

Minnesota's Lake Superior Coastal Program

St. Louis River Area of Concern (AOC) Data Visualization

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November 30, 2016

MLSCP Project Number: 15-306-06F
Agreement Number: 105908/3000089723
NOAA Award Number NA15NOS4190126

NRRI Technical Report: NRRI/TR-2016/35



This project was funded in part under the Coastal Zone Management Act of 1972, as amended by NOAA's Office of Ocean and Coastal Resource Management, in conjunction with Minnesota's Lake Superior Coastal Program. Additional 50% matching support came from the Natural Resources Research Institute at the University of Minnesota-Duluth.

I. RATIONALE

As we enhance our ability to assess Great Lakes nearshore environmental conditions and consolidate real-time, historical, and modeled data on central Web sites, it is critical that we get the resulting data into the hands of citizens and decision-makers in a format that is truly accessible, easily interpretable, timely, and relevant. Critical management decisions affecting nearshore health are made at the community and local government level as well as at the state and federal level, but data and resources that might improve decision-making are scattered among a number of widely-distributed, and often difficult to integrate sources. Many integrative tools have been developed (e.g., data visualizations such as those developed by NOAA's *Great Lakes Coastwatch* and the Natural Resource Research Institute's LakeSuperiorStreams.org, MNBeaches.org, LakeAccess.org, and WaterontheWeb.org websites (NRRI at the U. of Minnesota-Duluth); "mashups" (web page or application that combines data or functionality from two or more external sources to create a new service) such as the Great Lakes Observing System's *Harborview*(GLOS) that combine data from multiple distributed sources into web-based delivery systems. The enthusiastic use of these applications, in particular by regional educators and scientists (i.e. MN and WI Sea Grant Programs, Lake Superior National Estuarine Research Reserve (NERR), EPA-GLNPO, U. of Minnesota Duluth and Twin Cities campuses, U. of Wisconsin Superior and Madison campuses, Lake Superior College, College of St. Scholastica, Fond du Lac Tribal & Community College, Lac Courte Oreilles Tribal & Community College, Leech Lake Tribal College, et al.), regional secondary schools, and the Great Lakes wide Center for Great Lakes Literacy (CGLL) and Center for Ocean Sciences Education Excellence (COSEE) - Great Lakes community of formal and non-formal science educators .

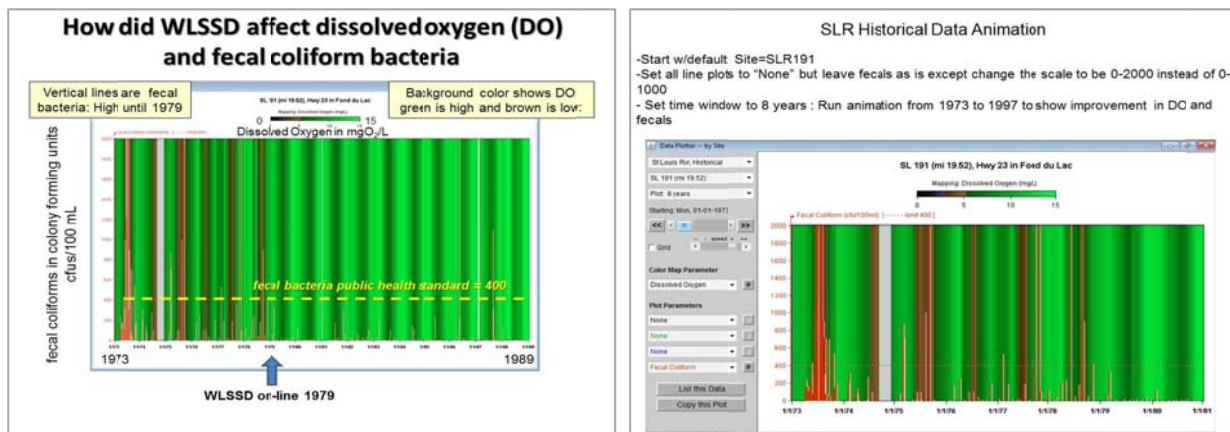
As the amount of environmental data collected for the St. Louis River Area of Concern (SLR AOC) continues to increase, lagging behind the data are the user-friendly interfaces, data visualization, systematic outreach and training, and assessment needed to ensure that these resources are truly institutionalized and implemented at the local and watershed level for improved environmental planning and management. The time and resources are seldom available to work closely with potential users, as has been done by the local Sea Grant and NERR programs at the front-end of indicator, tool, or interface development to ensure that the resulting delivery system reaches and truly serves its target audiences.

Steps recommended by the digital library community to make geoscience data more accessible in the educational community are equally relevant steps to be taken in making environmental data more accessible to the management community (e.g. Shapiro-Ledley et al. 2008. *Recommendations for Making Geoscience Data Accessible and Usable in Education*. *Eos Trans. AGU*, 89:290-291). Based on these guidelines, we have continued to develop new and modify existing tools and web/data interfaces so that:

1. "users" can find and use appropriate data easily
 - The level of knowledge needed to use the data is clear
 - Information is provided on the relevance of the data to societal, educational, or scientific problems
 - Examples of use of the data are included
 - Data are archived for reliable, long-term access

- The interface to, and the organization of, the data is user-friendly.
2. users can ascertain data quality and the impact of the data on their conclusions
 3. data are provided in ways that facilitate their manipulation through a variety of tools
 - as much as possible, data are provided in common formats accessible via desktop tools
 - tools are provided or supported to facilitate use of the data
 4. the data site supports, through these tools, data manipulation to answer questions
 - where possible, visualizations are provided to enable viewers to discern patterns or trends or comparisons to other data sources

Funding from the Great Lakes Restoration Initiative and Minnesota Legacy Act in concert with the creation of the Lake Superior NERR in the past five years or so have created an interest and need for better ways to help inform the public and decision makers about the function and condition of the St. Louis River Estuary (SLRE) and SLR AOC. Since 2002, the *LakeSuperiorStreams* project has delivered area trout stream and (since ~2011) SLR/SLRE flow and water quality data, using novel and award winning visualization tools in the context of stormwater impacts to stakeholders and the general public, and especially to educators and students. The currently available SLR data visualization tool (<http://www.lakesuperiorstreams.org/streams/SLR/monitoring/DataViewer.html>) was designed for near real-time (5-15 minute data hoses) and later modified to allow for multi-year strings of data typical of grab sample monitoring programs (i.e. bi-weekly or monthly frequency). The figures below illustrate how well the tool tells the restoration story of how the creation of the Western Lake Superior Sanitary District (WLSSD) and its improved wastewater treatment affected dissolved oxygen concentrations in the St. Louis River.



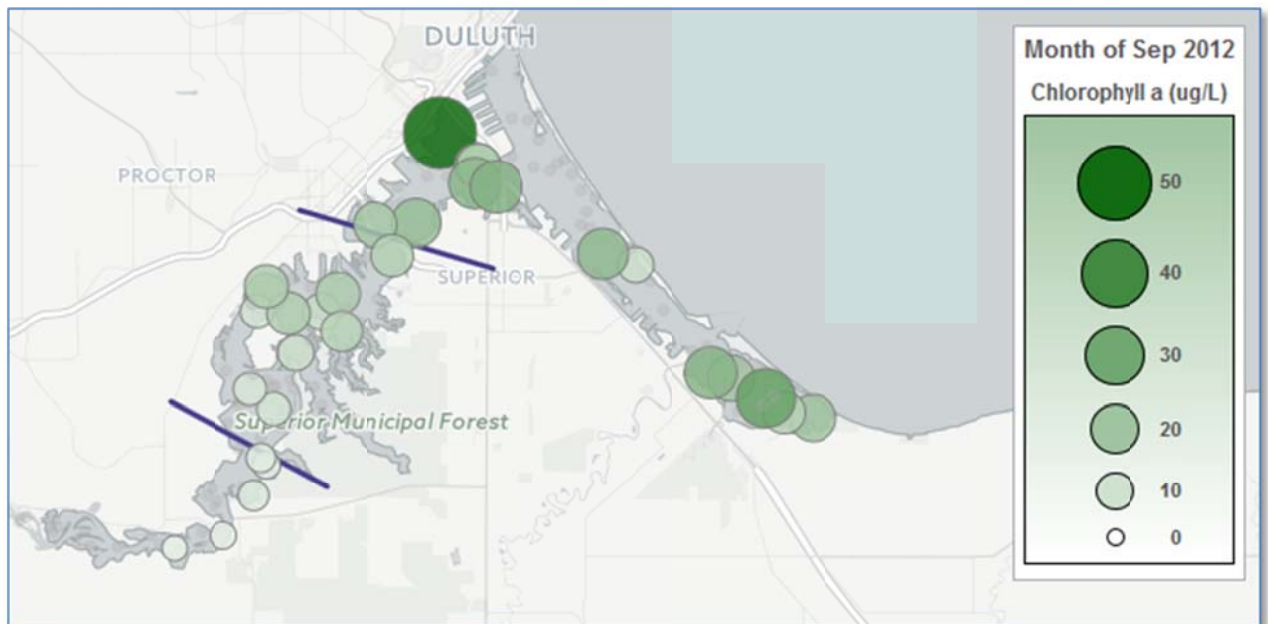
IV. St. Louis River Data Visualization Tool

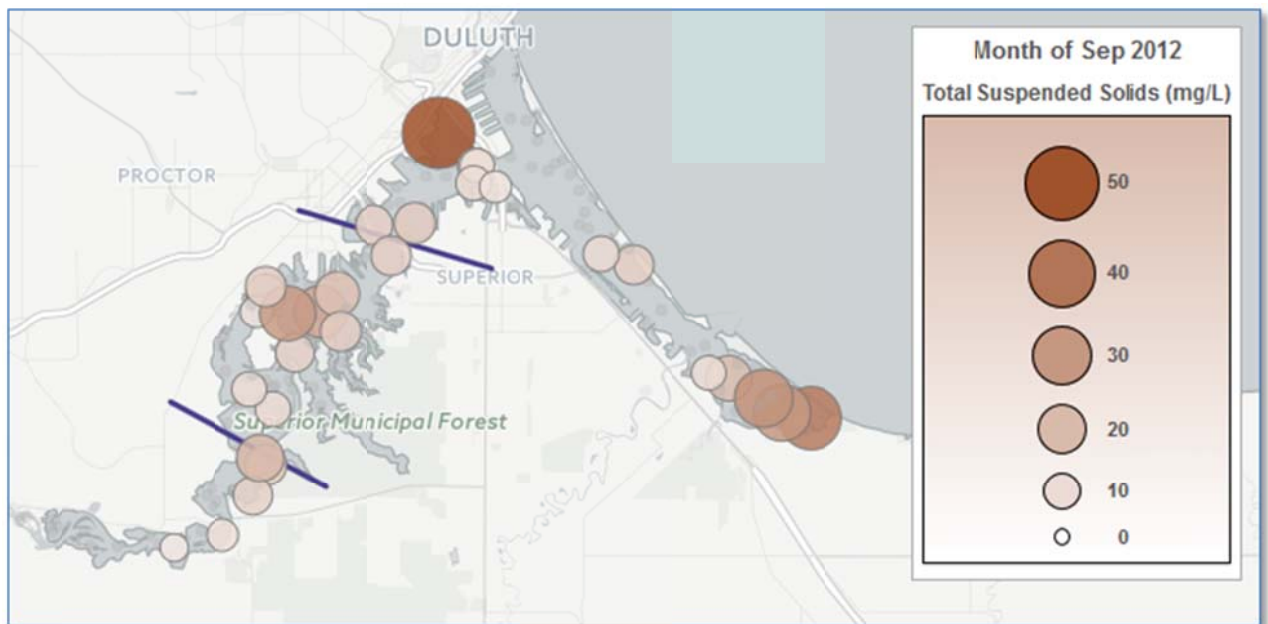
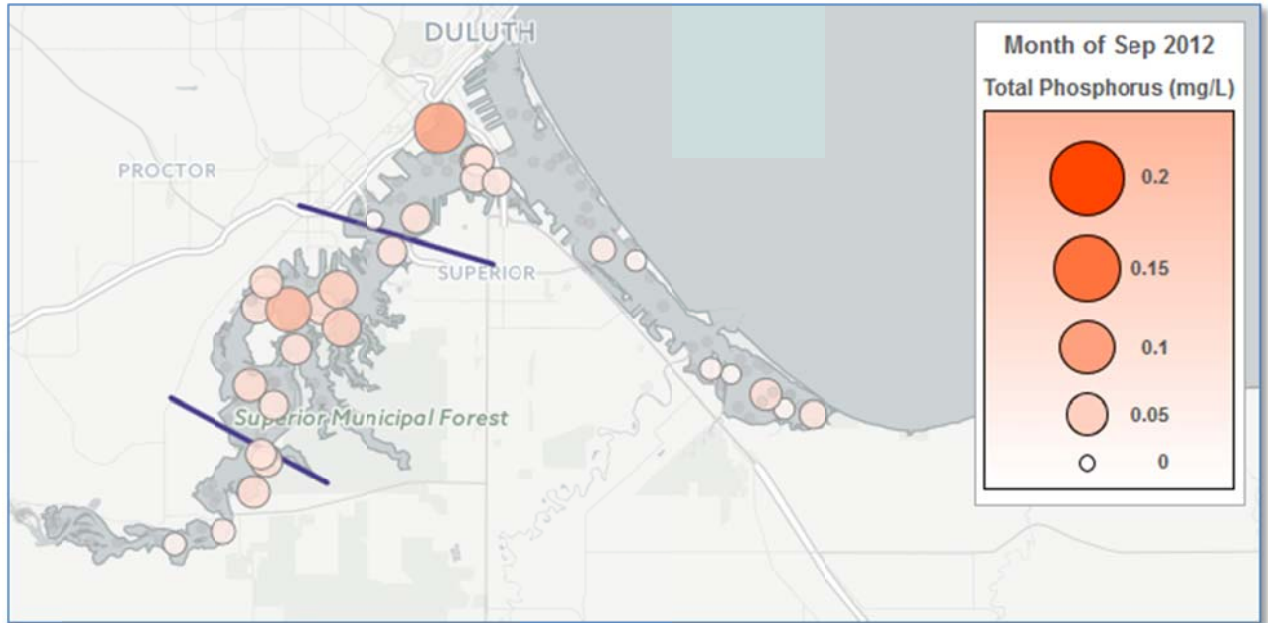
This on-line utility is used to explore St Louis River Estuary water quality data, collected by a number of different researchers and agencies during a time span of over 60 years. It presents these data using a simple mapping and graphing interface. Every attempt was made to make the app intuitive. Most actions provide immediate feedback; users should be able to glean most of the following information just by exploring and experimenting within the app.

All data files are loaded when the web page is first opened, no further communication with the server is necessary. Because of this design the user is able to quickly and simply create visualizations from any desired combinations of data sources, dates, and parameters with virtually instantaneous results.

The app uses 2 complementary approaches to visualize the data: the map providing the ability to visualize the data from many sites for a user specified date (or range of dates), and the XY plot providing the ability to visualize the data from a user specified site (or set of sites) over a range of times.

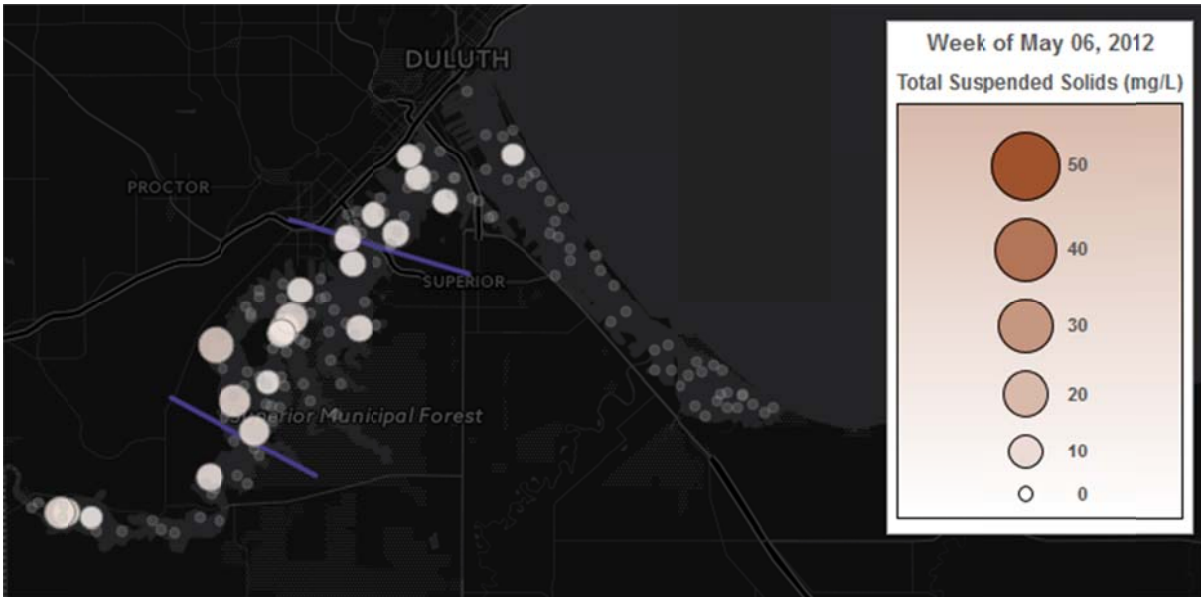
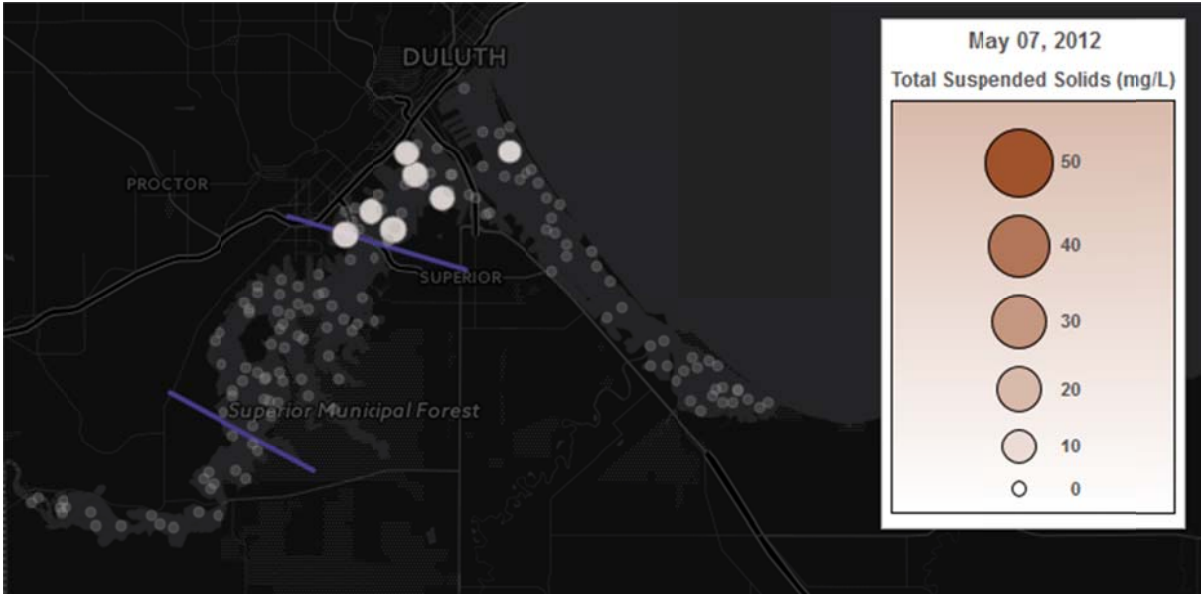
1. Map

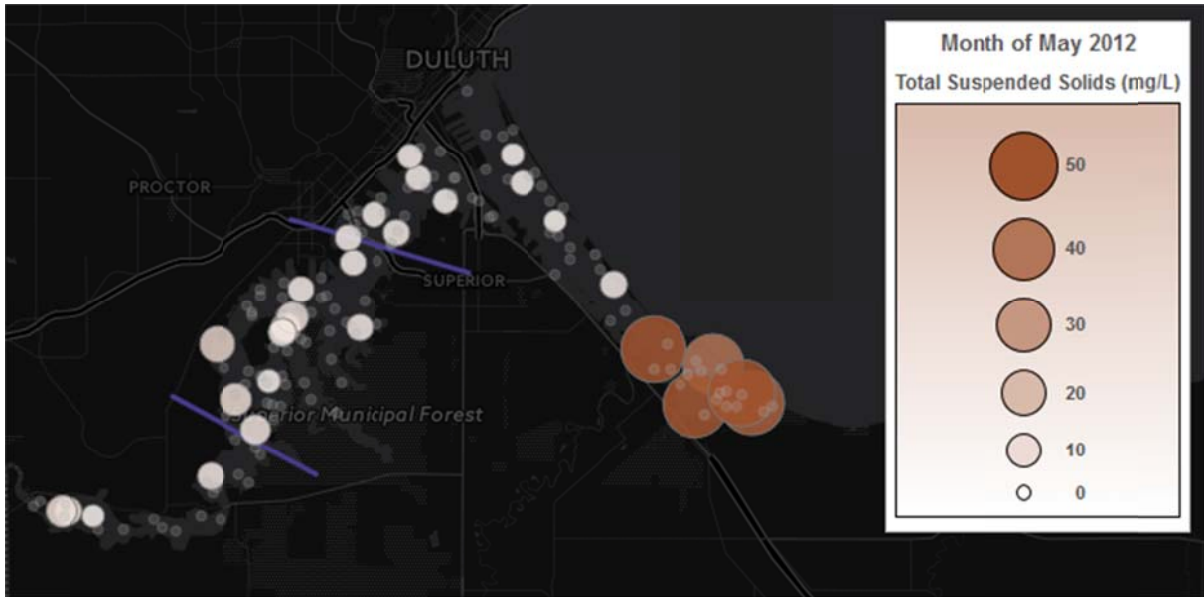




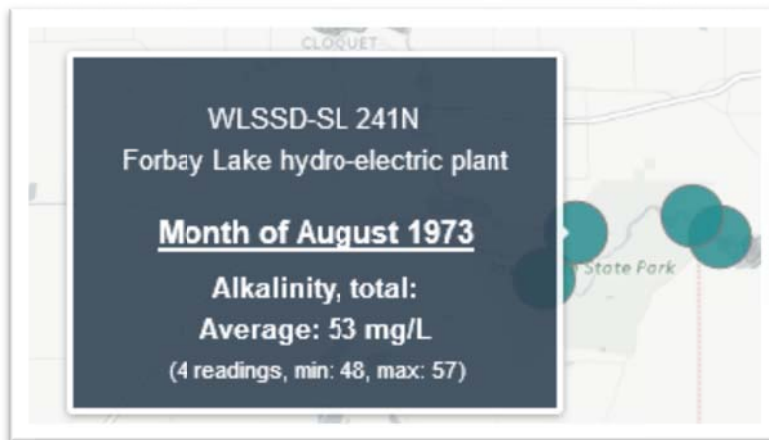
Circle markers are used to indicate each sampling location on the map. If the site has no value for the selected parameter within the requested time period, the marker is rendered as a small gray circle with reduced opacity. If there is a value, the area of the circle is set proportional to a range which has been pre-determined for each parameter. The color is assigned based on its position in a gradient of colors which have been applied to the same range of values. A legend in the upper-right corner of the map shows the range of values, colors, and sizes being used for the mapped parameter.

Data from different sites and/or from different sources may have been collected on different days, but the measurements were taken close enough in time to be relevant to each other. Users are given the option to aggregate the data from each site by day, week, or month, allowing these data to appear on the same map. The following 3 images illustrate the differences.





If the user hovers their mouse pointer over a marker an info-balloon will pop-up with more information about the site and the parameter being displayed.



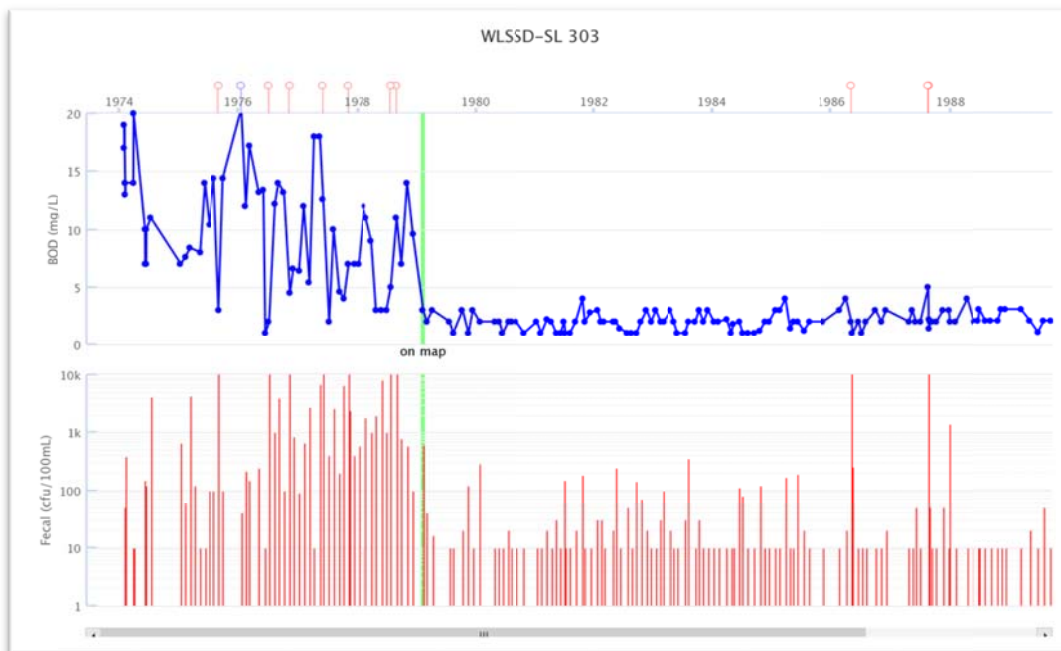
Default color gradients for individual parameters generally followed those that we have used previously for the data visualizations used for lakes in www.waterontheweb.org, and for streams in www.lakesuperiorstreams.org. For example temperature varies from blue (cold) to red (warm). The color changes to from orange to red where temperatures increase to greater than 20°C (68°F) since this is a commonly used marker for chronic stress to cold water species of fish. Similarly our default color gradient for dissolved oxygen is set so that higher concentrations are shown as green above 7 mgO₂/L (the typical minimum criterion for cold water fish), changing to brown below 5 mgO₂/L (the lower level for cool water species), then to purple below 3 mgO₂/L (the lower level for warm water species), and finally to black below ~1 mgO₂/L (variously referred to as “facultative” anoxia or hypoxia).

Similarly we have set the color gradient for specific electrical conductivity (EC25) as per our trout stream sensors so that values near the chronic brook trout acute toxicity criterion of 232 mg Cl/L (as estimated by EC25 in area trout streams) change dramatically from dark blues to magenta so users can easily see where salt concentrations are stressful to brook trout.

The pH value gradient was simply set to mirror one of the more commonly used brands of pH papers in the range of pH 6-9.

Since most other water quality parameters lack generally accepted regulatory criteria, we chose specific colors and simply allowed for a pale to darker ramp of color intensity. We used green for chlorophyll-a and brown for turbidity and TSS since these made sense.

2. XY plots

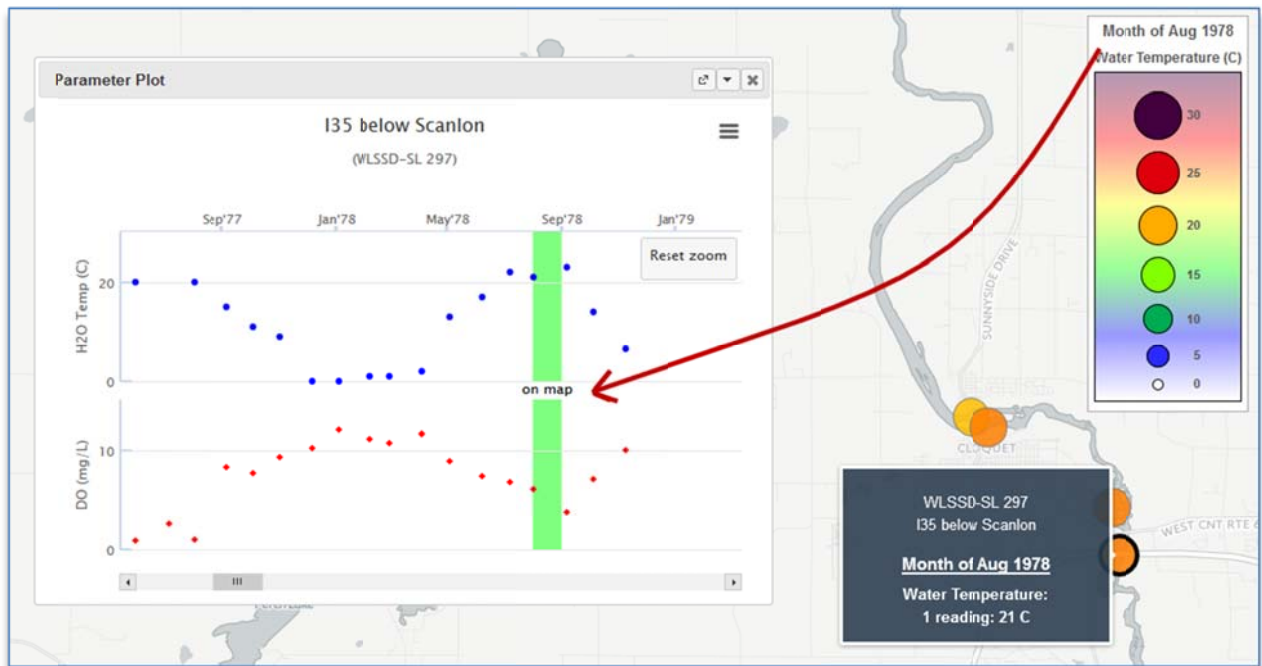


Clicking on a marker opens a movable and resizable window showing an XY plot. By default, the X-axis shows the range of dates for all of the readings for the parameter that is being mapped that were taken at that site. The plot can also show the values for an optional second parameter. Setting these plot options will be covered in more detail below.

Users can zoom in on the plot simply by clicking and dragging their mouse over their desired time range. If the plot is zoomed-in a scrollbar will appear beneath the plot which allows the user to scroll the dates being plotted. A “Reset zoom” button will appear in the upper-right corner of the plot which allows the plot to zoom back out to showing all readings. Buttons in the upper-right corner of the window are used to maximize, collapse, restore or close the plot. An icon with 3 bars, located below those buttons, provides options to print or save the current plot.

A special quality of this app is the high degree of interplay between the mapping and the plotting features:

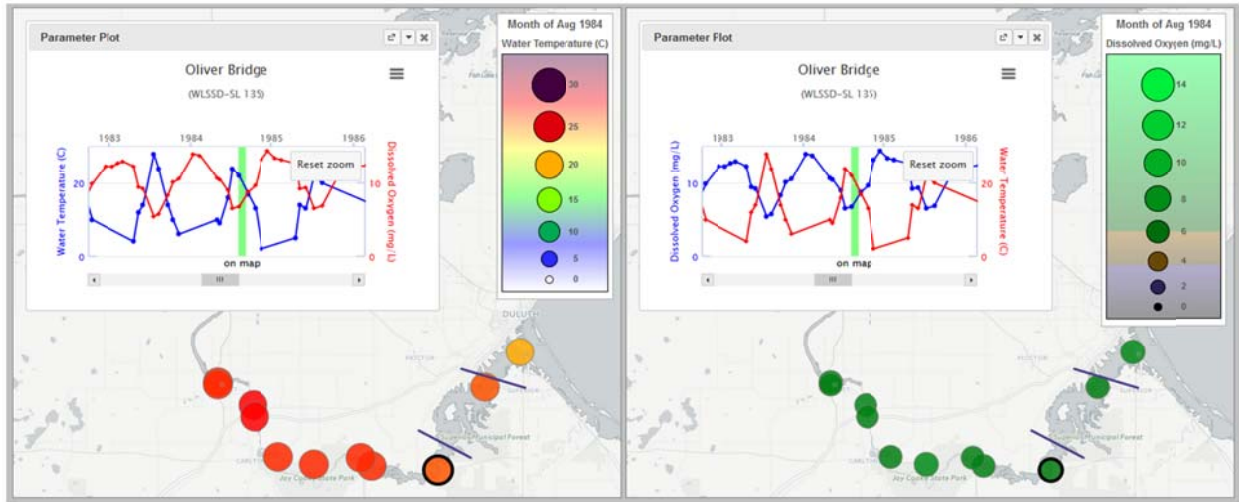
- A green band on the plot indicates the current day (or week or month) appearing on the map.



- If a user clicks any data point on the plot the map will immediately be set to show that time range.
- Clicking a different marker on the map will immediately replace the plot with a new plot showing the values at the new site. If the user was zoomed-in to a specified time range on the preceding plot the new plot will be set to the same time range. If the user was not zoomed-in the new plot will show the entire temporal range of the data at the new site.
- The marker that is currently being plotted will have its outline highlighted on the map (in either black or white, chosen to maximize its contrast with the current base map).
- Users may want to show readings that were taken at a number of sites at nearby locations in the estuary on the same plot. This can be accomplished by holding down the “Ctrl” button on the keyboard when clicking on a map marker. This toggles that site’s inclusion in the current plot. This can be handy, for example, if one dataset has result for a site over one range of years, and another covers a different period.

There are several keyboard shortcuts that can come in very handy:

- If the plot is showing 2 parameters, users can press the “S” key on the keyboard to “swap” these parameters. Since the first plot parameter is always shown on the map this results in instantly switching the map to show the other parameter. This provides the ability to quickly toggle the map between the 2 chosen parameters, which can be useful for detecting interrelations. This behavior holds even if the plot window is not currently open.



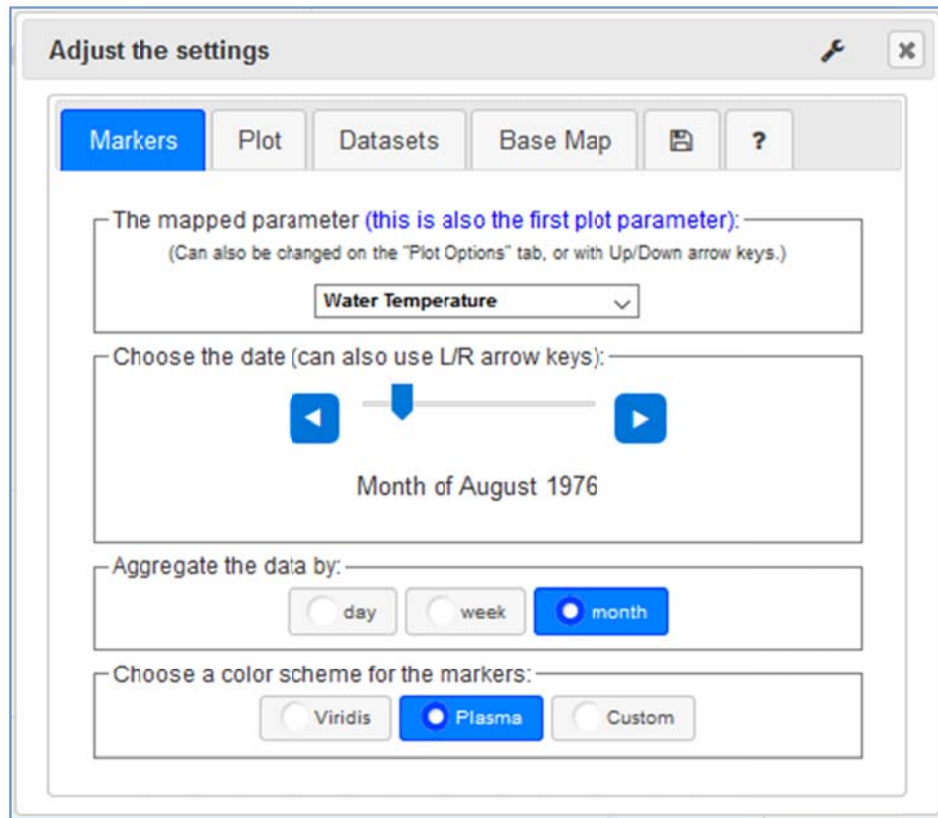
- Press the up or down arrow keys to quickly move through the available parameters for the map. This also changes the first plot parameter. Hold down the “Shift” key while pressing the up or down arrow keys to quickly change the second plot parameter. Note: Although the map updates immediately, the plot is not updated until after a slight delay following the last keypress, otherwise the app would bog down.
- Use the left or right arrow keys to change the date being mapped. Only dates in the currently active datasets that have some data for some parameter will be available, but it is possible that none of the current sites have data for the particular parameter being mapped on the particular date chosen. If so, all markers will be small and gray. The plot will scroll to show the new date if possible. Again, for performance reasons, this will not occur until shortly after the arrow key is released.

3. Control Panel

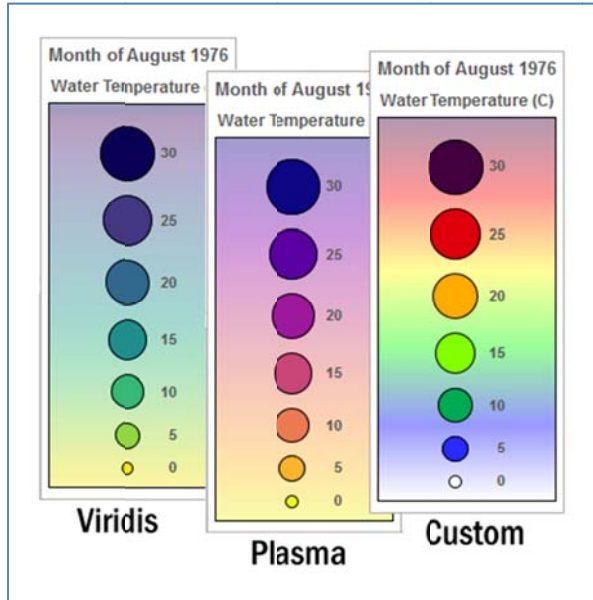
The controls are located in a dialog box which is open by default when the webpage is loaded. The dialog box behavior follows common GUI conventions. It can be moved to any location on the webpage by clicking and dragging its title bar, resized by clicking and dragging any edge or corner, and closed completely by clicking the **X** icon in its upper-right corner. Reopen the control panel by clicking the **Wrench** icon in the upper-left corner of the map (just below the +/- zoom icons).

Below the control panel title bar there are 6 “tabs”, each tab panel containing the controls used for the specified feature. Click on a tab to move its contents to the top.

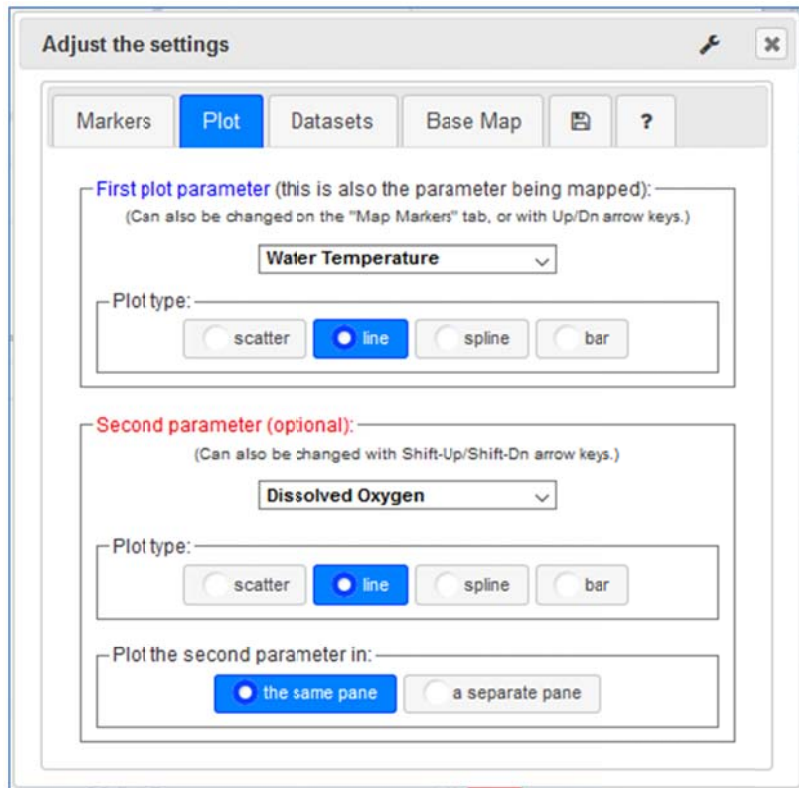
- The controls in the **Markers** tab are used to set the options for the markers appearing on the map. (Remember that there are keyboard shortcuts for some of these controls.)



- A dropdown choice box lists all of the parameters available in the currently active datasets. A change here is immediately applied to the map. This also changes the first parameter shown in the plot.
- A scroller that can be used to change the date being mapped. Left and right arrows can be used to move one date at a time. It will only stop on dates that have some data from a currently active dataset.
- Radio buttons that toggle between the options to aggregate mapped data by day, week, or month.
- Radio buttons to select a color scheme used for assigning colors to the markers on the map. The first 2 choices (Viridis and Plasma) were designed to be perceptually uniform – equal steps in the data are perceived as equal steps in color. These colors also have the qualities of providing a usable gradient when printed in black and white, and being distinguishable by people with common forms of color vision deficiency. The third option (Custom) uses a color scheme chosen for each parameter. Some of these were chosen to provide additional visual cues as described above.



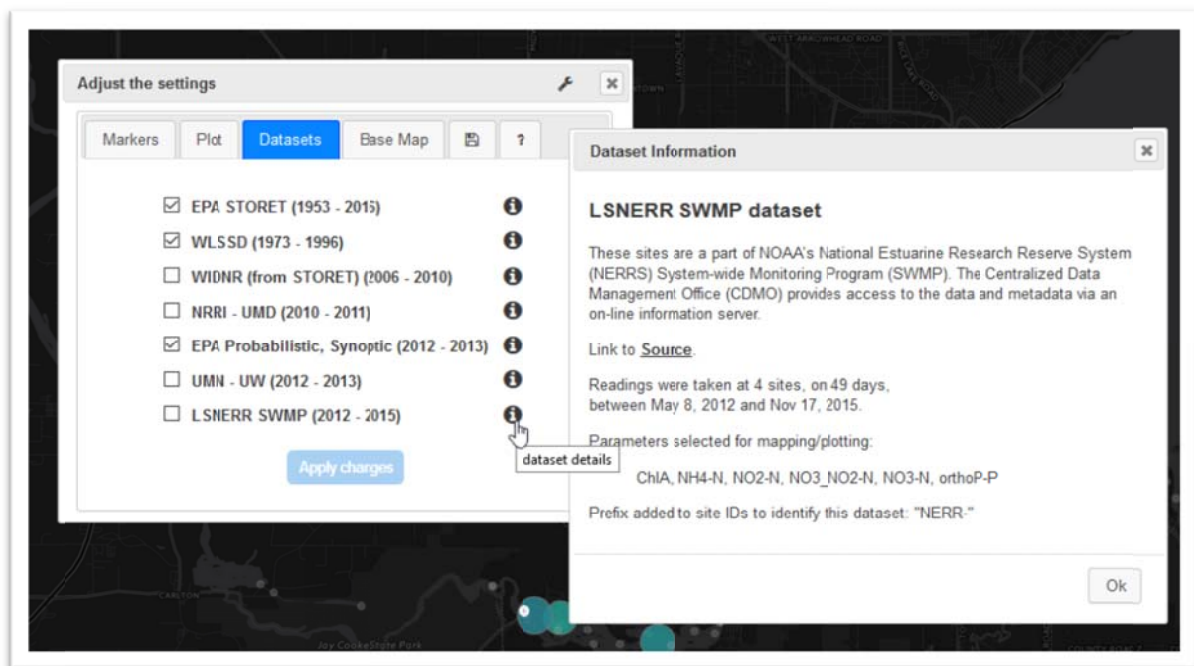
- The controls in the **Plot** tab are used to set the options for the current plot.



- A dropdown choice box lists all of the parameters available in the currently active datasets. A change here is applied to the first plot parameter. A change here will also change the

currently mapped parameter. This control is a mirror of the one in the Markers tab and is duplicated here for user convenience.

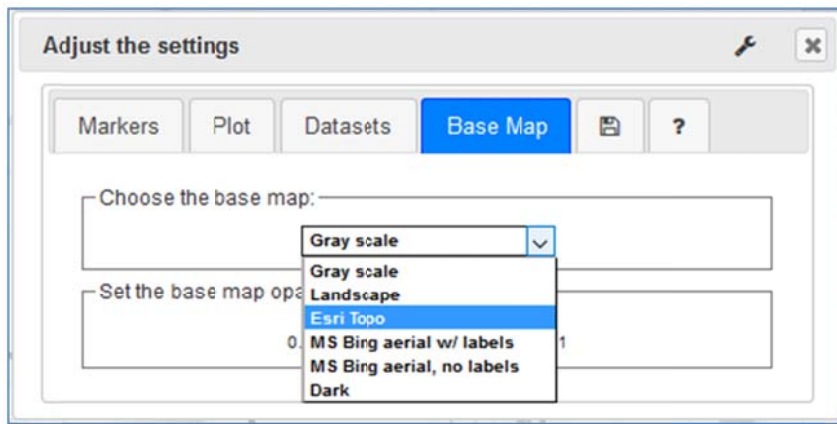
- Radio buttons to choose the plot type for the first parameter. Options are scatter, line, spline, and bar.
 - The next two controls repeat those above, with the choices being applied to the second plot parameter. The only difference is an additional choice for the 2nd parameter: choose “Do not plot a second parameter” to have the plot only show a single parameter.
 - The final control in this tab is a pair of radio buttons to choose between plotting the second parameter in the same pane as the first parameter appears, or a separate pane. The difference will be obvious when a change is made.
- The **Datasets** tab has checkboxes used to select the active datasets from all of the available datasets. A brief description of the dataset will appear when the user hovers their pointer over a selection. Clicking on the “i” icon next to the selection will open a window with more details for the dataset, including the measured parameters, the number of sampling sites, and the number of days with data. Each dataset has a link that either points to a website with

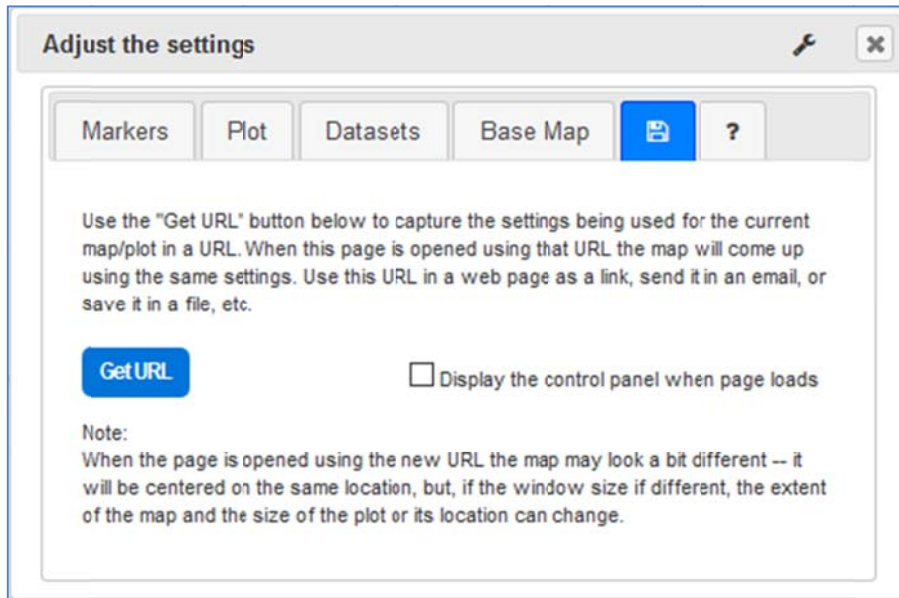


more information and raw data files, or, if that is not available, a link directly to the raw data file that was used to extract the data for the app. A link to a csv file containing only the data being used will be added.

Users can select all or any combination of datasets. When the “Apply changes” button is pressed the Marker and Plot controls will be updated to reflect the changes -- only parameters recorded in one or more of the active datasets will be available as options. The same is true for the date available when scrolling with the scroller in the Markers tab or when using the keyboard L/R arrow keys.

- The **Base Map** tab – used to select the base map; among the options are a basic grayscale map, topographical map, and a satellite image map.





- The tab with the image of a diskette has a button that, when clicked, will create a URL that captures the current state of the app.

Users are prompted to hit Ctrl-C to copy this URL to their clipboard. Use this URL to open the app with these settings preselected – i.e. the same datasets, the same mapped and plotted parameters, the same date, the same base map, etc. The map will have the same zoom level, and it will be centered on the same location, however, because the new user’s window size may be different, the outer bounds of the map may be different. If a plot is open its window size might also be changed if required to fit, and its position will be in the original default location. By default, the control panel box will not be shown – the assumption being that it will be in the way. The user creating the URL is given an option to select if they **do** want the control panel to be open when the URL is launched.

- Finally, the “?” tab contains a brief description of the main features of the app.

4. Access to the SLRE Data Visualization Tool (DVT)

We have provided access to the SLRE DVT via the LakeSuperiorStreams website in several websections including:

- the St. Louis River websection (<http://www.lakesuperiorstreams.org/streams/stlouis.html>)

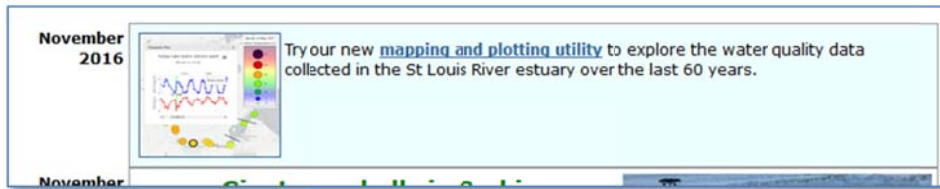


- the main Dataviewer websection (<http://www.lakesuperiorstreams.org/streams/data/Java/index.html>)



- the Data Index websection (http://www.lakesuperiorstreams.org/streams/duluthStream_selector.html)

- An announcement in the What's New websection (<http://www.lakesuperiorstreams.org/general/whatsnew.html>)



5. Peer review of the SLRE DVT

Because of the short amount of time allowed for the development of this new tool (~8 months), it is essentially a “beta” version for which we will solicit critical review from a number of potential users, in particular the state, tribal, and federal agencies that provided most of the data. We expect to be able to make minor “tweaks” to the tool if necessary and hope that other useful suggestions for future improvements will emerge.

V. REFERENCES

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