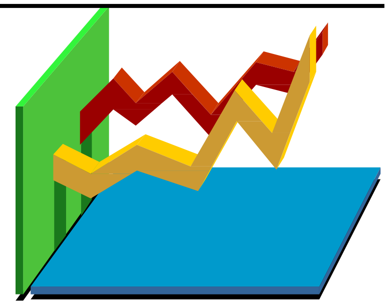
V-1. Illustrating Your Data

Key Terms

bar graph	mean
dependent variable	line graph
independent variable	spreadsheet



It can be challenging to interpret your data in raw form. The data will appear even more confusing to those who were not involved in its collection. Both your group and outside audiences will better understand the meaning of your data if it is presented in graphical form (it will be much more interesting to look at, too). This section will help you to chart and graph data. The next section, “Reflecting on Your Data,” will help you to interpret it.

To decide which form(s) of data illustration best suits your purpose asks yourself the following questions. Suggested chart and graph types are provided.

How do you summarize your data?

The first step in illustrating data is to organize it. You may want to first enter data by hand onto a ledger or graph paper and then transfer the information to a computer **spreadsheet** program (Excel, Lotus 1-2-3, Quattro Pro). Computer spreadsheet programs will help you to summarize and analyze the data. They will also allow you to create charts and graphs directly from the spreadsheet.

Rocky Creek Water Quality Monitoring Data (1999-2000)

	9/20/99		3/14/00		5/20/00		7/17/00	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Temperature (°C)	9.0	9.5	5.0	5.2	13.5	14.0	19.8	20.5
Turbidity (NTU)	8	9	35	40	50	55	15	20
DO (mg/liter)	9.0	9.0	10.0	10.5	8.5	8.0	7.0	6.5
Nitrate (mg/liter)	.100	.200	.150	.400	.200	.450	.150	.180
Phos. (mg/liter)	.030	.040	.200	.300	.150	.200	.050	.070
pH	7.5	7.5	7.0	7.0	7.5	7.5	8.0	8.0
EPT Value	15	8	9	6	10	6	14	9
Flow (cfs)	25	30	50	60	75	85	30	35

Table V-1. Example of a spreadsheet with monitoring at 2 sites and 5 dates.

What’s the first step in presenting our data?

After organizing your data, summarize it in table form. You might want to include the maximum and minimum values (which establish your range of values), and the **mean** – the average value. Make notations on your chart, if necessary, to help you to interpret your data later on. A table may be the final form for your data. It is also a useful step when creating a graph. Table V-2 below summarizes data for various water quality parameters.

Summary – Rocky Creek Water Quality Data			
parameter	average	minimum (date)	maximum (date)
temperature (°C)	11.8	5.0 (3/14/00)	19.8 (7/17/00)
turbidity (NTU)	27	8 (9/20/99)	50 (5/20/00)
dissolved oxygen* (mg/liter)	8.6	7.0 (7/17/00)	10.0 (3/14/00)
nitrate (mg/liter)	0.150	0.100 (9/20/99)	0.200 (5/20/00)
phosphate (mg/liter)	0.100	0.03 (9/20/99)	0.20 (3/14/00)
pH**	7.5	7.0 (3/14/00)	8.0 (7/17/00)
EPT value	12	9 (3/14/00)	15 (9/20/99)
Flow (cfs)	45	25 (9/20/99)	75 (5/20/00)
NOTES: * samples taken from riffle area ** tests conducted with pH strips			

Table V-2. Summary table of data shown on table V-1.

How do you want to represent your data?

There are many ways to present your data, but the two most common are pie charts and two-dimensional graphs.

Do you want to look at percentages of a whole?

A **pie chart,** such as Figure V-1, compares parts of a whole. The proportion of each part is represented by a "piece of the pie," with the pie equaling 100% of the total values of the data set. Pie charts are widely used because they are simple and easily understood.

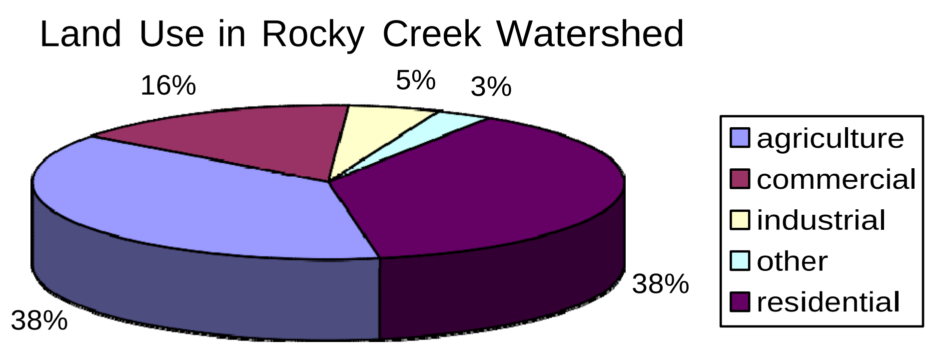


Figure V-1. Example of a pie chart to show percent of land use in an area.

Do you want to see how values change over time or distance?

Two-dimensional graphs (**line graphs** and **bar graphs**) show how values change over time or from one site to another. These graphs have an x-axis and a y-axis. The x-axis represents the **independent variable -** a constant, such as time and date, that is not influenced by other factors. The y-axis, the **dependent variable**, changes in response to other factors. An example of a dependent variable is water temperature.

In Figure V-2 below, the line graph shows how the temperature of Porcupine River fluctuates over the course of a year. The bar graph in Figure V-3 compares pH levels from site to site. Continuity of data is an important difference between line and bar graphs. Line graphs assume data points are connected to each other – they show a continuous trend. Bar graphs are used when data points are not connected.

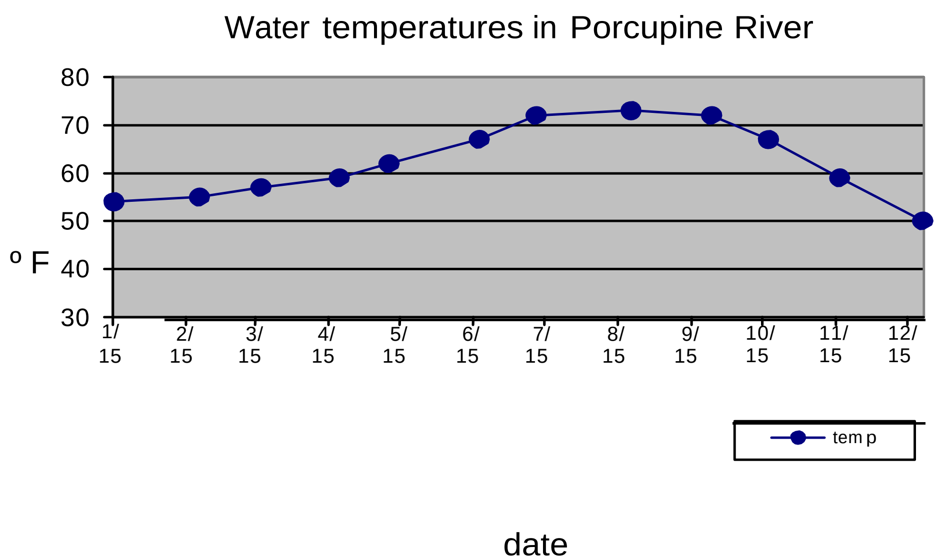
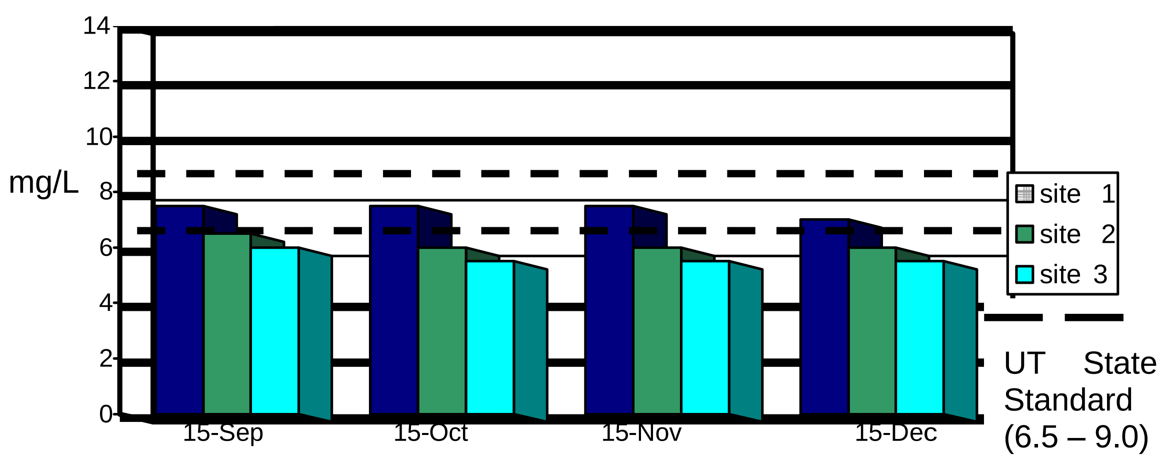


Figure V-2. Example of a line graph showing water temperatures over time.

pH Levels along Moose Creek

Figure V-3. Example if a bar graph showing pH levels over time at different sites.



NOTES:

- This is a good way to illustrate water quality upstream (site 1), downstream (site 2), and far downstream (site 3) of a suspected pollution source.
- Include the **Utah State Standard** on your graph to help you interpret water quality. See "Water Laws" for information on Utah's Water Quality Standards.

Do you want to look at relationships between parameters?

You can place the values for two or more parameters on the same graph to investigate a possible relationship. For example, the graph that follows, Figure V-4, contains values for both dissolved oxygen and temperature. We see that a rise in temperature coincides with a drop in dissolved oxygen concentration. Graphically illustrating these relationships will help you interpret your data later. Notice that this graph has two y-axes – one for temperature and one for dissolved oxygen. The x-axis – time – is the independent variable for both.

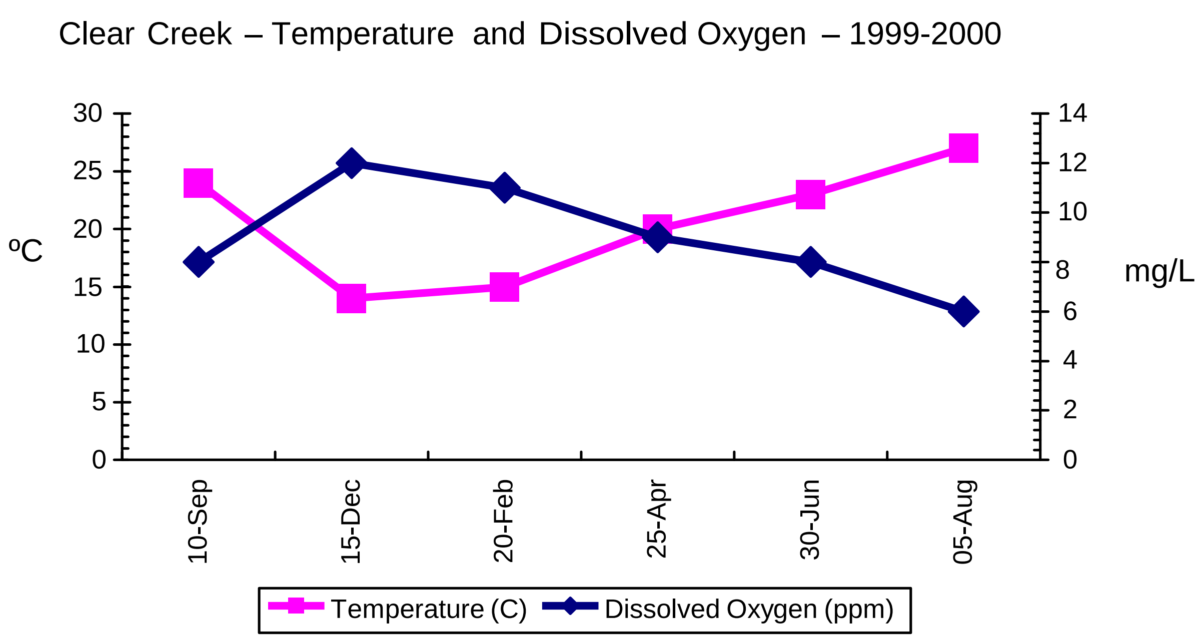


Figure V-4. Example of a line graph showing 2 parameters.

More tips on graphing

- Make sure your graph has a title and legend and that all units are labeled.
- The data points should be proportional to the actual values so the meaning of the graph is not distorted.
- Keep the graph simple. Limit the number of variables.
- Notations can help others better understand your graph.

Resources for further investigation

Streamkeepers Field Guide: Watershed Inventory and Stream Monitoring Methods. This manual addresses most major aspects of a classroom and field monitoring program including graphing and presenting data. Manual is adaptable for use by students ages 12-adult. Companion video also available. Contact: The Adopt-A-Stream Foundation at the Northwest Stream Center, 600-128th Street SE Everett, WA 98208-6353 (425)316-8592; Fax: 425-3381423; aasf@streamkeeper.org; www.streamkeepers.org

The Volunteer Monitor – This bi-annual publication by the Environmental Protection Agency (EPA) offers information and ideas for volunteer water quality monitors of all backgrounds, including school groups. The Spring 1995 issue specifically addresses the topic of "Illustrating Your Data." You will find articles such "Using Graphs to Tell Your Story," "Beyond Reports: Packaging Data Creatively," and "Using Data in the Classroom." You can obtain this free publication by mail or via the EPA's web site. Contact: Elanor Ely, Editor, 1318 Masonic Avenue, San Francisco, CA, 94117; (415) 255-8409. www.epa.gov/OWOW/volunteer/vm_index.html

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V-2. Reflecting on Your Data

Key Terms

accuracy, comparability, outlier, representativeness, cause, correlation, precision

So, does your stream have good water quality? Why or why not? Can you make a judgment at this point? This chapter will help you to analyze your water quality data and answer these questions. First, take a look at how well your group collected data. Then, investigate a series of graphs that illustrate common water quality data sets. The insight provided will help you interpret your own data.

Reflecting on the data collection process

Natural systems, such as streams, are inherently variable; their water quality changes due to climate, temperature, stream flow, and many other factors. Variability exists in our data collection procedures, as well. Each of us measures and interprets differently. Our differing ability to judge colors, distances and amounts affects the quality of data we collect. For example, we use a **color comparator** (color wheel) to determine the concentration of nitrogen in the water. One of us may judge the color differently than another and therefore determine a different nitrate concentration. Or, perhaps the equipment was faulty or used incorrectly. These differences can lead to variability in monitoring results.

> Remember, mistakes make excellent learning opportunities.

Measures of **precision**, **accuracy**, **representativeness** and **comparability** help us evaluate sources of variability and error, and thereby increase confidence in our data. No matter what standard of quality we set for our data, students should understand these measures. Their underlying principles apply to all scientific investigations and even everyday inquiries.

Precision

Precision – the closeness of measurements to each other – tells us how consistent our sampling procedures are. If data points are spread across a graph in a shotgun pattern, we can consider our sampling procedures to have a low degree of precision.

Accuracy

Accuracy tells us how much confidence we can have in our data. The smaller the difference between our measurement (e.g., nitrate concentration) and its "true" value the more accuracy we have. Data collected by the Division of Water Quality can serve as a comparison to help you determine accuracy.

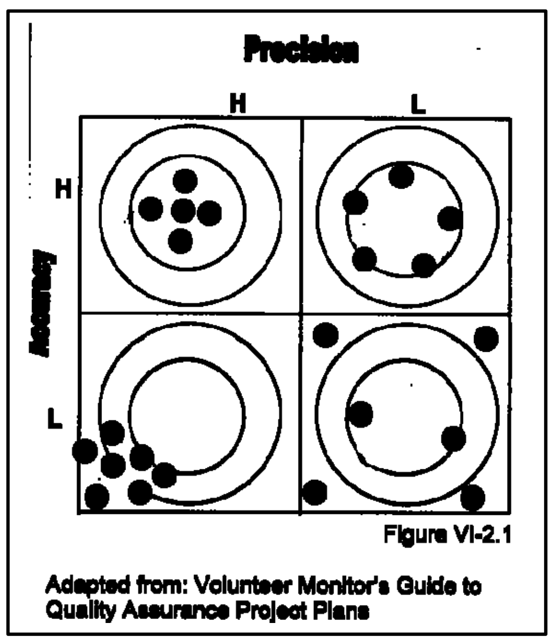


Figure V-5 A comparison of precision and accuracy. Top left corner shows data with high precision and high accuracy, bottom right shows data with low precision and low accuracy.

Representativeness

If you sampled only a small stretch of pristine headwaters in an otherwise highly polluted stream, then your measurements had a low degree of *representativeness* – how well measurements depict the true characteristics of the stream. Sampling at multiple sites or throughout the year are two ways to increase representativeness.

Comparability

Our water quality data gain real value when we can establish long-term trends or are able to compare different sites (upstream to downstream) on a stream to another. The degree to which we can compare data between dates, sites and other studies is called *comparability*. Consistent sampling techniques are needed to reach a high degree of comparability.

Cause vs. Correlation

Students of all ages tend to mistake **cause** with **correlation**. For example, if students are told that no fish live in a local cold-water stream, they may be quick to infer that the cold temperatures are to blame, without knowing anything else about the stream. Further, students, especially those of middle school age, are very quick to prove cause from only one event. This owes mainly to students' over-eagerness to fit information to their preconceived notions. This occurs even when there is insufficient information or when other, contradictory information exists. To counteract this, discuss the tendency, and the difference between the terms cause and correlation. Also, address misconceptions as they arise (e.g., all water quality problems are caused by man). Then, design ways for students to investigate for themselves those misconceptions (e.g., have them monitor changes in a pristine stream)

Reflecting on your water quality data

Here are some important points to remember about analyzing water quality monitoring data.

1. To interpret the value for a measurement, such as pH, we need to compare it to the **Utah State Standard**. The Utah Division of Water Quality determines a State Standard for many water quality parameters. State Standards can be found in the "Water Pollution" section and in the background information for each sampling parameter in Unit IV.

2. The "Background Information" supplied for each parameter in Section IV will also help you to investigate possible reasons (natural and human) for poor water quality.

3. If you find a potential water quality problem, re-sample to ensure that you properly collected the data. Then, consult with a local water quality expert (see the "Resources" appendix for contact information) to see if your data compares favorably with theirs. Always check your data against other sources before sharing your results.

What's the right answer?

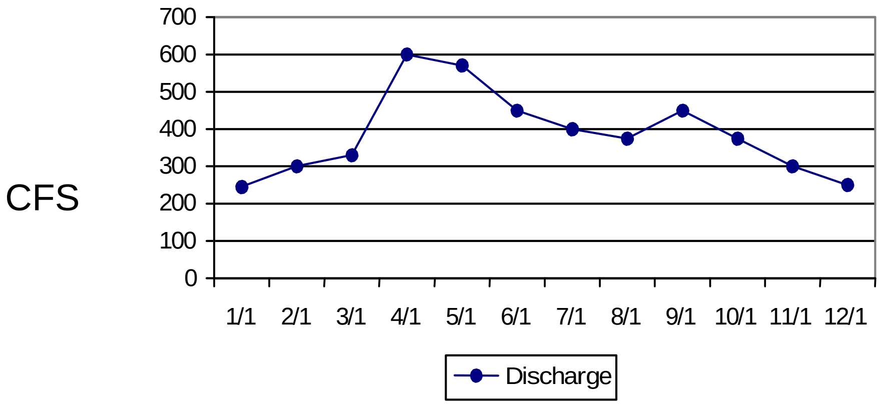
There are often several different ways to make sense out of a set of data. However, studies show that few middle-school students seriously consider alternative explanations. To address this, have teams of students separately develop explanations for a water quality graph and then share. Challenge each team to develop multiple explanations for a graph. Students will increase their understanding of the complex nature of science.

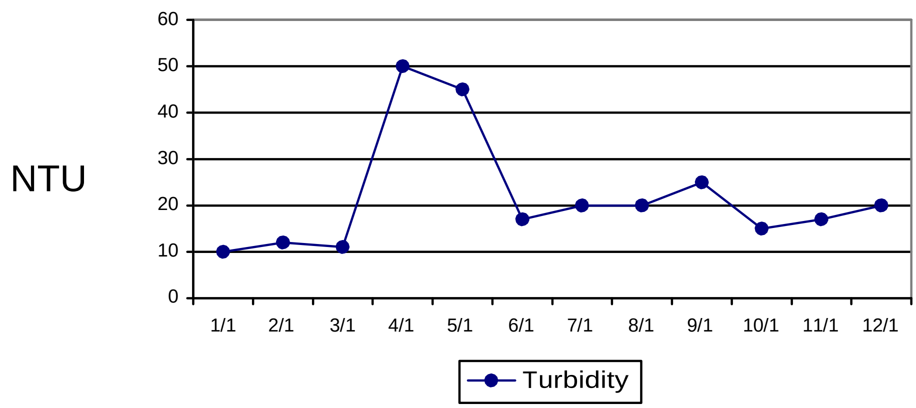
Sample Data Graphs

The following series of graphs represent common results from water quality monitoring. Share these graphs with students (you may want to make them into overheads).

Have students examine the data and propose hypotheses or ask questions about what they are observing. Compare their observations and questions with the conclusions listed below each graph. Note: Graph Sets 1 and 2 (Figures V-6 and V-7) are to be examined in pairs.

Figure V-6 Graph set 1. Example of flow and turbidity data.





What makes sense?

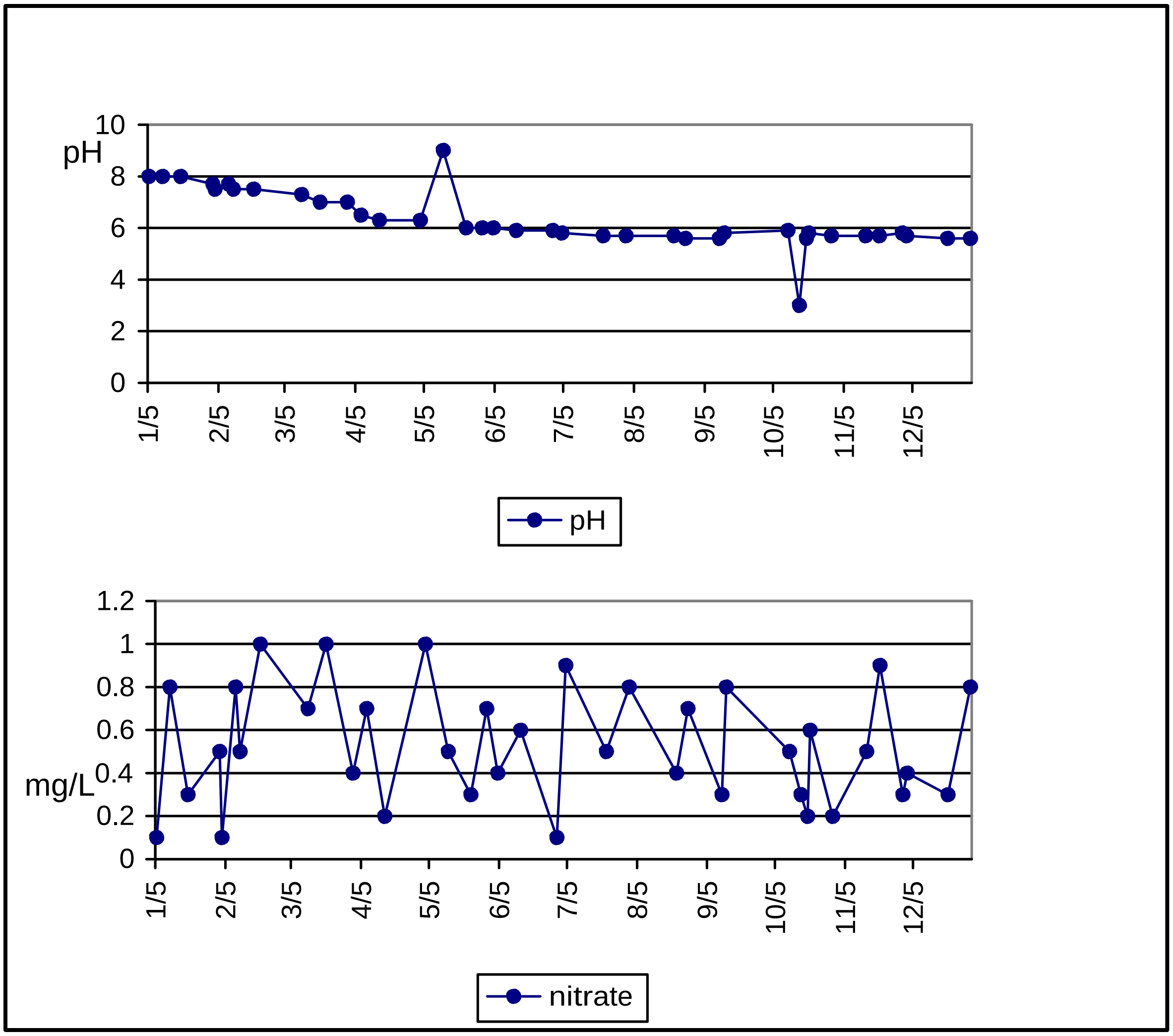
1. Both the turbidity and discharge values follow a seasonal trend; they rise during the spring snow melt period and relax over time. Since the small spike in September occurred on both graphs it is probably due to a real event, such as a rainy period or dam release, not human error.
2. Turbidity increases with an increase in discharge and decreases with a decrease in discharge.

What requires further investigation?

1. Discharge increased almost 100% in April. At the same time, turbidity increased 400%.
2. During January and February, when discharge was low, turbidity was 10-12 NTU's. Discharge returned to its low level in November and December. Turbidity did not (it measured 18-20 NTU's).

- These two outcomes may be due to increased erosion in the stream channel or watershed over the course of the year. They could also be due to sampling error or unusually low turbidity levels at the beginning of the year. Continue to sample and establish a trend. Assess any changes in **macroinvertebrate** populations to see if possible turbidity increases are affecting aquatic life.

Figure V-7 Graph set 2. Example of pH and nitrate data.



What makes sense?

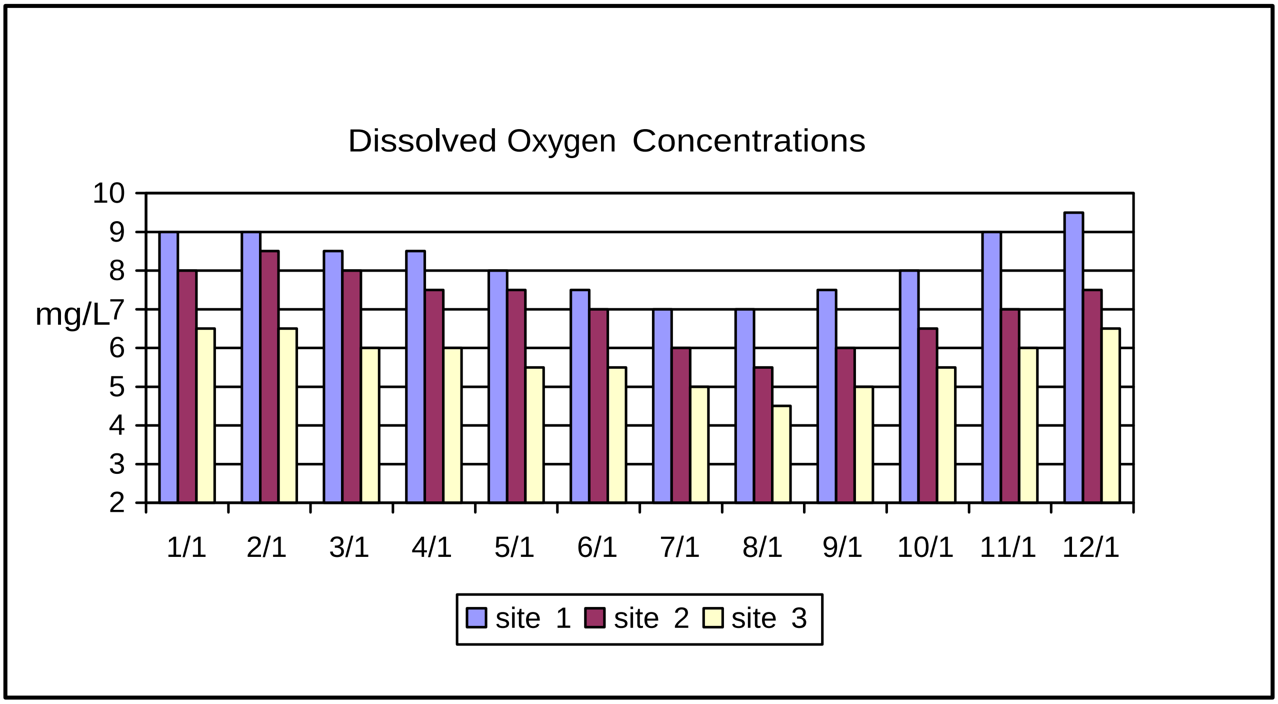
1. With the exception of two points the pH data points are very *precise*.
2. pH drops during then spring snow melt period as expected.
3. The nitrate data points all fall within acceptable limits (more than "4 mg/L" is considered a pollution indicator).

What requires further investigation?

1. Nitrate data has a very low degree of *precision* – the data points are scattered all over the graph. Sampling error is the likely cause.
2. Two points on the pH graph are **outliers** – they do not fit within the range of the rest of the data. Sampling error is a possible cause. Since there is an abundance of precise data points for pH, we can confidently discard these two outliers.
3. pH drops steadily over the course of the year; from 8 to 6 (6 is below the Utah State Standard for most beneficial use designations). This is worthy of attention. The abundance and precise

nature of the data points suggest sampling error is not a factor. Contact a water quality specialist to investigate further.

Figure V-8 Graph 3. Example of Dissolved Oxygen Data



What makes sense?

1. Dissolved oxygen concentration follows a predictable seasonal trend – higher during cold months and lower during warm months.
2. The smooth trend tells us that our data collection techniques were precise.

What requires further investigation?

1. We commonly take measurements above, at and below a site to determine the amount of pollution coming from that site. In this graph we see DO concentrations falling as we move downstream (from site 1 to site 3). We might be quick to assume that pollutants (probably nutrients) are entering around site 2 and 3 and causing DO levels to drop. However, as you read above, correlation does not prove causation. Without comparing nutrient data from the same sites we cannot say that nutrients are the cause. We should also look at changes in gradient and increases in water temperature from industrial output, channel alterations or lack of riparian shading. Interpreting data without considering other relevant data can lead to errors.

An important final note on data interpretation

The *Utah Stream Team* does not promote particular viewpoints for students or the larger community to adopt. Instead, it presents sound information and asks students to judge for themselves. Take this same approach when interpreting your data. Make sure students are confronted with a balance of information, materials and personal perspectives. Help students recognize and discuss their personal biases so they do not misinterpret a water quality situation.

Resources for further investigation

"The Volunteer Monitor: The National Newsletter of Volunteer Water Quality Monitoring." Volume 7, No. 1, Spring 1995. This bi-annual EPA publication addresses almost every aspect of water quality monitoring, including those specific to school and youth groups. This volume, available on the internet, focuses on Managing and Interpreting Your Data. www.epa.gov/volunteer/spring95/index.html

Streamkeepers Field Guide: Watershed Inventory and Stream Monitoring Methods – This manual addresses most major aspects of a classroom and field monitoring program including data interpretation. The manual is adaptable for use by students ages 12-adult. A companion video is also available. Contact: Adopt-A-Stream Foundation, 600-128th St SE, Everett, WA 98208, (425)316-8592; www.streamkeepers.org

Volunteer Stream Monitoring: A Methods Manual – This free manual from the Environmental Protection Agency provides background information, sampling directions and data sheets for monitoring stream water quality. You will also find a handy section on Graphing and Interpreting Your Data. For a free copy of the manual, contact Alice Mayio at USEPA (4503F), 401 M St. SW, Washington, DC 20460; 202/260-7018; mayio.alice@epamail.epa.gov. Also available on the web: www.epa.gov/owow/monitoring/vol.html.

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