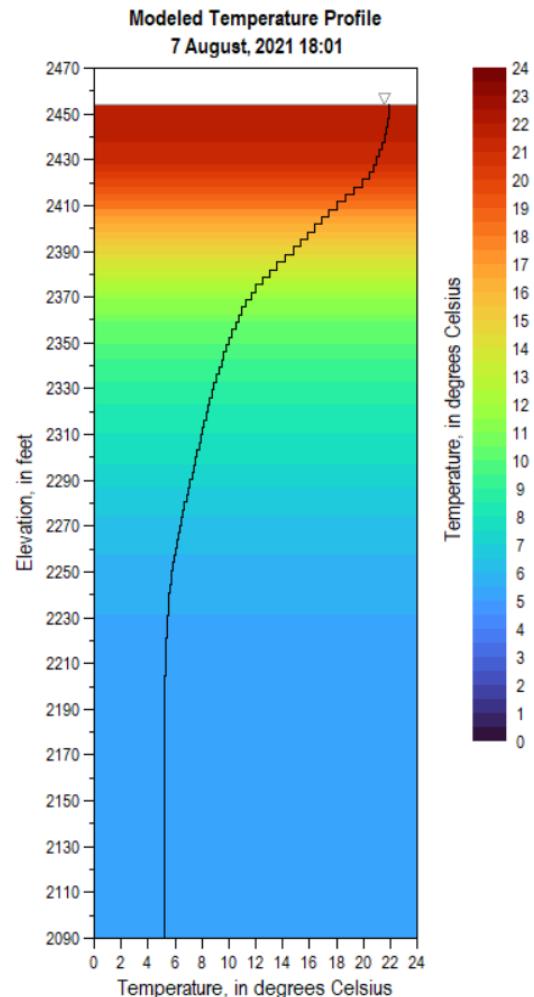
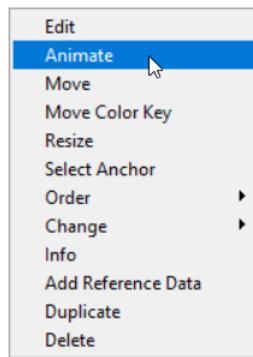
The Vertical Withdrawal Zone from Measured Data graph is perhaps best utilized when paired with a Measured Vertical Profile graph and some creative annotations. For example, the graphs and annotations below were all created in The W2 Animator. The text and triangles at the right side of the withdrawal zone graph are text and polygon objects that were exactly aligned to the appropriate elevations. The sketch of Detroit Dam and its outlets to the left was put together with various text, polygon, and rectangle objects. The release rates and release temperatures from each outlet and from the overall release are all linked objects, such that the text values and fill colors change as the visualization is animated.



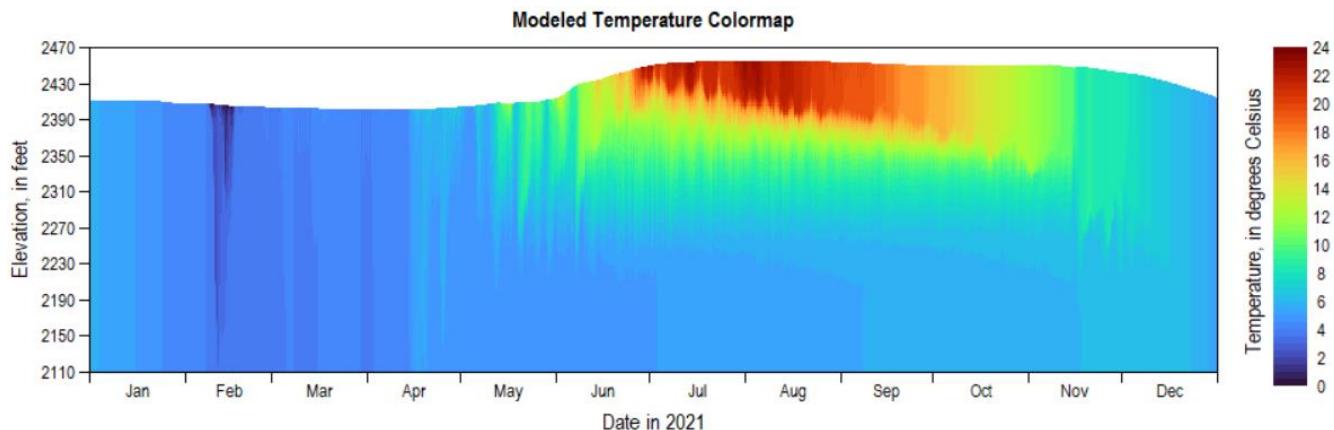
## W2 VERTICAL PROFILES

The W2 Vertical Profile graph type is similar to the Measured Vertical Profile graph type except that the profile data are from a CE-QUAL-W2 output file. A few of the extra functions also are different. For example, the W2 Vertical Profile graph is allowed to import measured vertical profiles as a reference dataset, from which goodness-of-fit statistics can be computed. Just as with the measured profile graph, a colormap over time also can be plotted. These graphs are built from W2 spreadsheet, contour, vector, or lake contour output files, and the best results are obtained if the model output frequency is relatively constant over the time period being plotted. The example to the right uses hourly results from a W2 spreadsheet output file, with elevation on the Y Axis and temperature on the X axis. These graphs also can be plotted with depth rather than elevation. The vertical profile is shown with a black line, stair-stepped for each layer in the model. An optional color-highlighting scheme can be added to emphasize the variation in the parameter value with depth. In this case, the Turbo color scheme is used to display temperatures between 0 and 24°C.

W2Anim can animate this type of vertical profile. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical profiles change over time.



The W2 Animator can also plot W2 vertical profiles as a colormap over time. In this type of graph, the X axis is a date/time or Julian Date axis, and the vertical profiles are represented as colors according to a chosen color scheme. In the example below, temperature profiles are represented using the Turbo color scheme.



## Creating a New Graph

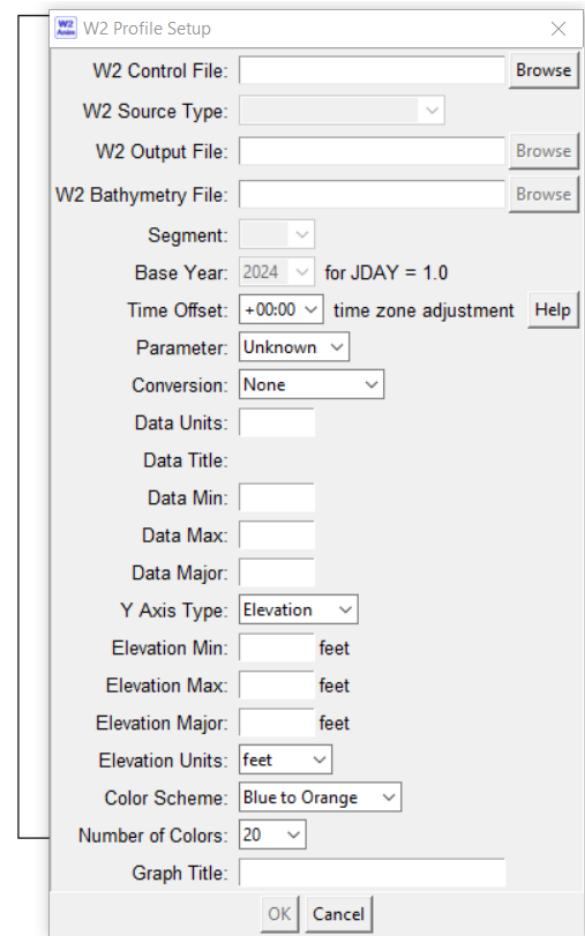
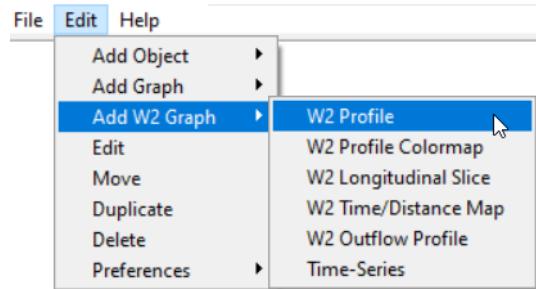
To create a W2 Vertical Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

The W2 Vertical Profile graph can be started by choosing the Edit/Add W2 Graph/W2 Profile option from the menu bar.

Alternatively, right-click on the canvas and choose the Add W2 Graph/W2 Profile option. If the W2 Vertical Profile Colormap is desired, choose the W2 Profile Colormap option instead. When either of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair also will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen below.

The only difference in the W2 Profile Setup menu between the W2 Profile and the W2 Profile Colormap graph is that the colormap menu will not ask for a Data Major entry. The first step is to specify a W2 control file. Find and set that file by clicking on the Browse button and selecting the file from your file system. W2Anim will scan that file for model grid parameters and the model year and so forth. Next, choose the W2 spreadsheet, contour, vector, or lake contour option as the source of the profile information and Browse to find and select the appropriate file. For all W2 output file types, W2Anim must read a W2 bathymetry file so that it can properly represent layer elevations. Select the model segment number and the profile parameter from among those available in the W2 output file. The time offset input is for W2 models that were run using a non-local time zone.

At this point, the user needs to set the axis limits and select an initial color scheme for highlighting the profile. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero. The [color scheme](#) input for this menu offers just a few options; other choices are available after the graph has been created. All inputs to this menu can be changed later, either through editing the graph properties or by choosing to change the segment, parameter, units, or data sources.

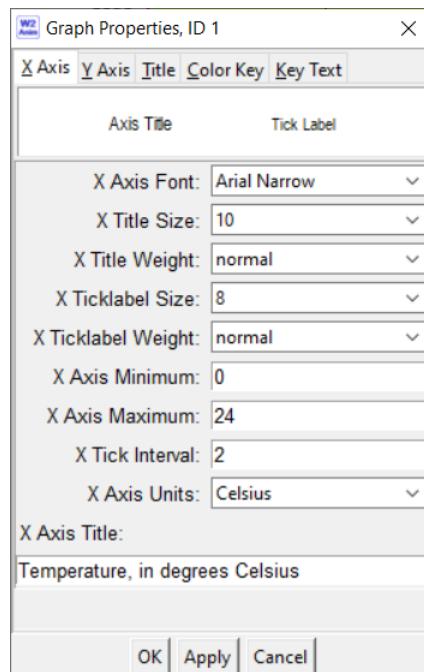
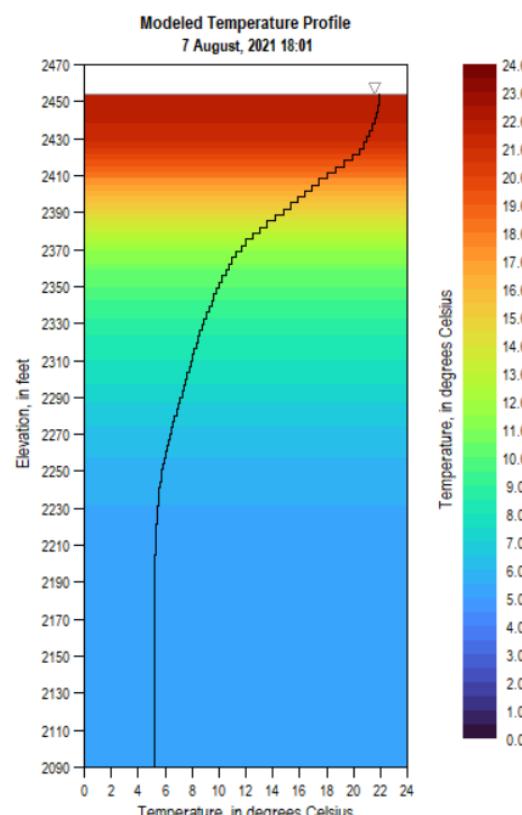
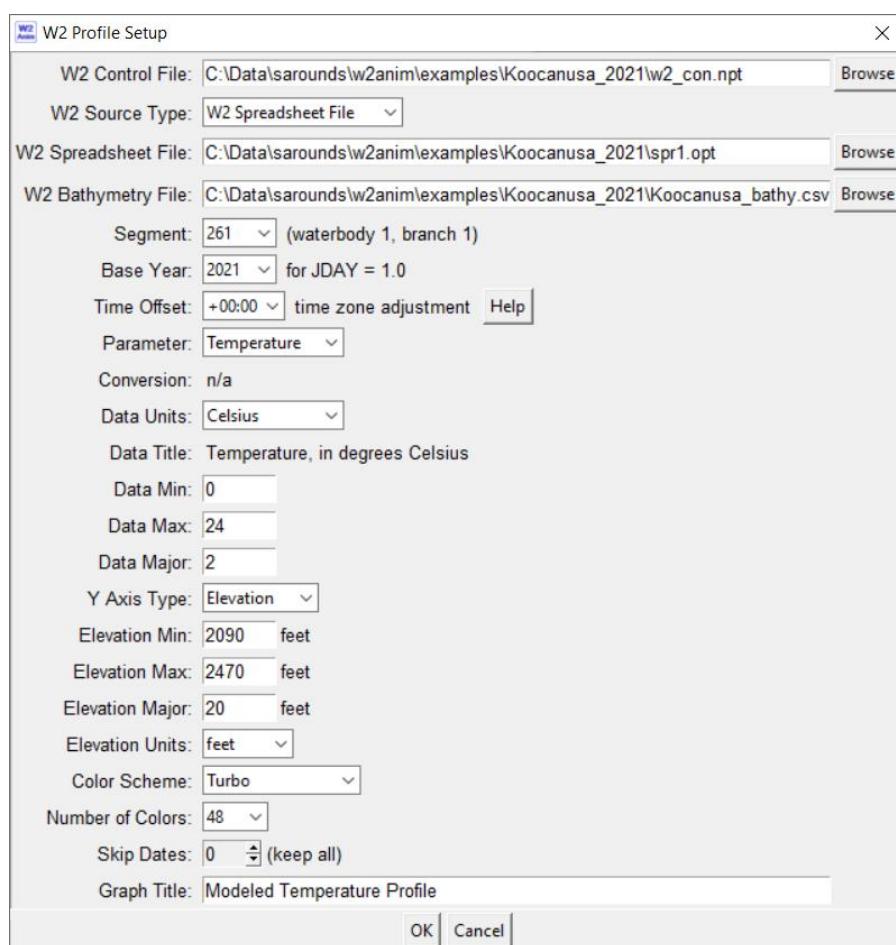


For this example, the Turbo color scheme was chosen with 48 colors because 48 is an even multiple of the temperature range when a minimum and maximum of 0 and 24, respectively, are chosen. The resulting filled-out menu is shown to the right.

Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The W2 Vertical Profile graph created from this example looks similar to the first W2 Vertical Profile graph shown in this section, and is also shown below.

The default font family for graph text can be set in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#). The initial font size for new graphs is scaled according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the right. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.



The various options of the Graph Properties menu should be fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked.

Under the Color Key tab, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same source data file.

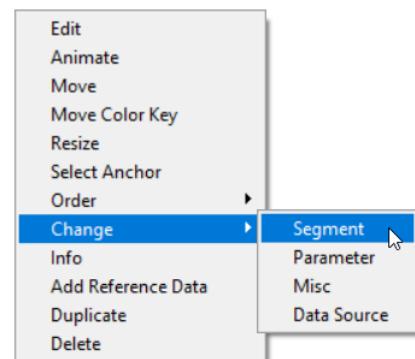
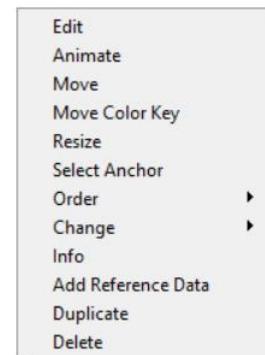
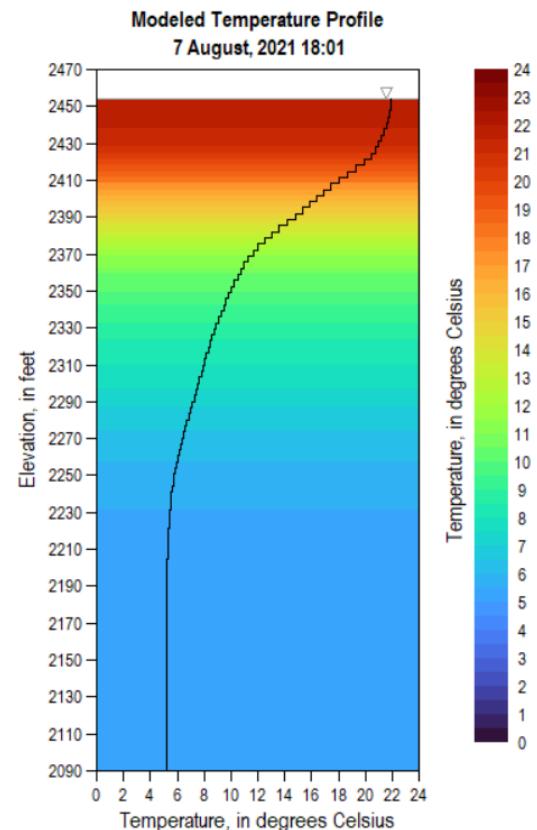
For W2 profile colormaps, the X Axis tab of the Graph Properties menu has different options relating to the date axis. The X Axis can be plotted as a Date/Time axis or as a Julian Date axis; to translate between them, a base year must be set. In Date/Time mode, X Axis tick labels can be set just to the Year or Month or to a Mon-DD or Mon-DD-YYYY format. In Month mode, the labels will adjust themselves according to how much space is available.

After changing the font size and the number of digits after the decimal for the color key, the updated W2 Vertical Profile graph is shown at the right.

Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, add a reference dataset, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.

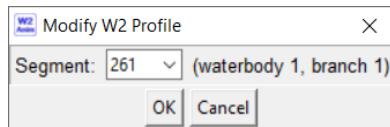
### **Changing the Segment, Parameter, or Data Source**

Through the Change submenu (at right), the user can change the model segment, modeled parameter, parameter units, W2 model begin year, a date-skip setting, and/or any of the data source files associated with the profile graph. This feature is handy not only for fixing user mistakes after the graph is originally created, but also for creating multiple similar graphs by duplicating a graph and then changing the model segment, parameter, and/or model output file used in the duplicated graph. In this way, a user can quickly set up an entire array of profile graphs for a suite of modeled parameters, or perhaps a set of profile graphs for the same parameter at many different locations in the model domain. Options under the Change submenu are slightly different when using a lake contour output file.

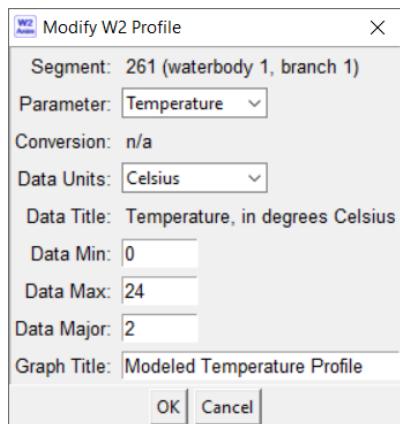


The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original profile graph. The menus for the main four options are shown below.

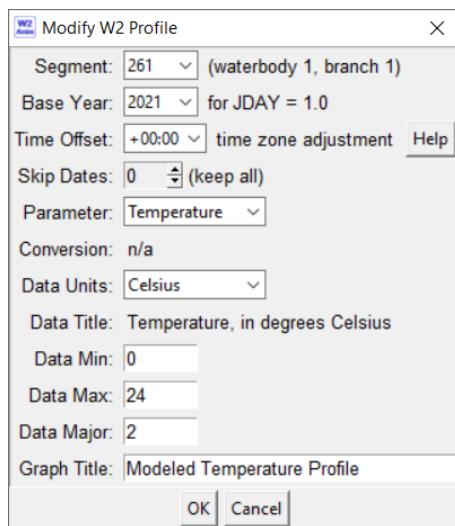
#### Segment:



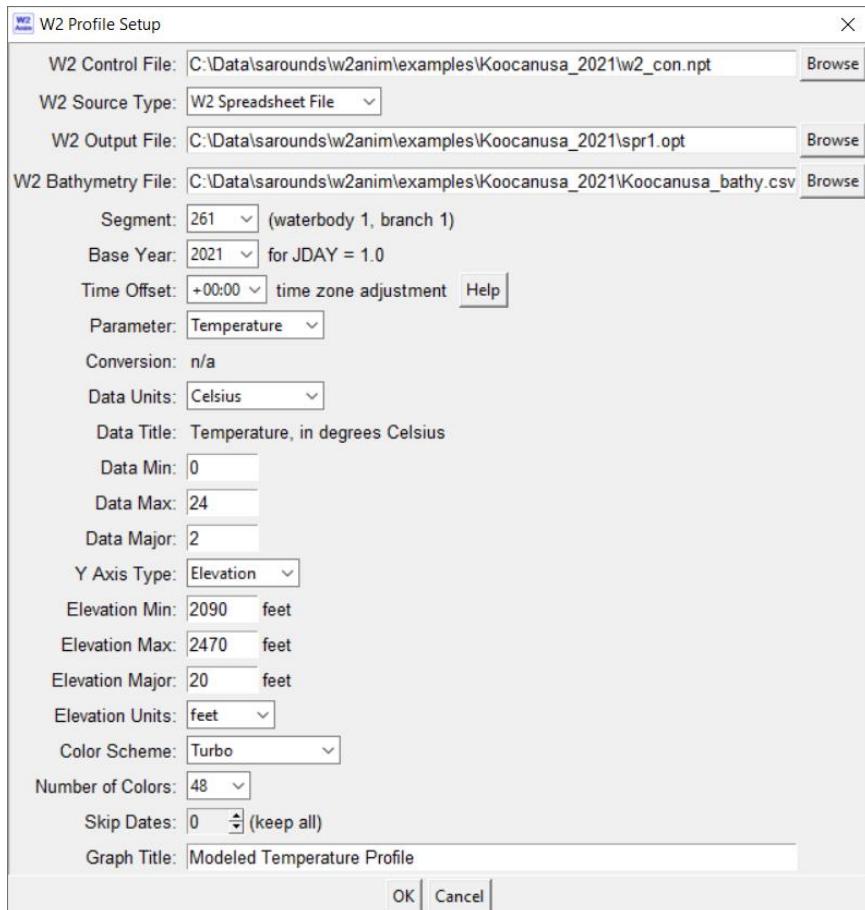
#### Parameter:



#### Misc:



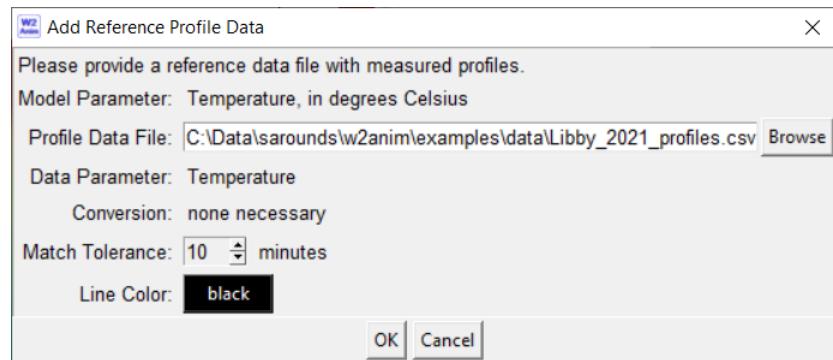
#### Data Source:



Any substantive change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the menu will result in no changes to the graph. Simply changing data limits (Min/Max/Major) or graph title is not allowed from these menus, as that is best done from the Graph Properties menu. Re-creating the graph will cause any reference profiles to be removed.

### [Adding Reference Profiles](#)

Reference profile data may be added to a W2 Profile graph so that a good comparison can be made between measured and modeled profiles. To add reference data, hover the mouse over the graph and click the right mouse button (or type Alt-p) then select the Add Reference Data option. The Add Reference Profile Data menu will pop up, showing the modeled parameter and prompting the user to provide the



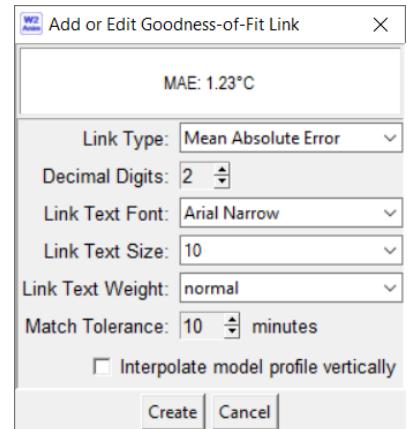
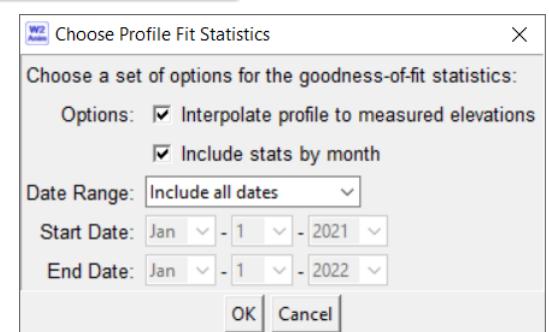
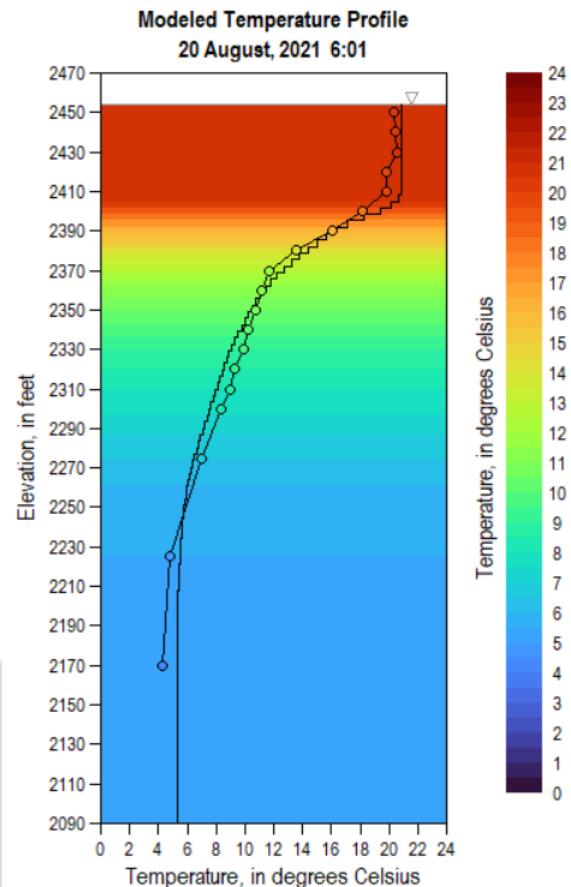
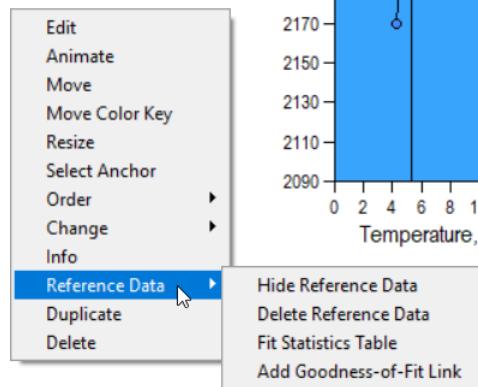
name of a data file. The profile data file is expected to be in the [same format](#) as the data required for a Measured Vertical Profile graph. W2Anim will scan the data file to confirm that it contains data for the correct parameter. The user can choose the color of the plotted data profile as well as the date/time match tolerance, which defaults to 10 minutes. None of these inputs can be changed after the reference profiles are added, but the reference data can be deleted and reloaded to modify the line color or match tolerance.

For any modeled date/time, W2Anim will search for and try to plot a measured profile with the same date or with a date that is close to the modeled date and within the match tolerance. The measured profile is plotted with circles and connecting lines showing the elevation or depth location of each measurement. If color highlighting is turned on, the circles are filled with a color corresponding to the measurement value, whereas the background colors of the graph still correspond to the modeled profile values.

As the profile is animated, both the modeled and measured profiles will be updated. The measured profiles will be shown whenever a measured profile is available within the match tolerance of the modeled date. The measured profiles can be hidden or deleted by hovering the mouse cursor over the graph, clicking the right mouse button (or typing Alt-p) and selecting the Reference Data option and

the Hide Reference Data or Delete Reference Data option. The Fit Statistics Table option will bring up a menu (at right) that can be used to compute [goodness-of-fit statistics](#) for the comparison of modeled and measured vertical profiles. The user can choose to interpolate the modeled profile to each of the measured elevations or depths, or simply compare each measured point to the value associated with the model layer it falls within. The user can choose to compute the fit statistics by month and/or for a specific date range. The results will also include goodness-of-fit statistics for the modeled water-surface elevation.

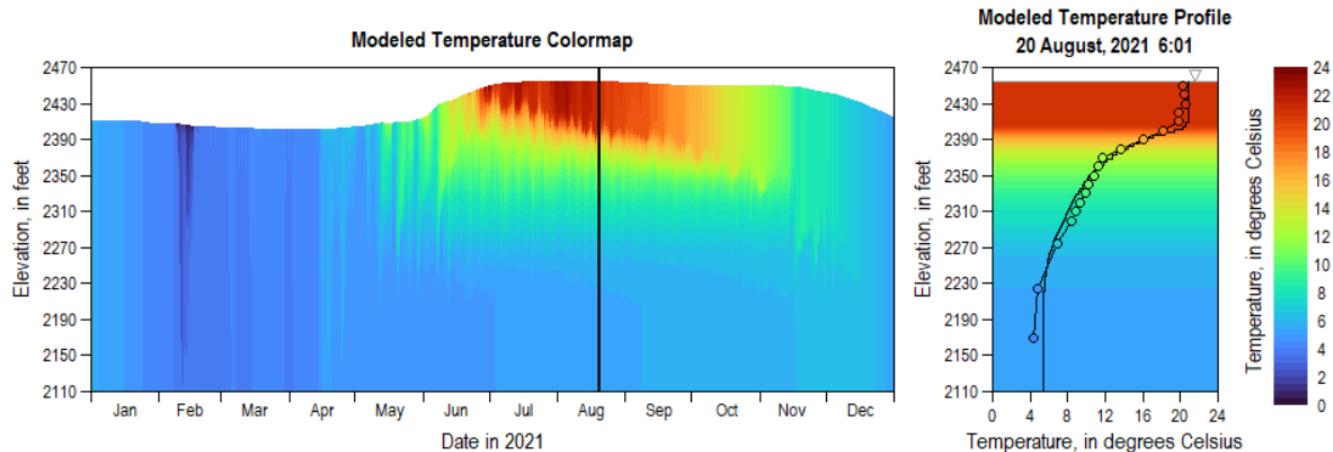
Lastly, the Add Goodness-of-Fit Link option allows the user to create one or more linked text objects that show a goodness-of-fit statistic for the current vertical profile. The menu at the right will appear. The possible link types are Mean Error (ME), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Stats Table. Choosing Stats Table will create four linked text objects in a right-justified table that show the number of data pairs being compared (N) along with the ME, MAE, and RMSE, similar to the example at the right. Before creating these linked stat objects, the user can choose the font family, font size and weight, the number of digits after the decimal, the match tolerance, and whether the statistics are computed with a vertically interpolated model



profile. If no measured profile is available for the current date, then each linked object will show an “na” value. After these linked statistic objects are created, they can be moved or edited like any other text object, except that their text is controlled by the graph to which they are linked.

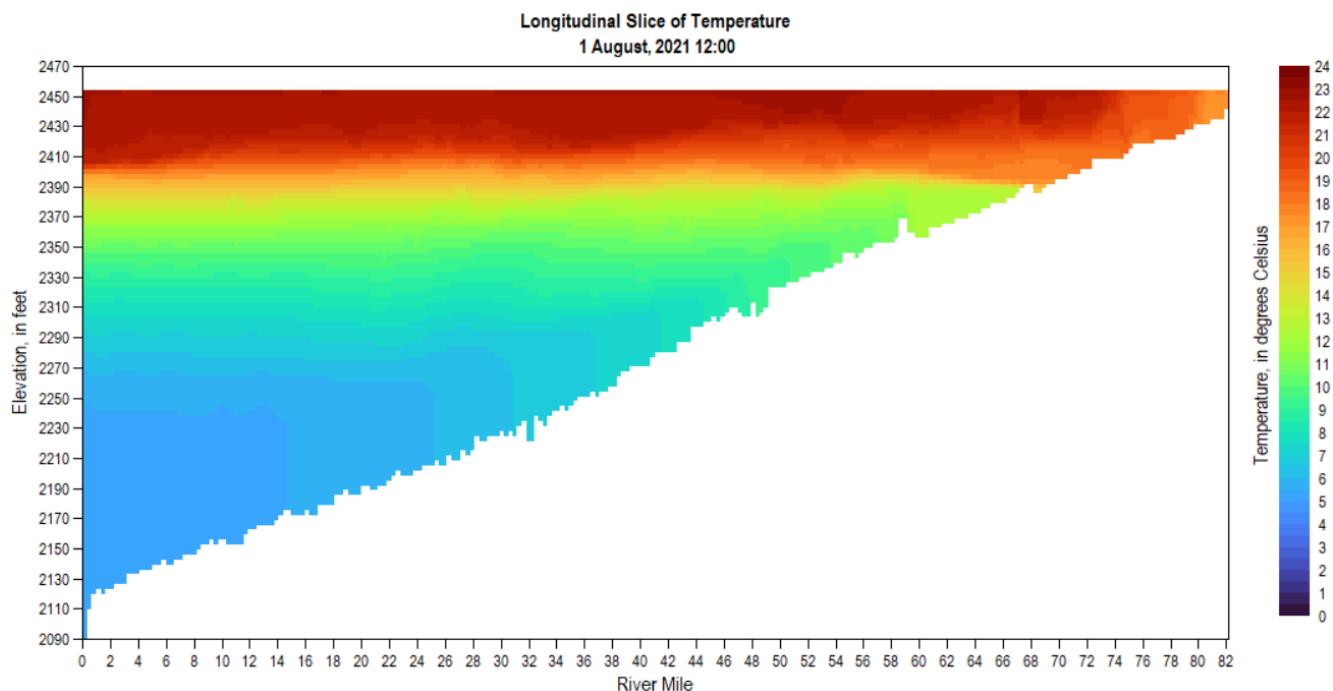
### **Pairing Profiles and Colormaps**

Often it is useful to pair a W2 Profile graph with a W2 Profile Colormap because the profile graph is specific to a particular date/time whereas the colormap provides a time-series context. When the profile is animated, a vertical black line is shown on the colormap to denote the current date/time.



### **W2 LONGITUDINAL SLICES**

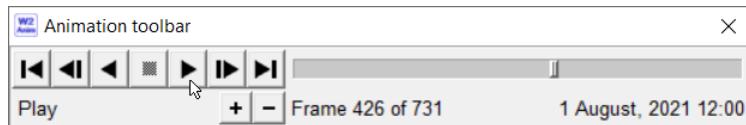
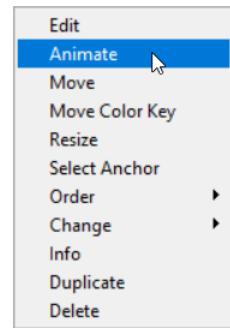
For lakes and reservoirs or any waterbody that stratifies, an animated visualization of modeled conditions along a longitudinal slice through the model domain can be an effective way of discerning spatial and temporal patterns and gaining insights related to important inputs, fluxes, or instream processes. The W2 Animator can read W2 contour and vector output files to create such longitudinal slices. An example slice of modeled water temperature is shown below, using the Turbo color scheme to display the spatial temperature variations.



Such longitudinal slices often embody some substantial vertical exaggeration, given that the depths simulated in a CE-QUAL-W2 model typically are small relative to the longitudinal distances. The graph depicted above, for example, has a vertical exaggeration of about 571; that information is available in W2Anim through the Info option from the menu that pops up when the user right-clicks over the graph.

The W2 Longitudinal Slice graph can be plotted with either elevation or depth on the Y axis, river mile or river kilometer on the X axis, and segment number on an optional segment axis along the distance (X) axis. The minimum X axis distance location need not be zero, and the user may set that value to any number. In addition, the slice depiction can be flipped left to right, such that the river miles or kilometers (or segment numbers) are reversed.

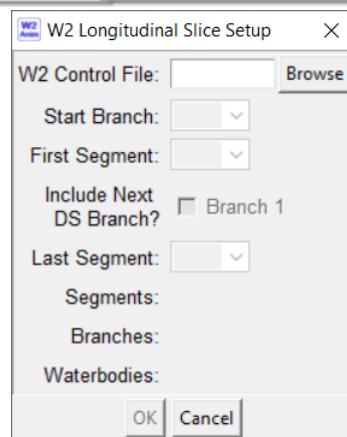
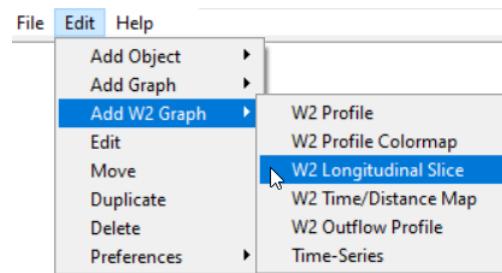
Of course, the longitudinal slices can be animated. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the longitudinal slices change over time. For the animations to work properly, the user must allow W2Anim to cycle through the available dates so that the slice images can be prepared and stored for quick swapping during animation.



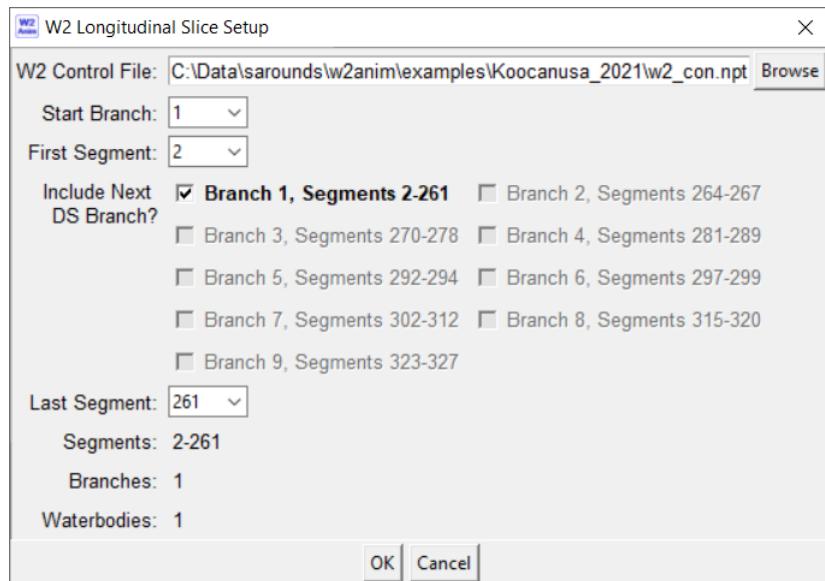
### Creating a New Graph

To create a W2 Longitudinal Slice graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

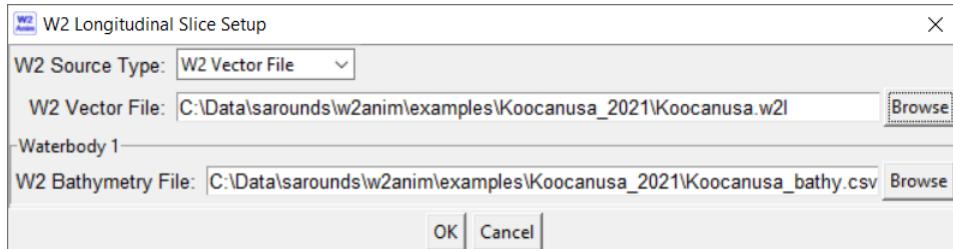
The W2 Longitudinal Slice graph can be started by choosing the Edit/Add W2 Graph/W2 Longitudinal Slice option from the menu bar. Alternatively, right-click on the canvas and choose the Add W2 Graph/W2 Longitudinal Slice option. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen at the right.



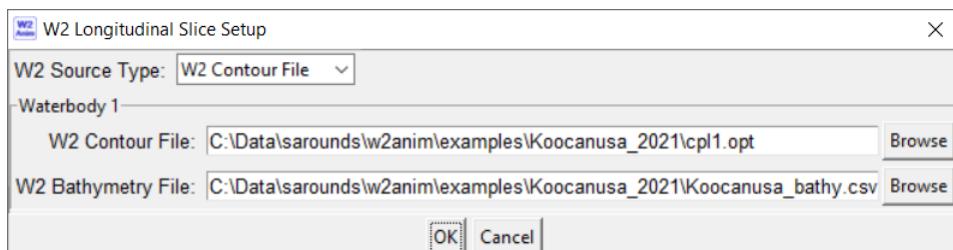
This is the first of three menus that gather the information needed to create a W2 Longitudinal Slice graph. In this first menu, the user starts by specifying a W2 control file, which W2Anim scans for segment, branch, and waterbody parameters. The user next chooses the starting branch and segment number for the upstream end of the slice, then selects the model branches to follow downstream and finally the most-downstream segment for the slice. In the example at the right, the choice was to select segments 2-261 in branch 1 of waterbody 1. Clicking the OK button moves on to the second menu, shown below.



In the second step, the user must choose the source for the slice data, either from one or more W2 contour output files, or from a W2 vector file. When using a W2 vector file for the slice data, it is still necessary to provide the name(s) of any associated bathymetry file(s), as shown in the menu below, even though some bathymetric information is included in the vector file.



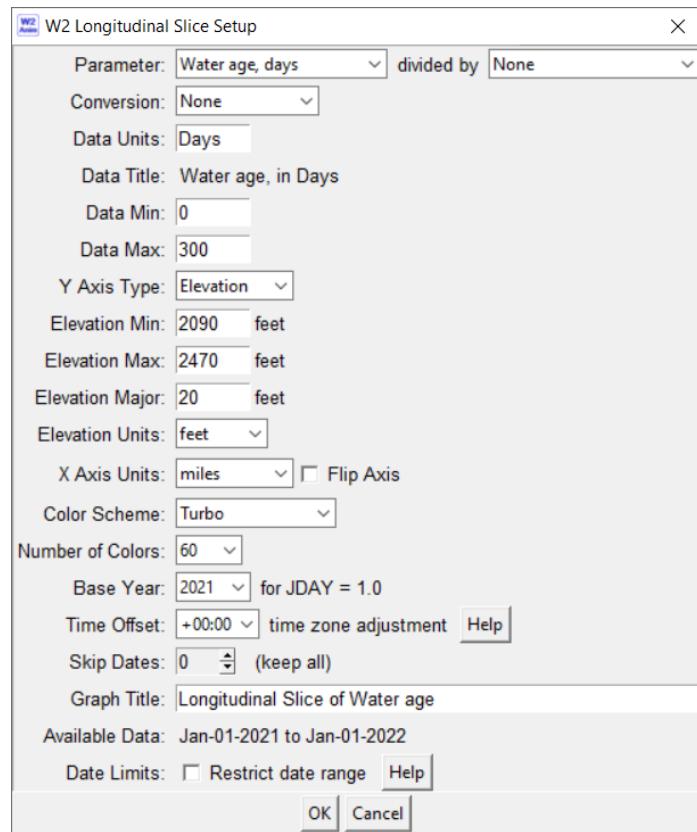
When the source type is set to use a W2 contour output file, the user must provide the names of the W2 contour and bathymetry files for each of the waterbodies included in the longitudinal slice, as shown in the example below.



Clicking the OK button moves on to the third and final input menu. Canceling aborts the graph creation.

The third W2 Longitudinal Slice Setup menu handles the choice of the modeled parameter, axis limits, color scheme, and base year, among other inputs. If the W2 contour or vector output frequency is less than 1.0 (more than one output per day), then the user is offered the choice to skip one or more dates in the source file. Skipping 1 would use every other output date, skipping 2 would use every 3<sup>rd</sup> date, and so forth. Skipping dates is a trade-off for the slice graph, as more dates provide more frequent detail in the animation, but require more time to process the additional data.

All of the inputs to this third menu can be changed later, either through the Graph Properties or Change menus. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero. An option to add a segment-number axis is available only through the Graph Properties menu after the graph has been created.



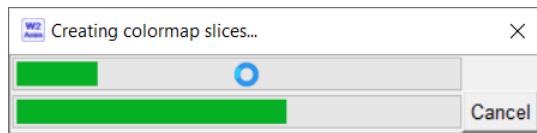
The “Water age” parameter was chosen for this example graph, and its native W2 units are days. Note that any parameter choice other than Velocity, Temperature, Density, or Habitat creates an option to divide the chosen parameter’s value by the value of a different parameter. When tracking heat sources with CE-QUAL-W2, many of the modeled heat-tracking parameters must have their simulated concentration divided by the modeled temperature (see Rounds and Stratton Garvin, 2022). Similarly, if the user wishes to visualize a nitrogen to phosphorus ratio or a dissolved to particulate ratio and both parameters are present in the output file, then this would be possible.

The example simulation was for one year, so a maximum of 300 days was chosen for the water age color scale. The [color scheme](#) input for this menu offers just a few options; other choices become available after the graph has been created. For this example, the Turbo scheme was chosen with 60 colors because 60 is an even divisor of the water age range of 0 to 300 days.

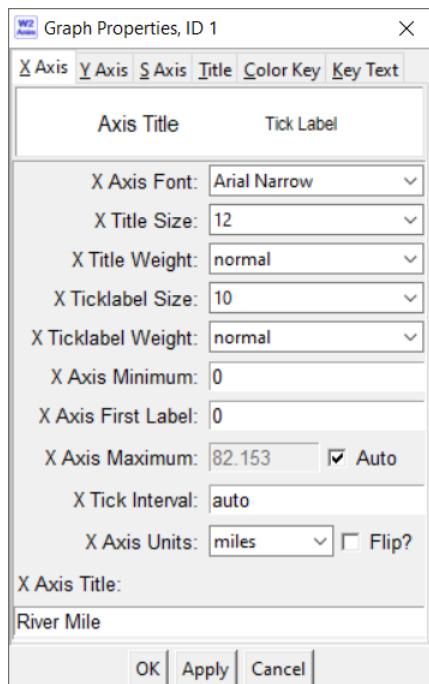
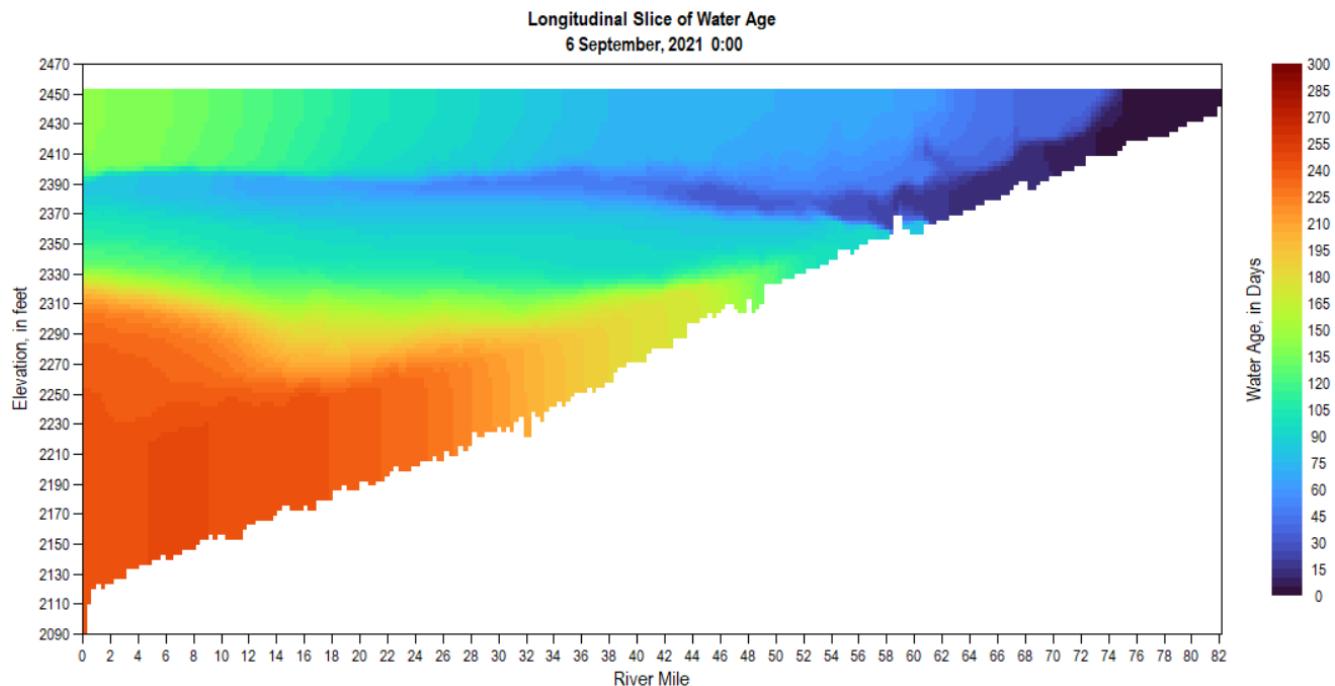
If the W2 output file has data for a long time period and the slice graph has a lot of pixels, then in some instances Perl may run out of memory while generating the slice images for each date. This sort of problem should be rare, but in such cases the user may wish to restrict the date range for the W2 Longitudinal Slice plot. Alternatively, if the output file has data for 30 years and the user wishes to examine only the first five, then a date restriction may be useful. Selecting the “Restrict date range” checkbox will bring up inputs for a start and end date. This date restriction can be modified from the Change menu later. The resulting filled-out menu is shown above.

Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The resulting W2 Longitudinal Slice graph created from this example is shown on the next page. As W2Anim works to create this graph, it must first read the W2 contour or vector output file, evaluate the limits of the data, and then create images of the longitudinal slices for each available date. This takes some time, and W2Anim informs the user of its progress with a two-part progress bar, where the lower bar shows the progress of creating an individual slice for each single date, and the upper bar shows the overall

progress of creating all of the required slice images. By pre-computing these slice images, an animation of the longitudinal slices later will be fast and efficient.



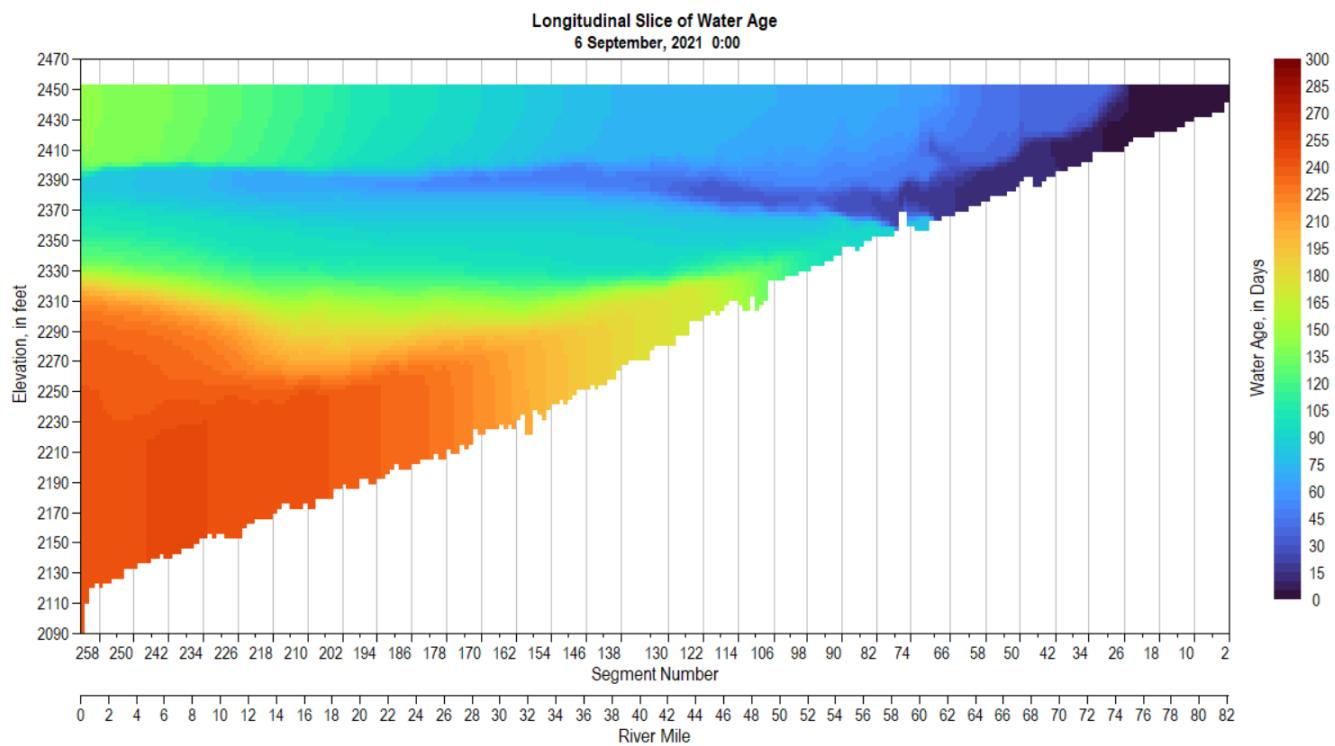
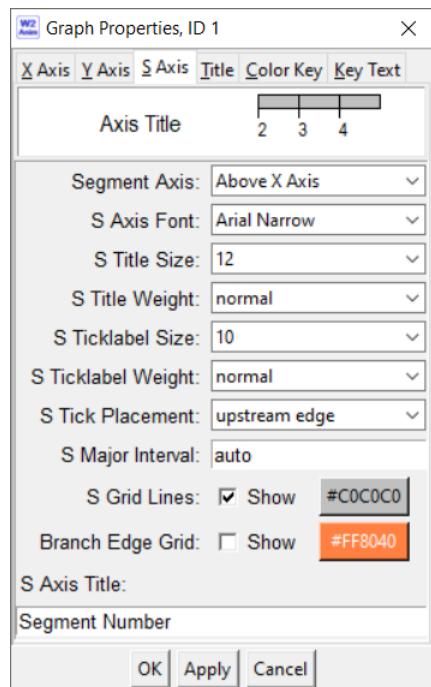
Note that the default font family for graph text can be set in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#). The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.



To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the left. For this graph type, six tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, S Axis, Title, Color Key, and Key Text.

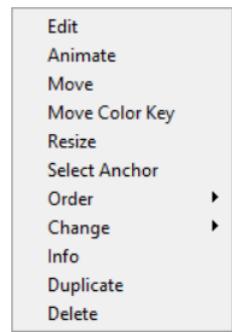
The various options of the Graph Properties menu should be fairly self-explanatory, and therefore most will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Note in particular the Flip option for the X axis, which will flip the slices left to right. Flipping the precomputed slice images requires some image manipulation, but is less time-consuming than generating all of the slices from scratch.

The S Axis (segment axis) tab of the Graph Properties menu is used to create or modify a segment-number axis along the X distance axis of the graph. A segment axis can be placed above or below the X distance axis or can replace the X distance axis. In the example to the right, the choice was made to put a segment axis above the X distance axis. Segment tick marks can be placed at the upstream or downstream edge of a segment or in the segment center. The preview at the top of the menu gives the user an idea of the final appearance. The segment major tick interval can be set to “auto” or to a user-defined number, and minor tick marks will be set automatically. Vertical grid lines can be shown at each of the segment tick marks, and optional vertical lines can also be shown at branch boundaries. An example W2 Longitudinal Slice graph with a segment axis is shown below.



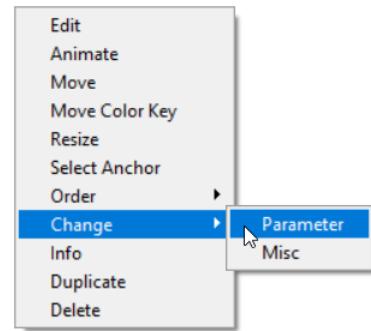
Under the Color Key tab of the Graph Properties menu, note that the color key Status can be set to visible or hidden. The hidden option hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.

Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.



### Changing the Parameter or Units

Through the Change submenu (at right), the user can select a different model parameter, parameter units, W2 model begin year, time offset, date-skip setting, or date restriction range. This feature is handy not only for fixing user mistakes after the graph is created, but also for creating multiple slice graphs by duplicating a graph and then changing the model parameter used in the duplicated graph. In this way, a user can quickly set up an array of slice graphs for a suite of modeled parameters. If the user wants a different slice composed of different segments or branches, however, a new slice graph must be created. Choosing a new date range will cause the slice graph to be rebuilt.



The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original slice graph. The menus for the two options are shown below.

Parameter:

W2 Modify W2 Longitudinal Slice

Parameter:	Water age, days	divided by	None
Conversion:	None		
Data Units:	days		
Data Title:	Water Age, in Days		
Data Min:	0		
Data Max:	300		
Data Major:	15		
Graph Title:	Longitudinal Slice of Water Age		
<input type="button" value="OK"/> <input type="button" value="Cancel"/>			

Misc:

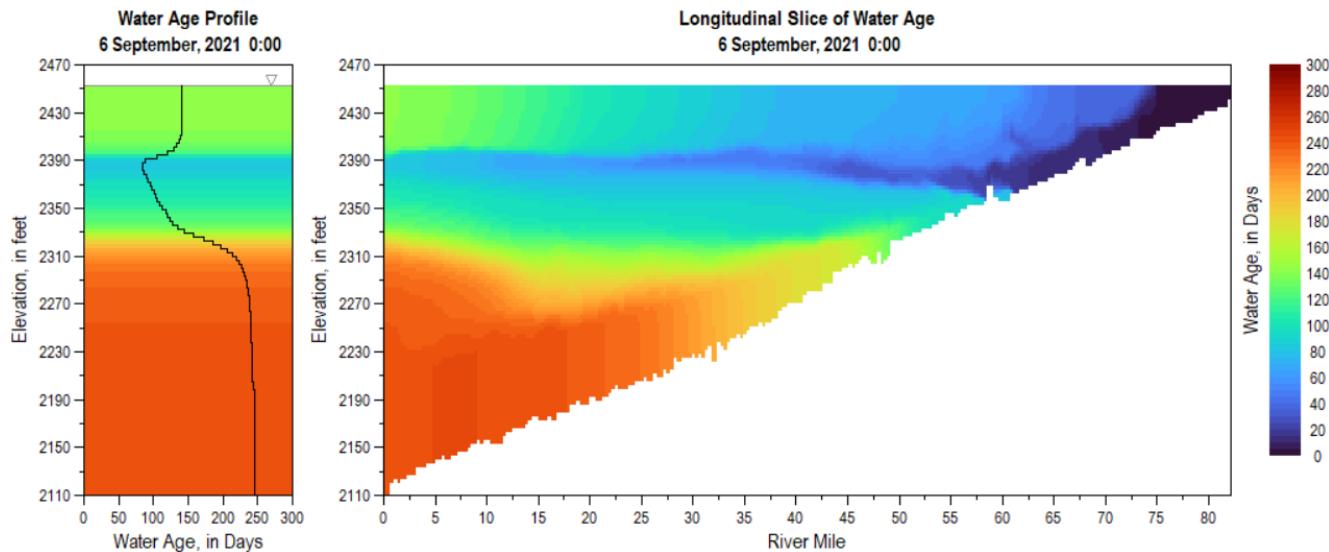
W2 Modify W2 Longitudinal Slice

Parameter:	Water age, days	divided by	None
Conversion:	None		
Data Units:	days		
Data Title:	Water Age, in Days		
Data Min:	0		
Data Max:	300		
Data Major:	15		
Graph Title:	Longitudinal Slice of Water Age		
Base Year:	2021	for JDAY = 1.0	
Time Offset:	+00:00	time zone adjustment	<input type="button" value="Help"/>
Skip Dates:	0	(keep all)	
Available Data:	Jan-01-2021 to Jan-01-2022		
Date Limits:	<input type="checkbox"/> Restrict date range	<input type="button" value="Help"/>	
<input type="button" value="OK"/> <input type="button" value="Cancel"/>			

The only difference between the Change Parameter menu and the Change Misc menu for W2 Longitudinal Slice graphs is that the latter allows the user to select a different W2 base year, time offset, date-skip setting, and date range restriction. Any substantive change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the menu will result in no changes to the graph. Simply changing data limits (Min/Max) or the graph title is not allowed from these menus, as that is best done from the Graph Properties menu. For W2 Longitudinal Slice plots derived from large data files, modifying the date restriction period can be a good way to prepare animations from a subset of the available data.

## Pairing Slices with Profiles

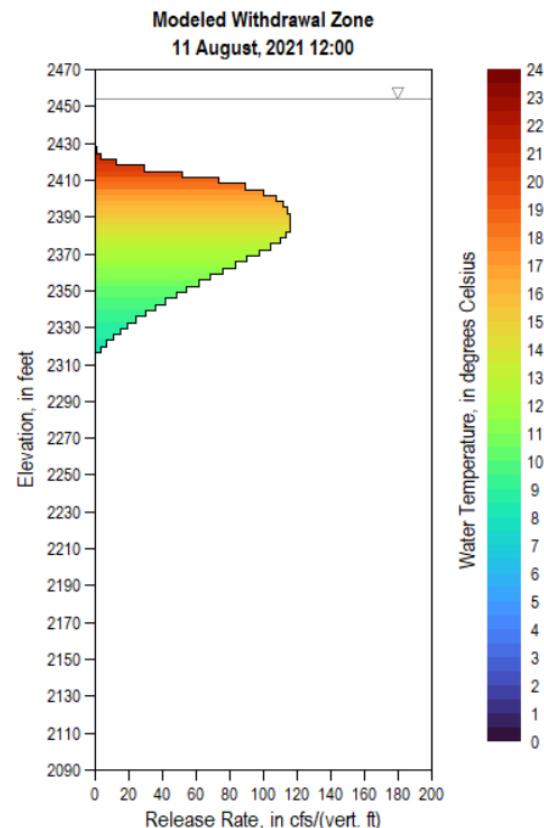
It can be useful to pair a W2 Longitudinal Slice graph with a W2 Vertical Profile graph because the profile graph provides a better depiction of the vertical profile than a vertical line of colored pixels. In the example below, a vertical profile of modeled water age at the downstream-most segment was paired with a longitudinal slice of water age, such that the profile of water age at the downstream end of the slice can be examined in more detail. In this instance, that is also the location of a dam, and the dam affects the depth of water releases from the reservoir, so having more detail on the vertical profile at the dam can be useful. When animation is invoked, both graphs track the changing date/time in a synchronized manner.



## **W2 OUTFLOW PROFILES**

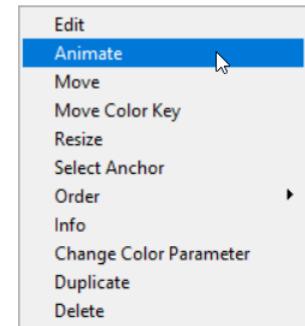
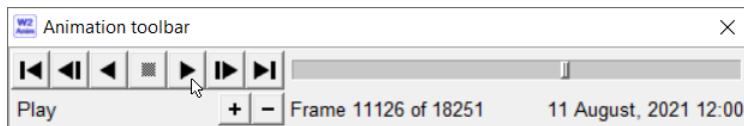
Selective withdrawal is the release of reservoir water from a specific vertical range of depths according to the interplay of the depth and dimensions of a dam outlet, the release rate, and the density profile of water in the reservoir near the outlet. The CE-QUAL-W2 model applies selective withdrawal algorithms to compute the vertical range of depths from which water is drawn to dam outlets and the amount of water that is drawn from each model layer as water moves toward those outlets. The model algorithms generally describe dam outlets as point or line sinks, where each line sink is given an effective width. Recent USGS modifications to CE-QUAL-W2 also allow a time-varying bulkhead configuration such as that constructed at Libby Dam to be part of selective withdrawal computations by using a set of virtual line sinks fronting a common wet well. Other code modifications also created a new [W2 Layer Outflow output file](#) that is used by W2Anim to visualize vertical withdrawal zones and the flows toward dam outlets.

The graph at the right is an example of a W2 Outflow Profile graph as made by The W2 Animator. In that graph, the vertical distribution of flows or velocities toward dam outlets on a particular date is plotted against depth or elevation on the Y axis. The release rate is plotted per unit depth (cfs per vertical



foot, or cms per vertical meter). Alternatively, the user can choose to plot the horizontal velocity (ft/s or m/s) toward the dam outlets on the X axis. Optional color highlighting of the model layers can be used to show the characteristics of water in each model layer where water is being drawn to the dam outlets. In this example, water temperature is used for the layer color highlighting according to the Turbo [color scheme](#) illustrated to the right of the graph. The water-surface elevation is shown in the example using a gray horizontal line and the universal water-level triangle symbol near the top of the graph.

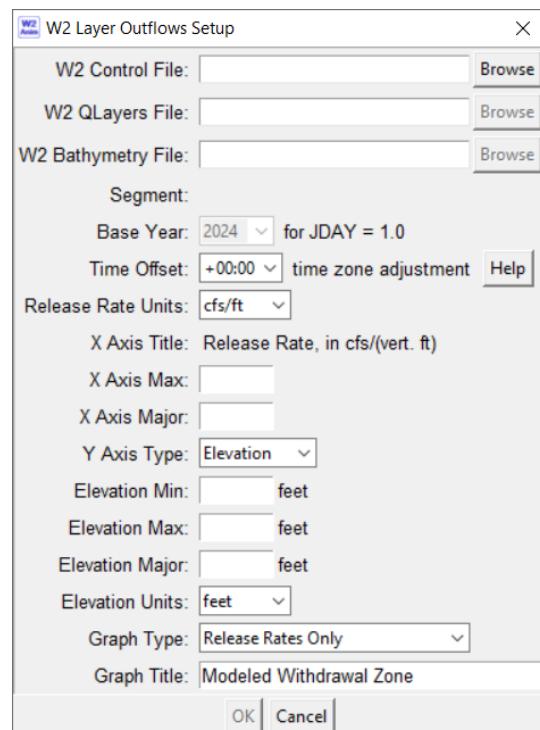
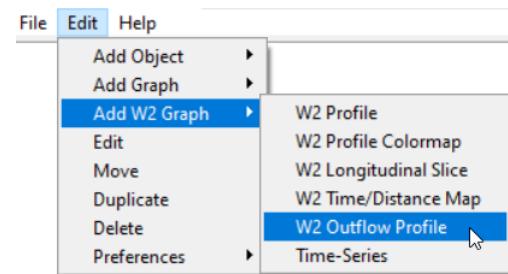
W2Anim can animate this type of vertical withdrawal zone graph. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical withdrawal zones change over time.



### Creating a New Graph

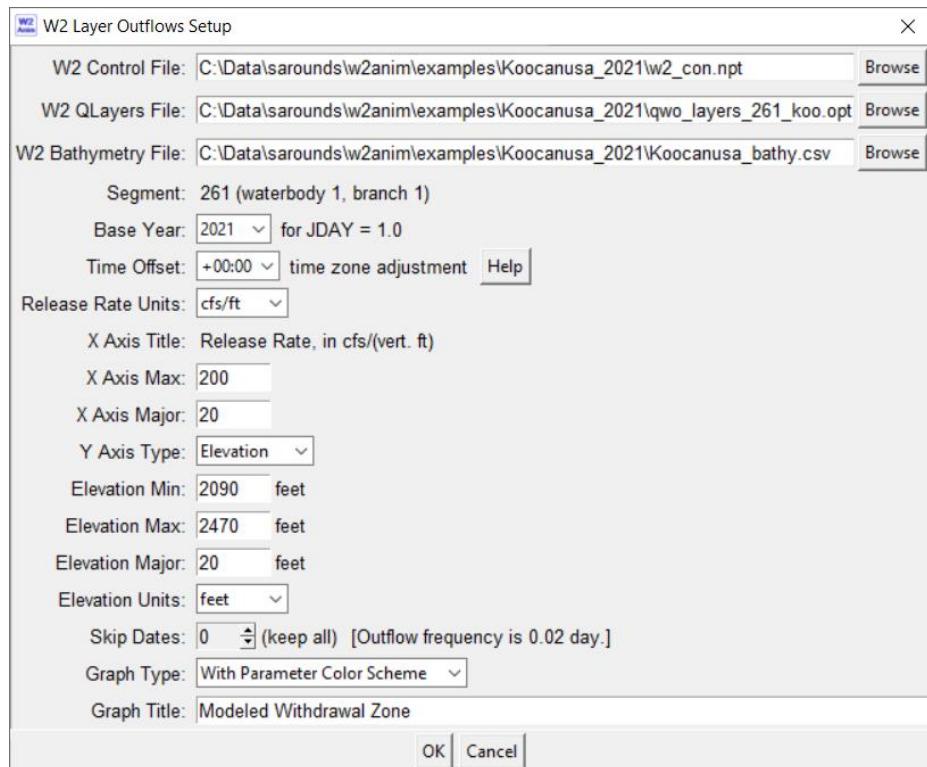
To create a W2 Outflow Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

The W2 Outflow Profile graph can be added by choosing the Edit/Add W2 Graph/W2 Outflow Profile option from the menu bar, or by right-clicking on the canvas and choosing Add W2 Graph/W2 Outflow Profile. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point can be set later. Then, move the mouse to specify the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y crosshair location (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen at the right.



This W2 Layer Outflows Setup menu is the first of two possible menus needed to create the graph; the second is required if the user chooses to include color highlighting with a modeled parameter. The first step is to provide the name of a W2 control file. Click the Browse button to find and select that file. W2Anim will scan the control file for segment, branch, and waterbody details, the begin year, and the frequency of layer outflow output. Next, W2Anim requires the name of the [W2 Layer Outflow output file](#) and the W2 bathymetry file.

W2Anim will identify the model segment associated with the layer outflow file and show its value as well as the waterbody and branch number on the menu. Inputs other than the file names, base year, and time offset can be changed after the graph is created. The user often will not know the best X Axis maximum value to specify, but the range of the data can be checked with the Info option after the graph is created. The menu reminds the user of the layer outflow output frequency specified in the W2 control file, and the user can skip every  $n^{\text{th}}$  date if they choose to do so. In this example, the choice was made to use color highlighting (With Parameter Color Scheme) rather than the Release Rates Only option. The filled-out menu for this example is shown above and to the right.



Clicking the OK button will move on to the second menu. Clicking the Cancel button will remove the menu and abort creation of the graph. In this case, the layer outflow output frequency was 50 times per day (0.02 day), and the choice was to put off a decision on skipping data points until the second menu was filled out.

The second W2 Layer Outflows Setup menu is shown at the right, with its fields filled out for this example. This menu focuses on inputs required to highlight model layers in the graph with colors corresponding to the values of a modeled parameter in W2.

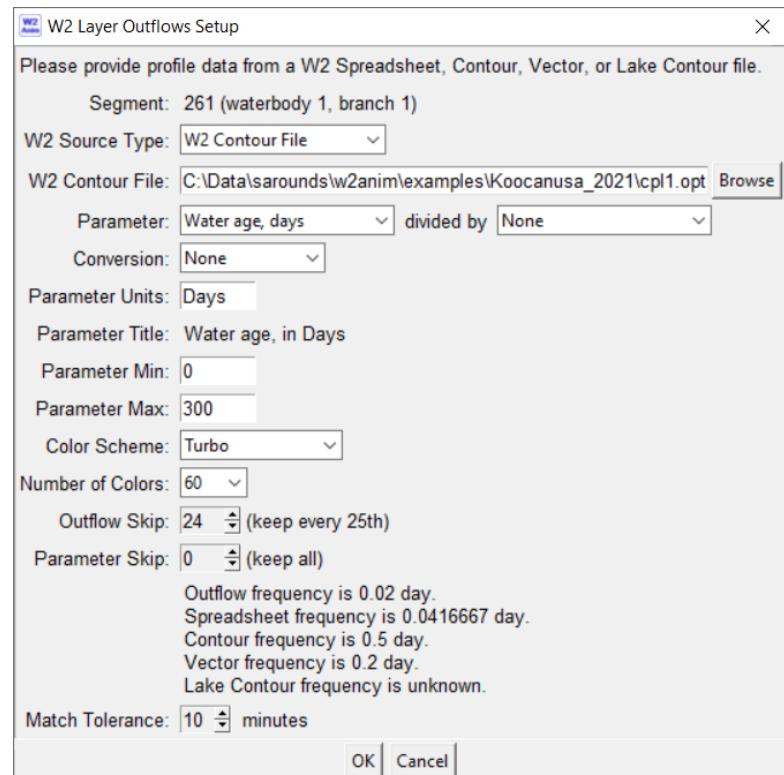
The user must first choose whether the modeled parameter values are to be read from a W2 spreadsheet, contour, vector, or lake contour output file. Both the original and the Tecplot format of the W2 contour file can be read by W2Anim. The user must choose an output file that includes information for the model segment chosen in the previous menu, which is noted near the top of this menu. In this example, the contour file option was chosen. Next, the user must choose the modeled parameter of interest; in this example, “Water age” was chosen. Note that any parameter choice other than Horizontal Velocity, Vertical Velocity, Horizontal Layer Flow,

Density, Habitat, or Temperature creates an option to divide the chosen parameter’s concentration by the value of a different parameter. When tracking heat sources with CE-QUAL-W2, many of the modeled heat-tracking parameters must have their simulated concentration divided by the modeled temperature (see Rounds and Stratton Garvin, 2022). Similarly, if the user wanted to visualize a nitrogen to phosphorus ratio or a dissolved to particulate ratio and both parameters were present in the spreadsheet or contour or vector output file, then this capability in W2Anim could be useful.

The example simulation was for one year, so a maximum of 300 days was chosen for the water age color scale. The [color scheme](#) input for this menu offers just a few options; other choices become available after the graph has been created. For this example, the Turbo scheme was chosen with 60 colors because 60 is an even divisor of the water age range of 0 to 300 days.

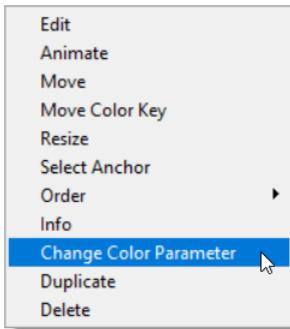
To ensure that the model output used for color highlighting is synchronized with the model output for layer outflows, it is important to pay attention to the output frequencies of the different output files. In this example, the layer outflow output frequency was 0.02 day (50 points per day) whereas the contour output frequency was 0.5 day (twice a day). To ensure that each date of the graph in an animated time series has color-highlighting information, the outflow skip input was set to 24 so that every 25<sup>th</sup> point was used, which corresponds to twice a day, the same output frequency as that used for the contour output file. Finally, to help line up output dates, a date match tolerance input value is available. The color highlighting information will be used as long as that information is available at a date that is within the match tolerance window of the dates on which layer outflow information is available. The default is 10 minutes.

If color highlighting with a W2 spreadsheet output file were used instead of a W2 contour, vector, or lake contour output file, then the date skipping and match tolerance would be somewhat different. The spreadsheet output frequency in this case was hourly. One option would be to retain the outflow skip input of 24 and also use a parameter skip input of 11, which would make them synchronized at twice a day. Alternatively, both the outflow skip and parameter skip inputs could be set to zero and the match tolerance value could be pushed up to 30 minutes. In that case, every outflow date would always be within 30 minutes of an hourly output date for the spreadsheet output file, and therefore each graph in the animation would have



color highlighting. These choices in the end come down to what sort of animation frequency the user wishes to have in the final visualization.

Clicking the OK button causes W2Anim to begin the process of creating the graph. It first reads the input files, which may take a bit of time if the files are large. A progress bar may be shown. After the files are read, the graph is created. After editing some font sizes, the example graph at the right was obtained.



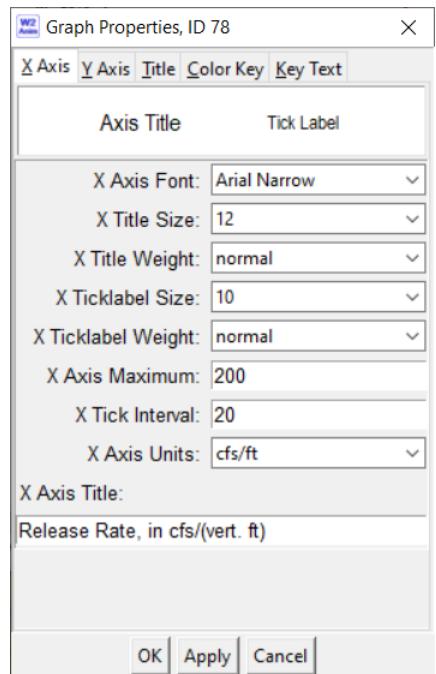
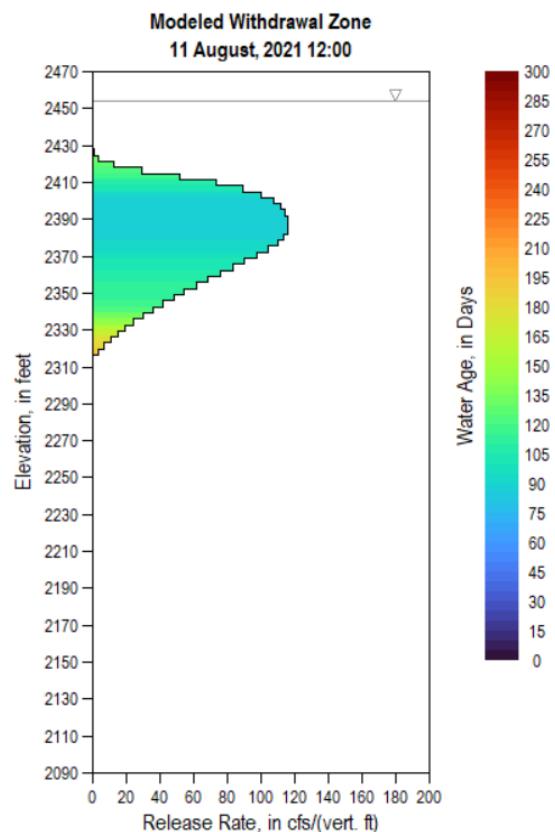
The color-highlighting parameter can be changed after the W2 Outflow Profile graph is created. To select a different parameter, hover the mouse over the graph, right click (or type Alt-p) and select the Change Color Parameter option. The second W2 Layer Outflows Setup menu will appear, and the user can fill out the menu as described above. If the

Release Rates Only option was selected at the time of graph creation, then the pop-up menu would have an option called Add Color Parameter. Once a color-highlighting parameter is added to a W2 Outflow Profile graph, it cannot be removed, but highlighting can be inactivated through the Graph Properties menu.

The default font family for graph text can be set in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#). The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

To edit the graph properties, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option, or select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the right. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text. If no color highlighting was chosen, the Color Key and Key Text tabs would be absent.

The options of the Graph Properties menu are fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Under the Color Key tab, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.



Setting the X axis maximum value can be a challenge for a W2 Layer Outflow graph, but the limits of the data are available from the Object Info box. Right-click over the graph, select the Info option, examine the Outflow Range, and adjust the X axis maximum value accordingly.

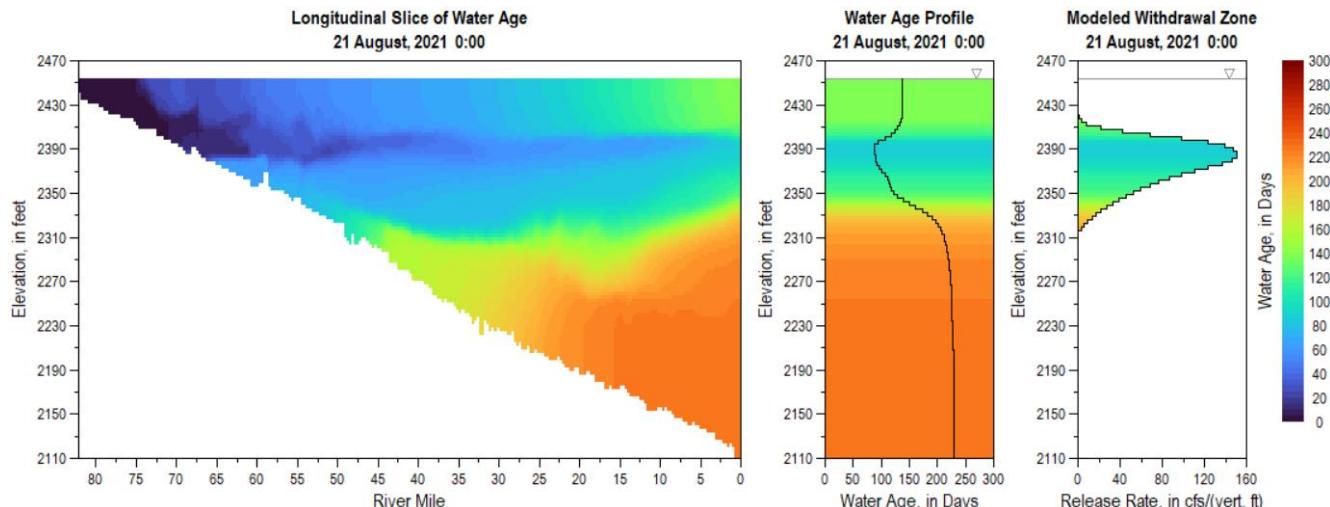
Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, choose a different color-highlighting parameter, make a duplicate, or delete the graph. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself if its placement is not ideal. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.

W2 Animator	Object Info
	Object: W2 Outflow Profile
	Elevation Range: 2090.03 to 2453.99 ft
	Depth Range: 0.00 to 363.96 ft
	Outflow Range: 0.00 to 209.77 cfs/(vert. ft)
	Color Parameter: Water age, days
	Parameter Range: 0.00 to 344.41 Days

### **Pairing Outflow Profiles with Other Graphs**

The W2 Outflow Profile graph is probably most useful when paired with a W2 Longitudinal Slice graph and/or a W2 Vertical Profile graph. The vertical profile or longitudinal slice graphs provide a visualization of conditions throughout the water column, whereas the outflow profile is focused on the water being released through dam outlets, which may have characteristics that are quite different than water at different depths in the profile.

In the example below, three graph types are used to show water age along a longitudinal slice through a large reservoir, with more detail in a vertical profile at the most-downstream model segment, and finally in an outflow profile that illustrates the vertical withdrawal zone and the conditions being exported via dam releases. The conditions shown are for late August when the waterbody is strongly stratified and releases are from a location somewhat high in the water column, such that water in the hypolimnion is generally not released downstream and continues to get older. Water entering the upstream portion of the reservoir is new to the model (lower water age) and cooler than water near the surface of the reservoir, so it sinks to find its place in the reservoir's density profile. Enough water is displaced along that flow line through summer that the younger water appears to be transported through the metalimnion and directly toward the dam outlet. Indeed, the model shows that releases are definitely younger than water at the surface or in the hypolimnion. This sort of visualization clearly shows patterns of water transport that might be hard to discern otherwise. When animation is invoked, all three graphs track the changing date/time in a synchronized manner.



## **W2 TIME/DISTANCE MAPS**

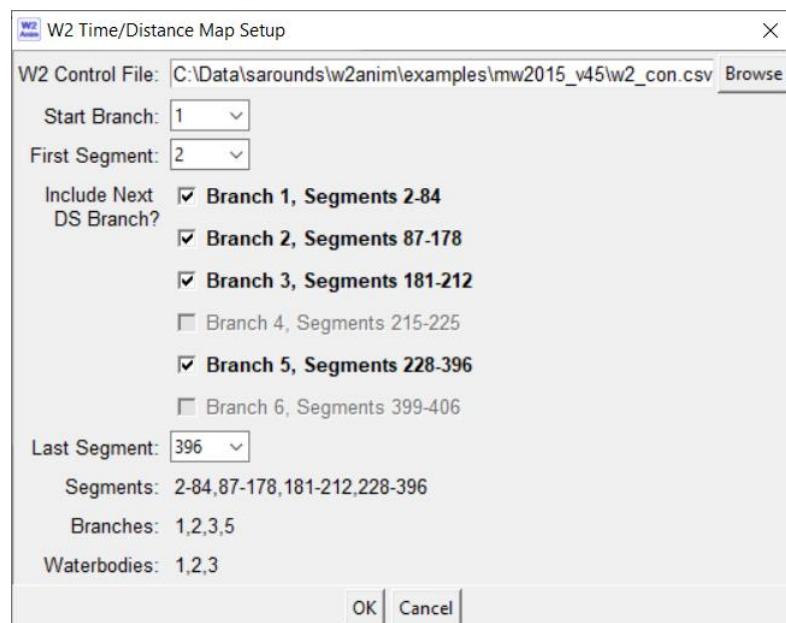
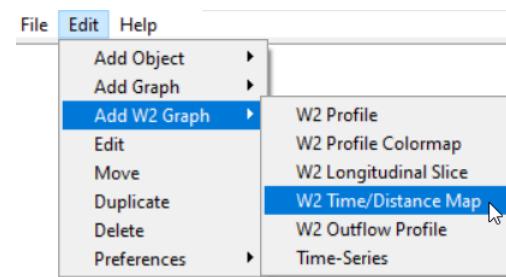
For river systems, a date/time versus distance graph showing results as a function of color can be a powerful way to visualize spatial and temporal patterns. These types of plots also can be used to show differences in two different parameter values, or parameter differences from two different model scenarios. Multiple plots can be created to show longitudinal space/time variations along a river corridor that spans multiple model domains.

### **Creating a New Graph**

To create a W2 Time/Distance Map, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

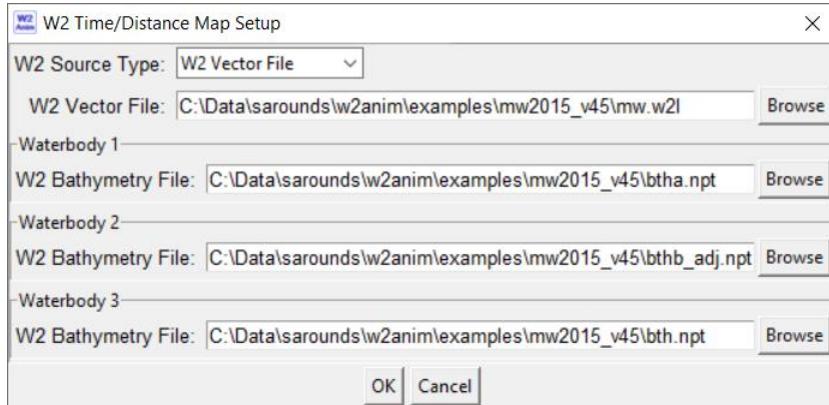
A W2 Time/Distance Map can be started by choosing the Edit/Add W2 Graph/"W2 Time/Distance Map" option from the menu bar, or by right-clicking on the canvas and choosing Add W2 Graph/"W2 Time/Distance Map." The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen below.

This first setup menu is identical to the first menu in the creation of a W2 Longitudinal Slice graph, and is the first of three menus needed to create a W2 Time/Distance Map. In this first menu, the user starts by specifying a W2 control file, which W2Anim scans for segment, branch, and waterbody parameters. W2Anim uses the information from the control file to determine how model branches connect, and the menu is interactive, allowing only choices that comprise an upstream to downstream pathway. The user must choose the starting branch and segment number for the upstream end of the map, then select the model branches to follow downstream and finally the most-downstream segment. In the example at the right, the choice was to select all of the segments in branch 1 and to follow that downstream through branches 2, 3, and 5. The chosen segments, branches, and waterbodies are listed at the bottom of the menu.

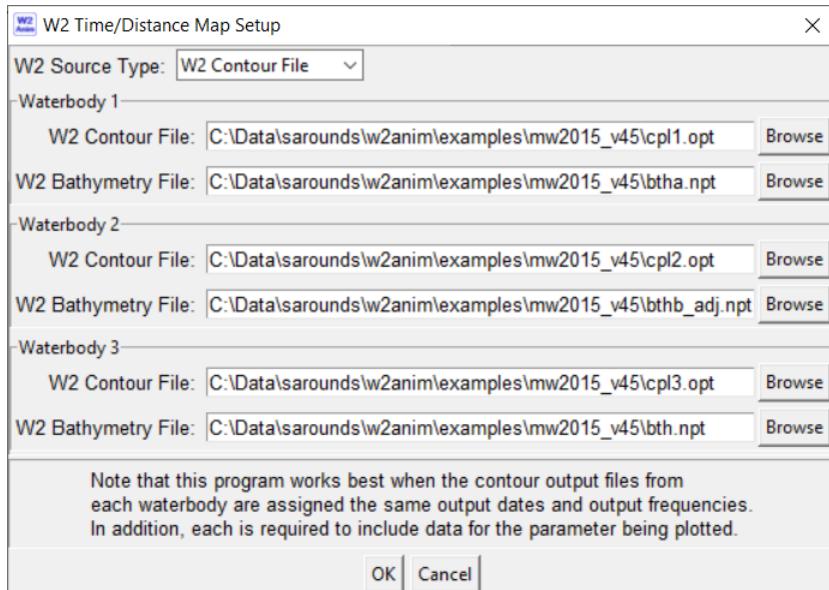


Clicking the OK button moves on to the second menu. In this second step, the user must choose the source for the time/distance data from one or more W2 contour output files, from a W2 vector file, from one or more W2 River Contour output files, or from a custom W2 SurfTemp, VolTemp, or FlowTemp output file. The SurfTemp, VolTemp, and FlowTemp output files are available from a customized USGS edition of CE-QUAL-W2; these output files include results from every segment in the model and contain either surface values, volume-weighted averages, or flow-weighted averages.

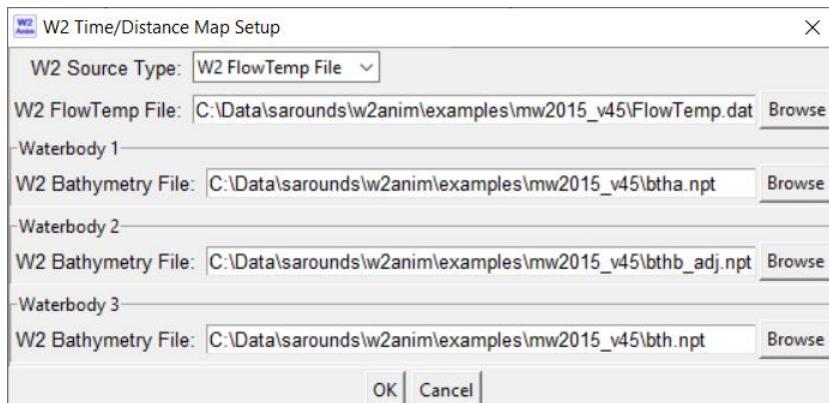
When choosing a W2 vector file for the time/distance data, it is still necessary to provide the associated bathymetry file(s), as shown in the menu to the right. Although the vector output file includes some bathymetric data, those data are not necessarily correct for sloping branches; therefore, W2Anim must read the bathymetry file(s).



When the source type is set to use a W2 contour output file, the user must provide the names of the W2 contour and bathymetry files for each of the waterbodies included in the time/distance plot, as shown in the menu to the right. The menu indicates the waterbodies for the required files.



When the source type is set to use a W2 SurfTemp, VolTemp, or FlowTemp file, only one such file is required because it contains results from every segment in the model. The bathymetry files are required so that the model can compute downstream distances from the segment lengths. In the example at the right, a flow-weighted vertical average was chosen through the use of the W2 FlowTemp file. Remember that these \*Temp files are custom outputs from a USGS version of CE-QUAL-W2.



W2Anim also can use the W2 River Contour output file format for time/distance plots. Both formats 1 and 2 are honored by W2Anim, but it is important for the starting date and output frequency to be identical for each River Contour output file. The menu at the right provides input fields for all of the model branches used in the plot, even though some River Contour files may contain output from multiple branches in a single waterbody. In the example at the right, the second River Contour file contained output

from branches 2 and 3, and the menu identified that content after a quick scan of the output file.

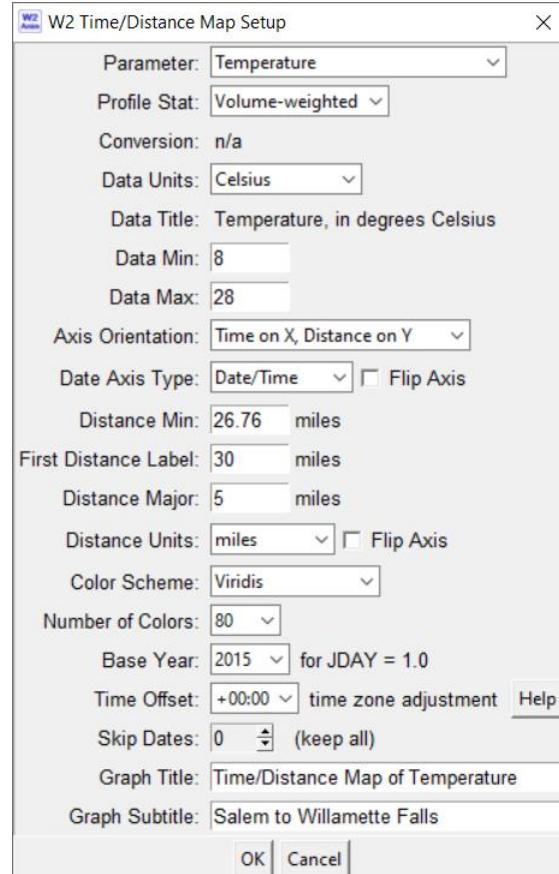
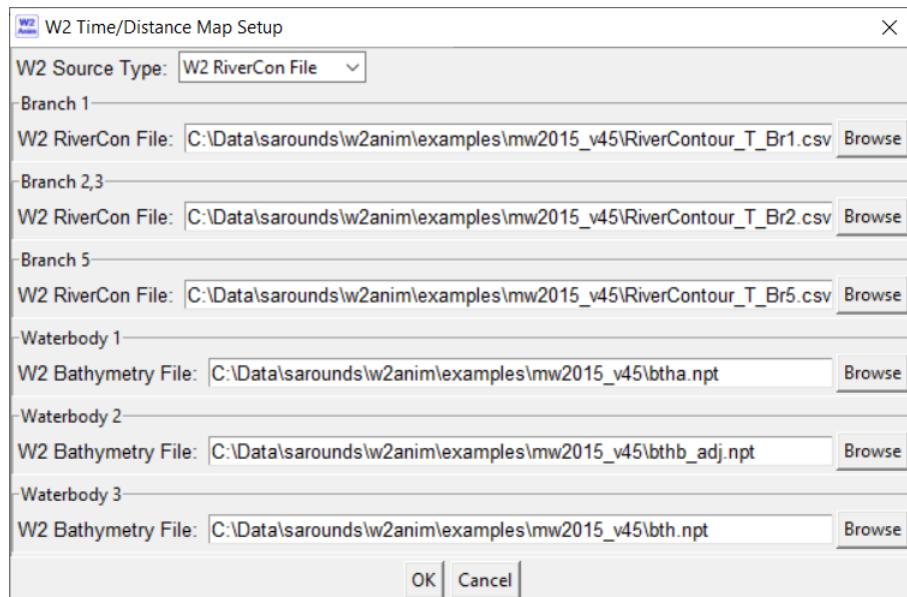
Clicking the OK button takes the user to the third and final setup menu for the W2 Time/Distance Map, shown at the right, where the user can choose the desired parameter and set the profile statistic and many other characteristics for the plot. Most of these settings can be changed later.

In this example, the W2 contour output was used, and several parameter choices were available. The contour output includes sufficient information to choose either the surface value or to compute a volume-weighted vertical average value for each date and location in the time/distance plot. A flow-weighted vertical average is available only from the custom W2 FlowTemp output.

When using the W2 River Contour output option, CE-QUAL-W2 at this time only includes one parameter in each output file (either water temperature or dissolved oxygen concentration) and includes only the surface value, so the parameter and profile statistic cannot be changed when using this type of output file.

As is the case with all W2 plots in W2Anim, some modeled parameters can be divided by the values of other modeled parameters. When using the USGS custom heat-tracking features of CE-QUAL-W2, the output for certain parameters sometimes must be divided by the water temperature to compute the desired result. This feature also allows the user to dream up and plot other potentially useful ratios from model output.

W2 Time/Distance Maps can be created with time on the X or Y axis. By default, time marches forward to the right on an X axis, and from top to bottom on a Y axis, but this default can be “flipped.” Similarly, distance by default proceeds downstream to the right on an X axis, or top to bottom on a Y axis, and also can be flipped. Time can be shown as either a date or a Julian Date.

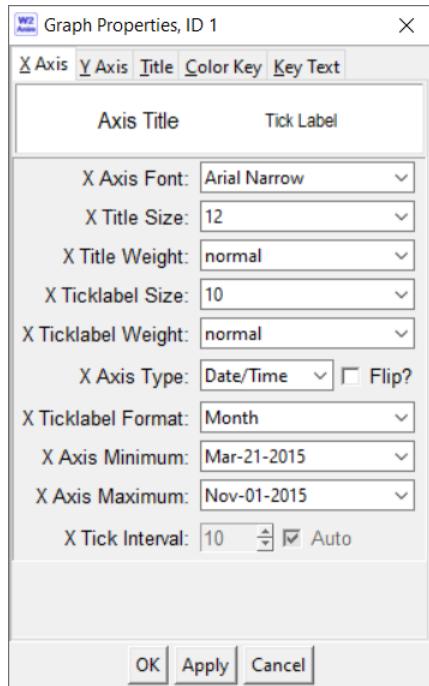


In this menu, it may be useful to specify a distance minimum value that is different from the first labelled distance tick mark. In this case, the most downstream distance location was 26.76 river miles, but the first labelled tick mark was set to 30 miles.

After clicking on the OK button, W2Anim will read the output files, perform any unit conversions or other required computations, and find the date, distance, and parameter limits from the available data. The resulting W2 Time/Distance Map for this example is shown at the right.

The default font for graph text can be set in the [Program Defaults](#) or by configuring a [W2Anim Initialization File](#). The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

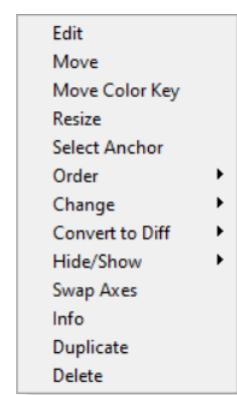
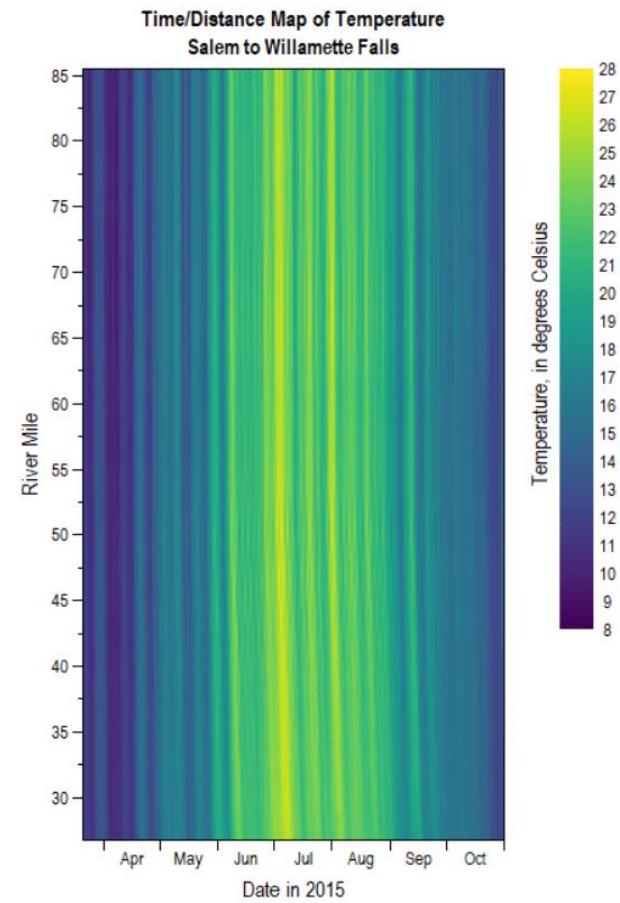
To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.



The options of the Graph Properties menu should be self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Under the Color Key tab, note that the color key Status can be set to visible or hidden. The hidden option hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.

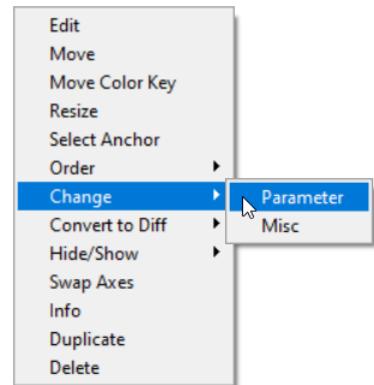
Now that the graph has been created and edited, the user has a number of other options to move, resize, select a different anchor point, move it up or down in the drawing order, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu.

The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The time and distance axes may be swapped (X vs Y) using the Swap Axes option. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame relative to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on [Object Anchors](#) and [Manipulating Drawing Objects](#) for more information on many of these options.



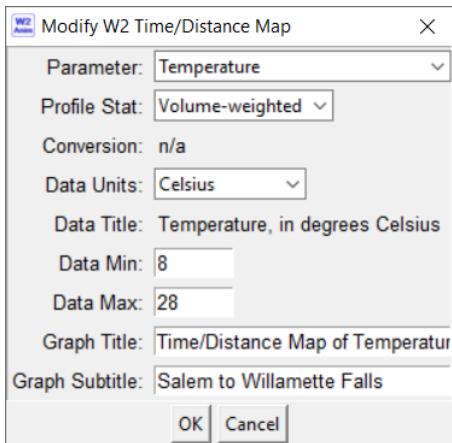
## Changing the Parameter or Skip Date

Through the Change submenu (at right), the user can select a different model parameter, parameter units, W2 model begin year, time offset, and/or a date-skip setting. This feature is handy not only for fixing user mistakes after the plot is created, but also for creating multiple time/distance maps by duplicating a graph and then changing the model parameter used in the duplicated map. In this way, a user could quickly set up an array of time/distance maps for a suite of modeled parameters. If the user wants a plot composed of different segments or branches, however, a new time/distance map must be created. The Change submenu is not available when using W2 River Contour output files because such files contain only one parameter.

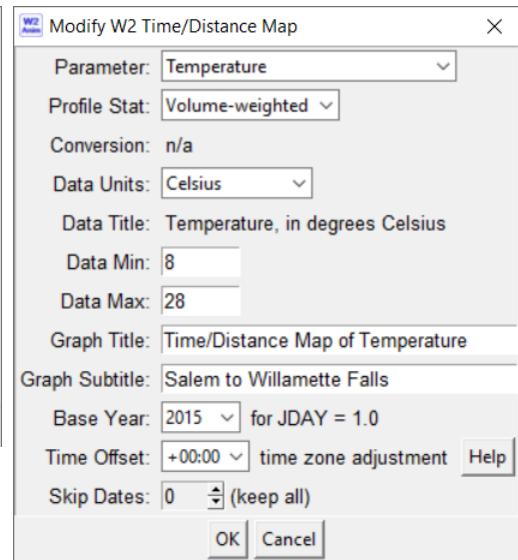


The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original W2 Time/Distance Map. The menus for the two options are shown below.

### Parameter:



### Misc:



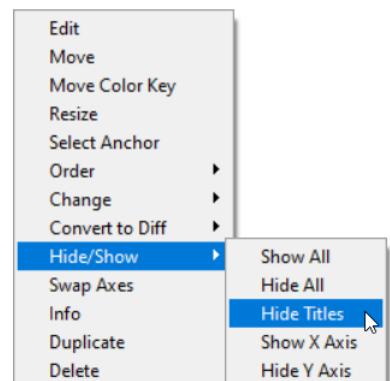
The only difference between the Change Parameter menu and the Change Misc menu is that the latter allows the user to select a different W2 base year, time offset, and/or date-skip setting. Any substantive change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the

menu will result in no changes to the graph. Simply changing data limits (Min/Max) or the graph titles is not allowed from these menus, as that is best done from the Graph Properties menu.

## Combining Plots from Multiple Models

When multiple W2 models are used to simulate flow and transport through various reaches of a river system, it may be useful to combine multiple W2 Time/Distance Maps to visualize spatial and temporal variations through the entire system. W2Anim helps to make such multiple-model maps possible by allowing the titles and axes of each time/distance map to be shown or hidden according to the wishes of the user.

Right-clicking on any W2 Time/Distance Map (or typing Alt-p while hovering over such a map) brings up the options menu, and the Hide/Show submenu allows the user to choose whether titles or axes are hidden. The example menu at the right shows an instance where the X axis, with all of its tick marks and labels, is already hidden.



An example using three W2 Time/Distance Maps to illustrate spatial and temporal variations in daily maximum temperature along the Willamette River in western Oregon is shown at the right. (The USGS custom SurfTemp and FlowTemp output files were used to obtain the daily maximum temperatures.) In this instance, the top two maps have their X axes hidden, and the lower two maps have their titles hidden. Each plot uses the same X axis limits and the same color scheme, but the color keys for two of the plots are hidden.

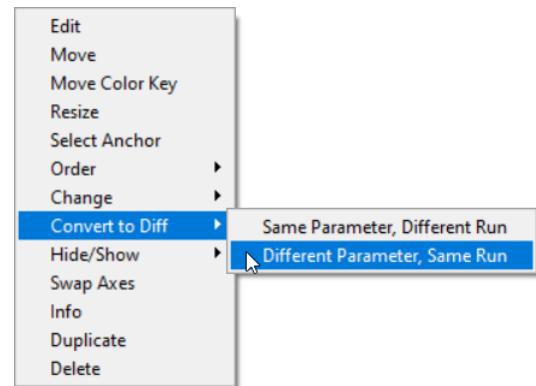
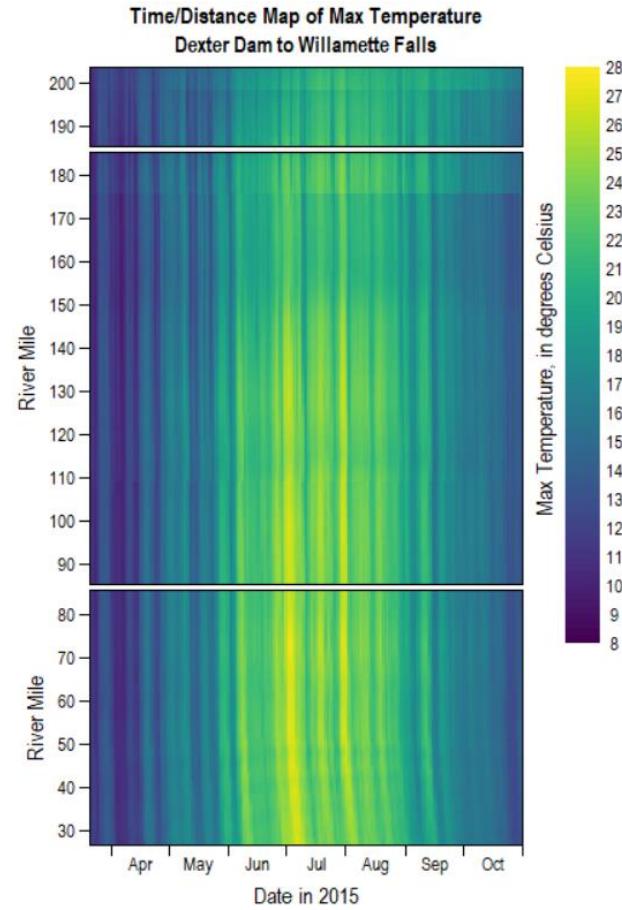
It is important when displaying multiple time/distance maps in this way to scale the distance dimension of each plot so that each map uses the same ratio of river distance to display pixels. In this example, the middle plot is 300 pixels in height and spans 99.778 river miles. The lower plot spans 58.738 river miles, and therefore was configured to be  $58.738 \times 300/99.778 = 176.6$ , or 177 pixels in height. Similarly, the top plot spans 18.378 river miles, and therefore was configured to be 55 pixels in height. The longitudinal distances are easy to find in the Object Info box; just right-click over a graph, select the Info option, and find the values given for Distance Range and Height. Resize the plot with *Snap to Grid* turned off, and monitor the plot size in the status bar while resizing to set the desired plot height or width. If the X axis was used for distance, then the widths would be scaled as opposed to the heights. The scaled maps can be positioned with a small gap, as shown in the example, or with edges that touch each other. See the sections in this manual on [Moving Objects](#) and [Aligning Objects](#) for more information on moving and positioning objects.

### **Creating a Difference Plot**

Once a W2 Time/Distance Map has been created, a difference plot can be created by subtracting results from another dataset. The second dataset can be for (1) the same parameter from a different model scenario, or (2) a different parameter from the same model run, as indicated in the option menu to the right.

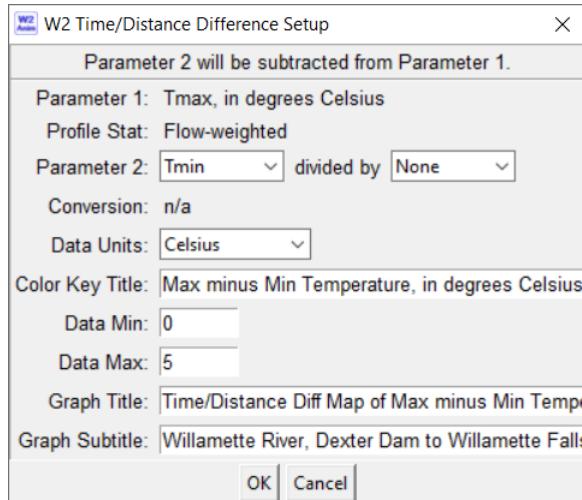
When choosing the same parameter from a different run, the second dataset can be from a different source file type, as long as the other source type can support the same profile statistic. Regardless, the W2 output file must be from a model that uses the same model grid.

When choosing a different parameter from the same model run, W2Anim requires the use of the same source file. As a result, the “Different Parameter, Same Run” option is not available when a time/distance plot is created from W2 River Contour output files, as those files only contain one parameter.



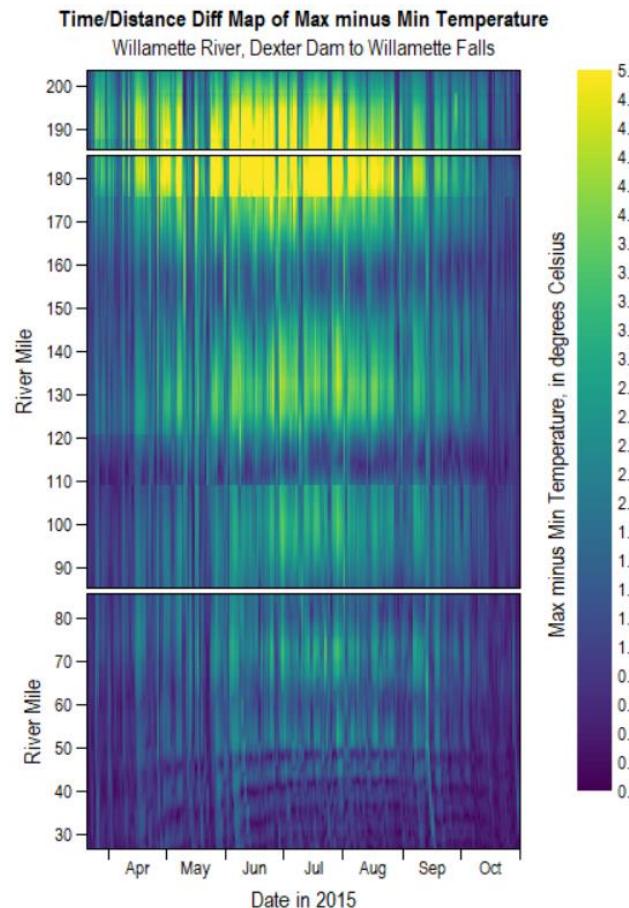
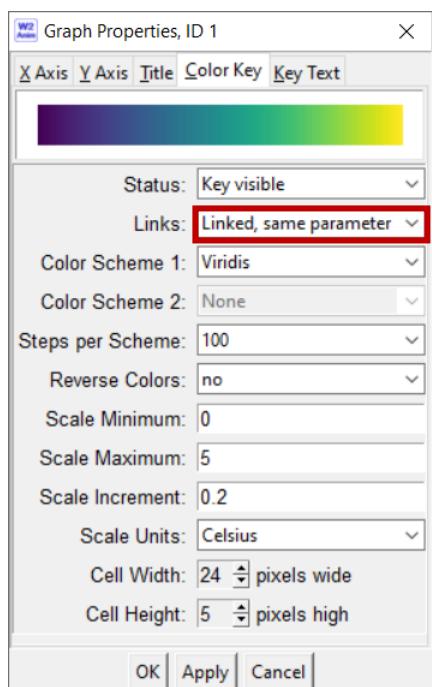
## Different Parameter, Same Run

When choosing the “Different Parameter, Same Run” option, a difference setup menu will appear, as shown below. The menu reminds the user of the first parameter and profile statistic, and prompts the user to choose the second parameter, any unit conversion, numeric plotting limits for the computed difference, and any modifications to the graph titles and color key title. In this example, the daily minimum temperature (Tmin) was subtracted from the daily maximum temperature (Tmax). The color scale was reconfigured to run from 0 to 5 degrees Celsius, and the titles were adjusted to denote the appropriate difference. The resulting difference maps, after repeating the process for all three plots in the example, is shown below on the right.



When multiple plots are intended to use the same color scheme, it is useful to link the color schemes in the Graph Properties menu as shown below with the red

rectangle. When specifying such a link, a change to the color scheme of one plot will cause the same change to occur in other plots that use the same parameter combination.

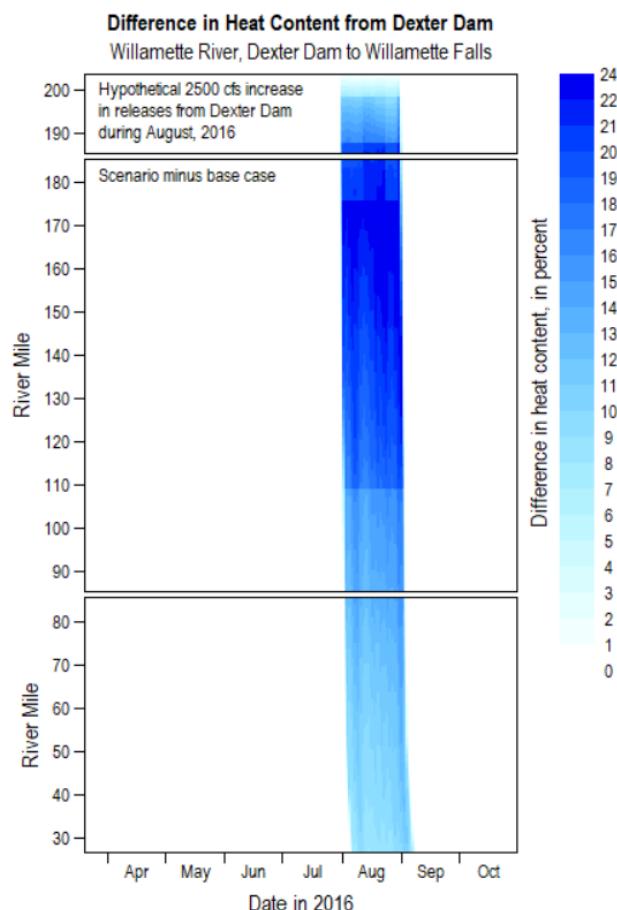
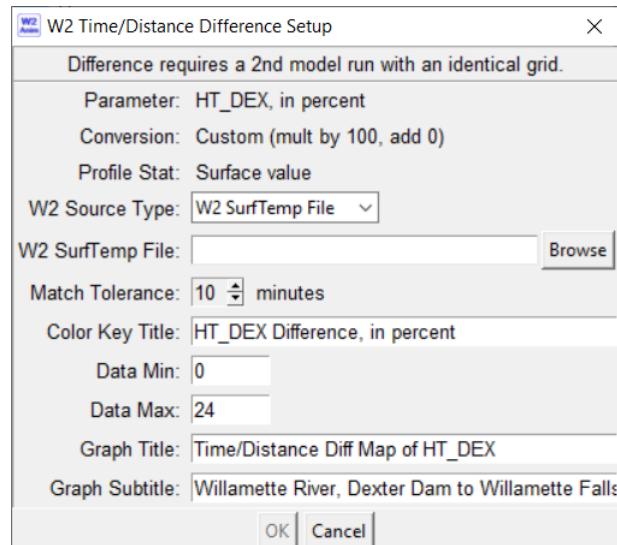


## Same Parameter, Different Run

When choosing the “Same Parameter, Different Run” option, a difference setup menu will appear, as shown to the right. The menu reminds the user of the chosen parameter and profile statistic, and prompts the user to choose a source type and source file(s) that contains data for the chosen parameter from a different model run. To help account for any differences in output frequency, a match tolerance can be set by the user to ensure that W2Anim can align the date/time markers of the two datasets. Finally, the user is prompted for the numeric plotting limits for the computed difference and any modifications to the graph titles and color key title.

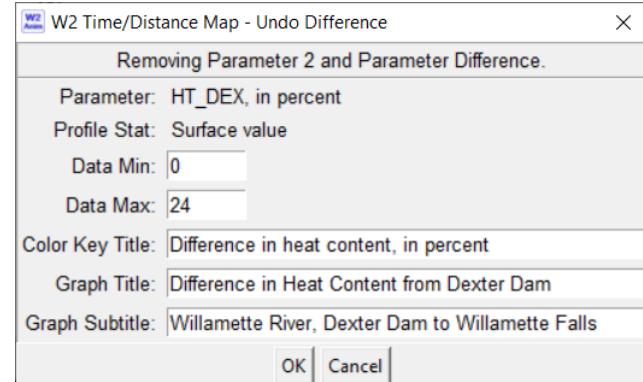
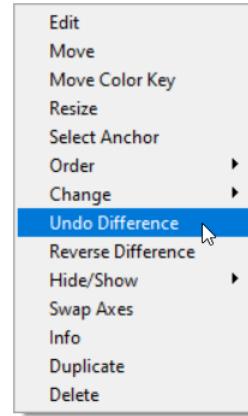
In this example, a generic tracer was used to track the heat content associated with releases from Dexter Dam on the Middle Fork Willamette River, and track that heat downstream in the Willamette River in western Oregon through three different W2 models. A customized USGS edition of CE-QUAL-W2 was used to track the heat, as documented by Rounds and Stratton Garvin (2022). The three W2 Time/Distance Maps shown at the right represent the difference in heat content sourced from Dexter Dam as simulated by two scenarios. Results from a base case were subtracted from results in which Dexter Dam releases were hypothetically increased by 2,500 ft<sup>3</sup>/s during August. As a result, travel times were decreased, and heat content in the river was replaced less quickly by environmental heat fluxes across the air/water surface.

In the custom SurfTemp or FlowTemp output files, heat content from various sources is output as a fraction, so a multiplier of 100 was applied in a custom unit conversion in W2Anim to express the results as a percentage. A white-to-blue color scheme was used so that any differences less than 1 percent show up as white, which allows the more-significant differences to be highlighted with various shades of blue. The resulting plot is similar to the one published as figure 19D in the report by Rounds and Stratton Garvin (2022).



## Reverting and Reversing Differences

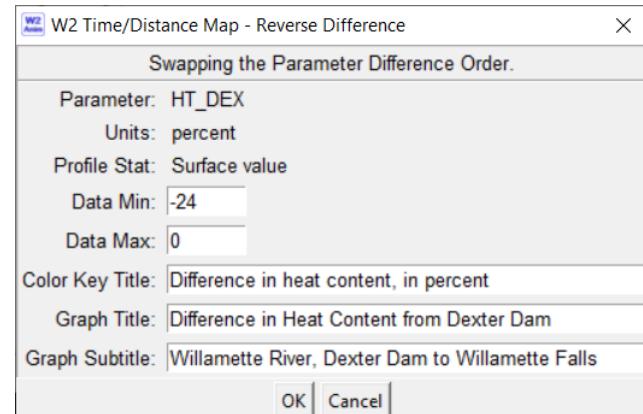
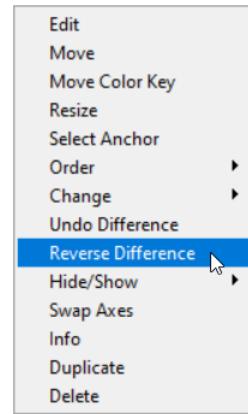
Once a W2 Time/Distance Map has been converted into a difference plot, the user has several options to undo, reverse, or modify those differences. All such options are available from the options menu, accessed by right-clicking on the graph of interest or typing Alt-p while hovering over the graph. The “Undo Difference” option allows the user to eliminate the



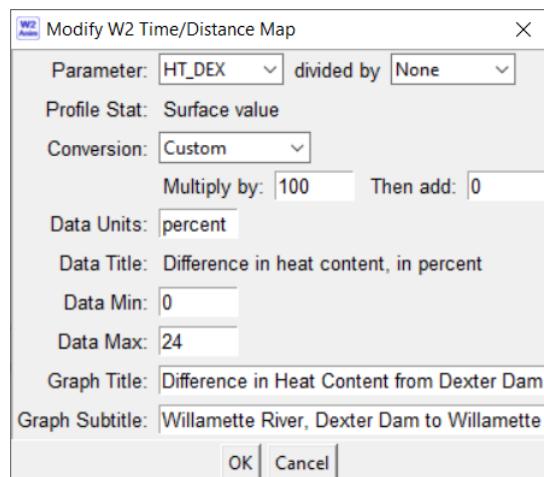
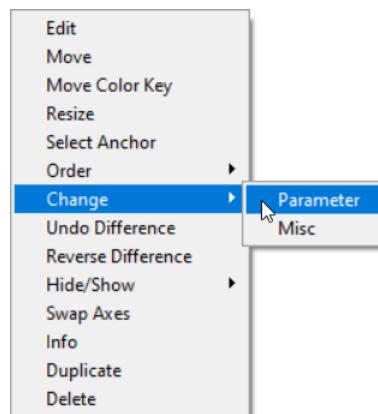
difference and revert to a map of values from the original dataset. Choosing that option will open a menu (above, right) that allows the user to refine the limits of the color scheme as well as the titles for the graph and color key. Clicking OK will proceed, whereas clicking Cancel will abort the operation and preserve the original difference map.

The “Reverse Difference” option allows the user to reverse the computed differences, such that positive differences become negative and vice versa.

Choosing this option will open a menu (shown at right) that allows the user to refine the limits of the color scheme and edit the titles of the graph and color key. W2Anim will populate the initial data limits in the menu based on the non-reversed values. Clicking OK will proceed, whereas clicking Cancel will abort the operation and preserve the original difference map.



Even when a difference has been computed, the first parameter of a “Different Parameter, Same Run” difference or the only parameter of a “Same Parameter, Different Run” difference can be changed. Select the Change submenu as described earlier in the section [Changing the Parameter or Skip Date](#) and use that menu (shown at the far right) to select a different parameter.



## TIME-SERIES GRAPHS

The W2 Animator can make general time-series graphs from many different types of time-series input files. See the [Recognized File Types](#) section for a list of file types that are recognized by W2Anim. Most input and output files from CE-QUAL-W2 have time-series datasets that can be read and plotted by W2Anim, along with many publicly available time-series formats from USGS, USACE, and others.

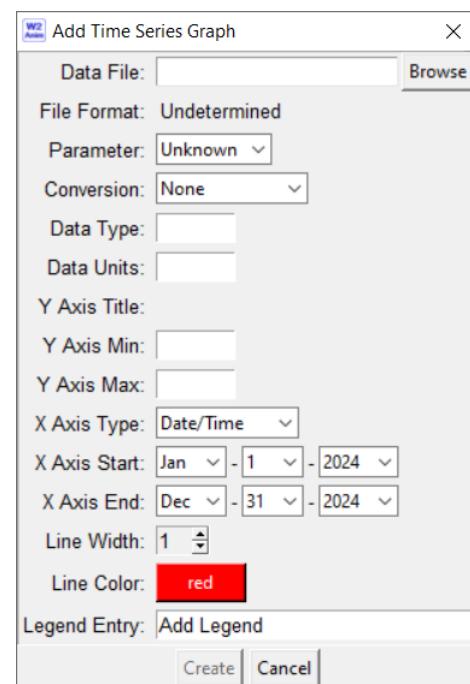
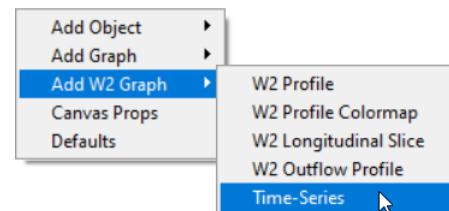
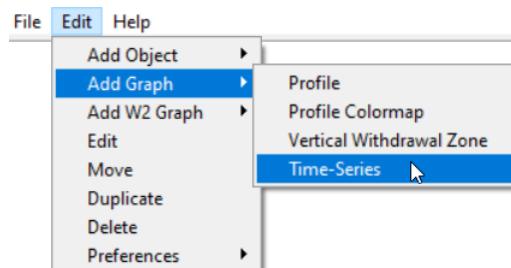
### Creating a New Graph

To create a new Time-Series graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at [Canvas Properties](#).

A Time-Series graph can be created by choosing Edit/Add Graph/Time-Series or Edit/Add W2 Graph/Time-Series option from the menu bar. Alternatively, right-click on the canvas and choose the Add Graph/Time-Series or Add W2 Graph/Time-Series option. These choices all lead to the same graph type. When any of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the anchor point for the graph; a different anchor point can be selected later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen at the right.

Start by providing W2Anim with the name of a time-series data file. Click the Browse button to find and select the file containing the first dataset. The program will scan that file in an attempt to identify its format and determine whether it is a [recognized file type](#). If the file is recognized, W2Anim will try to create a list of parameters contained in the file so that the user may choose one. Some file types provide detailed parameter names, while others provide almost no information, which may result in a list of generic parameter names.

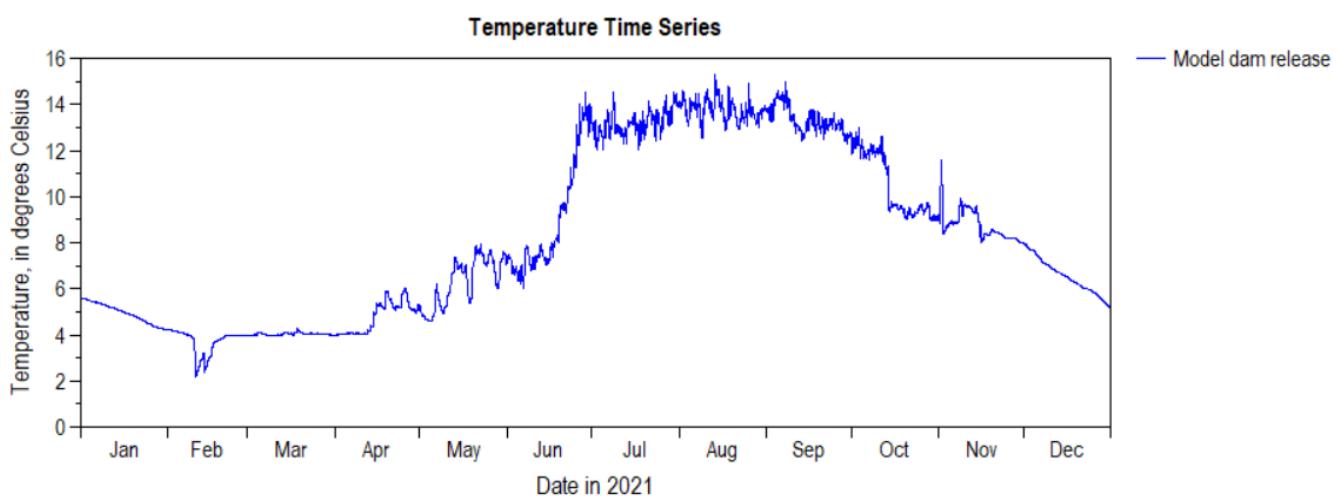
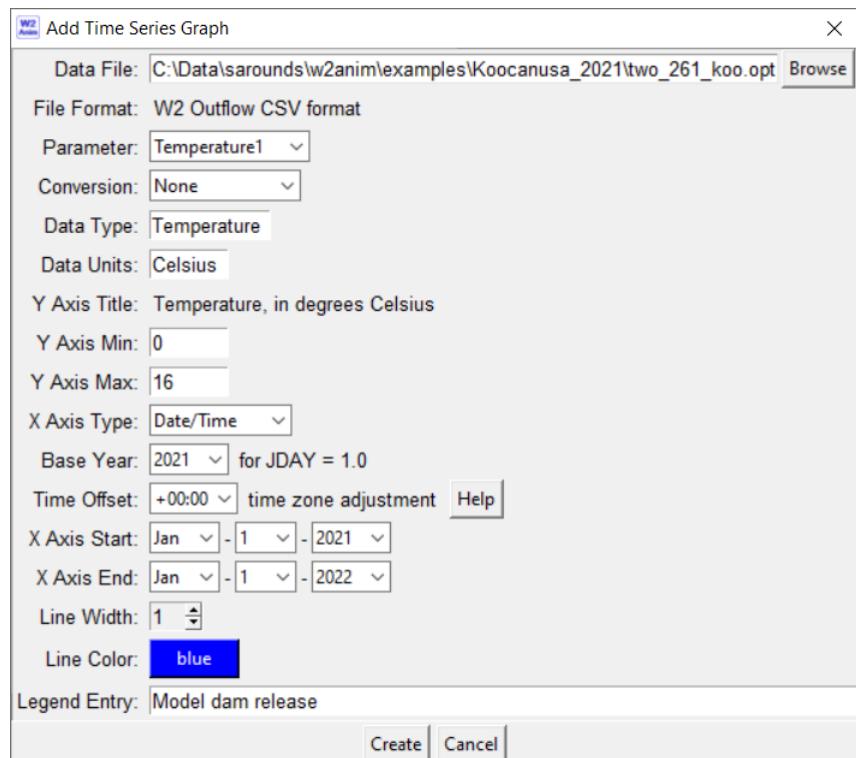
The user should make an attempt to be familiar with the units of the time-series parameter of interest in the data file, so that those input units can either be converted to different units, or just so that the information can be provided to W2Anim. A number of [unit-conversion filters](#) are available, along with a custom filter that allows the user to input a multiplicative factor and an additive factor, which covers many possible unit conversion equations. The Data Type input (for example, Temperature) cannot be changed later, but it serves mainly as a



reminder to the user when additional datasets are added. Currently, only one Y axis is possible in the Time-Series graph type, so only one type of parameter may be plotted at a time.

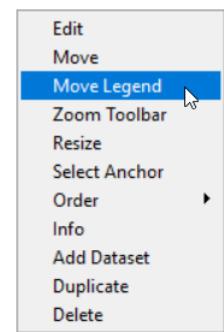
Either a “Date/Time” or “Julian Date” X Axis Type can be chosen, and a Base Year must be chosen for certain combinations of file formats and axis types. Most of the inputs in this menu can be changed later, but the user should pay particular attention to the Base Year input for time-series files that specify only the Julian Date, because W2Anim will convert the Julian Date to a date/time for internal use, and that date/time index cannot be changed later, other than by removing the dataset and adding it back again with a different Base Year.

For this example, a W2 outflow temperature file was selected for the first time-series dataset, and the menu to the right shows the rest of the inputs that were specified. The resulting time-series graph is shown below.



The legend entry can be moved independently from the graph itself. Hover the mouse over the graph and right-click (or type Alt-p) and select the Move Legend option. The legend then can be moved by the mouse to a different position. If *Snap to Grid* is enabled, then a magenta anchor point for the legend will be shown. Left click the mouse to establish the new legend position; note that the legend position is an offset relative to the upper right corner of the graph frame, so resizing the time-series graph may also move the legend position in such a way that it may need to be repositioned again.

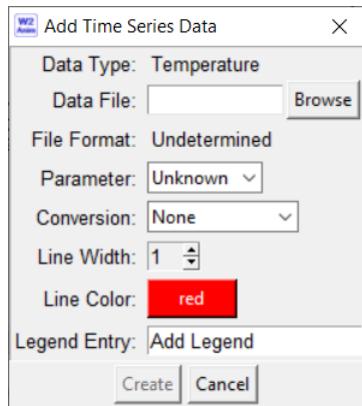
As with other graph types, the option menu to the right shows that the graph may be edited, moved, resized, duplicated, and deleted. A new anchor point for the graph may be



selected, and the graph may be moved up or down in the drawing order. Information about the graph and the range of its datasets can be displayed. Finally, additional datasets may be added to the graph.

### **Adding More Datasets**

Additional datasets can be added to a Time-Series or Linked Time-Series graph by hovering the mouse over the graph and clicking the right mouse button (or typing Alt-p) and selecting the Add Dataset option. These time-series graphs can only display one Y axis at this time, so any new datasets should be such that they can be plotted with the graph's existing Y axis. Selecting the Add Dataset option brings up the Add Time Series Data menu, as seen below.

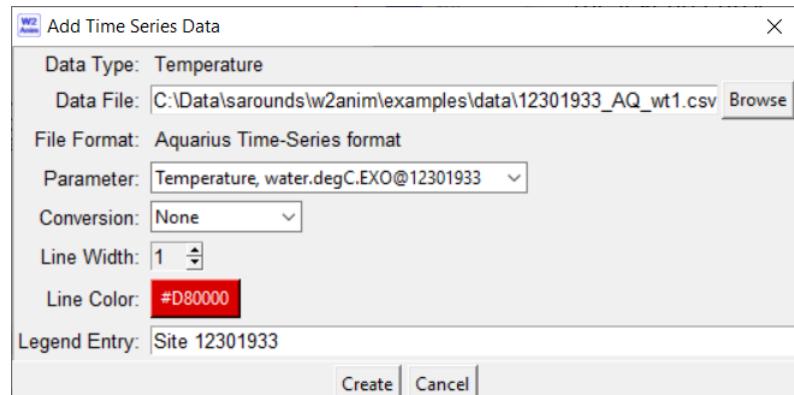


As a reminder, the menu displays the current data type assigned to the time-series graph, then prompts the user to find and choose another time-series dataset by clicking the Browse button to find and specify a file name. When the file is selected, W2Anim will scan the file (just as it did for the initial dataset) to try to identify its format and determine whether it is a [recognized file type](#). If the file is recognized, W2Anim will try to create a list of parameters contained in the file so that the user may choose one. Some file formats provide descriptive parameter names, while others provide almost no information. Once the parameter is selected, the user should determine whether its units need to be converted. A number of [unit-conversion filters](#) are available, along with a custom filter that allows the user to input a multiplicative factor and an additive factor, which covers many possible unit conversion equations. Finally, the user should choose a line width and line color and specify a legend entry. W2Anim will not accept "Add Legend" or an empty string for the legend entry.

additive factor, which covers many possible unit conversion equations. Finally, the user should choose a line width and line color and specify a legend entry. W2Anim will not accept "Add Legend" or an empty string for the legend entry.

For this example, a measured temperature time-series was specified from a location not far from the downstream end of the model. The filled-out menu is shown at the right. Most of the parameters of the time-series graph can be modified through the Graph Properties menu, which is activated by hovering the mouse over the graph and clicking the right mouse button (or typing Alt-p) and selecting the Edit option.

Alternatively, select the Edit/Edit option from the menu bar and then click the left mouse button when hovering the mouse over the graph of interest. The Graph Properties menu for this time-series graph is shown on the next page.

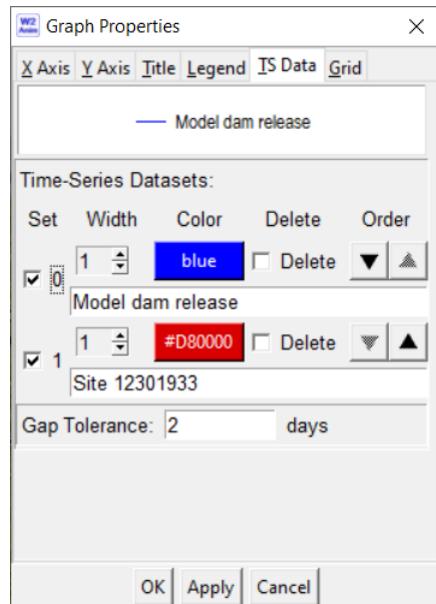
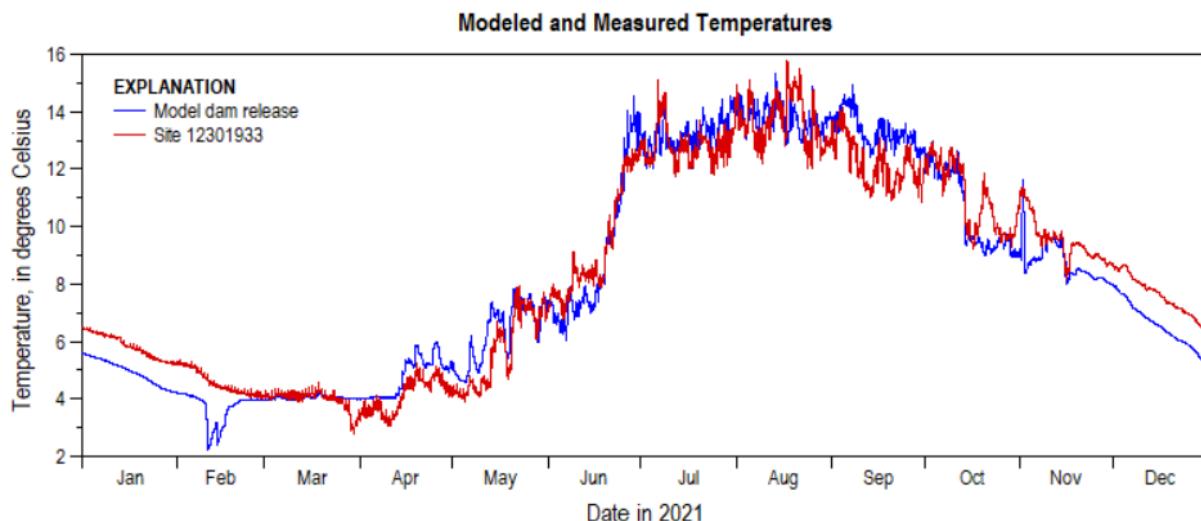


The Graph Properties menu for Time-Series graphs has six tabs across the top of the menu to control aspects of the X Axis, Y Axis, Title, Legend, the time-series data (TS Data), and an optional Grid. Most options in this menu should be fairly self-explanatory, and therefore are not discussed in detail here. The user is advised to play with the various options and observe the results when the Apply button is clicked.

The line width, line color, legend entry, and order of plotting for each time-series dataset can be modified from the TS Data tab of the Graph Properties menu. The triangular Order buttons are used to move a dataset up or down in the list, where the datasets are plotted in list order from top to bottom. Any dataset may be hidden by unchecking the checkbox next to the dataset number at the left of each entry, and shown again by checking the box. Nothing happens until the OK or Apply button is clicked. If the Delete box is checked, then the dataset will be removed after the OK or Apply button is clicked. W2Anim has no Undo function at this time, so be sure that you really want to delete a dataset before clicking OK or Apply. The dataset can always be added back through the Add Dataset menu option. Note that Legend Title (on the Legend tab) is optional.

A gap tolerance value can be set for a Time-Series graph such that any date/time gap exceeding the gap tolerance will break the line between adjacent points. An entire time series can be plotted with points rather than a line if the gap tolerance is sufficiently small, such as zero, but be careful because doing so with a large dataset will cause the user interface to slow considerably (because so many objects for the points will have been created). The default gap tolerance is 2 days, and can be changed from the Graph Properties menu in the TS Data tab.

After changing a few font sizes and moving the legend inside the graph frame, the example Time-Series graph is shown below.

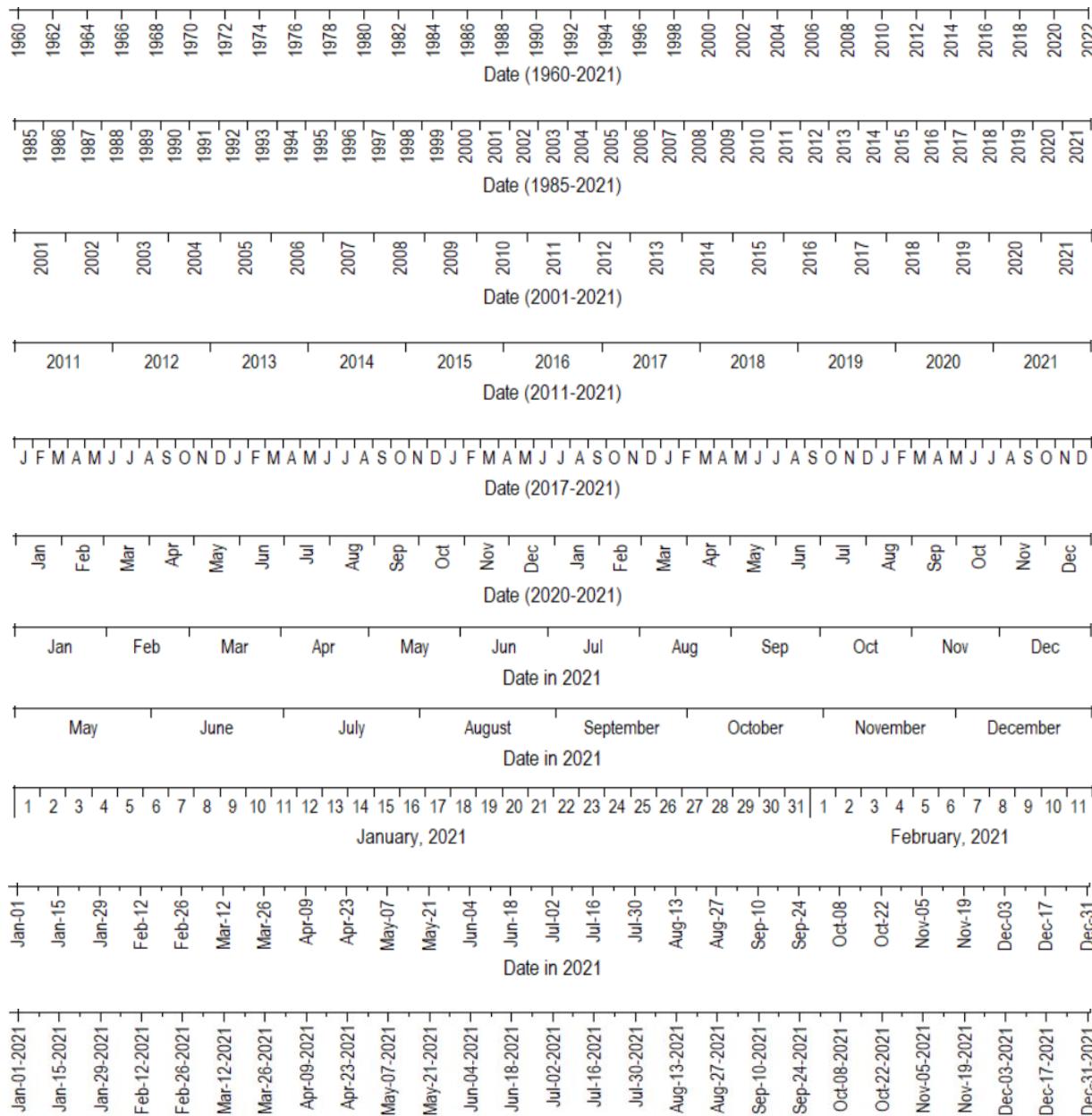


## X AXIS FORMATS

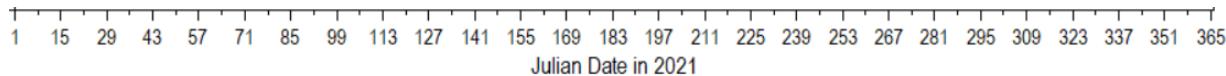
Any X axis that is a date axis can have several different formats. In Date/Time mode, the axis will show calendar dates with one of four formats:

- Year: In this format, the year is displayed between or at year-boundary tick marks. When showing the year, the format will adjust automatically according to how much space is available.
- Month: In this format, the month name is displayed between or at month-boundary tick marks. When showing the month name, the format will adjust automatically according to how much space is available, either spelling out the entire month name, shortening it to one or three letters, or rotating the three-letter abbreviation. The font size affects these determinations. If sufficient room is available, the day of the month also will be plotted between tick marks for each day.
- Mon-DD or Mon-DD-YYYY: In these modes, the dates are shown in Mon-DD or Mon-DD-YYYY format next to the major tick marks.

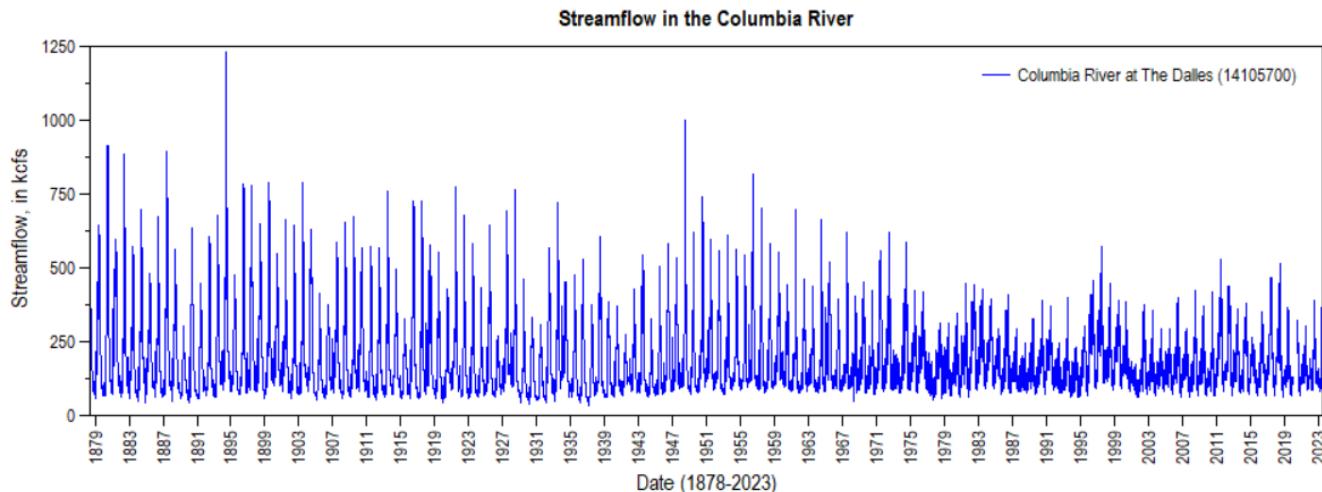
Examples of different Date/Time axis formats are shown below:



When the X axis is in Julian Date mode, the X axis is numeric and the values displayed depend on the specified base year.



With the Year format, long time-series datasets can be plotted. Daily mean streamflow data are plotted below for Jun-01-1878 through Jun-09-2023 from the Columbia River at The Dalles station (USGS gage 14105700).



Because the Time-Series graph type may often be used to compare modeled and measured time-series datasets, a goodness-of-fit option becomes available if at least two datasets are included in the graph. Hover over the graph and right-click (or type Alt-p) and select the Fit Statistics option. A menu will appear (see below, right), prompting the user to select the test dataset and a reference dataset. See the [Goodness-of-Fit Statistics](#) section of this User Manual for more details.

W2 TS Goodness-of-Fit Statistics				
Goodness-of-Fit Statistics				
	Test: Model dam release			
	Reference: Site 12301933			
n	Mean Error	Mean Absolute Error	Root Mean Squared Error	
All*	18208	-0.1108	0.7445	0.8995
Jan	1547	-0.9000	0.9000	0.9019
Feb	1398	-0.8511	0.8511	1.0362
Mar	1548	0.0560	0.1970	0.3250
Apr	1498	0.6768	0.6769	0.7180
May	1550	0.6343	0.7054	0.8858
Jun	1498	-0.2819	0.7041	0.8526
Jul	1531	0.3453	0.5784	0.7245
Aug	1550	0.1108	0.7095	0.8693
Sep	1498	1.1753	1.1812	1.2814
Oct	1543	-0.5091	0.6190	0.8305
Nov	1497	-0.7732	0.7889	1.0103
Dec	1550	-1.0419	1.0419	1.0487

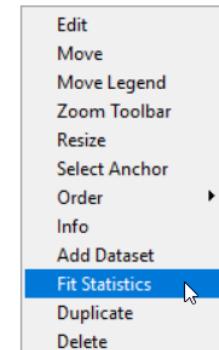
\*All = All available dates

OK Save

The “test” dataset in this case would be the model results, and the reference dataset would be the measured data. The menu shows the user what line colors are associated with the chosen datasets, as well as whether they are shown (active) or hidden.

Computations are only done on test/reference data pairs where a reference value can be found within the match tolerance of the date/time of the test value. The statistics can be computed by month, and the user can also choose a date range.

After clicking the OK button, W2Anim computes the goodness-of-fit statistics and pops up the results in a new window (see example at left). The legend entries for the test and reference datasets are noted in the header. Fit statistics are computed for the user-specified date range or for the entire time period where test and reference data are available for comparison, and also may be computed by month. The results can be saved to a text file by clicking the Save button.



Choose Datasets for Fit Statistics

Choose datasets and options for fit statistic computation:

Test Dataset: Model dam release active

Reference Dataset: Site 12301933 active

Match Tolerance: 10 minutes

Options:  Include stats by month

Date Range: Include all dates

Start Date: Jul 31 2019

End Date: Dec 31 2021

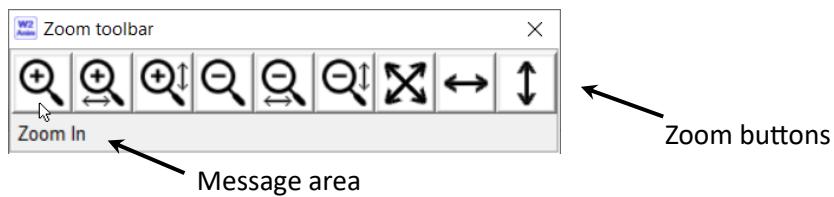
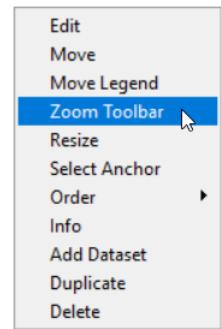
OK Cancel

## LINKED TIME-SERIES GRAPHS

At this time, linked time-series graphs can be created only from existing Measured Vertical Profile graphs and from existing Vertical Withdrawal Zone from Measured Data graphs. The creation and use of these linked time-series graphs are explained with their parent graph types in the sections on [Measured Vertical Profile](#) graphs and [Vertical Withdrawal Zone from Measured Data](#) graphs. Additional time-series datasets can be added to linked time-series graphs. See the [Time-Series](#) graph description for more information on adding datasets to time-series graphs.

## THE ZOOM TOOLBAR

The X and Y axis limits and major tick spacing for each graph in W2Anim can be modified from the Graph Properties menu. For Time-Series graphs, however, the Zoom toolbar also is available and provides some quick shortcuts to change the axis limits. Hover over any Time-Series graph and right-click (or type Alt-p) and select the Zoom Toolbar option. The function of each button on the Zoom toolbar can be discerned by hovering the mouse over a button and reading the text that appears in the lower left corner of the toolbar. The following is a list of the features of the Zoom toolbar:



Zoom in	Zoom out	Zoom to Full Extent
Zoom in, X only	Zoom out, X only	Zoom to X Full Extent
Zoom in, Y only	Zoom out, Y only	Zoom to Y Full Extent

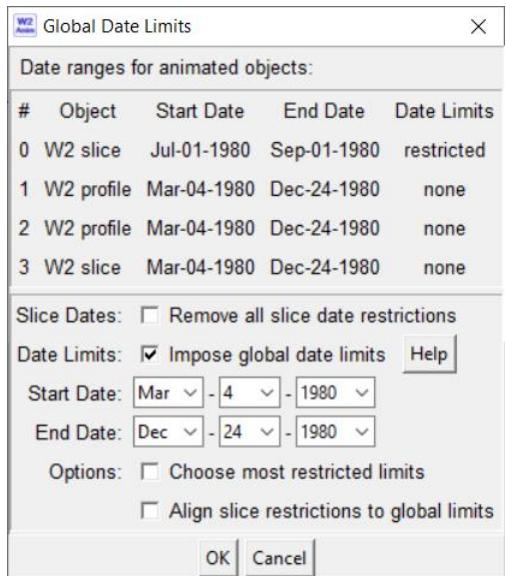
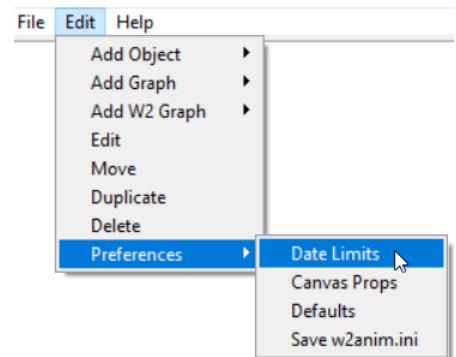
Clicking on any of the “zoom in” buttons will turn the mouse cursor into a crosshair, and the message area on the toolbar will prompt the user to draw a zoom box (for “zoom in”) or a zoom bar (for a zoom in just the X or Y direction) on any time-series graph. To create a zoom box or zoom bar, click and hold the left mouse button on a starting point within the graph frame and drag to the final point before releasing the mouse button. Alternatively, click the right mouse button to abort the action, or click on a different zoom button to choose to zoom in a different manner.

After clicking on any of the “zoom out” or “zoom to full extent” buttons, the mouse cursor will become a hand pointer, and the message area will prompt the user to choose a time-series graph for that zoom action. Clicking on a time-series graph implements the zoom action; clicking the right mouse button aborts the action. Zooming out in the X direction is limited to the range of the available non-hidden data, whereas the user can zoom out in the Y direction without limit. Zooming outward attempts to expand the axis limits by roughly 25 percent in each direction, with some constraints. Computing new Y axis limits may result in a compromise between the actual zoom-to value and a more-rounded value. Zooming to full extent will modify the X and Y axis limits to show the full range of all visible datasets; hidden datasets are ignored.

## GLOBAL DATE LIMITS

Each of the animated graphs in W2Anim retains its own datasets that are indexed to the date and time from its associated data files. The data files for each animated graph, however, will not necessarily have the same set of dates. For the purpose of animation, therefore, W2Anim uses a global list of dates derived from all of the animated graphs that are present on the canvas, and that global date list is automatically pruned and sorted such that any dates within 5 minutes of one another are deemed to be redundant and are removed. During animation, each animated graph is updated using the nearest date/time that is within about 10 minutes of the current date/time from the global list.

By default, W2Anim uses the entire global date list for animation. Now that W2 Longitudinal Slice graphs can have restricted date limits, however, the user also can place limits on the global dates list for the purpose of animation. Imposing limits on the global date list does not affect the data associated with any of the animated graphs, and the global date list is easily rebuilt if new date limits are chosen or if the global date limits are removed. To impose global date limits, choose the Date Limits option either from the Edit/Preferences menu or from the pop-up menu that appears when right-clicking (or typing Alt-p) when the mouse is hovering over no objects on the background canvas. The Date Limits option in the Edit/Preferences menu is only active when at least one animated graph is present on the canvas.



The Global Date Limits menu is shown at the left. The top part of the menu lists all animated graph objects that are currently on the canvas, including their type, their start and end dates, and whether any date restrictions have been imposed (for W2 slice plots). The bottom part of the menu allows the user to impose or change the global date limits, and also allows the user to either remove any date restrictions imposed on W2 slice plots, or to align W2 slice date restrictions to the imposed global date limits. Some parts of this menu will not appear if no W2 Longitudinal Slice plots are present on the canvas. If the various animated graphs have different date limits, the “Choose most restricted limits” option will impose global date limits that have the latest start date and the earliest end date from the available date ranges of the animated graphs.

When global date limits are imposed, the global date list will be truncated at the imposed start and end dates, the date/time

indices for animation will be updated, and the [animation toolbar](#) (if present) will be rebuilt. If any date restrictions for W2 Longitudinal Slice plots are modified, then the data files for those plots will be re-read and those graphs will be rebuilt. Clicking OK will cause the lower part of the menu to be wiped clean to make room for a set of messages to inform the user as to the status of the steps involved in rebuilding graphs or rebuilding the global date list.

Setting global date limits will cause a new section to be saved to the W2Anim project file. That optional section is described in the [W2Anim Project File Format](#) section of this User Manual.

# MODEL AND DATA FILES

## MEASURED VERTICAL PROFILES

For the Measured Vertical Profile (profile and colormap) and for the Vertical Withdrawal Zone from Measured Data graph types, a data file of measured vertical profiles must be provided, and in the latter case it must be for water temperature. The format of these measured vertical profile files is straightforward, with a time-series of water-surface elevations and parameter values at given elevations or depths, along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with a key word in the first field and a value in the second field. The expected key words and values are given in the table below, where some flexibility in the key words is possible when the measured profiles are for water temperature.

The Parameter line can be skipped if the parameter is temperature and the value TemperatureProfile is used for the DataType. The ElevOrDepth line tells W2Anim whether to expect profiles at fixed elevations or at specific depths. The ElevUnits line tells W2Anim the units associated with the input elevations or depths. Similarly, the InputUnits (or InputDegrees) line tells the program which input units to expect for the measured profile values. For temperature, W2Anim will store the data internally in degrees Celsius, but it must be told what units to expect for the data. The rest of the lines (Ytype, etc.) are used by W2Anim as suggestions to the user when a new graph is being created, and the values provided here are used as initial values in the program's interface.

After these header lines, the next line must have the key word ElevationOrDepth in the first field. The second field is ignored but typically may contain the word "Surface." The rest of the fields on this line are numeric and are the elevations or depths at which the profile data are measured. For example, if the measurements were made at fixed elevations, this line might look something like:

ElevationOrDepth, Surface, 2450, 2440, 2430, 2420, 2410, 2400, 2390, 2380, 2370, 2360, 2350, 2340, 2330, 2320, 2310, 2300, 2275, 2225, 2170

and if the measurements were made at fixed depths, the line might look something like:

ElevationOrDepth, Surface, 5, 10, 20, 30, 40, 60, 80, 100, 120, 140, 160, 180, 200e, 215e, 230e

Note that the second example includes several depths with an "e" at the end, which marks those depths as containing estimated data. Estimated profile points are plotted with a different color, and it can be useful to include estimates in some cases.

After the line containing ElevationOrDepth, the rest of the file contains the profile data. The first column is expected to contain a date or a date/time, where the following date formats are valid:

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the “-” separator may also be a “/”. The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital

Key Word	Possible Values
DataType	ProfileData or TemperatureProfile
Parameter	parameter name, such as Temperature
ElevOrDepth	Elevation or Depth
ElevUnits	ft or foot or feet or m or meter or meters
InputUnits (or InputDegrees)	parameter units (or Celsius or Fahrenheit)
Ytype	Elevation or Depth
Yunits	ft or foot or feet or m or meter or meters
Ymin	suggested Y axis minimum value
Ymax	suggested Y axis maximum value
Ymajor	suggested Y axis major spacing
ParmUnits (or WTunits)	parameter units (or Celsius or Fahrenheit)
ParmMin (or WTmin)	suggested parameter axis minimum value
ParmMax (or WTmax)	suggested parameter axis maximum value
ParmMajor (or WTmajor)	suggested parameter axis major spacing

letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

The second field is expected to be the measured water-surface elevation, in the expected units (see the ElevUnits line). The rest of the fields are expected to be the measured parameter values at the corresponding elevations or depths and in the expected units (see the InputUnits line). If any data points are missing, the text "na" (without quotation marks) is used as a placeholder to be ignored. Therefore, some data lines for a file containing daily temperature profiles in Fahrenheit at fixed elevations might look something like:

```
ElevationOrDepth,Surface,2450,2440,2430,2420,2410,2400,2390,2380,2370,2360,2350,2340,2330,2320,2310,2300,2275,2225,2170  
10/1/2020,2446.49,na,58.49,58.60,58.14,59.44,58.36,58.54,59.08,58.96,58.83,55.81,54.57,53.65,51.70,49.25,46.52,42.90,39.21,37.70  
10/2/2020,2446.42,na,58.01,58.20,57.81,59.11,58.04,58.23,58.74,57.41,55.84,54.29,52.43,50.71,48.41,45.35,43.55,41.71,39.20,37.98  
10/3/2020,2446.33,na,57.83,57.95,57.51,58.77,57.68,57.73,57.80,56.78,55.15,54.00,51.76,48.45,44.80,43.26,42.48,41.11,38.77,37.64  
10/4/2020,2446.13,na,57.53,57.66,57.10,58.40,57.32,57.48,57.77,56.75,55.45,53.13,48.54,45.31,43.98,43.53,42.83,41.41,39.02,37.83  
10/5/2020,2446.04,na,59.35,59.24,58.85,60.14,58.81,58.59,57.96,55.14,52.92,51.80,50.37,49.75,48.59,47.58,46.85,44.71,41.47,40.15  
10/6/2020,2446.01,na,59.14,59.28,58.69,60.01,58.03,56.39,55.58,53.15,52.09,50.60,49.17,48.39,47.49,47.13,46.45,45.32,41.43,40.22  
10/7/2020,2445.98,na,59.83,59.09,58.59,59.62,57.91,56.97,56.44,53.98,52.75,51.83,50.41,49.39,48.27,47.39,46.86,45.58,42.28,40.34  
10/8/2020,2446.00,na,59.06,59.03,58.51,59.20,57.18,56.13,54.78,53.01,51.82,50.64,48.96,48.28,47.40,47.14,46.42,45.03,41.68,40.18  
10/9/2020,2445.98,na,59.24,59.20,58.40,59.28,57.86,56.90,55.88,53.94,52.62,51.58,50.33,49.39,48.27,47.73,47.11,45.75,42.88,40.36  
10/10/2020,2446.00,na,58.34,58.49,58.11,58.96,57.63,55.96,54.85,53.07,51.84,51.02,49.52,48.72,47.88,47.29,46.53,45.55,41.71,40.16
```

Note the "na" values for the 2450 elevation when the water-surface elevation is less than 2450. Alternatively, some lines for a file containing hourly temperature profiles in Celsius at fixed depths might look something like:

```
ElevationOrDepth,Surface,5,10,20,30,40,60,80,100,120,140,160,180,200e,215e,230e  
5/1/2021 0:00,1537.30,9.82,9.25,8.81,8.37,8.1,7.83,7.41,6.84,6.57,6.07,5.6,5.46,5.43,5.43,5.43  
5/1/2021 1:00,1537.39,9.63,9.01,8.59,8.33,8.22,7.67,7.28,6.95,6.4,6.01,5.66,5.51,5.47,5.47,5.47  
5/1/2021 2:00,1537.46,9.74,9.01,8.53,8.35,8.15,7.55,7.31,6.78,6.34,5.99,5.87,5.61,5.55,5.55,5.55  
5/1/2021 3:00,1537.53,9.53,8.99,8.53,8.34,8.18,7.66,7.29,6.53,6.29,6.1,5.89,5.61,5.54,5.54,5.54  
5/1/2021 4:00,1537.63,9.47,8.89,8.51,8.39,8.23,7.65,7.15,6.61,6.34,6.15,5.97,5.65,5.57,5.57,5.57  
5/1/2021 5:00,1537.69,9.53,8.66,8.42,8.37,8.23,7.6,7.2,6.61,6.23,6.07,5.89,5.73,5.69,5.69,5.69  
5/1/2021 6:00,1537.71,9.47,8.77,8.5,8.38,8.14,7.69,7.19,6.68,6.27,6.02,5.8,5.58,5.53,5.53,5.53  
5/1/2021 7:00,1537.73,9.42,8.63,8.55,8.41,8.09,7.62,7.18,6.58,6.26,5.99,5.73,5.56,5.52,5.52,5.52  
5/1/2021 8:00,1537.76,9.48,8.79,8.64,8.33,8.11,7.57,7.12,6.42,6.26,6.01,5.72,5.59,5.56,5.56,5.56  
5/1/2021 9:00,1537.77,9.52,8.76,8.53,8.2,8.09,7.44,7.6,47,6.08,6.04,5.77,5.58,5.53,5.53,5.53  
5/1/2021 10:00,1537.80,9.75,8.69,8.4,8.21,7.97,7.42,7.01,6.53,6.08,6.06,5.83,5.6,5.54,5.54,5.54
```

This file format also is used for measured reference profile data that can be added to a W2 Vertical Profile graph so that measured and modeled vertical profiles can be compared and goodness-of-fit statistics computed. Note that if all of the measured water-surface elevations are missing (na), the Measured Vertical Profile or Vertical Withdrawal Zone graph can still be produced if the measured profiles are provided at fixed depths and the graph uses a Depth Y axis. Without the water-surface elevation data, however, a fixed-elevation vertical profile or vertical withdrawal zone graph cannot be produced because W2Anim has no way of determining the location of the water surface. The code has been written to be as flexible as possible, but sometimes the measured water-surface elevation is required; therefore, if no measurements of the water-surface elevation are available, the user will need to estimate those values somehow in order to produce the graph of interest.

## MEASURED DAM RELEASE RATES

The Vertical Withdrawal Zone from Measured Data graph type requires release flow-rate data from each of the dam outlets for which withdrawal zones are being calculated. The format of these measured dam release-rate files is straightforward, with a time-series of release rates for each outlet along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with a key word in the first field and a value in the second field. The expected key words and values are given in the table to the right.

The ElevUnits line gives the units for the outlet centerline elevations, and the LineWidthUnits line provides the units to

expect for the input line widths. The InputFlowUnits line tells the program which input units to expect for the measured release rates. W2Anim will store elevation and line-width information in meters and release rates in m<sup>3</sup>/s, but it must be told what units to expect for those data. The NumOutlets line tells W2Anim how many outlets to expect. The Algorithm line specifies either LibbyDam or W2orig as an algorithm for computing the vertical withdrawal zone for each outlet. The code LibbyDam or W2orig must be specified for each of the outlets, with commas separating each entry. Similarly, the name of each outlet is given on the OutletName line, with each name separated by a comma; the outlet names are used in graph legends and in the W2Anim interface. The CenterlineElev line provides the centerline elevations of each outlet in a comma-delimited list; this input is ignored for outlets using the LibbyDam algorithm. The OutletType designates each outlet as either a Line sink or a Point sink in a comma-delimited list. The LineWidth line gives the effective outlet line widths for those outlets designated as line sinks. The TopLayerLimit and BottomLayerLimit lines specify CE-QUAL-W2 model layer numbers that are used to limit the extent of the vertical withdrawal zone; this is an option in the W2 model and the user must provide a W2 bathymetry file as input, so it makes sense to offer a similar vertical limit option here. The rest of the lines (FlowUnits, FlowMax, and FlowMajor) are used by W2Anim as suggestions to the user when a new graph is being created, and the values provided here are used as initial values in the program's interface.

The LibbyDam outlet algorithm is new and only available in a USGS modification of CE-QUAL-W2 based on versions 4.2 or 4.5. The documentation for that new algorithm will be published by USGS soon as part of a study on the Kootenai River in Montana. Libby Dam routes most of its releases through four hydropower generators that take water from the bottom of a wet well that is fronted by a grid of bulkheads whose configuration changes over the course of a year. The LibbyDam algorithm used in W2Anim is identical to the algorithm that USGS has added to the CE-QUAL-W2 model. In that algorithm, virtual line-sink outlets are used to mimic the flow through open bulkhead positions at various elevations, and the flow through each virtual outlet is estimated iteratively based on an algorithm proposed by Howington (1990). The full USGS report will be referenced when published.

After the header lines, the next line in the release-rate file must have the key word DateTime in the first field, and the names of the various outlets in the rest of the fields. The rest of the lines in the file provide a time series of release rates from each named outlet, with a date or date/time in the first field. As with the measured vertical profile data files, the following date formats are valid:

Key Word	Possible Values
DataType	<i>ReleaseRates</i>
ElevUnits	<i>ft</i> or <i>foot</i> or <i>feet</i> or <i>m</i> or <i>meter</i> or <i>meters</i>
LineWidthUnits	<i>ft</i> or <i>foot</i> or <i>feet</i> or <i>m</i> or <i>meter</i> or <i>meters</i>
InputFlowUnits	<i>cfs</i> or <i>cubic feet per second</i> or <i>cms</i> or <i>cubic meters per second</i>
NumOutlets	number of dam outlets
Algorithm	<i>LibbyDam</i> or <i>W2orig</i> , specified for each outlet, comma-delimited
OutletName	name of each outlet, comma-delimited
CenterlineElev	centerline elevation of each outlet, comma-delimited
OutletType	sink type, <i>Line</i> or <i>Point</i> , for each outlet, comma-delimited
LineWidth	line width of Line outlets, for each outlet, comma-delimited
TopLayerLimit	W2 model layer that is the top limit for withdrawal zone (default is 2)
BottomLayerLimit	W2 model layer number that is bottom limit for withdrawal zone (default is bottom-most possible layer)
FlowUnits	suggested units for plot, <i>cfs/ft</i> or <i>cms/m</i> or <i>ft/s</i> or <i>m/s</i>
FlowMax	suggested maximum outflow axis value
FlowMajor	suggested major outflow axis spacing

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the “-“ separator may also be a “/”. The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

If daily release rates are specified for three outlets, this part of the file might look something like:

```
DateTime,Wet Well 1,Wet Well 2,Spillway  
1/1/2021,180.7,0,0  
1/2/2021,113.8,0,0  
1/3/2021,113.8,0,0  
1/4/2021,113.3,0,0  
1/5/2021,113.3,0,0  
1/6/2021,113.3,0,0  
1/7/2021,113.3,0,0  
1/8/2021,113.3,0,0  
1/9/2021,113.3,0,0
```

Similarly, if hourly release rates were specified for four outlets, the file might look something like:

```
DateTime,Spillway,Power,URO,LRO  
5/1/2021 0:00,0,0,0,0  
5/1/2021 1:00,0,0,0,0  
5/1/2021 2:00,0,0,0,0  
5/1/2021 3:00,0,0,0,0  
5/1/2021 4:00,0,0,0,0  
5/1/2021 5:00,0,100,0,0  
5/1/2021 6:00,0,2230,0,0  
5/1/2021 7:00,0,2350,0,0  
5/1/2021 8:00,0,2350,0,0  
5/1/2021 9:00,0,2350,0,0
```

## LIBBY DAM BULKHEAD CONFIGURATION

If the user is creating a Vertical Withdrawal Zone from Measured Data graph in W2Anim and wishes to assign one or more of the outlets to the LibbyDam withdrawal algorithm, then a Libby Dam Bulkhead Configuration file is required to provide the time-varying configuration of the bulkheads fronting one or more of the dam outlets. The format of a bulkhead configuration file is fairly simple, with a time-series of open bulkhead positions for each outlet along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with key words in the first field and a value or values in the succeeding fields. The expected key words and values are given in the table to the right.

Key Word	Possible Values
Wet Wells	number of outlets using the LibbyDam algorithm
WW Names	names of outlets using LibbyDam algorithm, comma-delimited
Bulkhead Slots	columns of bulkheads fronting each outlet, comma-delimited
Bulkhead Rows	number of rows of bulkheads
Bulkhead Width	width of a bulkhead, then units ( <i>ft,foot,feet,m,meter,meters</i> )
Bulkhead Height	height of a bulkhead, then units ( <i>ft,foot,feet,m,meter,meters</i> )
Baseline Elevation	elevation of the bottom of the bulkhead array, then units ( <i>ft,foot,feet,m,meter,meters</i> )
Baseline Head Loss Coef	value of smallest head-loss coefficient, assigned to bottom-most virtual outlet
Head Loss Increment	amount to increment the head-loss coefficient for each virtual outlets above the bottom-most virtual outlet

The “Wet Wells” key-word line specifies the number of outlets using the LibbyDam algorithm. The “WW Names” line specifies the outlet names that are using the LibbyDam algorithm; these names should match those specified in the release-rates file. The “Bulkhead Slots” line specifies the number of vertical columns of bulkheads fronting each wet well; when more than one outlet uses the LibbyDam algorithm, specify the number of columns for each outlet in a comma-delimited list. The “Bulkhead Rows” line specifies the number of rows of bulkheads fronting each wet well, where the program assumes that if more than one outlet is of the LibbyDam type, they all have the same number of bulkhead rows; if that is not the case, just specify the larger number. The “Bulkhead Width” line provides the effective width of an individual bulkhead in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Bulkhead Height” line gives the height of an individual bulkhead in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Baseline Elevation” line tells W2Anim the elevation of the bottom of the bulkhead array (bottom of the bottom row) in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Baseline Head Loss Coef” line gives the value of the baseline head-loss coefficient used in Howington’s algorithm (dimensionless); this baseline value is assigned to the lowest-elevation virtual outlet that has a non-zero width. A good default value might be 0.5. The “Head Loss Increment” line gives the value that the head-loss coefficient for a virtual outlet should be incremented for each virtual outlet above the bottom-most virtual outlet. A good default value might be 0.2. In this way, if four virtual outlets are used to describe four discrete openings in a bulkhead array at different elevations, the bottom-most virtual outlet would be assigned a head-loss coefficient of 0.5, and the next three virtual outlets above would be assigned head-loss coefficients of 0.7, 0.9, and 1.1. The research documented by Howington (1990) states that (1) it is extremely difficult to measure or otherwise theoretically obtain an accurate value for a head-loss coefficient for outlets bordering a common wet well, and (2) the relative difference in magnitudes of the head-loss coefficients is often more important than the absolute magnitudes of the coefficients, depending on the overall release rate. The head-loss coefficients are calibration parameters, but they may not affect the results substantially.

The next couple of lines may contain some header information that is ignored, but is eventually followed by a time series of the number of open bulkhead positions in each row for each outlet that is using the LibbyDam withdrawal algorithm. The first column contains a date or date/time, and the second column contains a Julian Date representation of the date. The Julian Date field is ignored. As with previous files described in this section, the following date formats are valid:

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the “-“ separator may also be a “/”. The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

The following is an example showing the number of open bulkhead positions for two Libby-Dam-type outlets that each have 7 slots of bulkheads arranged in 18 rows:

The first three lines above are ignored, but the third line shows that each outlet is assigned 18 columns of input corresponding to the 18 rows of bulkheads, where row 1 is the lowest and row 18 is at the top. The time series then gives the number of open bulkhead positions in each row of the bulkhead array on the given date. In this case, with each outlet fronted by 7 slots or columns of bulkhead positions, the maximum number of open bulkheads in any row is 7. In addition, because the bulkheads stack on top of each other in their slots, the number of open bulkhead positions cannot decrease as the row index increases. A value of 0 means that all 7 bulkheads are installed for that row and no flow is possible through a virtual outlet at that elevation. In contrast, a value of 3 means that three bulkheads are missing in that row, and a value of 7 means that no bulkheads are installed in that row.

The format of this Libby Dam Bulkhead Configuration file is slightly different than that used with CE-QUAL-W2.

W2 LAYER OUTFLOW FILE

Modifications were made to USGS edition 9 of version 4.2, USGS edition 1 of version 4.5, and to the 14-Jul-2023 public release of version 4.5 of CE-QUAL-W2 to produce a new kind of output file that contains layer-specific outflow rates for a user-specified segment location. This W2 Layer Outflow file is tied to the WDO (withdrawal output) capability in CE-QUAL-W2, which has several lines in the W2 control file just before the restart output lines. This W2 Layer Outflow is tied to the WDO output dates, output frequencies, and segment locations. The new layer outflow file is named with the pattern *qwo\_layers\_XXX\_BASE* where the XXX is the segment number and BASE is the user-specified output file name for WDO output. This W2 Layer Outflow file is needed by W2Anim to create the W2 Vertical Withdrawal Zone graph type.

The W2 Layer Outflow file contains the following header lines:

Flow layers file for segment XXX  
Output is JDAY, total outflow, WS elev, and layer outflows starting w/ layer 2  
JDAY,O(m3/s),ELWS(m),LayerFlows(m3/s)

where the XXX in the first line is replaced with the segment number. Following those lines are model outputs in comma-separated format, where the first field is the Julian Date, the second field is the total outflow rate ( $\text{m}^3/\text{s}$ ) for that model segment, the third field is the water-surface elevation (m) for the segment of interest, and the rest of the fields are the layer-specific outflow rates ( $\text{m}^3/\text{s}$ ) for each layer of that model segment, starting with layer 2 and proceeding to the bottom-most active layer.

## RECOGNIZED FILE TYPES

### Data File Formats

The following types of time-series data files are recognized by and can be read by The W2 Animator:

- USGS Water Services time-series files
- USGS Aquarius database exported time-series files\*
- USGS getData format time-series files\*
- USGS [Data Grapher](#) table files
- USACE Dataquery 2.0 time-series files
- Generic csv format

\*Some of these file types may not be available to users outside of the U.S. Geological Survey (USGS).

For a time-series data file that is recognized to have a generic csv format, W2Anim will try to extract a list of available parameter names from a comma-delimited header line that begins with “DateTime”, “Date”, or “Date/Time”. For this type of time-series file, the following missing value codes are recognized:

na, NA, -99, -999, or the empty string

### W2 Model Files

The following types of CE-QUAL-W2 model files can be read and recognized by The W2 Animator:

- W2 Control file (up to the WDO input, both original and csv format)
- W2 Bathymetry file (both the original and csv format)
- W2 Spreadsheet output file
- W2 Contour output file (both original and Tecplot-style)
- W2 Vector (w2l) output file (DSI linkage file)
- W2 River Contour output file
- W2 Lake Contour output file
- W2 input time-series files (column format or csv)
- W2 TSR format
- W2 Outflow csv format (including structure withdrawal output files)
- W2 Water Level (wl) format
- W2 Heat Fluxes output file\*
- W2 Daily \*Temp.dat format\*
- W2 Subdaily \*Temp2.dat format\*
- W2 Layer Outflow csv format

\*Several of these file types are from a customized USGS version of the CE-QUAL-W2 model.

## ON-THE-FLY UNIT CONVERSIONS

When creating some new graphs and when reading new time-series files, W2Anim often provides an option to convert the input values from one unit system to another. The following unit-conversion options are available:

- None
- degC to degF (Celsius to Fahrenheit)
- degF to degC (Fahrenheit to Celsius)
- m to ft (meters to feet)
- ft to m (feet to meters)
- cms to cfs (cubic meters per second to cubic feet per second)
- cfs to cms (cubic feet per second to cubic meters per second)
- cfs to kcfs (cubic feet per second to thousands of cubic feet per second)
- mg/L to  $\mu\text{g}/\text{L}$  (milligrams per liter to micrograms per liter)
- $\mu\text{g}/\text{L}$  to mg/L (micrograms per liter to milligrams per liter)
- days to hours
- hours to days
- Custom

For the Custom option, the user can specify a multiplicative factor and an additive factor, such that:

$$V_n = mV_o + a$$

where:

- $V_n$  is the converted value in the new units,  
 $V_o$  is the original value,  
 $m$  is the multiplicative conversion factor, and  
 $a$  is the additive conversion factor.

Conversion from degrees Celsius to degrees Fahrenheit, for example, can be accomplished either by choosing that option from the list, or by choosing the Custom conversion option with a multiplicative factor of 1.8 and an additive factor of 32. In the saved W2Anim project file, this custom conversion type would be denoted as “Custom,1.8,32” without the quotation marks.

## COLOR SCHEMES

Two categories of color schemes for highlighting data patterns are implemented in The W2 Animator. In the first category, single or double diverging color ramps are blended together with a discrete number of colors. In the second category, publicly available and commonly used colormaps are used to derive a user-specified color scheme with the requested number of discrete colors.

### SIMPLE COLOR RAMPS

The user can choose a single color ramp (chosen color to white) or a blended two-color ramp (one color towards white and then towards the second color). These color schemes have a limited number of discrete colors because each color scheme is relatively simple and composed of only a couple dozen base color steps. For a single-color ramp, the user can choose either 8, 9, 10, 11, 12, 15, 17, 19, 21, or 23 discrete colors. The ramps using fewer colors are the result of skipping every other color and reducing the use of white and colors near white. For a two-color ramp, the number of available colors is essentially doubled, as the same number of colors is applied to each color ramp, but the user specifies only the number of colors for a single-color ramp. The base colors used for these color schemes are blue, orange, red, green, magenta, and brown. The blue to orange or blue to red two-color ramps are useful for water temperature. The color ramps can be reversed by the user. Here are some examples:

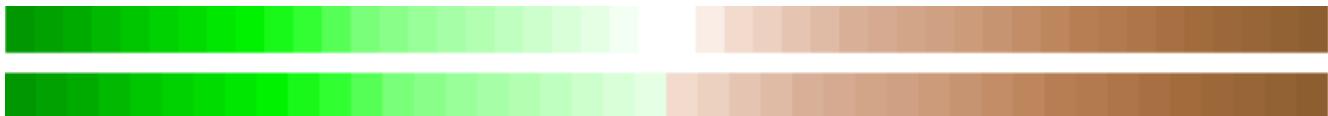
#### Blue to Orange



#### Blue to Red



#### Green to Brown



#### Green to Magenta



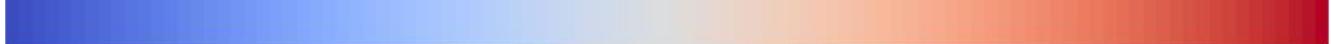
#### Brown to Magenta



## NAMED COLORMAPS

In addition to the simple color ramps, W2Anim offers a set of widely used colormaps developed by others. In these named colormaps, 256 index colors are used as the basis for interpolation and W2Anim allows the user to choose between 8 and 100 discrete colors drawn from the base colors. All color schemes used in W2Anim are free for use and redistribution, and their developers and any license agreements are listed below.

### CoolWarm



The CoolWarm color scheme is a blue-to-red diverging colormap with a smooth light gray transition in the middle. Diverging colormaps do not present perceptual issues or problems related to color-blindness. This colormap was developed by Kenneth Moreland and is free for others to use, modify, and redistribute ([public domain; CC0 creative commons](#)). See <https://www.kennethmoreland.com/color-advice/> for more information on this and some other color schemes. The CoolWarm colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### Turbo



The Turbo color scheme is a rainbow-like colormap that was designed to be more perceptually uniform than previous rainbow colormaps. The Turbo colormap is copyrighted (2019) by Google LLC under [version 2.0 of the Apache license](#), which allows for free, unlimited public use, modification, and redistribution. The Turbo colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### Jet



The Jet color scheme is representative of the classic rainbow colormap, which has been widely criticized for not being perceptually uniform and for issues related to color-blindness. It is included in W2Anim simply because some users may like it. The developer of the Jet colormap is unknown, but it is widely available and believed to be free to use, modify, and redistribute. The Jet colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### Viridis



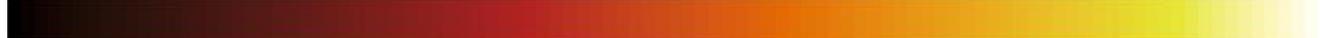
The Viridis color scheme is a perceptually uniform colormap with increasing luminance progressing from blue through green to yellow. This colormap was developed by Eric Firing and is free to use, modify, and redistribute ([public domain; CC0 creative commons](#)). The Viridis colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See <https://github.com/BIDS/colormap/blob/master/colormaps.py>.

### Plasma



The Plasma color scheme is a perceptually uniform colormap with increasing luminance progressing from blue through purple to yellow. This colormap was developed by Stefan van der Walt and Nathaniel Smith and is free to use, modify, and redistribute ([public domain; CC0 creative commons](#)). The Plasma colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See <https://github.com/BIDS/colormap/blob/master/colormaps.py>.

## BlackBody



The BlackBody color scheme is a perceptually uniform colormap with increasing brightness progressing from black through orange to yellow. The codes for this colormap were obtained from Kenneth Moreland at <https://www.kennethmoreland.com/color-advice/>. The BlackBody colormap has been in use for decades and the developer is unknown, with no known claims of intellectual property. It is shown here with 100 discrete colors interpolated from its 256 index colors.

## Inferno



The Inferno color scheme is a perceptually uniform colormap with increasing luminance that is similar to the BlackBody colormap but with some additional purple hues. This colormap was developed by Stefan van der Walt and Nathaniel Smith and is free to use, modify, and redistribute ([public domain; CC0 creative commons](#)). The Inferno colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See <https://github.com/BIDS/colormap/blob/master/colormaps.py>.

## Batlow



The Batlow color scheme is a perceptually uniform sequential-gradient colormap that varies from dark blue through green-brown to pink and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Batlow colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Oslo



The Oslo color scheme is a perceptually uniform sequential-gradient colormap that varies from black through blue to gray and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Oslo colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## GrayC



The GrayC color scheme is a perceptually uniform sequential-gradient colormap that varies from black through gray to white and was designed to be readable by color-vision deficient and color-blind people. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The GrayC colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Bam



The Bam color scheme is a perceptually uniform diverging-gradient colormap that varies from deep magenta through gray to dark green and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Bam colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Cork



The Cork color scheme is a perceptually uniform diverging-gradient colormap that varies from dark blue through gray to dark green and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Cork colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Roma



The Roma color scheme is a perceptually uniform diverging-gradient colormap that varies from dark orange to blue and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Roma colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Vik



The Vik color scheme is a perceptually uniform diverging-gradient colormap that varies from dark blue through gray to dark red and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his [Scientific Color Maps](#) package, which is free to use, modify, and redistribute ([MIT license](#)). The Vik colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

## Kindlmann



The Kindlmann color scheme is essentially a rainbow-type colormap with the colors adjusted for increasing luminance, thus making it more perceptually viable. The colormap was first proposed by Kindlmann, Reinhard, and Creem and is free to use, modify, and redistribute (no known claims of intellectual property). The codes for this colormap were obtained from Kenneth Moreland at <https://www.kennethmoreland.com/color-advice/>. The Kindlmann colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### Extended Kindlmann



The Extended Kindlmann color scheme modifies the Kindlmann colormap to add more hues and make the yellows more like pink. The resulting colormap retains an increasing brightness. The colormap is free to use, modify, and redistribute (no known claims of intellectual property). The codes for this colormap were obtained from Kenneth Moreland at <https://www.kennethmoreland.com/color-advice/>. The Extended Kindlmann colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### CubeYF



The CubeYF color scheme is a perceptually improved rainbow-like colormap created by Matteo Niccoli and available for [free use and redistribution](#). The CubeYF colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

### Cube1

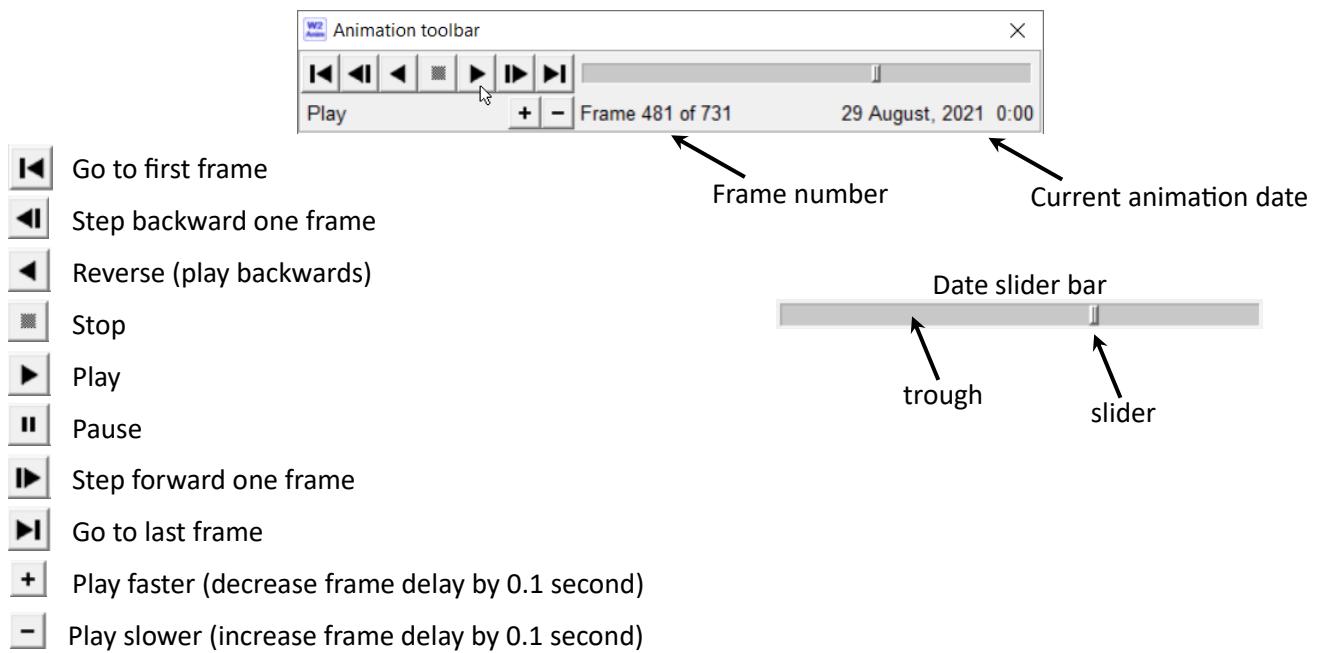


The Cube1 color scheme is another rainbow-like colormap created by Matteo Niccoli and available for [free use and redistribution](#). Compared to CubeYF, Cube1 has more red hues at the high end, but slightly deviates from 100% perceptuality. CubeYF is shown here with 100 discrete colors interpolated from its 256 index colors.

# ANIMATIONS AND EXPORTING VISUALIZATIONS

## THE ANIMATION TOOLBAR

One of the major goals in creating The W2 Animator was to allow users to produce visualizations of data and model results that could then be animated over time. Several of the current graph types in W2Anim can be animated. To use the animation features, a user first must bring up the Animation toolbar. That toolbar is activated by hovering the mouse cursor over any graph that can be animated, clicking the right mouse button (or typing Alt-p), and choosing the Animate option. The animation toolbar is a compact set of tools in a pop-up window; most of the tools and icons should be familiar to users, but the function of each button can be discerned by hovering the mouse over a button and reading the text that appears in the lower left corner of the toolbar. The following is a list of the features of the Animation toolbar:



The step forward and step backward buttons may be held down to repeat the operation in rapid succession. After pressing either Play or Reverse, the button is replaced by the Pause button and the Stop button is activated. Pressing Pause or Stop reverts the Play or Reverse button to its original image.

The slider bar may be dragged left or right with the left mouse button and the animation will run forward or backward to follow the date. Clicking the left mouse button in the trough to the left of the slider bar is the equivalent of one step backward. Clicking the left mouse button in the trough to the right of the slider bar is the equivalent of one step forward. Holding the left mouse button down in the trough to the left or right of the slider bar will repeat the step forward or backward. Clicking the right mouse button anywhere in the slider bar's trough will immediately jump to that date position. Dragging the right mouse button anywhere along the trough will animate the visualization forward or backward according to the date position on the slider bar.

Holding the Ctrl key down and clicking the left mouse button in the trough to the left of the slider bar will move the slider bar to the far left. Holding the Ctrl key down and clicking the left mouse button in the trough to the right of the slider bar will move the slider bar to the far right.

Each of the tools in the Animation toolbar can also be invoked with the keyboard. Hit the Tab key on the keyboard to move the focus from one item in the toolbar to the next. Type Shift-Tab to reverse the movement of the focus from one item to the previous item. When the focus is on one of the buttons, pressing the space bar will “press” the button once. When the focus is on the Step Forward or Step Backward button, holding the

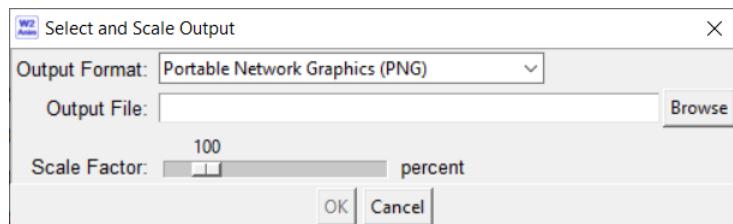
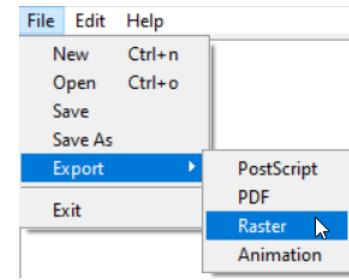
space bar down will cause the button to be invoked repeatedly (be careful with this, as it might mess things up). When the focus is on the slider bar, pressing the Up or Left arrow key will step backward; pressing the Down or Right arrow key will step forward. Pressing the Home key moves the slider to the far left. Pressing the End key moves the slider to the far right. Holding the Ctrl key down while pressing the Up or Left button will move the slider bar to the left by  $1/10^{\text{th}}$  of the number of frames. Similarly, holding the Ctrl key down while pressing the Down or Right button will move the slider bar to the right by  $1/10^{\text{th}}$  of the number of frames.

If the Animation toolbar is visible when a new animated graph is added to the canvas, the available date/time list for animation will be regenerated and the Animation toolbar may be refreshed automatically if the number of frames changes.

## EXPORTING CANVAS SNAPSHOTS

All objects on the drawing canvas can be exported to an Encapsulated PostScript (EPS) file, which in turn can be printed or imported to another program. If [Ghostscript](#) is installed as a [helper program](#), then W2Anim will use Ghostscript to convert the EPS output to either a Portable Document Format (PDF) file or to a raster image file in any of several formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF). To export a canvas snapshot, use the menu bar to select the File/Export menu and select the PostScript, PDF, or Raster option. The PDF and Raster options will only be active if Ghostscript has been installed and W2Anim was able to find it; see the menu for [helper programs](#) under the Help/Configure menu.

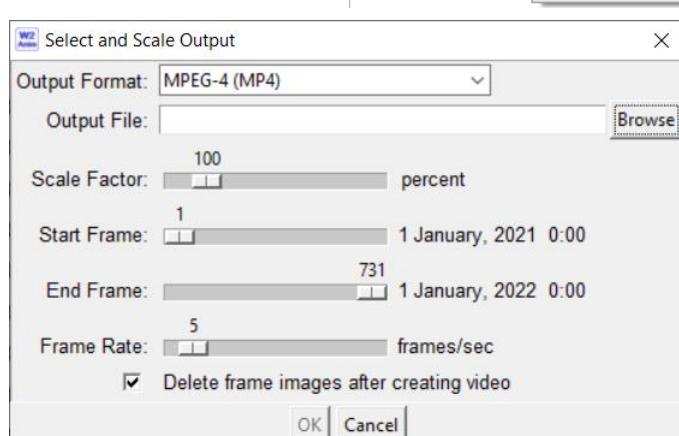
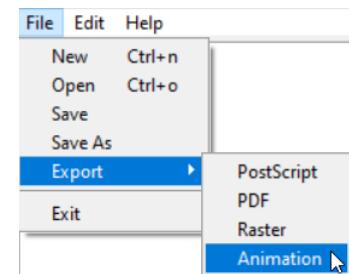
When exporting a raster image, the user must choose the file format, the file name, and a scale factor. On some high-resolution screens, the user may have to increase the scale factor above 100% to create a graphic the same size as what is seen on the W2Anim canvas.



## EXPORTING VIDEO FILES

If any of the animated graph types are present on the drawing canvas, and if both [Ghostscript](#) and [FFmpeg](#) have been installed as [helper programs](#), then W2Anim can be used to export a video file of the animated graphs. Everything on the drawing canvas will be included in the video. To create the video, W2Anim will draw the items on the canvas for the first specified date, export an EPS file, use Ghostscript to create a PNG image, and then move on to the next date to create the next image for the video. Once all of the user-specified frames of the video have been created in a temporary space, W2Anim will use FFmpeg to stitch the frames together to create the video in the user-specified [video format](#) (AVI, FLV, GIF, MOV, MP4).

On high-resolution computer screens, the user may have to specify a scale factor greater than 100% to reproduce the size of the canvas in W2Anim. If the user wishes to create the same video in more than one format, uncheck the box to delete the frame images, and the second video file can be created immediately after the first by using the same frame images.



## ALTERNATE EXPORT METHODS

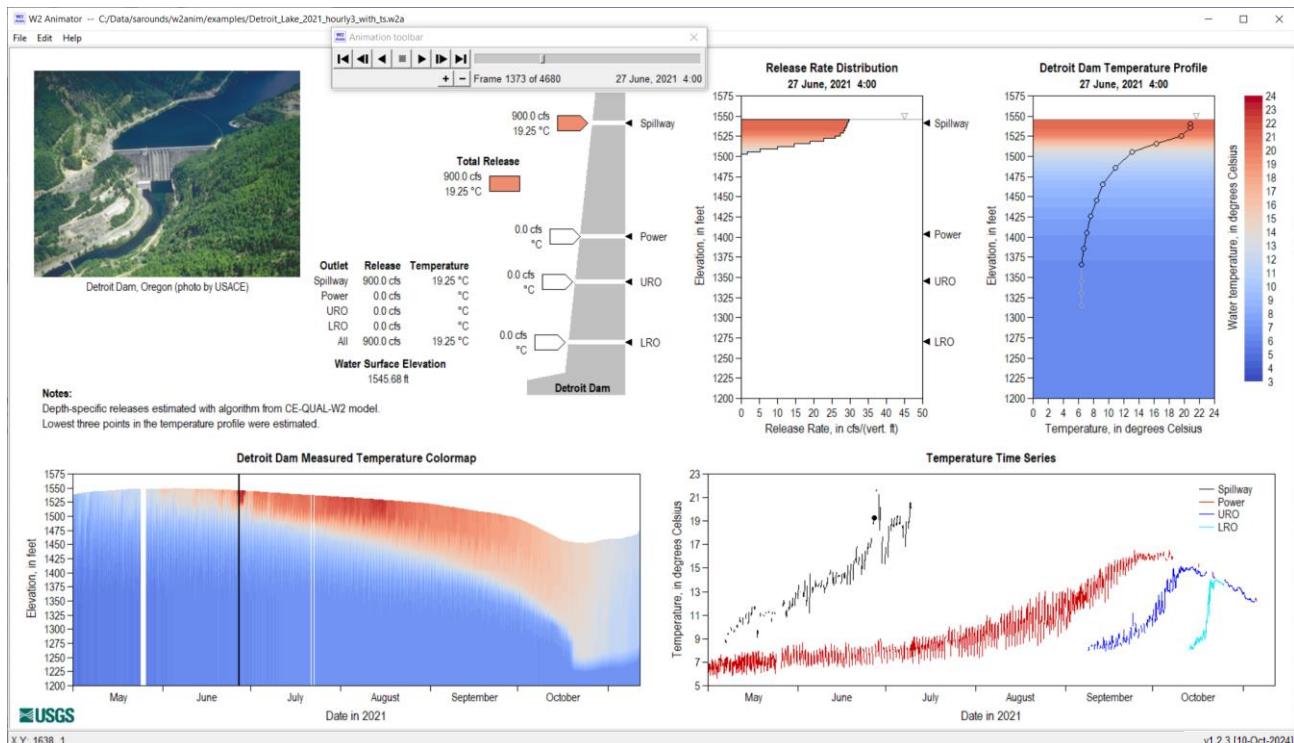
For those who cannot or choose not to install the W2Anim [helper programs](#), the native export option from W2Anim will be limited to a static encapsulated PostScript output format. Other methods can be employed, however, to capture screenshots and the animations displayed by W2Anim. Adept users will be able to find and use these other methods and programs; just a few are mentioned here.

### Screenshots

On a Windows-based computer, many options are available to capture a screenshot of the W2Anim canvas. For example, one can simply make the W2Anim canvas visible and then press the Alt-PrtScn keys on the keyboard, which copies a screenshot to the Windows clipboard. From there, the image may be pasted into any of a variety of Windows document-processing or graphics programs such as [IrfanView](#) or Word or PowerPoint. Some programs like Irfanview also have their own screen capture ability (see the Options/Capture menu option in Irfanview). Windows 10 and 11 have the Snipping Tool (or Snipping mode) for screen captures. Windows also has the built-in Xbox Game Bar (or Game Bar) for capturing screenshots. Given the number of built-in options to capture screenshots in Windows, along with a large number of free programs with such capabilities, W2Anim users should be able to create static images from W2Anim visualizations with ease, even without using the W2Anim helper programs.

### Video Capture

Exporting W2Anim animations directly to video files with the help of [Ghostscript](#) and [FFmpeg](#) is probably the easiest option, but other methods can be applied to capture W2Anim animations to video files. On a Windows-based computer, for example, the built-in Xbox Game Bar (or Game Bar) can be used to capture video from the user's computer screen. Just bring up the W2Anim visualization, start up a video capture session with the Game Bar, and begin animating the W2Anim visualization. When finished, stop the video capture. Easy instructions can be found online, or some simple shortcuts can be found under the Game Bar topic in the Windows Settings. Under Windows 11, the Snipping Tool also allows for video capture. Other programs for video capture are also available online, but the author of W2Anim cannot endorse any at this time.



## GOODNESS-OF-FIT STATISTICS

W2Anim can compute several goodness-of-fit statistics to compare measured and modeled vertical profiles or measured and modeled time-series. The goodness-of-fit statistics are always reported relative to the model dataset, such that a positive computed mean error, for example, implies a positive overall bias in the model results. The statistics are computed and reported for the entire time period of comparison as well as for each month of the comparison. The following statistics and parameters are computed:

$$\begin{aligned}\text{Mean Error: } ME &= \frac{1}{n} \sum (v_m - v_r) \\ \text{Mean Absolute Error: } MAE &= \frac{1}{n} \sum |v_m - v_r| \\ \text{Root Mean Squared Error: } RMSE &= \sqrt{\frac{1}{n} \sum (v_m - v_r)^2}\end{aligned}$$

where:

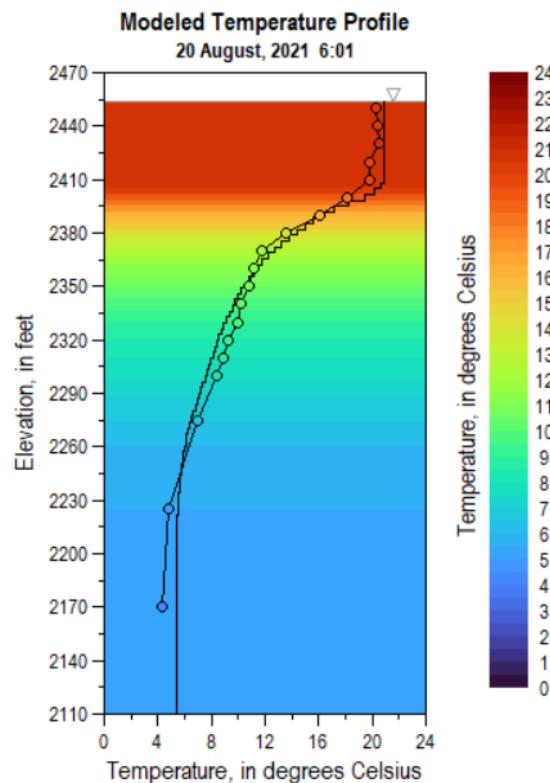
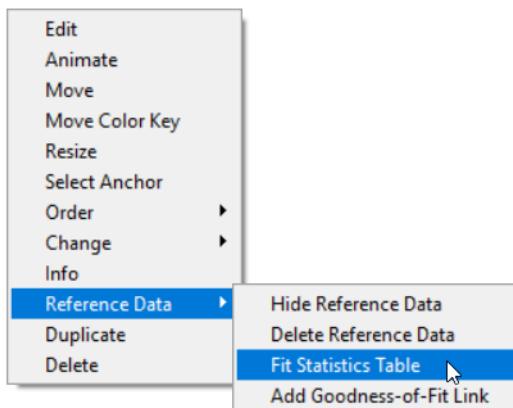
$ME$  is the mean error,  $n$  is the number of comparisons,  
 $MAE$  is the mean absolute error,  $v_m$  is a modeled value,  
 $RMSE$  is the root mean squared error, and  $v_r$  is a reference value.

When including a comparison in each statistic, a reference value must be found within some user-specified tolerance of the date/time of the modeled value; the default value is 10 minutes. When comparing vertical profiles, the modeled value for comparison to a measured value is either (1) taken from the model layer that encompasses the depth or elevation of the measured value's location, or (2) interpolated to the elevation or depth of the measured value.

## STATISTICS FOR W2 VERTICAL PROFILE GRAPHS

W2Anim allows a reference dataset to be plotted alongside model results in a W2 Vertical Profile graph, such as in the example at the right. The points represent a measured vertical profile of water temperature, whereas the solid stair-stepped line and the color highlighting represent the modeled temperatures.

To compute goodness-of-fit statistics for these modeled temperature profiles, hover the mouse over the graph and right-click (or type Alt-p) to bring up the menu, then choose the Reference Data/Fit Statistics Table option.



Choosing the Fit Statistics Table option will bring up a menu (seen at the right) that allows the user to choose whether the model profile will be vertically interpolated to each measured depth or elevation, or whether the comparison is made simply with the modeled value from the layer in which the measured point falls. The user also can choose whether to compute the fit statistics by month, and whether to calculate the statistics only for a certain range of dates.

Clicking on the OK button causes W2Anim to compute the

goodness-of-fit statistics and pop up a new window with the results, as shown at the right for the interpolated option.

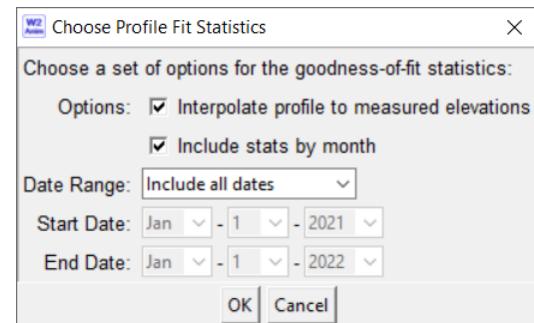
Fit statistics for the profile are reported for the aggregate total of comparison points and also as mean fit statistics generated from each profile. In the example at the right, 139,964 point comparisons were made and a total of 8,503 profiles were compared.

The fit statistics are computed for both the profile data as well as the modeled and measured water-surface elevations (if measured water-surface elevations are available). The fit

statistics are reported in the units currently being used in the visualization; in this example, that was degrees Celsius for temperature and feet for water-surface elevation.

The goodness-of-fit statistics are reported for the chosen date range, and also optionally by month. For the vertical profiles, each comparison of a model result to a measurement adds to the total number of comparisons (n), which explains why the n value for the temperature points is so much larger than the n value for the profiles or for the water-surface elevation statistics. In this example, some measured profiles were missing, which explains why the number of profiles compared (8503) is less than the number of water-surface elevations compared (8601).

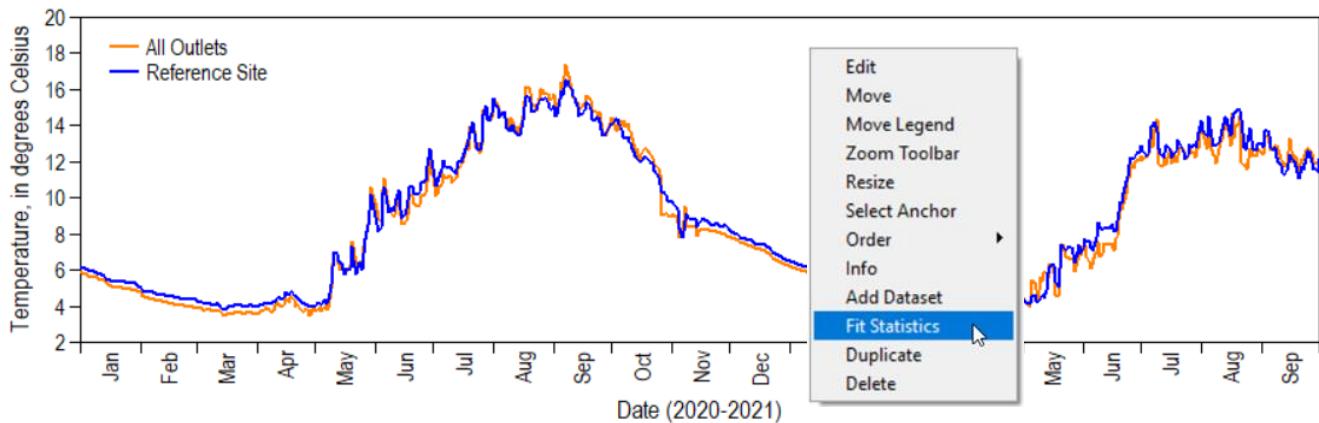
The results can be saved to a text file by clicking on the Save button. The table for the non-interpolated fit statistics is similar, but with a different message denoting the method of calculation. When a date range is specified by the user, that date range is also echoed to the reporting window and to the saved file.



Profile Goodness-of-Fit Statistics (Vertically Interpolated)												
	Goodness-of-Fit Statistics				Mean Fit Statistics By Profile				Goodness-of-Fit Statistics			
	Temperature (Celsius)				Temperature (Celsius)				Water-Surface Elevation (feet)			
	n	Mean Error	Mean Absolute Error	Root Mean Squared Error	n	Mean Error	Mean Absolute Error	Root Mean Squared Error	n	Mean Error	Mean Absolute Error	Root Mean Squared Error
All*	139964	0.2174	0.7661	1.0118	8503	0.2019	0.7566	0.9032	8601	-0.1022	0.1236	0.1757
Jan	10699	-0.5737	0.5748	0.5919	731	-0.5739	0.5750	0.5911	744	0.0332	0.0623	0.0998
Feb	9338	-0.5646	0.6769	0.9367	667	-0.5646	0.6769	0.7216	672	-0.1076	0.1148	0.1503
Mar	10408	0.4437	0.4547	0.5702	744	0.4436	0.4546	0.4861	744	-0.1631	0.1631	0.1665
Apr	9226	0.7802	0.8042	0.8967	659	0.7802	0.8042	0.8786	720	-0.1994	0.1997	0.2079
May	10466	0.6133	0.9239	1.1544	739	0.6185	0.9251	1.0698	740	-0.2601	0.2608	0.2806
Jun	12049	0.2513	0.7794	1.0909	711	0.2430	0.7722	1.0047	711	-0.3760	0.3760	0.3946
Jul	13766	0.7000	1.0191	1.4639	726	0.6996	1.0191	1.4058	727	-0.0956	0.0967	0.1122
Aug	13772	0.5841	0.8859	1.2551	725	0.5840	0.8858	1.2132	734	-0.0002	0.0321	0.0407
Sep	13401	0.6490	0.9670	1.1988	713	0.6482	0.9667	1.1767	713	0.0019	0.0224	0.0278
Oct	12610	0.3078	0.6859	0.8145	700	0.3081	0.6860	0.8004	704	-0.0018	0.0294	0.0416
Nov	13138	-0.2572	0.5581	0.6931	718	-0.2602	0.5601	0.6768	718	-0.0246	0.0739	0.1043
Dec	11091	-0.5686	0.7546	0.8016	670	-0.5728	0.7563	0.7999	674	-0.0285	0.0451	0.0589
Modeled profiles were vertically interpolated to match the measured vertical profile measurement points for each comparison. *All = All available dates.												
OK   Save												

## STATISTICS FOR TIME-SERIES GRAPHS

For time-series graphs, the user may generate goodness-of-fit statistics between any two time-series datasets present in the graph, but of course this option is meant to compare model results to a reference measurement dataset. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu, then select the Fit Statistics option:



The next step is to choose the datasets for the comparison. The “test” dataset could be the model results, and the reference dataset could be the measured time series. For convenience, the menu shows the user what line colors are associated with the chosen datasets, as well as whether they are shown (active) or hidden.

Computations are only done on test/reference data pairs where a reference value can be found within the match tolerance of the date/time of the test value.

The user may specify a specific date range for the calculation of goodness-of-fit statistics, and whether the fit statistics should be computed by month. After clicking the OK button, W2Anim computes the goodness-of-fit statistics and shows the results in a new window, as shown to the right. The legend entries for the test and reference datasets are noted in the header. As with the vertical profiles, fit statistics are computed for the user-specified date range, and also optionally by month. The results can be saved to a text file by clicking the Save button. When a date range is specified by the user, that date range is echoed to the reporting window and to the saved file.

	Goodness-of-Fit Statistics			
	Test: Temperature (C) - All Outlets			
	Reference: Reference Site			
	n	Mean Error	Mean Absolute Error	Root Mean Squared Error
All*	631	-0.2168	0.4005	0.4709
Jan	62	-0.3025	0.3025	0.3041
Feb	56	-0.3383	0.3383	0.3406
Mar	62	-0.3782	0.3782	0.3807
Apr	57	-0.2623	0.2981	0.3242
May	61	0.0252	0.3479	0.4557
Jun	58	-0.5375	0.6146	0.7031
Jul	61	-0.3347	0.4060	0.4912
Aug	62	-0.1810	0.4836	0.6201
Sep	60	0.2766	0.3600	0.4169
Oct	31	0.1367	0.5590	0.6172
Nov	30	-0.3707	0.4963	0.5122
Dec	31	-0.2957	0.2957	0.2973

\*All = All available dates

OK Save

# W2ANIM PROJECT FILES

Any visualization created in W2Anim can be recreated later by saving its input sources and object characteristics in a W2Anim project file. Previously saved project files may be opened from the menu bar under the File/Open option or by typing Ctrl-o. Loading a saved project will discard any objects that were on the drawing canvas prior to the load.

## OPENING A W2ANIM PROJECT FILE WITH A DOUBLE-CLICK

The Windows operating system allows users to open files and their associated programs by double-clicking on the file of interest in the File Explorer. Similar capabilities are built into the graphical user interfaces of other operating systems. Under Windows, saved W2Anim project files can be opened in The W2 Animator through the File Explorer by associating files with the “.w2a” file-name extension with the w2anim.bat Windows batch file. My copy of w2anim.bat is located at C:\Data\sarounds\w2anim and contains just one line:

C:\Data\sarounds\w2anim\w2anim.pl %\*

You will want to edit your copy to provide the proper path to your w2anim.pl file. To create the proper association between “.w2a” files and the w2anim.bat Windows batch file, follow these steps:

- Open the Windows File Explorer.
- In the File Explorer, navigate to any folder containing a saved W2Anim project file, such as the examples folder that was provided with the W2Anim scripts.
- Find a file with the .w2a file-name extension, right-click on it, and choose “Open with...”.
- A menu should pop up with a question such as “How do you want to open this file?”
- Check the box next to “Always use this app to open .w2a files”.
- Under “Other options” click on the “More apps” link.
- Scroll down and choose the “Look for another app on this PC” option.
- An “Open with...” dialogue box will appear. Navigate to the folder where the W2Anim scripts reside on your computer, then choose the “w2anim.bat” file.

As soon as you choose w2anim.bat as the program to associate with your .w2a files (W2Anim project files), Windows will run the w2anim.bat batch file to open W2Anim and load the project file on which you had originally right-clicked. You can close that instance of W2Anim at this point. Now you should be able to double-click on any .w2a in the File Explorer, and Windows should open up that saved project file in W2Anim.

### Associating an Icon with W2Anim in the File Explorer

Even if you are successful in associating the w2anim.bat batch file with all .w2a files in the File Explorer, Windows doesn't know that we have an icon file to associate with w2anim.bat. To make that association, you either need to find and run a separate program (several are available from the internet) or you need to edit the Windows registry, and the required registry edits require Administrator privileges. If you are successful in associating the w2anim.ico icon file with the .w2a file type in the Windows registry, the icon used in the File Explorer will identify .w2a files as W2Anim project files. Here are a couple screenshots from the File Explorer:

Name	Date modified	Type	Size
time_series2.w2a	6/19/2023 7:51 PM	W2A File	3 KB
time_series1.w2a	6/19/2023 7:51 PM	W2A File	2 KB
Willamette_River_streamflow.w2a	6/19/2023 7:51 PM	W2A File	3 KB
Columbia_River_streamflow.w2a	6/19/2023 7:50 PM	W2A File	2 KB
Libby_Dam_2020-21d.w2a	5/29/2023 2:18 PM	W2A File	17 KB
object_examples.w2a	5/29/2023 2:09 PM	W2A File	3 KB
object_examples2.w2a	5/29/2023 2:08 PM	W2A File	3 KB
photo_crop.w2a	5/29/2023 2:08 PM	W2A File	2 KB
photo_examples.w2a	5/29/2023 2:08 PM	W2A File	2 KB
Libby_Dam_2020-21.w2a	5/29/2023 8:17 AM	W2A File	15 KB
Koocanusa_wy2020_profiles.w2a	5/29/2023 8:16 AM	W2A File	3 KB

 time_series2.w2a W2A File 2.22 KB	 time_series1.w2a W2A File 1.89 KB
 Willamette_River_streamflow.w2a W2A File 2.24 KB	 Columbia_River_streamflow.w2a W2A File 1.91 KB
 Libby_Dam_2020-21d.w2a W2A File 16.9 KB	 object_examples.w2a W2A File 2.80 KB
 object_examples2.w2a W2A File 2.94 KB	 photo_crop.w2a W2A File 1.21 KB
 photo_examples.w2a W2A File	 Libby_Dam_2020-21.w2a W2A File

To tell Windows how to associate a “DefaultIcon” in the Windows registry with .w2a files and then to use that icon, several steps are required:

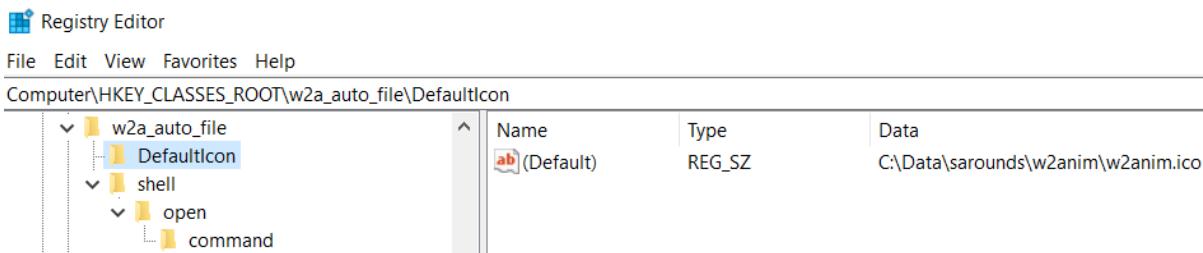
- Edit the Windows registry.
- Clear and reset the thumbnail cache in Windows.
- Remove the current icon cache in Windows and reboot.
- Force Windows to rebuild the icon cache database.

Each step can be done easily enough, but some steps require Administrator access and the user must be careful and pay attention to details. Here are some instructions that you may choose to follow. I followed these steps on my Windows 10 machine, and it worked well, but do so at your own risk.

### Edit the Windows Registry

This is the tough part, but it is straightforward, so just focus and proceed. Do the following:

- Type “regedit” into the Windows search bar, and it should find the Windows registry editor. You’ll need to either find and click on the “Run as administrator” option or you will need to right-click on the program name and choose the “Run as administrator” option. You’ll probably need to provide the proper credentials.
- In the registry editor, scroll all the way up to the top of the folder tree on the left side and find the HKEY\_CLASSES\_ROOT folder. Expand that part of the tree and find the entry for “.w2a”. Just one key is likely to be there, and it probably refers to “w2a\_auto\_file”. That’s good.
- Now, keep scrolling down the folder tree, well into the program names, until you find the entry for “w2a\_auto\_file”. The list should be in alphabetical order, and it is likely that the w2a\_auto\_file has a subfolder named “shell”. If you were to look in that part of the tree, you would find shell/open/command folders and the command folder would include an entry with a path name to the w2anim.bat file that you specified in the earlier part of this section of the manual.
- You need to add a new registry key under “w2a\_auto\_file”. Right-click on the “w2a\_auto\_file” entry in the folder tree on the left-hand side of the registry editor, and choose “New” and “Key”. The system will create what looks like a new folder under w2a\_auto\_file; type in a name of “DefaultIcon”.
- Now that you have a DefaultIcon key under w2a\_auto\_file, you need to set the value of that key. Left-click on the DefaultIcon key on the left-hand side, then notice the entry on the right-hand side, which should show one line. Double-click on the “(Default)” entry. The registry editor will pop up a menu and you should be able to type in a path to the w2anim.ico file that resides in the same folder as your W2Anim scripts. An example for my computer is shown below:



At this point, you should be able to simply close the registry editor. You have made the required change!

### Clear and Reset the Thumbnail Cache in Windows

For Windows 10, you may choose to follow the instructions at:

<https://www.tenforums.com/tutorials/5655-clear-reset-thumbnail-cache-windows-10-a.html>. The Disk Cleanup menu is activated by right-clicking on Drive C: in the File Explorer, choosing the Properties option, then clicking on the “Disk Cleanup” button. From there, choose the “Thumbnails” category and click the OK button.

## Remove the Current Icon Cache in Windows and Reboot

For Windows 10, you may choose to follow the instructions at:

<https://www.tenforums.com/tutorials/5645-rebuild-icon-cache-windows-10-a.html>. The instructions there can be boiled down to the following steps. Open a command window and enter the following five commands exactly as written, and one at a time. These commands will terminate your File Explorer program, then delete the icon cache database and the File Explorer's icon cache.

```
ie4uinit.exe -show  
taskkill /IM explorer.exe /F  
DEL /A /Q "%localappdata%\IconCache.db"  
DEL /A /F /Q "%localappdata%\Microsoft\Windows\Explorer\iconcache*"  
shutdown /r /f /t 00
```

After the last command above, your computer will reboot.

## Force Windows to Rebuild the Icon Cache

After rebooting, you need to force Windows to rebuild its icon cache database. The easiest way to do this is to change one of the default programs in the Windows Settings, and then change it back. That process invokes the program that will rebuild the icon cache. Follow these steps:

- Open the Windows Settings utility, either by typing “settings” into the Windows search bar, or by clicking on the Start icon (lower left of task bar) and selecting the icon shaped like a gear.
- Choose the “Apps” category, then the “Default apps” subject from the left-hand side.
- The easiest way to change a default is to select the “Photo viewer” app. Windows will bring up a menu with a list of potential programs. Remember the default, and choose a different option.
- After Windows sets the default program to that other app for viewing photos, just re-select the Photo viewer app and change it back to its original default. This action causes Windows to rebuild the icon cache database.



At this point, if all went well, your Windows File Explorer should recognize the W2Anim icon for .w2a files.

## W2ANIM PROJECT FILE FORMAT

The W2Anim project file is a simple text file that contains all of the information required to recreate a previously created visualization. By default, W2Anim project files have a “.w2a” file name extension. The characteristics of the canvas as well as each object on the canvas are saved in the W2Anim project file. All file names in the project file are saved with file paths relative to the location of the project file. Therefore, W2Anim project files can be moved to a different directory on a computer and they will still be properly read as long as the files they reference are also moved so that the relative path names are still valid.

The experienced W2Anim user will be able to decipher many of the saved parameters in W2Anim project files, such that previously saved visualizations can be adapted for, or used as templates for, new visualizations or updates with different model outputs.

Each W2Anim project file begins with a header that specifies when the file was created or updated along with the version of W2Anim that created the file. Those lines are followed by a section specifying canvas parameters, such as:

```
==== CANVAS ====  
width: 2000  
height: 750  
color: white  
text_slct: magenta  
snap2grid: 1  
grid_spac: 10  
==== END CANVAS ====
```

The width and height of the canvas and the grid spacing are specified in pixels. W2Anim use the RGB (Red Green Blue) color model, and colors are saved with names defined and standardized by the X Consortium (rgb.txt,v 10.41 94/02/20 18:39:36 rws Exp). See the color names and RGB codes in the w2anim\_rgb.pl source file if you need to track down a particular color name. Colors also can be expressed as an RGB hex code in #RRGGBB format (“red” would be #FF0000). *Snap to Grid* is either 1 (enabled) or 0 (disabled).

Following the Canvas section in the W2Anim project file is an optional section describing the potential presence of global date limits on any animated objects. That optional section might look like the following:

```
===== DATE LIMITS =====
gdt_begin: Jun-01-2020
gdt_end: Aug-31-2020
===== END DATE LIMITS =====
```

The *gdt\_begin* key word designates the global start date in Mon-DD-YYYY format, and the *gdt\_end* key word designates the global end date in Mon-DD-YYYY format. If no global date restrictions are present, then this entire section will not be present in the W2Anim project file.

Following the Canvas and optional Date Limits sections in the W2Anim project file is a potentially lengthy section describing each of the objects drawn on the canvas. The objects are saved in “drawing order,” where the first object in the list is drawn first, such that later objects could be drawn on top of previously drawn objects. The object list starts with the line:

```
===== OBJECTS ===== From lowest to highest
```

and ends with the line:

```
===== END OBJECTS =====
```

Within the objects section, the description of each object starts with a line denoting the object type and ends with a line that includes the word “end” and the object type. Object types include the following:

line, circle, ellipse, rectangle, diamond, polygon, polyline, text, image, graph

For example, a section of the W2Anim project file that describes a “rectangle” object would include the following lines:

```
rectangle
...a bunch of lines documenting certain parameters of the rectangle...
end rectangle
```

## KEY WORDS AND PARAMETERS IN W2ANIM PROJECT FILES

The following is an attempt to document the various parameters used in W2Anim project files. The key words are subject to change in later versions, but an attempt will be made to avoid such changes for backward compatibility.

### Canvas

width	canvas width, in pixels, starting at 0 and ranging to width-1
height	canvas height, in pixels, starting at 0 and ranging to height-1
color	background canvas color name or RGB code
text_slct	color name or RGB code for text selection and graph frame selection
snap2grid	snap to grid option, where 1 is enabled and 0 is disabled
grid_spac	grid spacing, in pixels

## Line Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, midpoint)
color	line color name or RGB code
width	line width, in pixels
arrow	arrowhead code: 0=none, 1=start, 2=end, 3=both
ahd1	arrowhead center length
ahd2	arrowhead side length
ahd3	arrowhead half width
coordlist	comma-separated list of the X,Y coordinates of the two points of the line, in pixels

## Circle Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
coordlist	comma-separated list of the X,Y coordinates of the two opposite corners of the circle's bounding box, in pixels

## Ellipse Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
hw	half width, in pixels
hh	half height, in pixels

## Rectangle and Diamond Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels

fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
smooth	code for smoothed corners, where 1 is enabled and 0 is disabled
coordlist	comma-separated list of the X,Y coordinates of the four corners of the rectangle, in pixels

### **Polygon Objects**

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, corner, midpoint, center, center_rot)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
coordlist	comma-separated list of the X,Y coordinates of the vertices of the polygon, in pixels

### **Polyline Objects**

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, corner, midpoint, center, center_rot)
color	line color name or RGB code
width	line width, in pixels
angle	rotation angle, in degrees counterclockwise starting from east
arrow	arrowhead code: 0=none, 1=start, 2=end, 3=both
ahd1	arrowhead center length
ahd2	arrowhead side length
ahd3	arrowhead half width
coordlist	comma-separated list of the X,Y coordinates of the points along the line, in pixels

### **Text Objects**

text	The desired string of text. No need for quotation marks.
x	X location of anchor point
y	Y location of anchor point
anchor	anchor point type (w, nw, n, ne, e, se, s, sw, center)
color	color name or RGB code for text color
family	font family name, such as Arial or Calibri
size	font size, in points
weight	text code for font weight (bold, normal)
slant	numeric code for font slant (1=italic, 0=normal)
underline	numeric code for font underline (1=enabled, 0=disabled)
angle	rotation angle, in degrees counterclockwise starting from east

## Image Objects

x	X location of anchor point
y	Y location of anchor point
anchor	anchor point type (w, nw, n, ne, e, se, s, sw, center)
angle	rotation angle, in degrees counterclockwise starting from east
crop	comma-separated list of crop fraction factors for left, right, top, and bottom, where 0.0 means no cropping from that side, and the sum of the left and right crop factors and the sum of the top and bottom crop factors cannot be as large as 1.0
scale	numeric multiplier for scaling the image, where 1.0 means no scaling
flip	flip type code: none, h=left to right, v=top to bottom, vh=left to right and top to bottom
file	relative path and file name of the image

## Linked Objects

Several types of objects can be linked to time-series values generated from certain graph types. The types of objects that can be linked to a graph time series are text, circle, ellipse, rectangle, diamond, and polygon. When a link is present, the following lines are added to the W2Anim project file for those linked objects:

In_gnum	graph number to which the object is linked
In_type	link parameter type (Water Surface Elevation, Flow, Temperature)
In_outlet	link outlet name (outlet names specified in flow file, or All Outlets)
In_form	link form (Text, Circle, Ellipse, Rectangle, Diamond, Polygon)
In_units	link units (such as ft, m, cfs, cms, Celsius, Fahrenheit)
In_digits	number of digits after the decimal in a text link

If the linked object is text showing a goodness-of-fit statistic, then the properties of the linked object are slightly different, as follows:

In_gnum	graph number to which the object is linked
In_form	link form ("stat" is the only option here)
In_type	link statistic type (n, me, mae, rmse)
In_tol	number of minutes to allow (plus or minus) as a window to match dates between the modeled and measured vertical profiles, for computation of a goodness-of-fit statistic
In_interp	code denoting whether the model profile is to be vertically interpolated to the depth or elevation of a point in the measured profile (0=no, 1=yes)
In_digits	number of digits to display after the decimal (0 for type "n")

## Graph Objects

The several graph objects are distinguished from each other by codes associated with the "meta" key word, which for convenience and clarity is the first item listed in the W2Anim project file for a graph object.

### **Measured Vertical Profile**

This graph type plots elevation or depth on the Y axis and the value of a measured parameter on the X axis. Graphs are plotted for a particular date, and can be animated over time.

meta	data_profile
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)

color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
src_file	relative path and file name of the data file containing measured vertical profiles over time
parm	the measured parameter name, such as <i>Temperature</i>
parmuunits	parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>
prof_type	profile type (standard, difference)
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or "auto")
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis

gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

If the profile type (prof\_type) is set to “difference” then several other key words are required. For a difference profile with a constant reference value, the parameters are:

dref_type	difference type (Constant)
dref_val	the constant reference value (a number)

For a difference profile with a time-series reference value, the parameters are:

dref_type	difference type (Time-Series)
dref_file	file name of the reference time series
dref_ftyp	file type code for the reference time series (see <a href="#">Recognized File Types</a> )
dref_line	number of data lines in reference time-series file
dref_parm	chosen parameter name in the time-series input file
dref_ctyp	unit conversion choice (see <a href="#">Unit Conversions</a> )
dref_tol	number of minutes to allow (plus or minus) as a window to match dates between the measured and reference time series
dref_byr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year, used only for W2 time-series file types
dref_tzof	time offset to convert model time to local standard time (default: +00:00), used only for W2 time-series file types

### Measured Vertical Profile Colormap

This graph type plots elevation or depth on the Y axis and time on the X axis. Values of the measured parameter are represented with a color scheme in vertical profiles, where the measured profiles are interpolated to vertical increments of 1 foot or less.

The key words and parameters used for this graph type are the same as those for the Measured Vertical Profile, except for the following:

meta	data_profile_cmap
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD-YYYY)

In addition, the key word add\_cs is not needed because a color scheme is always used, and the key words gs\_size and gs\_weight are not used for this graph type because it does not have a graph subtitle.

### Vertical Withdrawal Zone from Measured Data

This graph type plots elevation or depth on the Y axis and a depth- or elevation-specific horizontal velocity or flow rate per unit height in a vertical withdrawal zone next to a set of dam outlets. The key words and parameters used for this graph type have many in common with those from the Measured Vertical Profile. Additional or modified key words and parameters are as follows:

meta	vert_wd_zone
------	--------------

<code>wt_file</code>	relative path and file name of the data file containing measured vertical temperature profiles over time
<code>flow_file</code>	relative path and file name of a data file containing time-series of release rates from each of the dam outlets
<code>bth_file</code>	relative path and file name of a CE-QUAL-W2 bathymetry file that is relevant for describing the bathymetry next to the dam
<code>wd_alg</code>	code for the withdrawal algorithm to use (W2 original, Libby Dam)
<code>seg</code>	model segment number that is next to the dam
<code>elbot</code>	elevation of the top of the bottom-most layer in the W2 bathymetry file
<code>cs_min</code>	minimum temperature value for the color-highlighting scheme
<code>cs_max</code>	maximum temperature value for the color-highlighting scheme
<code>qunits</code>	X axis flow-like units (cfs/ft, cms/m, ft/s, m/s)
<code>wt_units</code>	water temperature units (Celsius, Fahrenheit)

Key words from the Measured Vertical Profile graph that are not used for the Vertical Withdrawal Zone include the following:

`src_file`, `parm`, `parmunits`, `prof_type`

as well as all of the key words associated with the difference profile type (`prof_type`):

`dref_type`, `dref_val`, `dref_file`, `dref_ftyp`, `dref_line`, `dref_parm`, `dref_ctyp`, `dref_tol`, `dref_byr`, `dref_tzof`

If the withdrawal algorithm (`wd_alg`) code is set to "Libby Dam," then a few additional lines are expected to bring in information and parameters on the variable bulkhead configurations:

<code>lbc_file</code>	relative path and file name of a Libby-Dam-type bulkhead configuration time-series file
<code>bh_show</code>	code denoting whether the bulkhead configuration is shown on the graph (1=yes, 0=no)
<code>bh_docked</code>	code denoting whether the bulkhead diagram is "docked" to the graph or has been repositioned to an alternate location by the user (0=no, 1=yes)
<code>bh_xpos</code>	X pixel location of upper left corner of bulkhead diagram
<code>bh_ypos</code>	Y pixel location of upper left corner of bulkhead diagram
<code>bh_font</code>	font family used in the bulkhead diagram
<code>bh_size</code>	font size used in bulkhead diagram, in points
<code>bh_weight</code>	font weight used in bulkhead diagram (normal, bold)
<code>bh_tcolor</code>	color name or RGB code for text color in bulkhead diagram
<code>bh_bwidth</code>	line width for box grid in bulkhead diagram
<code>bh_bcolor</code>	color name or RGB code for lines in box grid of bulkhead diagram
<code>bh_bcellw</code>	box cell width in bulkhead diagram, in pixels
<code>bh_bcellh</code>	box cell height in bulkhead diagram, in pixels

## W2 Vertical Profile

This graph type plots elevation or depth on the Y axis and the value of a modeled parameter on the X axis. Graphs are plotted for a particular date, and can be animated over time. For completeness, all of the key words and parameters for the W2 Vertical Profile graph are as follows:

<code>meta</code>	<code>w2_profile</code>
<code>gnum</code>	graph number, used internally for links
<code>x</code>	X location of anchor point for graph frame
<code>y</code>	Y location of anchor point for graph frame
<code>xc</code>	X location of graph frame center
<code>yc</code>	Y location of graph frame center
<code>anchor</code>	anchor point type (corner, midpoint, center)
<code>color</code>	line color name or RGB code for graph frame (black)

width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file
src_type	type of W2 output file used (W2 Spreadsheet File, W2 Contour File, W2 Vector File, or W2 Lake Contour File)
src_file	relative path and file name of a CE-QUAL-W2 spreadsheet, contour, vector, or lake contour file
src_lines	number of lines to read in the source file, for purposes of making a progress bar (omitted for a W2 vector file, where the progress bar uses the file size in bytes)
tplot	code denoting whether a W2 contour file uses the Tecplot format (0=no, 1=yes) (omitted for W2 spreadsheet, vector, and lake contour source files)
parm	the modeled parameter name, such as <i>Temperature</i>
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmuunits	parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>
ctype	unit conversion choice (see <a href="#">Unit Conversions</a> )
seg	model segment number of interest for the vertical profile
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the output file to skip (0=none, 1=every other, etc.)
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or "auto")
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis

xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

## W2 Vertical Profile Colormap

This graph type plots elevation or depth on the Y axis and time on the X axis. Values of the modeled parameter are represented with a color scheme in vertical profiles, where the modeled values are displayed for each active cell in the profile.

The key words and parameters used for this graph type are the same as those for the W2 Vertical Profile, except for the following:

meta	w2_profile_cmap
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)

In addition, the key word add\_cs is not needed because a color scheme is always used, and the key words gs\_size and gs\_weight are not used for this graph type because it does not have a graph subtitle.

## W2 Longitudinal Slice

This graph type plots elevation or depth on the Y axis and longitudinal distance on the X axis. Values of the modeled parameter throughout a longitudinal slice through the model domain are represented with a color scheme, where the modeled values are displayed for all active cells in the chosen longitudinal slice. For completeness, all of the key words and parameters for the W2 Longitudinal Slice graph are as follows:

meta	w2_slice
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)

width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
src_type	type of W2 output file used (W2 Contour File, W2 Vector File)
w2l_file	file name of W2 vector file, if vector input source type is used (omitted when using W2 contour file as input)
cpl_info	three values: file index number, Tecplot code, and number of lines to read in the contour file. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info, cpl_files, and bth_files key words will be present. (omitted when using W2 vector file as input)
cpl_files	two values: file index number, and relative path and name of a CE-QUAL-W2 contour file (omitted when using W2 vector file as input)
bth_files	two values: file index number, and relative path and name of a CE-QUAL-W2 bathymetry file
seg_list	text string showing the segments included in the longitudinal slice
wb_list	text string showing the waterbodies included in the longitudinal slice
parm	the modeled parameter name, such as <i>Temperature</i>
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmuunits	parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>
ctype	unit conversion choice (see <a href="#">Unit Conversions</a> )
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the contour file to skip (0=none, 1=every other, etc.)
dt_limits	code designating whether date restrictions are in place (1=yes, 0=no)
dt_begin	begin date for date restrictions, if present (Mon-DD-YYYY format); absent if dt_limits = 0
dt_end	end date for date restrictions, if present (Mon-DD-YYYY format); absent if dt_limits = 0
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or "auto")
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
xtitle	X axis title text
xfont	X axis font family

xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum longitudinal distance value for the X axis
xmax	maximum longitudinal distance value for the X axis
xmajor	major tick label spacing for the X axis, or "auto"
xflip	code denoting whether the X axis should be flipped (0=no, 1=yes)
xunits	X axis units (miles, kilometers)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
stype	segment axis type (none, above X axis, below X axis, replace X axis)
sfont	segment axis font family
st_size	segment axis title font size, in points
st_weight	segment axis title font weight (normal, bold)
sl_size	segment axis label font size, in points
sl_weight	segment axis label font weight (normal, bold)
stic_loc	segment axis tick mark location (upstream edge, center, downstream edge)
smajor	segment axis major tick label spacing, or "auto"
sgrid	segment axis vertical grid lines at major tick label spacing (0=off, 1=on)
sgrid_col	segment axis vertical grid line color at major tick label spacing
bgrid	segment axis vertical grid lines at branch boundaries (0=off, 1=on)
bgrid_col	segment axis vertical grid line color at branch boundaries
stitle	segment axis title text
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

## W2 Outflow Profile

This graph type plots elevation or depth on the Y axis and a depth- or elevation-specific horizontal velocity or flow rate per unit height in a modeled vertical withdrawal zone next to a set of dam outlets. For completeness, all of the key words and parameters for the W2 Outflow Profile graph are as follows:

meta	w2_outflow
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center

yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file
qla_file	relative path and file name of a CE-QUAL-W2 “qlayers” output file
qla_lines	number of lines to read in the qlayers file, for purposes of making a progress bar
seg	model segment number of interest for the vertical profile
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the qlayers output file to skip (0=none, 1=every other, etc.)
qla_parm	code denoting whether a modeled parameter is used for color highlighting (0=no, 1=yes)
src_type	type of W2 output file used for color highlighting (W2 Spreadsheet File, W2 Contour File, W2 Vector File, or W2 Lake Contour File)
src_file	relative path and file name of a CE-QUAL-W2 spreadsheet, contour, vector, or lake contour file
src_lines	number of lines to read in the source file, for purposes of making a progress bar (omitted for a W2 vector file, where the progress bar uses the file size in bytes)
tplot	code denoting whether a W2 contour file uses the Tecplot format (0=no, 1=yes) (omitted for the W2 spreadsheet, vector, and lake contour source types)
parm	the modeled parameter name for color highlighting, such as <i>Temperature</i>
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmunits	parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>
ctype	unit conversion choice for the color highlight parameter (see <a href="#">Unit Conversions</a> )
parm_skip	number of dates in the parameter output file to skip (0=none, 1=every other, etc.)
match_tol	number of minutes to allow (plus or minus) as a window to match dates between the qlayers input and the parameter highlighting input
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points

kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
qunits	X axis flow-like units (cfs/ft, cms/m, ft/s, m/s)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

## W2 Time/Distance Map

This graph type plots date/time on one axis and longitudinal distance on the other axis, then uses colors from a color scale to represent the values of a W2 modeled parameter or parameter difference. All of the key words and parameters for the W2 Time/Distance Map are as follows:

meta	w2_tdmapper
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
map_type	the type of time/distance map (standard, parmdiff, filediff) The code is parmdiff for a difference plot using “Different Parameter, Same Run.” The code is filediff for a difference plot using “Same Parameter, Different Run.”

con_file	relative path and file name of a CE-QUAL-W2 control file
src_type	type of W2 output file used for plotting data (W2 Contour File, W2 Vector File, W2 River Contour File, W2 SurfTemp File, W2 VolTemp File, or W2 FlowTemp File)
w2l_file	file name of W2 vector file, if vector input source type is used
src_file	file name of a W2 SurfTemp, W2 VolTemp, or W2 FlowTemp output file, if any of these sources is used as input
src_lines	number of lines to read in the source file, for purposes of making a progress bar (used here only for SurfTemp, VolTemp, and FlowTemp source files)
cpl_info	three values: file index number, Tecplot code, and number of lines to read in the contour file. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info, cpl_files, and bth_files key words will be present. (omitted when not using W2 contour file as input)
cpl_files	two values: file index number, and relative path and name of a CE-QUAL-W2 contour file (omitted when not using W2 contour file as input)
riv_info	three values: file index number, starting branch number, and number of lines to read in the river contour file. If more than one river contour file must be read, more than one line with the riv_info and riv_files key words will be present. (omitted when not using W2 river contour file as input)
riv_files	two values: file index number, and relative path and name of a CE-QUAL-W2 river contour file (omitted when not using W2 river contour file as input)
bth_files	two values: file index number, and relative path and name of a CE-QUAL-W2 bathymetry file. A bathymetry file is needed for each W2 waterbody that is included.
src_type2	type of W2 output file used as a second input source for plotting differences (W2 Contour File, W2 Vector File, W2 River Contour File, W2 SurfTemp File, W2 VolTemp File, or W2 FlowTemp File) (used only when map_type is filedif)
match_tol	number of minutes to allow (plus or minus) as a window to match dates between the first and second datasets for plotting differences (used only when map_type is filedif)
w2l_file2	file name of W2 vector file for second source input for plotting differences, if vector input source type is used for that second input file (used only when map_type is filedif)
src_file2	file name of a W2 SurfTemp, W2 VolTemp, or W2 FlowTemp output file for second source input for plotting differences, if any of these sources is used for that second input file (used only when map_type is filedif)
src_line2	number of lines to read in the file for second source input for plotting differences, for purposes of making a progress bar (used here only for SurfTemp, VolTemp, and FlowTemp source files) (used only when map_type is filedif)
cpl_info2	three values: file index number, Tecplot code, and number of lines to read in the contour file if a contour file is used for second source input for difference plots. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info2 and cpl_file2 key words will be present. (omitted when not using W2 contour file as input for second source inputs) (used only when map_type is filedif)
cpl_file2	two values: file index number, and relative path and name of a CE-QUAL-W2 contour file if a contour file is used for second source input for difference plots

	(omitted when not using W2 contour file as input for second source inputs) (used only when map_type is filediff)
riv_info2	three values: file index number, starting branch number, and number of lines to read in the river contour file if a river contour file is used for second source input for difference plots. If more than one river contour file must be read, more than one line with the riv_info2 and riv_file2 key words will be present. (omitted when not using W2 river contour file as input for second source inputs) (used only when map_type is filediff)
riv_file2	two values: file index number, and relative path and name of a CE-QUAL-W2 river contour file if a river contour file is used for second source input for difference plots (omitted when not using W2 river contour file as input for second source inputs) (used only when map_type is filediff)
seg_list	text string showing the segments included in the time/distance map
wb_list	text string showing the waterbodies included in the time/distance map
parm	the modeled parameter name, such as <i>Temperature</i>
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
ctype	unit conversion choice (see <a href="#">Unit Conversions</a> )
parm2	the second modeled parameter name, such as <i>Temperature</i> (used only when map_type is parmdiff)
parm2_div	name of a modeled parameter name to divide into the second chosen parameter, or None (used only when map_type is parmdiff)
ctype2	unit conversion choice for second parameter (see <a href="#">Unit Conversions</a> ) (used only when map_type is parmdiff)
diff_swap	code to reverse the order of a calculated parameter difference (0=no, 1=yes) (used only when map_type is parmdiff or filediff)
parmundits	parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>
prof_stat	profile statistic (Surface value, Volume-weighted, Flow-weighted) The Flow-weighted statistic currently is only available for W2 FlowTemp output files. The W2 river contour file only contains surface values.
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the input source file to skip (0=none, 1=every other, etc.)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color scheme
cs_max	maximum parameter value for the color scheme
cs_major	scale interval used for color scheme legend (number, or "auto")
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points

kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
date_axis	code denoting which axis is the date/time axis (X or Y)
ttitle	date/time axis title text
tfont	date/time axis font family
tt_size	date/time axis title font size, in points
tt_weight	date/time axis title font weight (normal, bold)
tl_size	date/time axis tick label font size, in points
tl_weight	date/time axis tick label font weight (normal, bold)
tmin	minimum date (Mon-DD-YYYY) or Julian date value for the date/time axis
tmax	maximum date (Mon-DD-YYYY) or Julian date value for the date/time axis
tmajor	major tick label spacing for the date/time axis, in days, or "auto"
ttype	date/time axis type (Date/Time, Julian Date)
tflip	code for flipping the date/time axis (0=no, 1=yes)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for a Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dtitle	distance axis title text
dfont	distance axis font family
dt_size	distance axis title font size, in points
dt_weight	distance axis title font weight (normal, bold)
dl_size	distance axis tick label font size, in points
dl_weight	distance axis tick label font weight (normal, bold)
dmin	minimum value for the distance axis
dmax	maximum value for the distance axis
dmax_auto	code denoting whether the maximum value for the distance axis should be calculated from the minimum distance value and the map's total distance (0=no, 1=yes)
dfirst	value for the first major tick mark on the distance axis
dmajor	major tick label spacing for the distance axis (number, or "auto")
dflip	code for flipping the distance axis (0=no, 1=yes)
dunits	distance axis units (miles, kilometers)
gtitle	graph title text
gstitle	graph subtitle text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)
hidetitle	code denoting whether to hide the graph title and subtitle (0=no, 1=yes)
hidetaxis	code denoting whether to hide the date/time axis (0=no, 1=yes)
hidedaxis	code denoting whether to hide the distance axis (0=no, 1=yes)

## Time-Series Graph

This graph type plots a parameter value on the Y axis and time on the X axis. The key words and parameters for the Time-Series graph are as follows:

meta	time_series
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center

yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xmajor	major tick label spacing for the X axis, or "auto"
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum parameter value for the Y axis
ymax	maximum parameter value for the Y axis
ymajor	major tick label spacing for the Y axis
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gridx	code to enable vertical grid lines (1=enable, 0=disable)
gridy	code to enable horizontal grid lines (1=enable, 0=disable)
gridwidth	width of any enabled grid lines (default is 1 pixel)
gridcolor	color of any enabled grid lines (default is #COCOCO, a light gray)
leg_title	legend title text (can be blank)
legfont	legend font family
lt_size	legend title font size, in points
lt_weight	legend title font weight (normal, bold)
le_size	legend entry font size, in points
le_weight	legend entry font weight (normal, bold)
xleg_off	X distance offset for left edge of legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of legend, in pixels from the top edge of the graph frame
gap_tol	gap tolerance for breaking the lines of time-series datasets (default is 2.0 days)
ts_type	time-series parameter type (user specified)
ts_units	time-series parameter units; <i>Celsius</i> or <i>Fahrenheit</i> when parameter is <i>Temperature</i>

The rest of the key words and parameters for a time-series graph each start with a dataset number (beginning with zero) as the first parameter, followed by a comma and the second parameter value. These key words and parameters are repeated as often as necessary to include all of the datasets that are included in the graph.

add_data	set number, relative path and file name of time-series data file
add_ftype	set number, file type code (see <a href="#">Recognized File Types</a> )
add_ctype	set number, unit conversion choice (see <a href="#">Unit Conversions</a> )
add_parm	set number, parameter name choice from input file
add_show	set number, code denoting whether dataset is shown (1) or hidden (0)
add_width	set number, line width in pixels
add_color	set number, color name or RGB code for the line color
add_text	set number, legend text for the dataset
add_byear	set number, base year for which a JDAY of 1.0 equals the start of Jan-01 on that year, or "n/a"
add_tzoff	set number, time offset (default: +00:00), only for W2 time-series file types
add_seg	set number, model segment number of interest for the input data, or "n/a"

### Linked Time-Series Graph

Two of the W2Anim graph types (Measured Vertical Profile, Vertical Withdrawal Zone from Measured Data) allow for a time-series graph to be created and linked to one of the time-series datasets associated with the original graph. This capability likely will be expanded to some other graph types later. These linked time-series graphs are similar to a regular time-series graph, but have at least one dataset that is linked to another graph.

This graph type plots a parameter value on the Y axis and time on the X axis. The key words and parameters for the Linked Time-Series graph are as follows:

meta	linked_time_series
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xmajor	major tick label spacing for the X axis, or "auto"
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points

yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum parameter value for the Y axis
ymax	maximum parameter value for the Y axis
ymajor	major tick label spacing for the Y axis
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gridx	code to enable vertical grid lines (1=enable, 0=disable)
gridy	code to enable horizontal grid lines (1=enable, 0=disable)
gridwidth	width of any enabled grid lines (default is 1 pixel)
gridcolor	color of any enabled grid lines (default is #COCOCO, a light gray)
leg_title	legend title text (can be blank)
legfont	legend font family
lt_size	legend title font size, in points
lt_weight	legend title font weight (normal, bold)
le_size	legend entry font size, in points
le_weight	legend entry font weight (normal, bold)
xleg_off	X distance offset for left edge of legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of legend, in pixels from the top edge of the graph frame
gap_tol	gap tolerance for breaking the lines of time-series datasets (default is 2.0 days)
ts_gnum	graph number to which the linked time-series graph is linked
ts_type	time-series parameter type (determined by the linked parameter)
ts_units	time-series parameter units; specified when link is created
ts_show	comma-separated list of codes for each outlet, and All Outlets, denoting whether each dataset is shown (1) or hidden (0); ignored for Water Surface Elevation
ts_width	comma-separated list of line widths for each outlet, and All Outlets, in pixels; only the first entry is used for Water Surface Elevation
ts_color	comma-separated list of line color names or RGB codes for each outlet, and All Outlets; only the first entry is used for Water Surface Elevation

The rest of the key words and parameters for a linked time-series graph are only relevant if the user has added extra time-series datasets to the linked time-series graph. Each of these lines starts with a dataset number (beginning with the next dataset number after accounting for the outlets and All Outlets) as the first parameter, followed by a comma and the second parameter value. These key words and parameters are repeated as often as necessary to include all of the added datasets that are included in the graph.

add_data	set number, relative path and file name of time-series data file
add_ftype	set number, file type code (see <a href="#">Recognized File Types</a> )
add_ctype	set number, unit conversion choice (see <a href="#">Unit Conversions</a> )
add_parm	set number, parameter name choice from input file
add_show	set number, code denoting whether dataset is shown (1) or hidden (0)
add_width	set number, line width in pixels
add_color	set number, color name or RGB code for the line color
add_text	set number, legend text for the dataset
add_byear	set number, base year for which a JDAY of 1.0 equals the start of Jan-01 on that year, or "n/a"
add_tzoff	set number, time offset (default: +00:00), only for W2 time-series file types
add_seg	set number, model segment number of interest for the input data, or "n/a"

## REFERENCES CITED

Howington, S.E., 1990, Simultaneous, multiple-level withdrawal from a density stratified reservoir: U.S. Army Corps of Engineers Technical Report W-90-1, 68 p. plus appendix, accessed October 30, 2022, at <https://erdc-library.erdc.dren.mil/jspui/handle/11681/4366>.

Rounds, S.A., and Stratton Garvin, L.E., 2022, Tracking heat in the Willamette River system, Oregon: U.S. Geological Survey Scientific Investigations Report 2022–5006, 47 p., <https://doi.org/10.3133/sir20225006>.