

Handbook for Water Quality Analysis of Western Pennsylvania Waterways

Prepared by:

Mark L. Lord, Chris Resek, James O. Palmer,
Allison Roy, Lynn Willey, Amy Shema, Steve Myers,
Laura Wies, Nick Radio, Matt Rowles

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Updated for 2017-2018

for

CREEK CONNECTIONS



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Handbook for Water Quality Analysis of Western Pennsylvania Waterways

Fourth Edition

Prepared by: Chris Resek, Mark L. Lord, James O. Palmer

**With contributions by: Laura Wies, Nick Radio, Matt Rowles,
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The French Creek Environmental Education Project

Now called **CREEK CONNECTIONS**

located at Allegheny College
Meadville, Pennsylvania 16335

First Edition, 1995

Second Edition, 1996

Third Edition, 1997

Fourth Edition, 1999 (Updated, 2017)

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CREEK CONNECTIONS

Handbook for Water Quality Analysis of Western Pennsylvania Waterways

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Project History

In 1995, the French Creek Environmental Education Project was founded by two Allegheny College professors with the hopes of building a successful collaboration between Allegheny and local public schools. Dr. James Palmer, Departments of Environmental Science and Biology, and Dr. Mark Lord, Department of Geology, decided to use the environmentally important French Creek and its surrounding watershed for this investigative, environmental education project. With initial funding from the Toyota USA Foundation and Palmiero Toyota, Inc. of Meadville, the project began with 5 schools. In its second year, 15 schools began water monitoring different sections of the French Creek Watershed. By the 1998-1999 school year, 22 schools and 28 teachers were involved, 6 of which were from Pittsburgh area schools.

In the beginning, there were only five.....

Original Schools

1. Meadville Area Sr. High School
2. Saegertown High School
3. Maplewood High School
4. Cambridge Springs Sr. High School
5. Rocky Grove High School

Building upon the success and transferability of FCEEP's watershed education model, decisions were made to expand the project for the 1999-2000 school year to include 14 additional schools in the Pittsburgh area, and a few more teachers in the French Creek Watershed. With the total of 33 schools and 44 teachers in two different corners of the state and New York, the project outgrew its name, and became **Creek Connections** in August of 1999. However, what has not changed is the project's mission of bringing regional public schools an authentic natural science research experience and an appreciation for local waterways. Today, even more schools, teachers, and students participate in Creek Connections than ever before, all testing and learning about their local waterways throughout Western Pennsylvania and beyond.

Project Information

Creek Connections, formerly the French Creek Environmental Education Project (FCEEP), has forged an effective partnership between Allegheny College and regional K-12 schools to turn the French Creek Watershed into outdoor environmental laboratories. Emphasizing an investigation of local waterways, this project involves a hands-on, inquiry based, natural science education for 49 different schools and 60 teachers (2017-2018 school year).

Allegheny College faculty and students provide the framework and assistance for school-



based investigative research in Western Pennsylvania watersheds. A Creek Connections school year begins in July or August at the Summer Institute, where teams of teachers and students visit Allegheny College for the one-day workshop. Equipment and background resources are supplied, and the methodology for water chemistry tests, biological sampling, and habitat assessment are reviewed. The students that attend the workshop will return to school to be peer educators and assistants to the teacher, helping the rest of the class or "creek club" learn the water testing

procedures.

Allegheny College students and staff act as liaisons between school by visiting classes periodically to assist with water sampling, data analysis, and research projects. Each school conducts water quality tests at their local field sites at least once every three weeks. All data is entered at the Creek Connection's web site (<http://creekconnections.allegheny.edu>) and is accessible for students and the public to conduct seasonal and geographic trend analysis and to do site comparisons. Classes also design and implement independent field research projects relating to water quality, watersheds, stream ecology, or water issues (for example, coliform testing, comparison of different streams, benthic sampling, fish sampling, comparison of groundwater with stream water, history of the waterway). Teachers are provided with a stipend to order equipment needed to support the independent projects and for classroom resources relating to watershed education.

The culminating events of the year is the annual Student Research Symposia in April where all participating schools and students convene at either Allegheny College or a location in the Pittsburgh Area to share their research findings with each other and the public. Students present and display their water data and independent research projects at this collaborative setting, which allows them meet the other schools, compare data and research projects, and witness the diversity of work that has been done in their watershed. Because two different corners of Pennsylvania are involved in Creek Connections, it is possible to compare Northwest Pennsylvania data and environmental problems with those from the Pittsburgh area. Students are teaching each other about the differing water quality issues in their regions.

By conducting water quality analyses throughout the year, students strengthen quantitative skills and understand the connection and impacts that they have to their waterways. With the opportunity to practice real science using a natural resource located in their own backyards, students gain a better appreciation for the quality of the waterways in their own communities. They are encouraged to share their knowledge, research, and concerns with others in the watershed community. The result of this water science education is a productive collaboration between students and faculty at the regional schools and Allegheny College, leading to a new focus on scientific literacy, environmental stewardship, and research for students at all levels

Project Recognition

We, the staff of Creek Connections, recognize, respect, and appreciate the vital role that ALL the participants of this project have had in its success. Just as all streams unite to form a watershed, Creek Connections participants provide the energy, innovation, and quality that embody and unite this project. Because of this, the Creek Connections' watershed education model and efforts have received state and national recognition.

In 1996, the French Creek Environmental Education Project (FCEEP, but now Creek Connections) was a finalist in the Consolidated Natural Gas Excellence in Education competition. The Pennsylvania Wildlife Federation presented FCEEP with the 1997 Conservation Educator of the Year Award, and FCEEP placed third in national competition for the Anheuser-Busch/Sea World



Left to Right: DEP Deputy Secretary Stacy A. Richards, Project Coordinator Chris Resek, Governor Tom Ridge, Project Director Jim Palmer, DEP Secretary James Seif

Pledge and a Promise program. In 1998 the state recognized FCEEP with a 1998 Pennsylvania Governor's Award for Environmental Excellence. In June 1999, FCEEP was a "finalist" in the higher education category for the Three Rivers Environmental Awards. The Pennsylvania House of Representatives and Senate have also given congratulatory citations of recognition to FCEEP. Creek Connections has been recognized for ongoing success in environmental education. In 2008 we received the Environmental Education Program award from the Pennsylvania Association of Environmental Educators. In 2009 we received an honorable mention in the University/Post-Secondary Educator category of the Carnegie Science Awards. This was followed in 2010 with the Special Achievement in Environmental Education at the Carnegie Science Awards. In 2014 the French Creek Valley Conservancy recognized us as a Friend of French Creek. The Pennsylvania Environmental Resource Consortium (PA Green Colleges) named us a Campus Sustainability Champion in 2015.



Left to right: Elliott Bartels, William Tolliver, Wendy Kedzierski, David Olson, and Jacob Turin accepting the Friend of French Creek Award.

Project Support

Creek Connections has been able to provide its watershed education program and resources to teachers each year because of the generous support of various funders. The funding that initiated the French Creek Environmental Education Project was provided by the Toyota USA Foundation in partnership with Allegheny College, Palmiero Toyota, Inc. of Meadville, and the French Creek Project. Former project funding has been provided by Alcoa Foundation, PPG Industries, the Pennsylvania Department of Environmental Protection Environmental Education Grants Program, Eden Hall Foundation, U.S. Environmental Protection Agency, The Nature Conservancy, Pennsylvania Environmental Council, Grable Foundation, Arthur Vining Davis Foundation, the Frick Fund of the Buhl Foundation, and private donations.

For the 2017-2018 school year, funding has been provided by Allegheny College, Richard King Mellon Foundation, the Frick Fund of the Buhl Foundation, Western Pennsylvania Conservancy and Dominion Charitable Foundation mini grant, PA Dept. of Environmental Protection Environmental Education mini grant, donations through the Educational Improvement Tax Credit Program and private donations.

Project Resources

To assist area teachers with bringing watershed education successfully into the classroom, Creek Connections provides numerous resources to participating teachers. Thanks to the generous financial support from various sources, Creek Connections is able to provide teachers with a start up package of water quality test kits and accessories, handbooks, field manuals, nets, and topographic maps. A list of that equipment follows. Each school year, teachers have also been provided an equipment stipend to spend on waterway research materials for student designed projects or on classroom aids - anything to help them teach about their watershed in the classroom.



In addition to the financial resources and equipment, Creek Connections offers teacher development workshops. These have included our annual Summer Institute, workshops for national curriculum/activity guides such as Project WET, and general workshops about French Creek and watersheds. Teachers are also provided various resource materials developed by the project which include: this handbook, Workbook of Freshwater Mussels, Fishes of the French Creek Watershed, Basic Hydrogeology, Data Analysis packet, macroinvertebrate identification guides, and a project newsletter (approximately 4 issues per year). These types of resources are continuously being developed. In addition, the project's website (<http://creekconnections.allegheny.edu>) offers teachers and students a database of water quality testing done by all participating schools, information on each water quality parameter studied, biological sampling information, Creek Connections newsletter articles, and links to other valuable water related websites.

One of the most important resources that we provide participating teachers is our Allegheny assistance. Allegheny College students and staff act as liaisons to schools to assist teachers with the ongoing water quality monitoring, data analysis, macroinvertebrate sampling, independent research project procedures, Student Research Symposium preparation, and classroom presentations. Allegheny College students may even become mentors for the middle and high school students because of their school visits during the year.

Starting in Fall 1999, Creek Connections introduced its Watershed Activity Module program. These loaner modules, based on watershed topics, are filled with equipment, activities, experiments, multi-media resources, visual aids for lectures, and websites to explore. These modules are free to any regional teacher. They have been designed to promote hands-on exploration of water related topics and can assist teachers in meeting the new Pennsylvania Academic Standards for Environment and Ecology. Currently there are seventeen module topics: Algae, Plankton & Aquatic Plants, Aquaponics & Sustainability, Aquatic Macroinvertebrates, Basic Water Chemistry, Drinking Water, Freshwater Fish, Freshwater Mussels & Gastropods, GPS units, Groundwater, Riparian Buffers, Reptiles & Amphibians, Stream Geology, Streamside Critters, Topographic Map, Water Pollution, Watersheds, and Wetlands; additional modules will be developed in the future. For more information on using these modules, consult the Creek Connections website.

Making Connections

The watershed education model of Creek Connections will help connect regional students to their waterways through authentic scientific research and their interaction with the creeks.

Creek Connections aims to build a great educational experience and an enthusiasm for their environment for students participating in the project.

If you want to connect with our project, contact information follows.

CREEK CONNECTIONS contact information:

Wendy Kedzierski, Project Director, (814) 332-5351, wkedzier@allegheny.edu
Laura Branby, Pittsburgh Area Educator (724) 452-8257, lbranby@allegheny.edu

Project Email: creek@allegheny.edu
Web: <http://creekconnections.allegheny.edu>

Address: Creek Connections, Allegheny College, 520 N Main ST,
Meadville, PA 16335

LIST OF SUPPLIES AND WATER QUALITY SAMPLING EQUIPMENT

Provided by Creek Connections for new teachers

Pocket Instruments and calibration solutions

- 1 thermometer
- 1 total conductivity meter (Tracer SAL/TDS/EC)
- 1 pH meter (Oakton pHTestr)
- 1 stock bottle of pH 7 standard calibration solution (yellow)
- 1 sample bottle of pH 7 standard calibration solution (yellow)
- 1 stock bottle of Conductivity calibration solution (clear)
- 1 sample bottle of Conductivity calibration solution (clear)

Chemical Test Kits

- 1 pH test kit (LaMotte Precision pH 5858-01)
- 1 dissolved oxygen test kit (HACH Dissolved Oxygen Test Kit Model #OX-2P)
 - + kit includes one extra square mixing bottle and one extra dissolved oxygen bottle so that two samples can be tested at the same time.
- 1 phosphate test kit (HACH Orthophosphate Test Kit Model #PO-19)
 - + kit includes one extra test/viewing tube & cap so that two samples may be tested at the same time
- 1 nitrate test kit (HACH Nitrate Test Kit Model #NI-14)
 - + kit includes one extra test/viewing tube & cap so that two samples may be tested at the same time
- 1 alkalinity test kit (HACH Alkalinity Test Kit Model #AL-AP)
 - + one extra square mixing bottle so that two samples may be tested at the same time.
- 1 turbidity test kit (LaMotte Turbidity Test Kit Model # TTM)

Chemical Testing Miscellaneous Equipment

- 1 large plastic container- to carry all equipment
- 2 1 liter sample bottles – labeled Sample A and Sample B
- 2 small sample bottles for meters – labeled Sample A and Sample B
- 1 cadmium waste bottle
- 1 waste bottle – 1 liter
- 1 distilled water wash bottle
- 1 plastic shoe box sized container —to carry pocket meters, calibration solutions
- 1 stopwatch
- 1 pair of scissors

Biological Sampling Equipment

- 1 kick net for benthic sampling (optional – only if likely to use)
- 1 benthic invertebrate identification and sorting kit (tray, white sheet, 2 spoons, 2 forceps, 2 laminated ID sheets)

Resources

- Handbook for Water Quality Analysis of Waterways*, by French Creek Environmental Education Project (now available on-line)
- 2 *Workbook of Freshwater Mussels: A Teacher's Resource Guide*, by Amy Shema, French Creek Environmental Education Project
- 2 *Fishes of the French Creek Watershed*, by Laura Wies, French Creek Environmental Education Project
- 2 *Basic Hydrogeology*, by Neal Alexandrowicz, French Creek Environmental Education Project
- 1 *Save Our Streams Monitors Guide to Aquatic Macroinvertebrates*, by Loren Larkin Kellogg and Izaak Walton League of America
- 1 SOS DVD – A Guide to Water Quality Monitoring
- 1 Laminated Chemical Data Sheet
- 1 Laminated Biological Data Sheet
- 1 China Pencil
- 1 Teacher Manual

Project Personnel

Wendy Kedzierski, Project Director, Creek Connections

Laura Branby, Pittsburgh Area Educator, Creek Connections

Dr. Jim Palmer, Project Founder, French Creek Environmental Education Project now renamed Creek Connections. Retired Associate Professor of Biology and Environmental Science, Allegheny College.

2017-2018 Project Assistants:

Seniors: Melissa McCann, Johanna Stanley, Paul Sutkowski

Juniors: Matthew Hutchinson, Kala Mahen

Sophomores: Grace O'Malley, Brianna O'Neil-Hankle, Mary Elizabeth Zipparo

Freshmen: Gretchen Barbera, Isabella Petitta



2017-2018 Creek Connections Staff

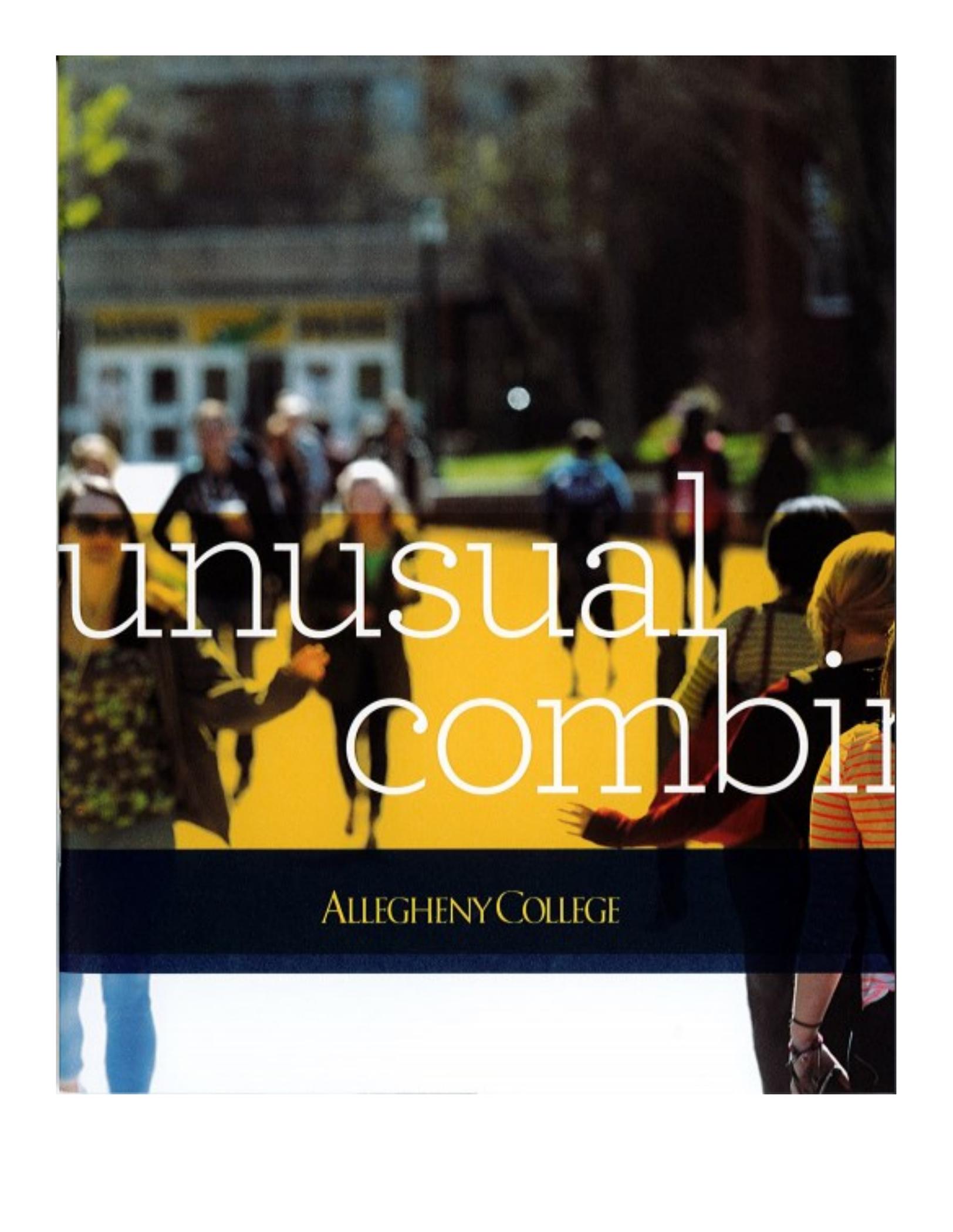
Check out current staff photos on our website.

2017-2018 Creek Connections Participating Teachers

NW Pennsylvania Schools	Teacher	School Phone	School Email
Beaty-Warren Middle School	Jeremy Criswell	814.723.5200	jeremy.criswell@wcsdpa.org
Bradford High School	Pam Digel	814.362.3845	pdigel@bradfordareaschools.org
Cochran Jr./Sr. High School	Simoan Ray	814.452.7421	Simoan.ray@crow.org
Conneaut Area Senior High	Eugene Bocan	814.683.5551	ebocan@conneautsd.org
Conneaut Lake Middle School	Peg Jacobs	814.382.5315	pjacobs@conneautsd.org
Crawford Central School District Gifted	Marie Rozakis	814.724.1124	marie.rozakis@crow.org
Creating Landscapes Learning Center	Ellen Cass	814.332.0202	ellen@creatinglandscapes.org
East Elementary	Jan Abernethy	724.588.1173 Ext. 3110	jabernethy@greenville.k12.pa.us
Fort LeBoeuf High School	Valerie Young	814.796.2616	youngv@flbapps.net
Fort LeBoeuf Middle School	John Campbell	814.796.2681	campbellj@flbapps.net
Hermitage School District	Nancy Bires		nancy.bires1106@gmail.com
Hillview Intermediate Center	Heather Fry	724.458.7570	heather.fry@gcasdk12.org
Lakeview School District	Marie Kohr	724.376.7911	m_kohr@lakeview.k12.pa.us
Maplewood High School	Jason Drake	814.337.1673	jdrake@penncrest.org
	Jeremy Peterson		jpeterson@penncrest.org
North East Middle School	Amy Brown	814.725.8671	ambrown@nesd1.org
Northwestern High School	Cindy Murray	814.756.9400	cmurray@nwsd.org
Saegertown High School	Christopher Greco	814.763.2615	cgreco@penncrest.org
	Phil Young		phyoung@penncrest.org
Seneca High School	Todd Talbot	814.824.3400	todd.talbot@wattsburg.org
Titusville Middle School	Mike Reynolds	814.827.2715	mreynolds@gorockets.org
Union City High School	Racquel Gray	814.438.7673	rgray@ucasd.org
Wattsburg Area Middle School	Paul Semrau	814.824.3400	Paul.Semrau@wattsburg.org
Youngsville High School	Laura Dorunda	814.723.8763	Laura.Dorunda@wcsdpa.org
	Kimberly Blum		blumk@wcsdpa.org
Pittsburgh Area Schools	Teacher	School Phone	School Email
East Allegheny High School	Holly Spallone	412.824.9700	dolphinhs@verizon.net
Elizabeth Forward Middle School	Amy Duschek	412.896.2335 Ext.7706	aduschek@essd.net
Environmental Charter School	Laura Micco	412.247.7970	laura.micco@ecspgh.org
	Caitlin Carey		caitlin.carey@ecspgh.org
Fern Hollow Nature Center/Quaker Valley	April Claus	412.741.7536	fhcnaturalist@verizon.net
Franklin Regional High School	Amy Smith	724.327.5456	akerschner@franklinregional.k12.pa.us
Gateway Middle School	Amy Baer	412.373.5780	abaer@gatewayk12.org
	Chris Grainer		cgrainer@gatewayk12.org
	Joseph Field		jfield@gatewayk12.org
Holiday Park Elementary	Kevin Shaffer	412.795.0100	shafferke@pbsd.k12.pa.us
Hopewell Memorial Junior High	Paula Cosnek	724.375.7765	cosnekp@hopewell.k12.pa.us
Leechburg Area Jr/Sr High School	Amy Barley	724.842.0571	abarley@leechburg.k12.pa.us
North Allegheny High School	Amy Baschnagel	724.934.7200	
North Hills High School	Laura Clark	412.318.1400	clarkl@nhsd.net
Pittsburgh Allderdice High School	Kathy Hoelzle	412.422.4800	khoelzle@pghboe.net
Pittsburgh Brashear High School	Regan Cupps	412.571.7300	Rcupps1@pghboe.net
	Jessica Muscaro		Jmuscaro1@pghboe.net
Pittsburgh CAPA 6-12	Winnie Corr	412.338.6100	Wcorr1@pghboe.net
Pittsburgh Carrick High School	Richard Rostauscher	412.885.7700	Rrostauscher1@pghboe.net
Riverside Middle School	Cindy Dietrich	724.758.7512	cdietrich@riverside.k12.pa.us
	Kathy Hooker		khooker@riverside.k12.pa.us
Riverview High School	Brooke Pegher	412.282.1800	bpegher@rsd.k12.pa.us
Seneca Valley Intermediate High School	Patti Griest	724.452.6040	griestpc@svsd.net
	Jenifer McMurray		mcmurrayje@svsd.net
Seneca Valley Middle School	Traci Kuntz	724.452.6043	kuntzta@svsd.net
Seneca Valley Senior High School	Dana Hadley	724.452.6040	hadleydn@svsd.net
Shady Side Academy Middle School	Matt Brunner	412.968.3100	mbrunner@shadysideacademy.org
Western Pennsylvania School for the Deaf	Erin Mascaro	800.624.3323	emmascaro@wpsd.org
West Mifflin Area Senior High School	Chriss O'Lare	412.466.7220	olarec@wmasd.org
	Alisa Kellington-Welsh		welsha@wmasd.org
Woodland Hills Jr/Sr High School	Paula Purnell	412.242.2344	pgpurnell@gmail.com
NY/OH/MI/CR Schools	Teacher	School Phone	School Email
Allendale Public Schools, MI	Keith Piccard		piccarke@gvsu.edu
Bristol High School, OH	Rebecca Dobson	330.889.2621	Rebecca.Dobson@neomin.org
Discovery Days Learning Center, MI	Lori Barr		lbarrbarr2277@gmail.com

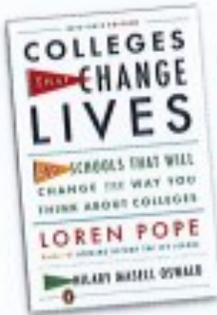
Creek Connections Participating Schools and Sampled Creeks in Northwest Pennsylvania and New York





unusual
combination

ALLEGHENY COLLEGE



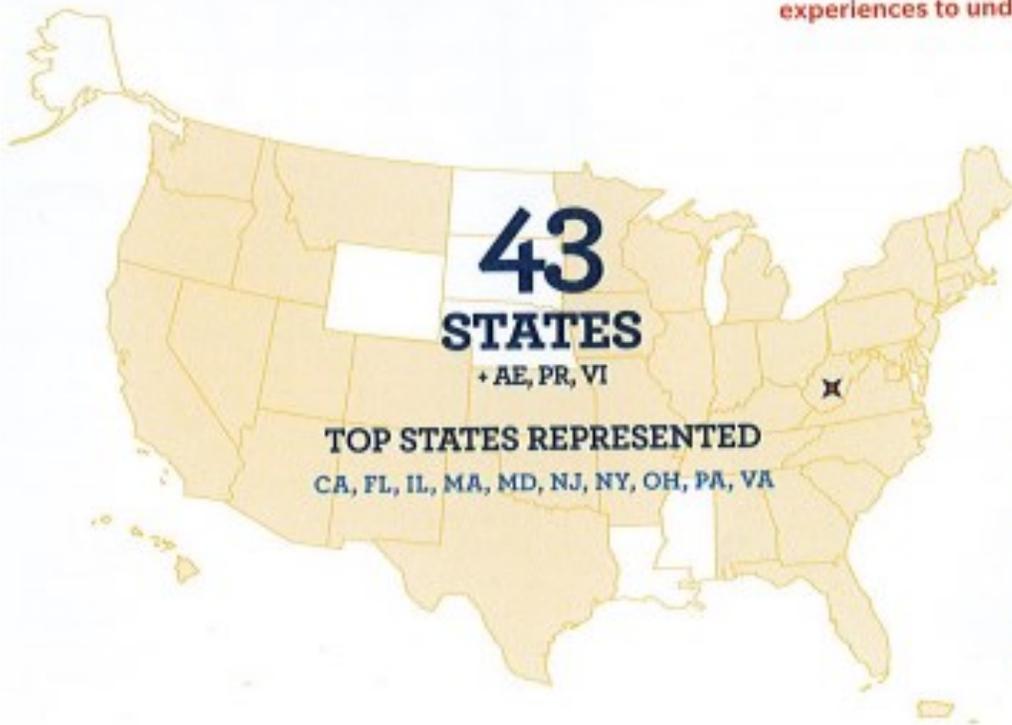
“Today Allegheny shuns the ethos of prestige places and delivers an education at least on par with—and perhaps better than—those places.”

One of the 12 Most Innovative Liberal Arts Colleges in the Nation

Named by U.S. News & World Report for having recently made “the most innovative improvements in terms of curriculum, faculty, students, campus life, technology or facilities.”

No. 1 in Undergraduate Research

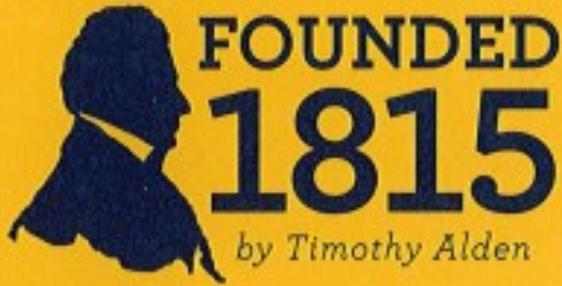
Recognized by the Council on Undergraduate Research as the top baccalaureate college in the nation for providing high-quality research experiences to undergraduates.



53 COUNTRIES

Countries Most Often Represented in the Last Four Years
(Including Abroad Students)

- Brazil
 - Canada
 - China
 - France
 - Germany
 - India
 - Japan
 - Nigeria
 - Pakistan
 - South Korea
 - United Kingdom
-



**2,100
GATORS**

**BLUE &
GOLD**

America's Best Kept College Secrets

"Gators love their school, stay loyal to the college after they leave, and universally consider themselves fortunate to have had an Allegheny education."



No. 2 in Environmental Science

Allegheny's Environmental Science/Studies Department ranks No. 2 in the country, according to EnvironmentalScience.org. The program "teaches students to analyze the relationships between humans and the environment that we live with and use."



great exp

WHAT ALLEGHENY WILL EXPECT FROM YOU

Curiosity & Persistence

An education in the liberal arts and sciences gives you more choices, more opportunities, and, yes, more challenges. Allegheny is one of the few liberal arts colleges in the country that will ask you to choose both a major and a minor. The scientist who can present her research in an engaging yet persuasive manner will be more successful in her career; likewise, the international aid worker who can quickly integrate the latest quantitative data will be that much more effective in his work.

11:1

Student-faculty ratio
Average class size, introductory, 19;
advanced, 12

68%

Graduates who completed one or more
internships in their four years

100%

Seniors who complete a major
research project

WHAT YOU SHOULD EXPECT FROM ALLEGHENY

Rigor & Support

At Allegheny, you'll be asked to complete the type of work that is the caliber of graduate school inquiry. Is it rigorous? You bet. But our faculty members are people who pride themselves on being teachers first—they will advise and support you to move beyond what you can even imagine now. They will provide you with opportunities and challenges that will lead you from hard work and dedication to extraordinary outcomes.

WASHINGTON MONTHLY RANKINGS

**Top
25**

**Liberal Arts
College in the
Country**

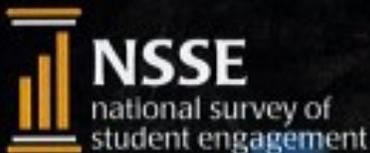
*Based on not only what
colleges do for their
students but what colleges
are doing for the country*

ectations

The Final Outcome

According to the National Survey of Student Engagement, an annual survey of first-year and senior students at four-year schools, Allegheny students give the College high marks.

- 94% of Allegheny seniors report having participated in two or more high-impact practices such as internships and community service
- 94% of Allegheny seniors report that their ability to think critically and analytically improved "very much" or "quite a bit" at Allegheny
- 95% of Allegheny seniors rate their overall college experience as "excellent" or "good"



Decide where you want to make a difference. Allegheny will prepare you.

Academic Programs

Natural Sciences

Applied Computing
Astronomy
Biochemistry
Biology
Chemistry
Computer Science
Environmental Geology
Geology
Mathematics
Neuroscience
Physics

Humanities

Art (Studio, History)
Art & Technology
Communication
Dance & Movement Studies
English
Environmental Writing
Jewish Studies
Languages, Modern & Classical (*Arabic, Chinese, French, German, Latin, Spanish*)
Music
Philosophy
Religious Studies
Theatre
Writing

Social Sciences

Economics
History
Political Science
Psychology

Interdivisional

Art & the Environment
Asian Studies
Black Studies
Chinese Studies
Classical Studies
Community & Justice Studies
Education Studies
Environmental Science
Environmental Studies
French Studies
Global Health Studies
International Studies
Journalism in the Public Interest
Latin American & Caribbean Studies
Medieval & Renaissance Studies
Middle East & North African Studies
Women's, Gender, & Sexuality Studies

Dual Degree/Accelerated Medicine

Accelerated Master's—Occupational Therapy (3/2, Chatham)
Accelerated Master's—Physician Assistant (3/2, Chatham)
Accelerated Doctorate—Osteopathic Medicine (4/4, Philadelphia College of Osteopathic Medicine; 4/4, Lake Erie College of Osteopathic Medicine)
Accelerated Doctorate—Physical Therapy (4/2, Chatham)

Public Policy & Management

Accelerated Master's—Arts Mgmt., Public Policy and Mgmt., Health Care Policy and Mgmt., Information Systems Mgmt. (3/2, Carnegie Mellon)

Engineering

Dual Degree—Aero, Civil, Elec, Chem., Mech., Industrial, Biomedical, Petroleum (3/2, Columbia, Case Western Reserve, Pittsburgh, and Washington Universities)
Master of Science in Engineering (4/2, Columbia)

Teaching

Master of Arts in Teaching—University of Pittsburgh
Accelerated MEd—Xavier University
Guaranteed Interviews for Qualifying Students—Columbia University Teachers College

Nursing

Accelerated Master's (3/3, Case Western Reserve)
Accelerated Doctorate (3/4, Case Western Reserve)

Recent Self-Designed Majors

Forensic Biology • International Development
• Journalism & U.S. Politics • Neurochemistry •
Philosophy of Art

Core curriculum?

All Gators complete First-Year and Sophomore Seminars, which introduce them to academic life at a liberal arts college and help them to develop the skills necessary for academic and career success. Then students work closely with their advisors to choose courses that interest them most.

Students are not required to take an additional prescribed set of introductory courses; instead, Allegheny students must complete one course in each of the following categories throughout their four years. These areas provide the breadth and depth of learning that prepares students for the careers of today.

- ✓ Civic Learning
- ✓ Human Experience
- ✓ International and Intercultural Perspectives
- ✓ Modes of Expression
- ✓ Power, Privilege, and Difference
- ✓ Quantitative Reasoning
- ✓ Social Behavior and Institutions
- ✓ Scientific Process and Knowledge

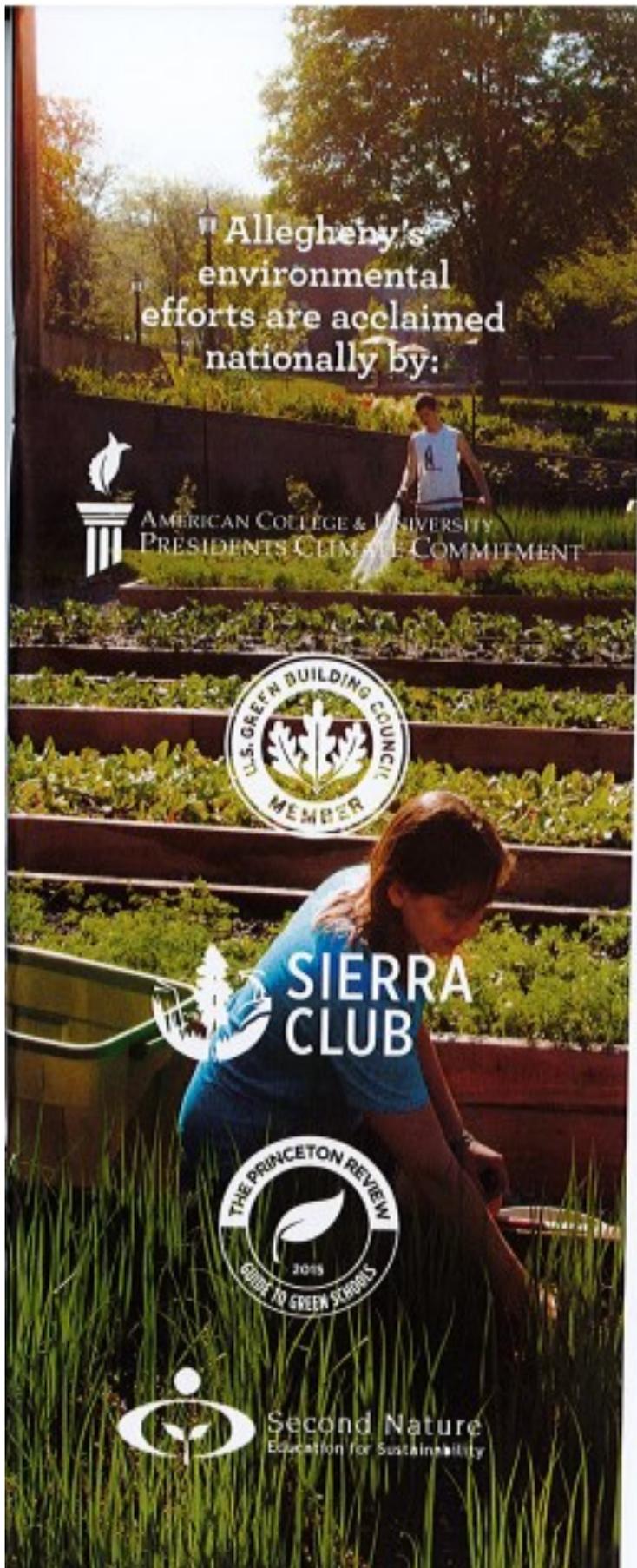
Every Allegheny student conducts significant research with faculty mentors, culminating in our distinctive undergraduate thesis—the Senior Comp.

New Allegheny students often ask “How do I get started in research?” All Allegheny seniors work both independently and with faculty mentors to complete—and defend—an intensive research thesis, or “comp.” However, students often engage in research prior to the senior project, including in classroom/lab opportunities, independent study, and summer research opportunities.

Allegheny students don’t have to wait behind graduate students for research positions on faculty-led projects but instead are actively engaged as research collaborators. Students follow the guidance of faculty mentors through research, conference presentations, co-authored articles, and faculty-led study tours.

Ph.D. Top 5%

Allegheny ranks among the **top 5%** of all schools in the country for the percentage of graduates who go on to earn a Ph.D. Allegheny is in the top 4% in the sciences and top 2% in chemistry.



blue&gold &green

A recent greenhouse gas inventory indicates Allegheny is 71% of the way to achieving our goal of climate neutrality by 2020. Every year sees great strides toward this goal. This past year was no exception.

2015-16 RECOGNITIONS

- No. 2 Environmental Science college in the nation – environmentalscience.org*
- Guide to 353 Green Colleges (top score) – Princeton Review*
- Top GreenPower Partner List – EPA*
- 100 Colleges Doing “Green” Right – bestcollegrankings.org*
- Greenest college campus in PA – eCollegeFinder*
- Cool Schools – Sierra Club*

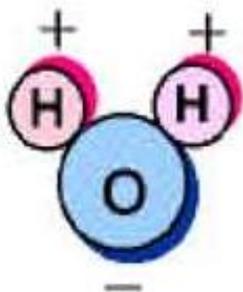
2015-16 EVENTS & ACHIEVEMENTS

- As of January 2016, as a participant in the Better Buildings Challenge, we have achieved 14% efficiency in our energy use intensity. Our ultimate goal is 20% efficiency by 2020.*
- The 13th Annual DeHart Local Foods Dinner sold out and featured the products of dozens of local farmers.*
- The annual Energy Challenge resulted in an 8.2% reduction in electricity consumption and savings of \$6,700.*
- The College added a dozen filtered water refill stations across campus and provided a free stainless steel water bottle to each incoming freshman to discourage the purchase of disposable bottled water.*
- The mandatory reusable takeout container program in Brooks Dining Hall saved over \$17,000 and reduced enough landfill waste to fill six Baldwin Hall dorm rooms this year.*

LEARNING ABOUT WATERSHEDS

Water Basics

Water (H_2O) has two parts hydrogen (H^+) and one part oxygen (O^{-2}) forming the most important molecule on earth. Covalent bonds join the atoms within each molecule. Hydrogen atoms are left with a weak positive charge and oxygen with a slight negative charge, causing water molecules to be attracted to neighboring water molecules. Two water molecules attach to each other with a hydrogen bond. Because of its chemical structure, water has many useful properties and characteristics.



It comes in three forms: liquid, gas, and solid. Most of the time water is in liquid form and is the only common substance that expands rather than contracts when it freezes. Its high heat capacity (takes a long time to heat or boil) allows it to absorb a great amount of heat without much rise in temperature. It has surface tension, adhesion, and cohesion properties that allow it to attach to solid substances, create a surface film on which things can float, and make it stick together as it moves

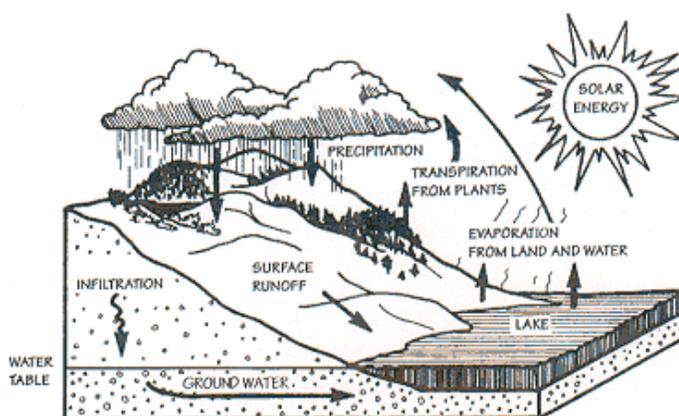
through things (hose, soil) or upward against gravity in a plant. Water could be considered the universal solvent because it dissolves many substances or changes the forms of other substances. It is a necessity of life – our most important natural resource. We have a fixed amount of water on the earth to use and it is always on the move, changing forms in a continuous cycle.

Water Cycle

The global water cycle is the *continuous* cycle of water between the atmosphere and the Earth's surface. The amount of water circulating through the cycle never changes. However the form in which the water exists – either gas, liquid, or solid – does change. Solar energy powers the water cycle, transferring water into the atmosphere, and then precipitating the water to the Earth's surface. A series of storage phases and transfer processes exist between the land and the sea.

Surface water may not stay there for long. **Evaporation** (process by which a liquid becomes a gas) occurs from a range of hosts, including oceans, lakes, plant tissue, and rivers. **Transpiration** is the term often given to the specific process of water vapor being given off by plants. This gaseous form of water will rise into the atmosphere. Once there, **condensation** of the evaporated water converts the vapor into a liquid (or solid) in the atmosphere, helping to form our clouds. Condensation relieves the atmosphere of the water vapor that it had been stockpiling, sending the water back to the earth as **precipitation** (rain, snow, hail, and sleet).

Water Cycle



Source: Project WET: Curriculum and Activity Guide

Where does the fallen precipitation go once it reaches the Earth's surface? Eighty five percent of precipitation falls directly into the oceans. The rest of the precipitation will be

absorbed by vegetation, another portion runs off into neighboring lakes and streams, some will be locked up as solid ice on glaciers, and the remaining precipitation is absorbed into soil and rock, percolating downward to become ground water. **Infiltration** is the process by which water seeps down into the ground through the pores or spaces in soil and rock. This water will reach a ground water **saturation zone** (area underground where all pore space is filled with water).

This process of constantly replenishing the Earth's water supply below the Earth's surface is called **recharge**.

What is a Watershed

The water that does not evaporate or soak into the soil usually drains into streams, rivers, marshes, lakes, and eventually the ocean.



*The land area from which the water drains to a given point is a **watershed**.* Drainage basin is another term for watershed. The watershed boundaries or divides are determined by the high points of land (hill tops and mountains in Western Pennsylvania). Anywhere you stand on the earth's land, you are standing in a watershed. All water on land drains to somewhere, and any type of land and topography can compose a watershed.

You can think of a watershed as the *drainboard* that carries rinse water into your kitchen sink. The excess water of the drainboard makes its way down into the drain of the sink. The drainboard here can be thought of as the total land area that contributes its excess water into a waterway, (the drain).

Think of a small stream in your community. Water from a few acres drained into that little stream. Those few acres were its watershed. Small streams will drain into larger streams. The land areas drained by the small streams make up the watershed of the larger stream into which they flowed...*small watersheds make up the larger watersheds.*

A good example of small creeks or rivers flowing into larger waterways is the Mississippi River. The Mississippi River drains a watershed of about 1,243,000 square miles. Thousands of smaller watersheds compose this massive watershed, including our Ohio River Watershed of Western Pennsylvania.

As inhabitants of the watershed, we are also part of the watershed, for we influence what happens within the watershed-good or bad. We have a tremendous responsibility to ensure that we do not disrupt the watershed in any way. It is important to realize that if we contaminate the water running into the waterway, we also contaminate the waterway itself. Furthermore, by contaminating the waterway, we also affect our neighbors downstream from us who will suffer from the water we are polluting.

- The Six Major Watersheds (Drainage Basins) of Pennsylvania**
(largest to smallest)

 1. Susquehanna River
 2. Ohio River
 3. Delaware River
 4. Potomac River
 5. Lake Erie
 6. Genesee



Map Source: PA Department of Environmental Protection.

Why Study Water and Watersheds?

The inhabitants of a watershed influence its water quality. We have a tremendous responsibility to ensure that we do not disrupt the watershed in any way that will negatively affect our waterways. The more you learn about your watershed, the more likely you will understand the importance of taking care of it. Recognizing the affects that poor land use practices have on our waterways is important because the land interacts with surface water as water drains through a watershed. The bigger your watershed, the more the water comes in contact with the land and the possible pollutants on it. Because waterways and watersheds connect to create bigger waterways and watersheds downstream, impacts from the land and humans can affect downstream areas. We are all connected to each by our waterways. In Western Pennsylvania and New York, how we take care of our waterways can affect the water quality for people in New Orleans, Louisiana, at the mouth of the Mississippi River.

Many people believe that there is an endless amount of clean water available for humans to use, but that is not true. Earth is often called the “water planet” because it has 1.36 billion cubic kilometers of water (if placed on top of the United States land area, it would submerge the 50 states under 145 km of water) (Press and Siever, 1994). However, only a small fraction (between .003%- .01%) of the Earth’s water supply is available as attainable freshwater for human use (Table 1) (Miller, 1994; Cunningham and Saigo, 1999; Press and Siever, 1994; Eblen and Eblen, 1994). And there is no chance of making or finding more because we have the same amount of water on earth as we did millions of years ago, and through the water cycle, we continuously reuse this same water.

Table 1: The Distribution of Water on Earth

Water Compartment	% Total Water on Earth	Average Residence Time Depends on Depth and other factors
Ocean	97.6 %	3,000 to 30,000 years
Ice / Glaciers / Packed Snow	2.07 %	1 to 16,000 years
Groundwater	.28 %	From days to thousands of years
Lakes and Reservoirs	.009 %	1 to 100 years
Saline Lakes	.007 %	10 to 1,000 years
Soil Moisture	.005 %	2 weeks to a year
Moisture in Living Organisms	.005 %	1 week
Swamps and Marshes	.003 %	Months to years
Atmosphere	.001 %	8 to 10 days
Rivers and Streams	.0001 %	10 to 30 days

Source: Cunningham and Saigo, 1999. *Environmental Science: A Global Concern, 5th edition.*

We have placed much stress on our water supplies as the demand for clean water keeps rising. Every day, we become more aware of how pollution impacts aquatic life, surrounding habitats, and water quality – which can limit our uses of that water. Water monitoring helps us assess the present level of water quality, understand its threats, and help us make plans for maintaining healthy water quality for the future. Monitoring helps increase our understanding and appreciation for our waterways and all the benefits that they provide.

Benefits of Our Waterways and Wetlands

Our waterways and wetlands provide numerous services at no cost. Many of these natural services remain unnoticed until their alteration results in...a flood for example. Although it is difficult to place a value on aesthetic components of waterways and wetlands, we can estimate the ecological costs those rivers and wetlands provide. For example, we can estimate

the cost of cleaning the water that wetlands do naturally by computing the cost of installing a water treatment plant. In a 1990 study, without the Congaree Bottomland Hardwood Swamp in South Carolina, the area would need a \$5 million wastewater treatment plant (EPA, 1999). The reason for assessing services of waterways and wetlands is to make their purchase expensive and unlikely. Would developers be able to afford to purchase a section of land containing a wetland or river in it if they had to replace the natural services performed for free with expensive machinery to perform the same function? The current problem with economic assessment of natural resources is that most of the services performed naturally are left out of the cost.

Waterway Benefits:

1. Transportation of water, sediments, and nutrients from land to sea
2. Rivers are an efficient transportation mode of moving grain, corn, timber, steel, coal, and some manufactured goods
3. Mode of generating electricity through hydropower
4. Creates employment dealing with navigation, flood control, municipal & industrial water supply, electrical supply, fishing and food supply, water recreation, scientific research, and environmental education
5. Aesthetic and recreational value
6. Important source of drinking water for urban and rural areas
7. Important for fishing economy - 45% of 1992 fishing supply sales were generated from river use (National Waterways Conference, Inc., 1999)
8. Habitat for an array of unique animals and plants-including many endangered species
9. Serves as corridors for migratory birds and fish
10. Builds deltas and beaches when river deposits sediments onto its banks
11. Regulates salinity & fertility of estuaries and coastal zones

Wetland Benefits:

1. Natural water quality improvements, because wetlands retain excess nutrients, some pollutants, and reduce sediment that would clog waterways and affect fish & amphibian egg development
2. Flood protection, because wetlands act as natural sponges that traps and slowly releases surface water, rain, snowmelt, and flood waters
3. Shoreline erosion control, as wetland plants hold the soil in place with their roots, absorb energy of waves, and break up flow of stream or river current
4. Provide natural products that we eat or use: trout and other fish, cranberries, blueberries, cattails (these are edible), wild rice, timber, peat (incompletely decayed plant remains used for fuel or enriching garden soil)
5. Excellent fish and wildlife habitat - more than **1/3** of United States threatened & endangered species live *only* in wetlands (EPA, 1999)
6. Aesthetic and recreational value
 - In 1997, Pennsylvania earned an estimated 40 million dollars from canoeing supplies/trips alone (Kennedy, 1998)
 - An estimated 50 million people spend approximately \$10 billion each year photographing wetland-dependent birds (EPA, 1999)

THREATS TO WESTERN PENNSYLVANIA WATERWAYS

What is Water Pollution

Water pollution is an undesirable change in the physical, chemical, or biological characteristics of a body of water that can negatively affect the health, survival, or activities of humans and other living organisms. Water is valuable to us because it is necessary for so many things, but pollution limits its value and usefulness. Therefore, much attention has been given to studying sources of pollution, and finding ways to prevent and treat water pollution.

Often, pollution is classified into two categories: **point source** and **nonpoint source** pollution. Point source pollution is a single, identifiable source that **discharges** (empties) pollutants into the environment. Examples include a leaking waste storage container and a drainage pipe from a sewage treatment plant, industry, or off a city street. Nonpoint source pollution's source is more difficult to pinpoint because this pollution type can enter a stream with runoff from a widespread land area. Examples include farm fields, large construction sites, mining operations, lawns, and parking lots. To help distinguish the difference, think of point source pollution as pollution that could be stopped if a cap or seal was placed over the discharge source or small barrier around the source before entering the stream. However, to stop nonpoint source pollution, you would need to build a long cement barrier that would border beside the stream above and below ground and catch the runoff from the adjacent land.

Water Pollution Legislation

The Federal Water Pollution Control Act of 1972 renamed the Clean Water Act of 1977 (amended also in 1981, 1987, 1993) is the government legislation that seeks to protect the nation's vast water resources from pollution. The 1972 act changed outdated water pollution laws from 1899 and for the first time placed limitations on point source pollution discharges and created surface water quality standards. All factories, wastewater treatment plants, and other point sources were given limits and permits for the amount of conventional and toxic water pollutants they were allowed to discharge. In order to meet the act's goal of eliminating pollutant discharge into all navigable waters by 1985, industries were to implement the "best practicable" pollution control equipment by 1977 and more advanced equipment by 1983. All municipal treatment plants were supposed to have secondary treatment practices in place by 1977, and further improvements by 1983. Revisions to the act and deadline extensions have occurred with each of its amendments. However, the 1987 amendments called for state management programs for nonpoint sources, a pollution type generally overlooked previously. The Federal Government also enacted the Safe Drinking Water Act of 1974, requiring the EPA to establish national drinking water standards or maximum contaminant levels for all pollutants that "may" have adverse effects on human health.

Pennsylvania's water pollution control programs date back to 1905 (Purity of Waters Act), and the first comprehensive water pollution control state law, the "Clean Streams Law" was enacted in 1937. This law has been strengthened with amendments over time and addresses standards passed down by the Federal Government.

Sources of Western Pennsylvania Water Pollution

A 1994 Department of Environmental Protection assessment of water quality and biological conditions of waterways indicated 49,315 miles (91.4% of the 53,962 miles of Pennsylvania streams) were meeting the Clean Water Act's "fishable/swimmable" goal; and 4,647 miles (8.6%) failed to meet the above criteria because of pollution problems (Arway, 1997).

Acid Mine Drainage - point and nonpoint source

Of the 8.6% of polluted streams, the biggest threat (56% or 2,596 miles) can be attributed to mineral resource extraction. **Acid mine drainage** (AMD) affects 2,404 miles of streams. “The influx of untreated acid mine drainage into streams can severely degrade both habitat and water quality often producing an environment devoid of most aquatic life and unfit for desired uses” (Kimmel, 1983). AMD is acidic water with a pH often below 4.5 (see pH information sheet for more information).

Coal is mined in two ways – underground mines with tunnels or surface/strip mining (removal of land from the surface to dig down to the coal seam). Acid mine drainage is often the product of water running through abandoned mining operations from the early 1900s, and to a lesser extent active mining. Soil and crushed rock removed from above coal seams underground is called overburden and can contain iron pyrite (FeS_2 , fool’s gold). The disturbance of this rock and soil exposes the pyrite to air and water, creating a chemical reaction forming ferrous iron (Fe^{+2}), iron hydroxide ($\text{Fe}(\text{OH})_3$) and sulfuric acid (H_2SO_4). The acid can dissolve other minerals and metals from surrounding rock, and can itself dissociate (break apart) yielding sulfate (SO_4^{-2}) and extra hydrogen ions (H^+) to the water (lowering the pH). Then the acid mine drainage finds its way into groundwater and surface water, adding acidity (lowering the pH). In a different process it is possible that neutral or alkaline mine drainage (NAMD) may be produced.

AMD releases toxic metals such as iron, aluminum, and manganese from surrounding rocks. When iron in the water comes in contact with dissolved or atmospheric oxygen, it oxidizes and precipitates out (drops out) and becomes the yellowish-orange stain on the bottom of the stream. These streams are often nicknamed “yellow boys”. This can also happen with the other metals – aluminum (white) and manganese (black). These metals can clog fish gills causing breathing complications or cause deformities to young fish. When they settle on the stream bottom, they fill in spaces between rocks where insects live or insect and fish eggs are laid, often smothering the eggs.

Acid mine drainage can and does have a myriad of negative effects upon the environment. In streams that are not well buffered by carbonate rocks, severe stress is placed upon all life within the stream because of the lowered pH levels (see pH information sheet for more information). Surface coal mining can be the source of much soil erosion to a stream because of the removal of vegetation and disturbance of the land surface.

There are ways of treating acid mine drainage. Since the late seventies, state and federal laws require that surface/strip mining companies restore the land to a state which is, as near as possible, to its original state. This includes the replanting and landscaping of the old site. AMD coming out of surface and underground mining operations can be treated either passively or actively.

Active treatment methods use strong alkaline chemicals (limestone, soda ash or sodium carbonate, caustic soda or sodium hydroxide, and ammonia) to neutralize the acid. In the process, metals precipitate out and have to be removed and securely stored. Active treatment is expensive to use over long periods of time, can be chemically dangerous, and is labor intensive.

Passive treatment methods generally employ channels, limestone, vegetation,



ponds and wetlands to mitigate the acidity problem. Limestone rids the extra hydrogen ions that make the water acidic. Wetland plants can take up, store, and process metals. And the natural process of metals reacting with oxygen and settling out of the water can be a useful solution. An example of a passive system for mitigation of acid mine drainage has been undertaken by one project participating school, Chartiers Valley High School.

The Scrubgrass Run Watershed Project attempts to treat the acid mine drainage problem in Scrubgrass Run, which eventually empties into Chartiers Creek and the Ohio River. Two ponds were set up trying to remove the metals from the water. The first induces the reaction of iron and oxygen to take place allowing the iron to precipitate in the form of rust. The water, which ideally is devoid of iron as well as oxygen, is then channeled into the second pond. Aeration is the main purpose of the second pond, adding oxygen to the water before sending it off to Scrubgrass Run. The treatment process is a challenging work in progress as Chartiers Valley seeks ways to keep oxidized iron in the first pond, and to better aerate the second pond. For more information on this project contact them at <http://members.tripod.com/scrubgrass/>.
(photo from Scrubgrass website)

Oil and Gas Extraction – point source

Though less of a threat to streams as coal mining, this type of mineral extraction is still a problem in Western Pennsylvania. Oil and gas development includes the drilling, stimulation (fracturing of underground rock formations with pressure), and the production of oil and gas deposits buried underground. The geologic history of the region has created some rich reserves of gas and oil. Ever since Colonel Edwin Drake drilled America's first oil well in 1859 in Titusville, PA, the industry has grown to meet society's demand for fossil fuels.

Operating wells produce brine (salty water) with some toxics such as metals and phenols (organic hydroxy acid that is corrosive, smelly, and poisonous). Sometimes this brine enters streams untreated deliberately or illegally by an operator or through storage container leaks. Oil spills and broken pipes can also be a problem, adding crude oil to streams. In addition, forests are cleared for installing pumps and unpaved access roads are carved through the landscape, adding soil erosion and siltation threats to streams.

Agriculture – usually nonpoint source

Agriculture, the largest industry in Pennsylvania, is also the second major source of stream pollution (Arway, 1997). To keep land rich with nutrients, especially nitrates and phosphates, liquid and granular chemical fertilizers and animal manure are applied to farm fields. If applied in excess or during non-growing seasons, the fertilizers can be washed off the fields and into nearby streams, stimulating excessive plant growth (algae and aquatic weeds). This can turn a waterway into a green soupy mess and aquatic weeds can frustrate swimmers, fisherman, and boaters. When the vegetation dies, aerobic (oxygen using) bacteria decompose it and use oxygen from the water. The decline in oxygen can cause aquatic life to suffer or even die. This process is called **eutrophication**. See the nitrates and phosphates information sheets for more information.

Wind and rain runoff sends soil²³ into streams, creating turbid (cloudy) conditions. This soil settles out on the bottom of the stream (called sedimentation) and can destroy insect habitat, places for fish and insects to lay eggs, and even smother existing eggs. (See the turbidity

information sheets with more information). Soil erosion can be caused by poor plowing techniques, such as failing to till fields with the contours of the land. There are no-till or conservation tillage methods that hold moisture better and prevent erosion. Failing to have crop cover during non-growing seasons or on unused fields is another source of soil erosion. Plant roots help keep soil in place, and maintaining a healthy riparian (streamside) vegetative zone can reduce the amount of soil erosion that reaches a stream. In addition, plants in riparian zones can soak up extra nutrients before they enter a stream.

Livestock is both a source of nutrients and soil erosion. Animal manure can add nutrients and harmful bacteria to a stream, especially if the livestock graze near or even in



a stream. These animals can also erode banks and trample down vegetation that holds back erosion. Stream fencing and specially designed stream crossing areas can help keep livestock from damaging stream banks or

adding waste directly to the stream.

Pesticides (herbicides and insecticides) are chemicals used by farmers that were developed to control plant and animal pests. If applied incorrectly to fields or in excess, these chemicals can enter a stream through wind and water erosion and can negatively affect all creatures – pest and non-pest. Pesticides can be toxic to aquatic animals at even low levels and can contaminate drinking water sources. By following the label specifications for the amount and season for pesticide applications, and by being careful with aerial applications, the amount of these chemicals entering streams can be reduced. In addition, there are non-chemical approaches to pest management (biological control) practices that can be used.

Irrigation systems that withdraw water from nearby streams can disrupt the stream system. Lowering the water level can increase the temperature of the waterway because shallower water warms faster than deeper water. Plus shallow water can disturb fish habitats and mussels that were normally underwater along stream edges can become exposed and vulnerable to death and predators.

Deforestation – nonpoint source

Pennsylvania is fortunate to have some very productive forests filled with trees (such as black cherry, pine, and oak) well sought after by timbering / lumber companies. Unsustainable forestry practices can harm streams in a number of ways. When trees are removed, especially if all trees are removed from an area (clearcutting), soil erosion will increase because there are no roots to hold soil in place and there is no leaf cover to lessen the impact of raindrops. Removing riparian zone trees intensifies soil erosion and eliminates an effective tool for catching uphill soil that washes toward the stream. The removal of streamside vegetation eliminates shade from the stream, thus increasing the temperature of the water (thermal pollution) (See the temperature information sheet for more information). Soil and silt can also be washed off the many unpaved logging roads that are constructed to reach remote parts of a forest.

Acid Rain – nonpoint source

Rain is naturally acidic (pH of 5.6) because of carbon dioxide in the air reacting with water to form carbonic acid, which can dissociate producing extra hydrogen ions. Due to human activity (atmospheric pollutants from fossil fuel burning, industrial processes, and automotive

exhausts), we have increased the acidity of some precipitation. Sulfur dioxide (SO₂) and nitric oxide (NO_x) gases are sent into the atmosphere, are chemically changed, and return to the earth as wet deposition (rain, sleet, or snow) or dry deposition (dust particles).

The rain that falls in Pennsylvania averages a pH between 4.0 and 4.5. America's most acidic precipitation centers around Pennsylvania, Ohio, and New York. The Pennsylvania Fish and Boat Commission indicated that Pennsylvania receives more acid rain than any other U.S. state. Why is this? Pennsylvania is downwind of and is part of the industrial belt of the country – the big cities along the Great Lakes like Chicago, Detroit, Cleveland, and inland cities in Ohio, Illinois, Indiana, and Pennsylvania. Pittsburgh is also part of this industrial belt. These cities add air pollutants that create acid rain, and Pennsylvania is in the downwind weather patterns containing this rain.

Whether or not acid rain is a problem to streams depends on the geology of a region. Luckily, most of Western Pennsylvania rocks, bedrock, and soil contain calcium carbonate and magnesium carbonate, which can neutralize the acid (get rid of the extra hydrogen ions). Alkalinity represents the acid buffering capacity of the water (see the alkalinity information sheet later in the handbook). Acid rain does become a problem in Western Pennsylvania streams during major storm events, where surface runoff does not allow the acidic precipitation to come in contact with the buffering geology of the region. Quick acidic snowmelts can also cause these “acid spikes” to a stream. The stream's pH will recover eventually from these acid spikes. Acid rain can also add to the high acidity in acid mine drainage streams – streams that recover less successfully from their low pHs.

Sewage – point source

Sewage is the third worst Pennsylvania stream pollutant affecting 400 miles of streams (Arway, 1997). Even though wastewater treatment facilities are supposed to treat sewage before it is released to a waterway, some municipal plants in Western Pennsylvania are outdated. Some towns have storm drains connected to sewage lines. During storm events, the sewage treatment plant cannot handle the flood of water and sewage and may release untreated sewage to the stream. Some outdated treatment plants fail to remove all oxygen demanding organic solids through their treatment process, and some outdated plants are too small to meet the need of an increased community population. Great efforts have been taken to update facilities to meet government regulations. Rural homes use backyard septic systems to treat sewage, which can have failing processes or leaking storage components. This adds additional sewage to the groundwater and streams.

Sewage is harmful to a stream for a number of reasons. Sewage contains organic matter, which is broken down by bacteria in a stream. This aerobic (oxygen using) bacteria lowers oxygen levels in a stream (increased biological oxygen demand). There is a natural balance of organic substances in a stream (from dead plant and animal parts in and around a waterway) that need to be decomposed, but adding extra sewage organics can unbalance the system. Sewage is also rich in nutrients. As mentioned in the agriculture section, extra nutrients in a stream can also disrupt the stream ecosystem.

There are other problems with sewage additions. Turbidity (cloudiness) of the water can increase as sewage suspended solids are added. Untreated waste can also include chemicals, metals, and pesticides, possibly from industries connected to municipal systems. Pathogens (organisms that cause disease) exist in untreated sewage, and can be successfully killed with chlorination or ultraviolet light. However, chlorine can be toxic to a stream if used in excess during treatment. Wastewater can also be higher in temperature than the stream water, adding thermal pollution to the stream.

Industry – point source

Even though the Department of Environmental Protection Regional Offices regulate and control permits to reasonably limit industrial discharge, pollutants may still enter streams from various Western Pennsylvania industries. Below is a chart of industrial pollutants.

Power Plants	Heat, silt, chlorine
Steel Mills / Manufacturing	Heat, metals, acids, oil, cyanide, phenols (organic hydroxy acid that is corrosive, smelly, and poisonous)
Food Processing / Slaughterhouse	Organic matter (blood, fat, meat parts and juices), chlorine.
Paper Mill	Organic matter, acids, sulfites, metals, heat, chlorine.
Tannery	Organic matter, acids, metals
ALL of the above	Air pollution that can cause acid rain

Urbanization / Suburban Areas – point source and nonpoint source

Urban areas can place much stress on waterways because of the concentration of people and the alteration of land. Some of the problems previously discussed are associated with urbanization and suburban areas – industry, sewage disposal, and acid rain – but there are others worth mentioning.

Water withdrawal for municipal drinking water and industries is a problem that receives much attention especially during drought years. Lowering the water level can increase the temperature of the waterway because shallower water warms faster than deeper water. Plus shallow water can disturb fish habitats and mussels that were normally underwater along stream edges can be exposed.

Thermal pollution is a serious problem because shady streamside trees are often removed in urban areas, allowing sunlight to heat the water. Rainwater that flows over hot paved surfaces (roads and parking lots) is drained into a stream, possibly increasing its temperature. During the winter, road salt added to roads often washes into streams, increasing their salinity and total dissolved solids concentrations.



Cars driving₆ on those paved streets add air pollutants to atmosphere that can create acid rain, and vehicles can add pollutants more directly to a stream when they leak oil or antifreeze onto roads and parking lots.

Homeowners can impact a stream. Improper disposal of car waste (oil and antifreeze) changed at home, as well as the improper disposal of other household wastes and toxins can add to water pollution. Some homeowners dump wastes into storm drains that empty directly into nearby creeks. Many homeowners take great pride in a perfectly manicured lawn. However, if lawn fertilizers and pesticides are used improperly or in excess, they can wash into nearby waterways during rain

events.

As urban sprawl continues in Western Pennsylvania and more people move out of cities and into the suburban areas, the development of these areas can significantly degrade waterways. For instance, construction sites for homes, businesses, and roadways can cause soil erosion and siltation as vegetation is removed from the land.

Recreation Areas – point source

To escape the city or home for a while, many people head to the woods. The natural beauty of Pennsylvania draws millions of visitors to its forests and waterways. Pennsylvania's 4.5 million acres of public land include 116 state parks (one of the largest systems in the United States), and 2.1 million acres of state forests (one of the largest in Eastern United States). There are close to 54,000 miles of waterways, 2,500 lakes and ponds, and 5,000 miles of trails (Department of Conservation and Natural Resources, et. al., 1990's). Recreation use on public and private land can be detrimental to the waterways that many people come to enjoy.

Rural vacation homes and cabins can have faulty septic systems or none at all. All terrain vehicles (ATV's) can tear up land and cause soil erosion near streams. Illegal ATV riding in a creek can destroy fish, mussel, and insect habitats. Some hiking trails and "off roading" areas are being eroded. Litter from hikers, boaters, fisherman, and campers can also be an annoying problem.

Problem Streams of Western Pennsylvania

Based on a Pennsylvania Department of Environmental Protection (Resources) "1988 Pennsylvania Water Quality Assessment", a list of 20 waterways of most concern due to pollution was created. The following Western Pennsylvania waterways made that list - all are located in southwest corner of the state:

Waterway	Miles Affected	Problems
Allegheny River	14.5	Pesticides, industrial wastes, acid mine drainage
Monongahela River	12.2	Pesticides, industrial wastes, acid mine drainage
Ohio River	40.0	Metals, reduced oxygen levels, pesticides, acid mine drainage, industrial wastes, chemicals
Chartiers Creek (tributary to Ohio River)	35.0	Metals, reduced oxygen levels, acid mine drainage, pesticides, turbidity and suspended solids
Raccoon Creek (tributary to Ohio River)	78.0	Metals, reduced oxygen levels, acid mine drainage, turbidity and suspended solids, dissolved solids

Source: Cuff, D.J. et al., 1989. *The Atlas of Pennsylvania*

HOW TO STUDY A WATERWAY

There are three main ways of studying a waterway to determine its health and quality. They include chemical testing, biological monitoring, and land use assessments.

Chemical Testing

The condition of a waterway can be determined through a series of chemical tests. Chemical tests can sometimes pinpoint exactly what substance is polluting the waterway or pinpoint the pollution source. Chemical testing has a longer history for being used to determine stream health, although biological monitoring is becoming more common. A biological test can indicate that a waterway is polluted, but chemical tests can help identify the exact pollutants. Because chemical testing is the most specific and reliable method in water testing, chemical testing is the method performed on drinking water. Chemical testing may also assist in locating sources of pollution. For example, if the tests indicate that a high concentration of phosphates and nitrates are present in the water downstream of a farm but not upstream, one could hypothesize that fertilizer runoff is occurring around the farm. A list of chemical tests that are performed to determine water quality are listed below:

- **Alkalinity** - Resistance to change in pH or acidity
- **Ammonia** – Form of nitrogen, a nutrient for plants
- **Calcium** – Natural from rocks, incorporated into a “hardness” test
- **Chloride** – From salts, sea water, or industry
- **Chlorine** - Common disinfectant to kill pathogens
- **Chromium** - Toxic, corrosion inhibitor added to industrial cooling processes
- **Conductivity** - Dissolved organic matter within water
- **Copper** - May exist naturally as a soluble salt or suspended solid
- **Cyanide** – Toxic waste product of metal plating operations
- **Dissolved O₂** - Presence of oxygen molecule in water
- **Fluoride** – Added to municipal water to strengthen teeth
- **Hardness** – Calcium, magnesium and determines if water is soft or hard
- **Iron** - Natural, but in excess can indicate acid mine drainage
- **Magnesium** – Natural from rocks, incorporated into a “hardness” test
- **Manganese** - Needed by plants and animals, causes a bitter taste, also stains laundry
- **Nitrogen** - Required by plants and animals to produce protein
- **pH** - Measurement of hydrogen ion concentration, determines if water is acidic or basic
- **Phosphorus** - Limiting growth agent in most organisms, causes too much growth if in excess
- **Salinity** – Concentration of all ionic constituents of halides and bicarbonates (salts)
- **Silica** – Natural nutrient for diatoms, used in their skeletal structures
- **Sulfates** - Mineral common in water, nutrient, can be from acid mine drainage if in excess
- **Sulfide** – From anaerobic (no O₂) bacterial breakdown of organic waste, rotten egg smell
- **Temperature** - Different aquatic organisms thrive in different temperature ranges
- **Total Dissolved Solids** - minerals, organic matter, and nutrients dissolved (not merely suspended) in the water
- **Turbidity** - Cloudiness of water from visible sediments and particles
- **Zinc** - Industrial effluents contribute large amounts of zinc

Biological Testing

The plants and animals that inhabit waterways are good indicators of the water's quality. A person can study the insects, fish, mussels, algae, other plant life, bacteria, and streamside creatures to make conclusions about a stream's health. The more variety of aquatic life present in a waterway, the better. The variety of life in any habitat is called **biodiversity**. In a healthy stream, many different types of insects or fish will be found throughout the stream. If only a few species dominate the waterway, then it is likely something about the stream is unhealthy.

Insects, molluscs, and worms living in streams and rivers are examples of macroinvertebrates (big enough to be seen by naked eye), or **benthic** (bottom dwelling) organisms. Microinvertebrates are organisms that need a microscope to be seen. Sampling benthic macroinvertebrates can be very accurate in detecting overall changes in water quality (not necessarily specific chemical parameters) because they: 1) reflect long-term condition of the stream, 2) are ubiquitous, have high species diversity, and are more sensitive to changes in the ecosystem than fish communities, 3) live on the bottom of waterway, where pollution associated water quality problems can be magnified. Fish and mussels can also categorize the health of a stream. It is debatable about which can reflect long term pollution trends better – fish or insects.

Every waterway in the world has the potential to host a variety of macroinvertebrates in its waters. However, many streams lose this capability when altered by pollutants naturally or through human interference. By polluting waterways, we disturb where the organisms live in the stream, what they eat, and the chemical levels of the water that they can tolerate.

Different organisms have specific tolerances to pollutants found within the water. Organisms that are sensitive to pollution will not inhabit those waters that are degraded. Some of the **pollution sensitive** macroinvertebrates (sometimes referred to as “group 1” organisms) examples include mayfly nymph, stonefly nymph, caddisfly larva, and water penny beetle larva. Large numbers of pollution sensitive organisms generally indicate good water quality. Their response to extreme pollution can be to move by drifting (letting themselves get washed downstream to a different location) or to die.

A second group of aquatic organisms are more tolerable to a wide range of water quality conditions (group 2). Some of these organisms include water striders, crayfish, and whirllygig beetles. The **pollution tolerant** (group 3) organisms include blackfly larvae, leeches, and aquatic worms. These creatures are *not* sensitive to pollution, and may exist in very polluted waters.

A healthy stream will have organisms from each group. Just because pollution tolerant creatures are present does not mean the water is polluted. Check to see if there are any organisms from the other more pollution sensitive groups. If a stream only contains group 3 organisms, it can be hypothesized that the stream is currently significantly degraded. Based on macroinvertebrates that you collect, the health of the stream can be calculated using a **Pollution Tolerance Index (PTI)**.

Pollution sensitive indexes are not restricted to analyzing macroinvertebrate populations in a waterway. Other species, such as fish, mussels, algae, and bacteria populations have also been analyzed using the same strategy behind the macroinvertebrate pollution indexes. In addition, the health of a waterway can also be estimated by observing bird and mammal interaction with the waterway. If you never see a common riverbank predator eat from a creek, (such as a raccoon), or you never see deer drink from the waterway, then there might be something wrong with the water.

Land Use / Habitat Assessment

This approach analyzes the physical habitat in and surrounding the waterway to identify possible pollution sources running into the river. Land use assessment is a quick, practical method of locating the source of degradation to a waterway. The first step to assessing land usage surrounding the waterway is to determine how the land surrounding the waterway is being used. Different types of land use generate different types of pollutants. Land use assessment is especially useful when human infrastructures and land alterations surround the waterway. Classify the land surrounding the water source as residential, commercial, agricultural, natural, or industrial. There are two source types of pollution that enter waterways, point and nonpoint sources. **Point source pollution** is simply pollution that's source can easily be identified and pinpointed. Typical point sources of pollution are storm water drains, industrial waste discharge, sewage plants, and construction runoff. Even though point sources are regulated by law, they are still a major threat to waterways. **Nonpoint sources of pollution** are scattered and diffuse; and are harder to identify the exact location of entry. Nonpoint sources can be identified or hypothesized by observing the land use surrounding the water source. Examples include: a pollutant leaching through the soil, nutrient enrichment from agricultural areas, storm runoff over an urban setting, fertilizers and pesticides from lawns.

A land use / habitat assessment is the RCE, or Riparian, Channel, and Environmental inventory. The RCE assessment is an analysis of the physical and biological conditions for a 100-meter stretch in and along a stream. This assessment is used primarily used in streams that have been heavily modified by man. Land use, physical structures in the stream, and biota are explored by the RCE. The **riparian zone**, the vegetation alongside streams, is studied. Riparian areas important because they help control floods, prevent soil erosion, take up extra nutrients, and provide shade to the stream. Channel alteration, stream bank stability, and substrate condition are also studied by the RCE. To prevent flooding or to irrigate arid lands, humans have historically modified channels. However, the ecosystem of the steam is dramatically altered, for pools and riffle zones can become eliminated when the channels are manipulated. Smoothing a channel also removes plants, logs, and boulders (snag habitat). Alteration of a stream's channel can drastically reduce the biodiversity of the stream, because it removes habitat diversity. The biota of the stream is also analyzed by the RCE. A calculated score can be determined at the end of the RCE that correlates with an overall stream condition (excellent – poor).

How You Will Study Your Waterways in this Project:



There are tests and analysis methods to study the chemical, biological, and land use/habitat characteristics of waterways included in this handbook. Chemical testing is required by the project throughout the school year, and biological and land use/habitat assessment is encouraged. Together, they can help determine the health of your stream and help you to better understand its threats and protection needs.

Resources Used for the Learning About Watersheds section:

- Cauduto, Michael. (1985). Pond and Brook - A Guide to Nature Study in Freshwater Environments. (2nd Ed.). New Jersey: Prentice-Hall.
- Cunningham, W. P. and B. W. Saigo, 1999. Environmental Science: A Global Concern, 5th edition. Boston: WCB McGraw-Hill.
- Deming, H.G., 1975. Water: The Fountain of Opportunity. New York: Oxford University Press.
- Dobson, C., and G.G. Beck, 1999. Watersheds: A Practical Handbook for Healthy Water. Buffalo, NY: Firefly Books, Inc.
- Eblen, R.A, and W. R. Eblen (eds.), 1994. The Encyclopedia of the Environment. Boston: Houghton Mifflin Company.
- EPA or Environmental Protection Agency, 1999. Wetlands and People. Washington, DC: Office of Water, Environmental Protection Agency - <http://www.epa.gov/OWOW/wetlands/vital/people.html>
- Finlayson, M. and M. Moser (eds.), Wetlands. Oxford: Facts on File.
- Kennedy, L.R., 1998. Promoting Tourism in Rural America. Rural Information Center Publication Series, No 6. Beltsville, MD: Rural Information Center (USDA) – <http://www.nal.usda.gov/ric/ricpubs/tourism.html>
- Leopold, L. B. and K.S. Davis, 1980. Water. Alexandria, VA: Time Life Books.
- Miller Jr., G.T., 1994. Living in the Environment: Principles, Connections, and Solutions, 8th edition. Belmont, CA: Wadsworth Publishing Company.
- National Waterways Conference, Inc., 1999. Why Waterways Work. Washington, DC: National Waterways Conference.. - http://www.waterways.org/ww/ww_national.html
- Novak, J.M. and W. H. Woodwell, Jr., 1998. A Watershed Primer for Pennsylvania: A Collection of Essays on Watershed Issues. Pittsburgh, PA: Pennsylvania Environmental Council.
- Press, F. and R. Siever, 1994. Understanding EARTH. New York: W.H. Freeman and Company.
- United States Department of Agriculture, Soil Conservation Service, 1960. What is a Watershed? (pamphlet PA-420). Washington DC: U.S. Government Printing Office.

References used for Threats to Western Pennsylvania Waterways section:

- Arway, J.A., 1997. Water Pollution. Harrisburg: Pennsylvania Fish and Boat Commission.
- Cuff, D.J, W.J. Young, E.K. Muller, W. Zelinsky, R.F.Abler (editors), 1987. Atlas of Pennsylvania. Philadelphia: Temple University Press.
- Department of Conservation and Natural Resources, Pennsylvania Fish and Boat Commission, Pennsylvania Game Commission, and Dept. of Community and Economic Development, 1990's. Woods, Water, and Wildlife. Harrisburg.
- Department of Environmental Protection, 1998. Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Harrisburg, PA: Department of Environmental Protection.
- Eblen, R.A, and W. R. Eblen (eds.), 1994. The Encyclopedia of the Environment. Boston: Houghton Mifflin Company.
- Kimmel, W.G., 1983. The impact of acid mine drainage on the stream ecosystem. In: Pennsylvania Coal: Resources, Technology and Utilization, (S.K. Majumdar and W.W. Miller, eds.), The PA Academy of Science Publication, p.424-437.

- Laws, Edward A., 1993. Aquatic Pollution: An Introductory Text, 2nd edition. New York: John Wiley & Sons, Inc.
- Mason, C.F., 1991. Biology of Freshwater Pollution, 2nd edition. Essex, England: Longman Scientific and Technical (Longman Group UK Ltd).
- Miller Jr., G.T., 1994. Living in the Environment: Principles, Connections, and Solutions, 8th edition. Belmont, CA: Wadsworth Publishing Company.
- Novak, J.M. and W. H. Woodwell, Jr., 1998. A Watershed Primer for Pennsylvania: A Collection of Essays on Watershed Issues. Pittsburgh, PA: Pennsylvania Environmental Council.
- Pennsylvania Fish and Boat Commission, 1995. Acid Precipitation. Harrisburg, PA: Pennsylvania Fish and Boat Commission.
- Renn, C. E., 1969. Our Environment Battles Water Pollution. Chestertown, MD: LaMotte Chemical Products Company.

References for the How to Study a Waterway section:

- Allan, J.D., 1995. Stream Ecology: Structure and Function of Running Waters. London: Chapman and Hall.
- Andrews, William A., 1987. Investigating Aquatic Ecosystems. Scarborough, Ontario: Prentice-Hall.
- Cauduto, M. J., 1985. Pond and Brook - A Guide to Nature Study in Freshwater Environments. (2nd Ed.). New Jersey: Prentice-Hall.
- Campbell, Gayla and S. Wildberger, 1992. The Monitor's Handbook. Chestertown, MD. The LaMonte Company.
- Isaak Walton League of America, Inc. Save Our Streams, A Citizen Action Program. Arlington, VA.
- Karr, J. R., 1991. Biological Integrity: A Long Neglected Aspect of Water Resource Management. Ecological Applications 1(1) February: 66-84.
- Kerans, B.L. and J.R. Karr, 1994. A Benthic Index of Biotic Integrity (B-IBI) for Rivers of the Tennessee Valley. Ecological Applications: 4(4) November: 768-785.
- McDonald, B., Borden, W., & Lathorp, J., 1990. Citizen Stream Monitoring: A Manual for Illinois. Springfield, IL: Illinois Department of Energy and Natural Resources.
- Mitchell, Mark K., & Stapp, William B., 1990. Field Manual for Water Quality Monitoring (4th Ed.). Dexter, MI: Thomson-Shore, Inc.
- Murdoch, Tom, K. O'Laughlin, and M. Cheo., 1994. The Streamkeeper's Field Guide. Everett, WA: The Adopt-A-Stream Foundation.
- Peterson Jr., R.C., 1992. The RCE: a Riparian, Channel, and Environmental Inventory for Small Streams in the Agricultural Landscape. Freshwater Biology 27: 295-306.
- Renn, C. E., 1968. A Study of Water Quality. Chestertown, MD: LaMotte Company.
- Renn, C. E., 1970. Investigating Water Problems: A Water Analysis Handbook. Chestertown, MD: LaMotte Company.
- Sloat, S., & C. Ziel, 1992. The Use of Indicator Organisms to Assess Public Water Safety. Loveland, CO: Hach Co.

GEOLOGIC HISTORY OF WESTERN PENNSYLVANIA

Early Geologic History

The general geologic history for all of Western Pennsylvania is characterized by a multitude of geologic events beginning approximately 1.2 billion years ago. Under Pennsylvania are metamorphic rocks that were joined together long ago when an ancient micro-continent collided with North America. The metamorphic rock gneiss is Pennsylvania's basement rock located at the lowest portions of the Earth's crust. It is covered by younger sedimentary rocks.

Continent Collisions, Mountain Building, and Erosion Shape Pennsylvania

First Sedimentary Rocks

Sedimentary rocks constitute the majority of rocks present at shallow depths in the Western Pennsylvania. Sedimentary rocks form as a result of weathering of pre-existing rocks and sediments. The weathered products of rocks (gravel, sand, silt, clay, minerals, and dissolved ions) are transported by water and deposited where they **lithify** (harden) to become rocks. This takes time and pressure caused by a deep burial, as new layers are deposited on top. Some examples of these types of rocks include sandstone, siltstone, and shale. The sedimentary rocks in Western Pennsylvania watersheds were formed during a series of massive continental collisions, mountain building events (called **orogenies**), erosion, and deposition by moving water and shallow seas.

Approximately 570 million years ago (during the Cambrian period), the earth's continents were located and shaped differently than they exist today (Fig. 1). For instance, Pennsylvania was located approximately at the equator's present day location. During this time, the warm sunny waters were conducive to the deposition of carbonate rocks such as limestones and dolomites. A similar environment of carbonate deposition still exists today in the Florida Keys and Bahamas in the Gulf of Mexico

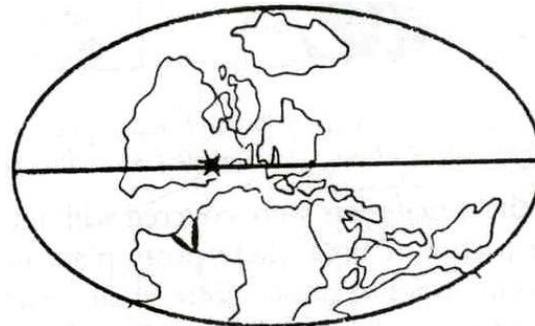


Fig. 1: The way the earth's surface appeared 480-570 million years ago. Pennsylvania's location = *

With the shifting of tectonic plates underlying the continents, the eastern margin of the ancient North America moved and began to collide with a volcanic island chain, approximately 480 million years ago (Ordovician Period). This event is comparable to the current movement of the Indonesian Islands in the South Pacific Ocean toward Australia. The collision of the island chain into the ancient North America caused the crust to fold and uplift, forming mountains (Taconic Orogeny) in Eastern Pennsylvania. The increase in elevation resulted in increased erosion and weathering of rock particles. The particles were transported westward by rivers, deposited, and left to lithify to form sedimentary rocks, during the Silurian and early Devonian periods.

Oil and Gas formation

The next mountain building event (Acadian Orogeny) occurred during the Devonian period (between 408 and 360 million years ago). When these mountains began to erode and fragment in Southeast Pennsylvania, their materials were deposited in shallow inland seas in

central and southwestern parts of the state. This eventually led to the creation of most of the rocks that would hold prolific sources of oil and gas. In 1859 at Titusville, “Colonel” Edwin L. Drake successfully drilled and discovered crude oil in sandstones that were formed during the Devonian period. Pennsylvania oil is found in the pore space of sandstones and limestones.

Coal Formation

When the Devonian period gave way to the Mississippian period (360-320 million years ago), most of Pennsylvania was still covered by inland seas, which allowed sediments to deposit and form more limestones, dolomites, and sandstones. Eventually the seas

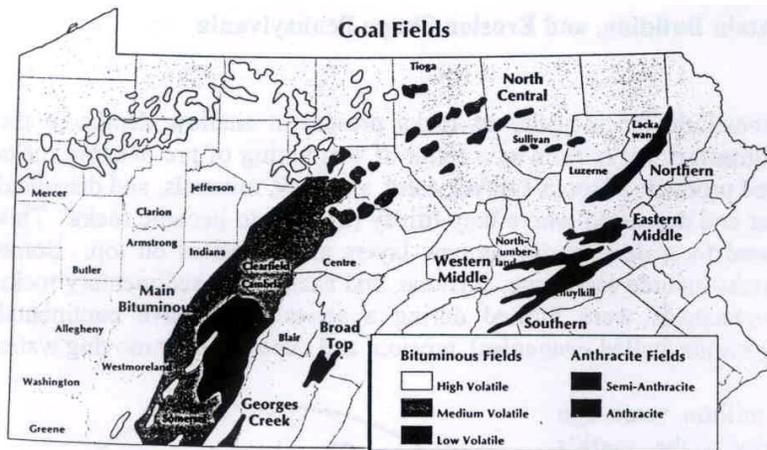


Fig. 2: The Coal Fields of Pennsylvania. Source: Cuff, D.J., et. al, 1987. *Atlas of Pennsylvania*. Philadelphia: Temple University Press.

became shallower and by the Pennsylvanian (320-286 million years ago) and Permian (286-245 million years ago) periods, most of the state was near sea level and covered by vast swamps and brackish marshes. More sandstones and shales formed, but more

importantly, this type of environmental condition favors peaty plant materials to accumulate. When these materials were covered with mud and other rocks, heat and pressure increased. Over a long period of time, these peaty plant materials were transformed into vast coalfields. The conditions were right to form coal seams in most of the western half of the state and mountainous stretches in eastern Pennsylvania. Northwest Pennsylvania and the French Creek Watershed were excluded from this special coal-making geologic event. The period is called Pennsylvanian because of the significance and uniqueness of the coalfields to Pennsylvania’s geology.

The Last Mountain Building Event

The most recent mountain building episode (Alleghenian Orogeny) occurred during the Permian period and is responsible for forming the present day Appalachian Mountains. These mountains were formed by a massive collision of eastern North America with Africa. Bringing these continents together along with Europe created the super-continent of **Pangea** (Fig. 3). The continent to continent collision was responsible for the formation of Himalayan sized mountains in central Pennsylvania that folded and compressed rocks formed since the Cambrian period. Following this final mountain building event during the Permian period, eastern North America was characterized by erosion of the landscape from the Triassic (250 million years ago) through the Cretaceous Period (more than 67 million years ago). During the Jurassic period (approximately 165

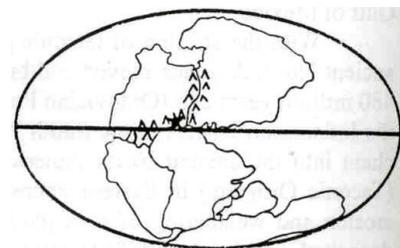


Fig. 3: The super-continent Pangea approximately 200 million years ago.

million years ago) the super-continent Pangea “rifted” and began to pull apart. The formation of the Atlantic Ocean began as the Americas continued to move farther away from Africa and Europe during the Cretaceous and Tertiary (less than 67 million years ago) periods. During these latter two time periods, erosion of the mountains continued and eventually formed the landscape of present day Pennsylvania, with one more significant geological event yet to occur and shape Pennsylvania.

Glaciers Leave Their Mark on Western Pennsylvania

The landscape of Northwest Pennsylvania was altered dramatically by glaciation during the **Ice Age** – a period of time starting 2 million years ago during which over half a dozen glacial and nonglacial periods occurred. Prior to glaciation, the waters of Western Pennsylvania (Allegheny River, Monongahela River, Ohio River, and French Creek) are hypothesized to have been part of a large, northward flowing drainage system that fed Lake Erie and eventually the St. Lawrence Seaway (Fig 4). In fact, then the Monongahela River was the dominant river flowing north to Lake Erie and draining the southwest section of the state. The Ohio River was actually a tributary to it, emptying into the Monongahela at present day New Castle. The Allegheny River was actually three separate and unconnected rivers. The Lower Allegheny emptied into the Monongahela at present day Pittsburgh. The Upper Allegheny started in north central Pennsylvania and flowed through New York into Lake Erie. The Middle Allegheny started in Warren County near Tidioute, flowed past present day Oil City and Franklin, and started to head northwest into Lake Erie through today’s French Creek Valley. The Middle Allegheny was the ancient French Creek (Figs. 4 and 5).

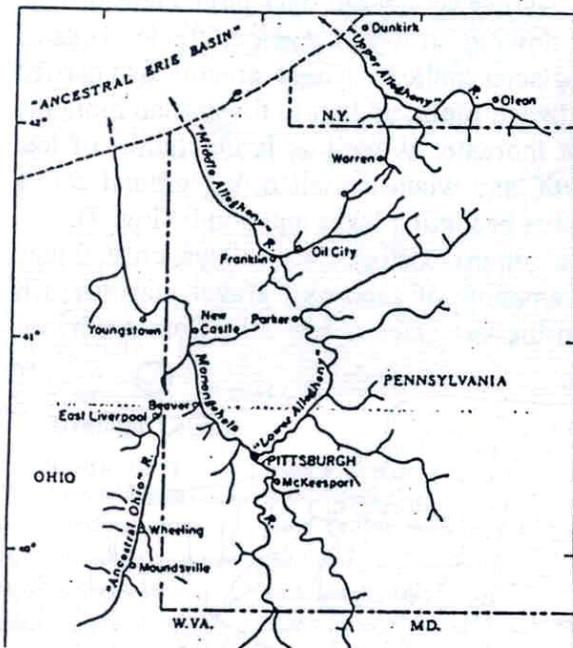


Fig. 4: Stream and river patterns before the Ice Age, approximately 2 million years ago.

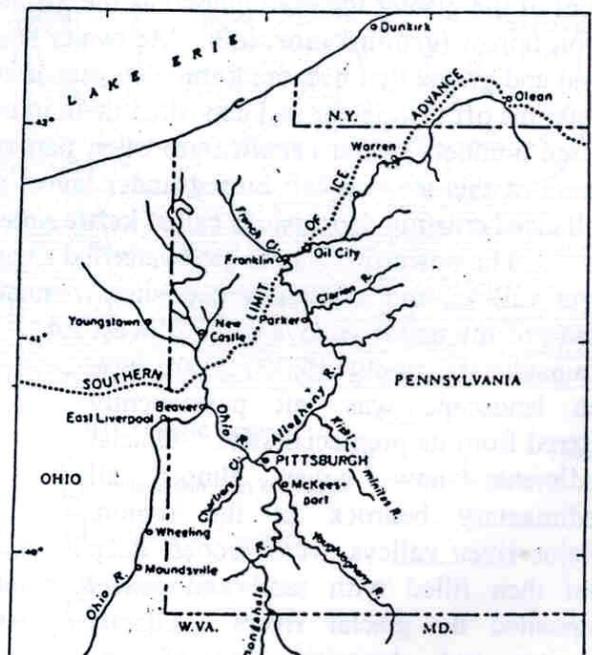


Fig. 5: Stream and river patterns as they appear today in Western Pennsylvania

Source of maps: Harper, J.A., 1997. *The Formation of the Allegheny River*. From *Allegheny Watershed Network Notes Newsletter* Volume 1, Issue 1: pg. 6.

A period of global cooling starting about 2 million years ago, leading to the onset of the Ice Age as an ice cap began developing over the Hudson Bay Region. The accumulation of snow and then compaction of snow into ice forms glaciers. When sufficient weight of ice has developed, the ice will begin to deform (flow), and a glacier is born. Glaciers during the Ice Age covered most of Canada and portions of central and eastern United States, including northern corners of Pennsylvania (Fig. 6).

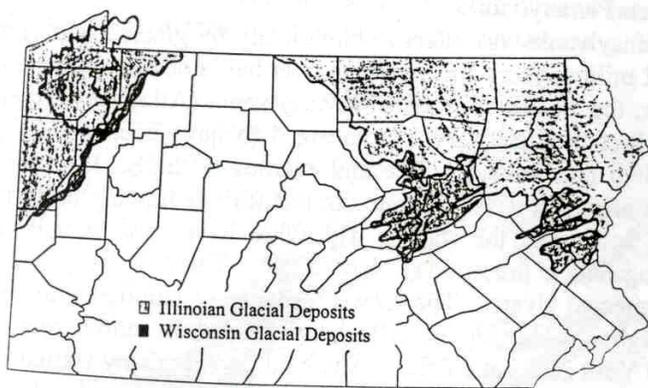


Fig. 6: Extent of glaciation in Pennsylvania for the Illinoian and Wisconsin Ages. The French Creek Watershed is outlined for your reference (Modified from Shepps, 1962).

Glaciers and their meltwater have tremendous erosional and depositional capabilities. As the glaciers advanced from the north, they brought eroded material from Canada and New York and deposited it in Pennsylvania. A mud-rich mixture of gravel, sand, silt, and clay (called **glacial till**) blankets most of the uplands of northwestern

Pennsylvania. Till was either deposited in **end moraines** (pile of till bulldozed and deposited by streams at the front of the glacier then left behind as the glacier retreats) or spread out over large areas of land upon retreat (**ground moraine**). Meltwater streams flowing on top of glaciers created beds of sand and gravel that became **kame** deposits after the glacier melted. These streams also carried materials off the glacier and deposited them in the **outwash plain**, adding to the ground moraine. Large boulders called **erratics** are often part of that moraine, as well as large chunks of ice. Some of this ice was left buried under layers of earth, and when it melted, the ground above collapsed creating depressions called **kettle holes** – often becoming lakes and ponds (Fig. 7).

The powerful, glacial meltwater fed rivers, enlarged preexisting river valleys, created new river valleys, and eventually deposited tremendous amounts of sand and gravel that now fill many of the major valleys of Northwest Pennsylvania. When the last glaciers retreated from this area, about 15,000 years ago, the landscape was left permanently altered from its preglacial state. Glacial sediments now cover almost all sedimentary bedrock in the region. Major river valleys were eroded deep and then filled with sand and gravel deposited by glacial rivers. Glacial erosion and deposition altered the landscape topography so much that the drainage patterns in Western Pennsylvania switched from a northerly journey into Lake Erie to a southerly path to the Ohio River Watershed (Fig 5).

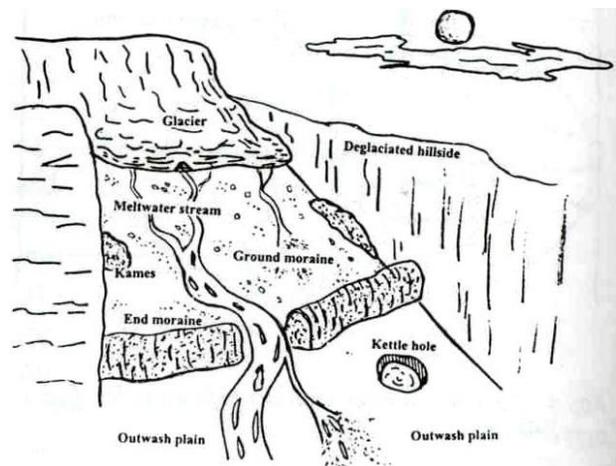


Fig. 7: Valley created by a glacier in Northwest Pennsylvania.

French Creek Watershed Today: A Legacy of its Geologic Past

The sediments that were shed off ancient mountain belts hundreds of millions of years ago now make up the sedimentary rocks that underlie the entire region. The fractures and strength characteristics of these rocks dictated how and where streams developed in the watershed and still control the directions and rates of deeper groundwater flow. One of these sedimentary rock formations, the Cussewago Sandstone, serves as the major groundwater aquifer in upland regions.

Glaciation, in addition to altering the landscape and river pathways, left a record of sediments that are critical to the quantity and quality of water resources in the French Creek Watershed. The sand and gravel, glacial river deposits (which fill major river valleys) create a vast groundwater aquifer that have very high groundwater yields. These valley aquifers provide drinking water to 80% of Crawford and Venango Counties and sustain the flow in French Creek between precipitation events.

The glacial sediments also contain calcium carbonate that buffers acid precipitation common to the region. The average pH value of precipitation in the eastern United States is approximately 4.5 whereas the average pH value for water in French Creek is above 7.0. The buffering of precipitation is in part responsible for the high biological diversity of French Creek.

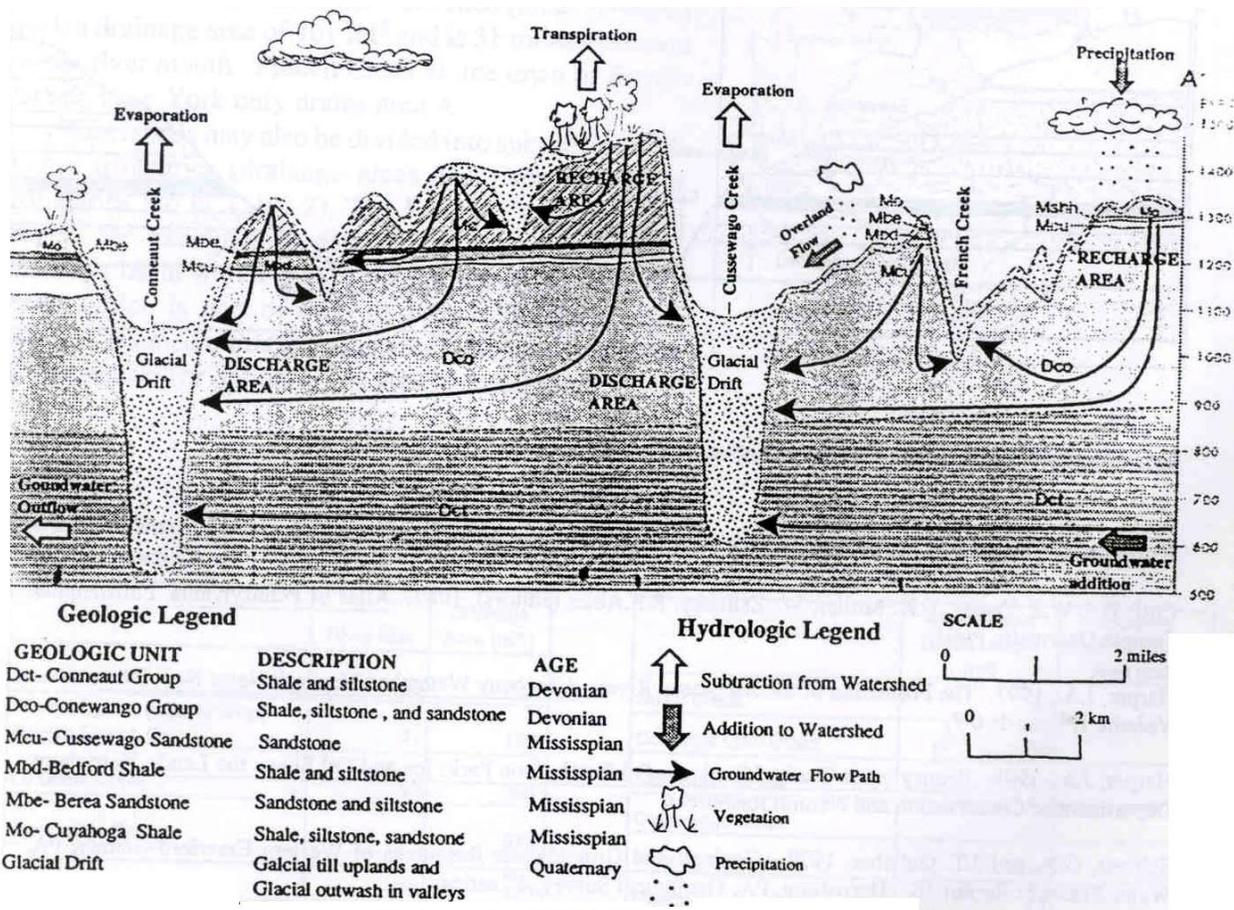


Fig. 8: Geologic cross section through French Creek Watershed in Crawford County, northwest PA, showing hydrologic processes and rock formations (modified from Schiner, G.R. and J.T. Gallaher, 1997).

Pittsburgh Area Waterways Today: A Legacy and Curse from its Geologic Past

Even though the glaciers did not enter southwest Pennsylvania dropping off till filled with calcium carbonate deposits, there is still an effective acid neutralizing capacity in the area. The geologic history of southwest Pennsylvania involved the creation of calcium carbonate rich limestones and sandstones with some calcium carbonate. These bedrocks are also excellent providers for vast groundwater aquifers for the region because water can easily move through these rocks' pore spaces. Shales, also found in the area, have less pore space, so water must use fractures and cracks instead.

The geologic history of the Pittsburgh area during the Pennsylvanian and Permian periods also created an economically important resource – coal. However, the mining process of these vast coalfields and the abandoned mines have a very negative impact on waterways, creating acid mine drainage, the release of metals, subsidence, and serious soil erosion. This geologic gift of coal to the region also gives the region its number one source of water pollution.

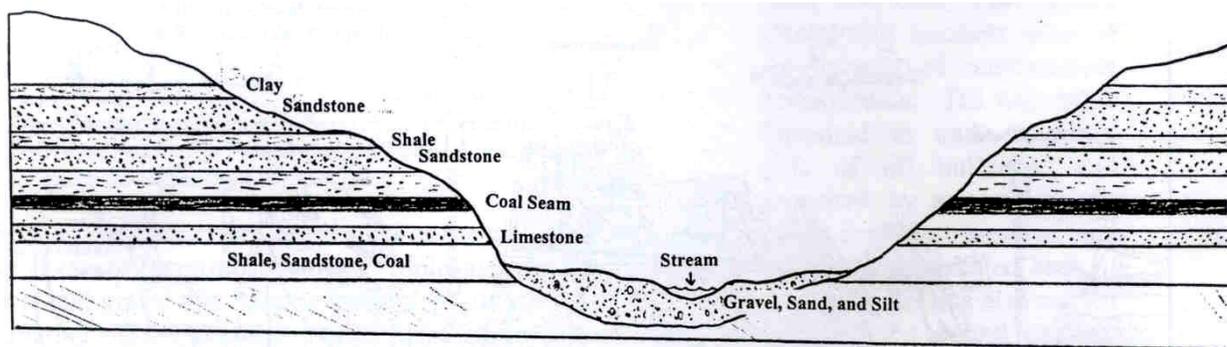


Fig 9: Cross Section of Southwestern Pennsylvania geology, which includes a coal seam.

References Used for Geologic History of Western Pennsylvania Section:

Cuff, D.J, W.J. Young, E.K. Muller, W. Zelinsky, R.F.Abler (editors), 1987. Atlas of Pennsylvania. Philadelphia: Temple University Press.

Harper, J.A., 1997. The Formation of the Allegheny River. Allegheny Watershed Network Notes Newsletter Volume 1, Issue 1: 6-7.

Harper, J.A., 1998. Pennsylvania Trail of Geology: Oil Creek State Park: Ice and Oil Shape the Land. Harrisburg: Department of Conservation and Natural Resources.

Schiner, G.R. and J.T. Gallaher, 1979. Geology and Groundwater Resources of Western Crawford County, PA. Water Resource Report 46. Harrisburg, PA: Geological Survey, 4th series.

Sevon, W.D. and G.M. Fleeger, 1999. Pennsylvania and the Ice Age. Harrisburg, PA: Pennsylvania Geological Survey and Department of Conservation and Natural Resources.

Van Diver, B. B., 1990. Roadside Geology of Pennsylvania. Missoula, MT: Mountain Press Pub. Co.

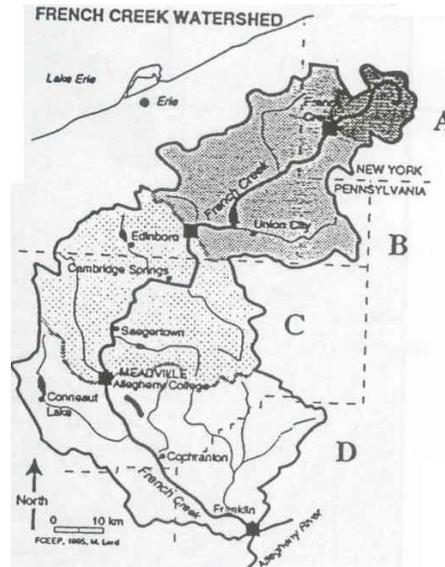
WESTERN PENNSYLVANIA WATERWAYS GEOGRAPHY

THE FRENCH CREEK WATERSHED: DRAINAGE BASINS AND RIVER MILES

The values of drainage basin area and stream length are important to understanding and interpreting water quality data. The drainage basin area (or watershed) is simply the total land area that a given stream drains. The drainage areas and stream lengths are given in the tables below for key positions within the French Creek Watershed (Table 1) and its major tributaries (Table 2). The total drainage basin area of French Creek is about 1235 mi² with a total river length of about 117 miles. This entire region affects the water quality of French Creek at its mouth in Franklin.

At points on French Creek upstream of Franklin, however, the drainage area that contributes water to French Creek becomes proportionally smaller. This point is exemplified in the map (see figure) of the French Creek Watershed. French Creek at Franklin drains the entire watershed (areas A+B+C+D) and has a drainage basin area of 1235 mi²; it is 0 miles upstream of the mouth of French Creek. French Creek at Meadville drains the northern half of the watershed (areas A+B+C) with a drainage area of 701 mi² and is 31 miles upstream of the river mouth. French Creek at the town of French Creek, New York only drains area A.

Watersheds may also be divided into sub-basins of its major tributaries (drainage areas and river lengths of tributaries are in Table 2.) The French Creek drainage basin, for example, is part of the Allegheny River drainage basin, which is part of the Ohio River drainage basin which is part of the Mississippi River drainage basin. This means that the ultimate destination of French Creek waters (or pollution) is the Gulf of Mexico.



French Creek Environmental Education Project © 1996

Table 1: Drainage areas and river miles for points along French Creek

	River Mile	Drainage Area (mi ²)
Sherman, NY	89	16
Wattsburg, PA (includes West Branch French Creek)	71	193
Le Boeuf Creek	59	399
Cambridge Springs	47	577
Saegertown	38	670
Meadville (includes Cussewago Creek)	31	701
Conneaut Lake Outlet	23	926
Cochranston (includes Little Sugar Creek)	16	1027
Franklin	0	1235

Table 2: Basin areas and creek lengths of major tributaries of French Creek

	Approximate Creek Length (mi)	Tributary Drainage Basin Area (mi ²)
Sugar Creek	20	167
Conneaut Lake Outlet	18	101
Little Sugar Creek	15	53
Cussewago Creek	18	7
Woodcock Creek	14	52
Muddy Creek	13	76
Conneauttee Creek	9	61
Little Conneauttee Creek	17	26
South Branch French Creek	19	84
Le Boeuf Creek	12	76
West Branch French Creek	20	78

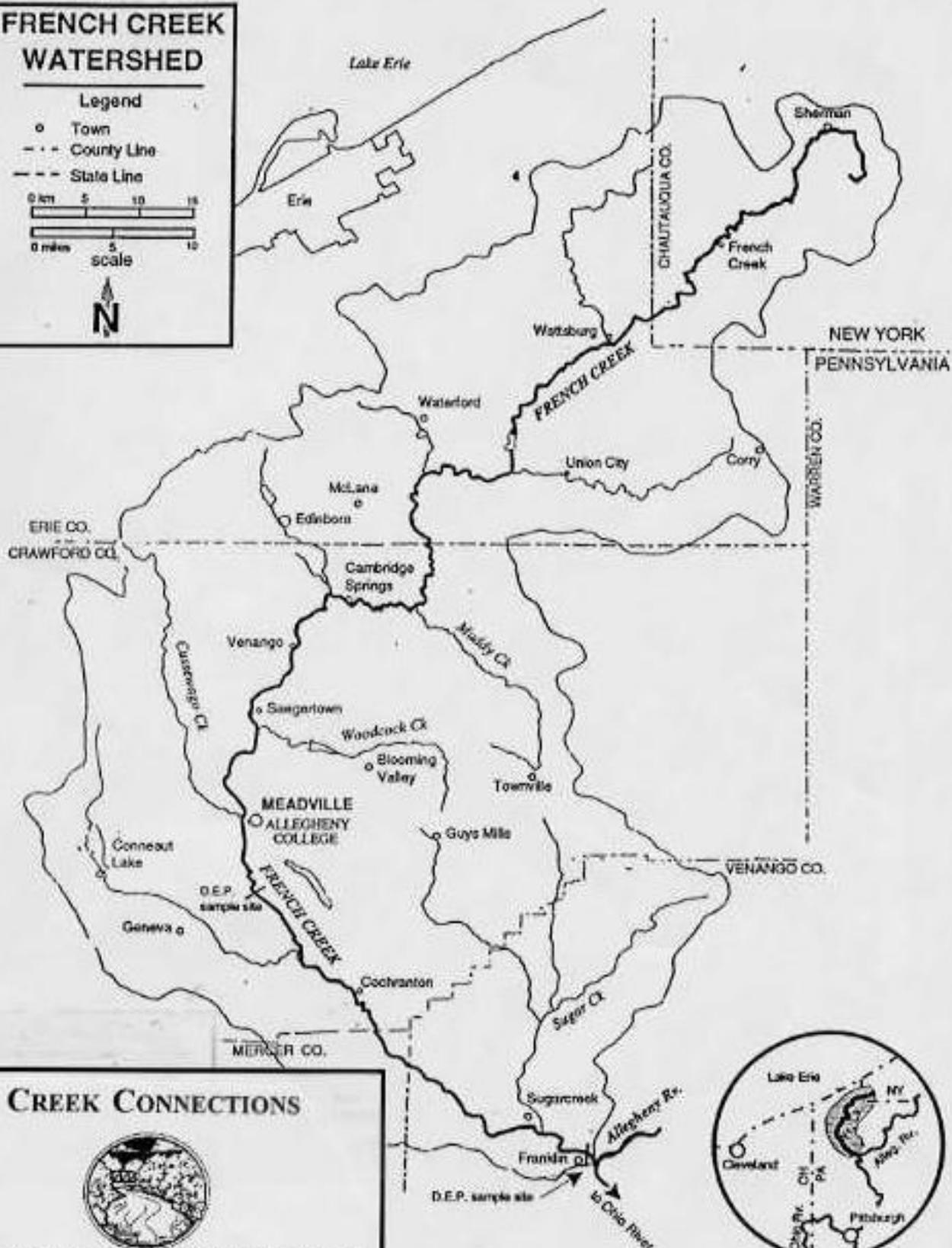
FRENCH CREEK WATERSHED

Legend

- Town
- - - County Line
- - - State Line

0 km 5 10 15
0 miles 5 10
scale

N



CREEK CONNECTIONS



Allegheny College, Meadville, PA 16335
Map by Mark Lord and Lynn Willey 1997



PITTSBURGH AREA WATERWAYS: DRAINAGE BASINS AND RIVER MILES

French Creek in Northwest Pennsylvania empties into the Allegheny River at Franklin, PA. From here, the water flows south to the Pittsburgh area, where the Allegheny River joins the Monongahela River to form the Ohio River. The Ohio River travels 981 miles to the Mississippi River, which eventually flows into the Gulf of Mexico. Because waterways are connected, how people treat them can affect downstream communities. If French Creek Watershed residents pollute French Creek, Pittsburgh area communities will be affected. All Western Pennsylvanians can impact communities downstream on the Ohio River.

Allegheny River – Mileage Points

Site along the River	River Mile
Mouth in Pittsburgh	0.0
Pine Creek	4.7
Plum Creek	10.6
New Kensington	18.0
Kiskiminetas River	30.2
Ford City	42.5
Cowanshannock Creek	49.1
Red Bank Creek	64.9
Clarion River	86.1
Emlenton	91.8
Kennerdale	110.0
Franklin, French Creek	126.6
Oil City, Oil Creek	134.2
Tionesta, Tionesta Creek	154.0
Tidioute, Tidioute Creek	169.5
Brokenstraw Creek	182.0
Warren, Conewango Creek	192.0
Salamanca, NY	240.0
Olean, NY	265.0
Coudersport	310.0
Head of River	325.0



Major Waterways in the Allegheny River Drainage Basin

Waterway	Length of waterway (mi.)	Size of Watershed (sq. miles)
Entire Allegheny River	314	11,770
Pine Creek		
Kiskiminetas River	125	1,886
Conemaugh River		1,372
Crooked Creek		292
Mahoning Creek	34	425
Red Bank Creek		576
Clarion River	120	1,252
French Creek	117	1,235
Oil Creek		328
Tionesta Creek		479
Brokenstraw Creek		337
Conewango Creek		919
Kinzua Creek		182
Oswayo Creek		195
Potato Creek		224

Source of Information:

Watershed Atlas of the Allegheny River, 1999
 (<http://www.watershedatlas.org/>); Kussart, 1938; Way, 1942.

Map based on maps from:

Watershed Atlas of the Allegheny River, 1999
 (<http://www.watershedatlas.org/>)

When the Allegheny River flows into Pittsburgh, it joins the Monongahela River at “the Point” or Point State Park to form the Ohio River. If you look up Pittsburgh in the dictionary, it is often defined by its location at these three rivers. Participating schools in the Pittsburgh area are monitoring the actual rivers themselves and tributaries to each of the three rivers. Detailed information on the Monongahela (often nicknamed the “Mon”) and Ohio Rivers follows, as well as the Youghiogheny River (major tributary to the Monongahela and sometimes referred to as Pittsburgh’s



fourth river), and Chartiers Creek (a tributary to the Ohio River sampled by a few schools).

The Allegheny River (left) joins the Monongahela (right) at the “Point”, where the fountain is, to form the Ohio River. It flows west out of this picture. Downtown Pittsburgh and its Golden Triangle are wedged between the Allegheny and the Monongahela.

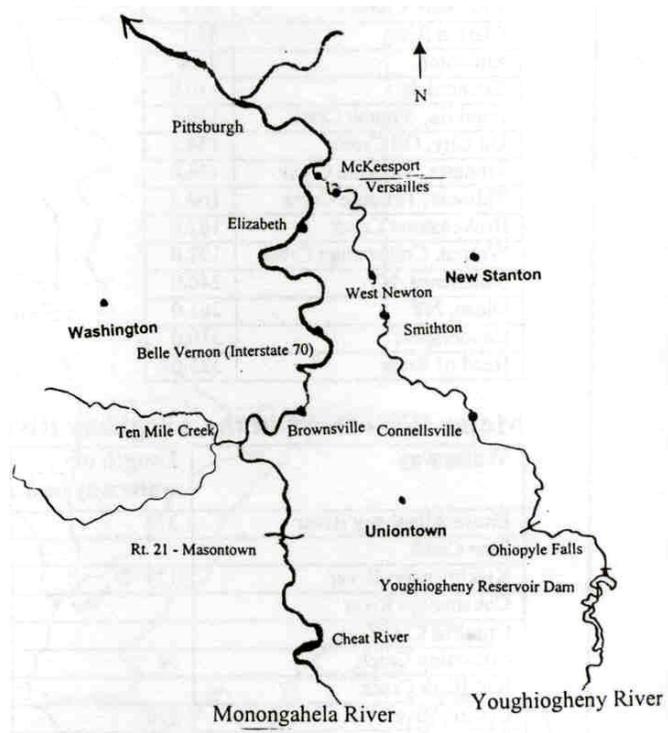
Monongahela River – Mileage Points

Site along the River	River Mile
Mouth at the Point	0.0
Nine Mile Run	6.9
Thompson Run	11.5
Youghiogheny River	16.1
Elizabeth	23.3
Belle Vernon (Interstate 70)	41.9
Brownsville	54.2
Ten Mile Creek	64.1
Rt. 21 - Masontown	75.9
Cheat River	86.8
Morgantown	97.9
Fairmont	121.1
Headwaters	200.0

(estimated mileage based on map work)

Youghiogheny River – Mileage Points

Site along the River	River Mile
Mouth at Monongahela River	0.0
McKeesport	2.0
Versailles	4.0
West Newton	19.0
Smithton	24.5
Connellsville	44.0
Ohiopyle Falls	61.2
Youghiogheny Reservoir Dam	73.0
Deep Creek Lake Dam	102.8
Head of River	132.0



**Major Waterways in Western Pennsylvania
(Non-Allegheny Watershed)**

Waterway	Size of Watershed (sq. miles)
Monongahela River	7,348
Youghiogheny River	1,763
Beaver River	3,153
Mahoning River	1,140
Shenango River	1,062
Chartiers Creek	277
Raccoon Creek	184
Little Beaver Creek	503
Connoquenessing Creek	838
Turtle Creek	148

Ohio River – Mileage Points

Site along the River in Pennsylvania	River Mile
Headwaters - Pittsburgh	0.0
Chartiers Creek	2.33
Neville Island	4.66
Interstate 79	8.2
Ambridge	14.0
Beaver River	22.1
Rt. 60 Expressway	24.5
Raccoon Creek	26.2
Rt. 168	30.9
Little Beaver Creek	35.5
State Line	36.1

Chartiers Creek – Mileage Points

Site along the Creek	Creek Mile
Mouth at Ohio River	0.0
Crafton	4.7
Carnegie	6.9
Scrubgrass Run	9.9
McLaughlin Run	11.5
Millers Run	14.0
Brush Run	20.4
Canonsburg Lake Outlet	23.9
Canonsburg	27.9
Route 18 Washington	34.9
Headwaters	40.8

Land Use Statistics for French Creek and the Allegheny River Watershed

Watershed	Percentage of Total Land Area in Watershed								
	Urban	Crops	Pasture	Forest -Mixed	Forest -Evergreen	Park, Golf	Surface Mines	Wetland	Open Water
French Creek	1.3	16.4	21.9	50.9	4.1	0.1	0.1	3.7	0.6
Allegheny	1.5	12.5	7.7	67.8	4.5	0.1	4.0	0.9	0.8

Note: percentages do not add up to 100% because of rounding.

Source: Watershed Atlas of the Allegheny River, 1999 (<http://www.watershedatlas.org/>)

Resources Used for Western Pennsylvania Waterways Geography section:

Kussart, S., 1938. The Allegheny River. Pittsburgh, PA: Burgum Printing Co.

Palmer, T., 1980. Rivers of Pennsylvania. University Park, PA: Pennsylvania State University Press.

Palmer, T., 1984. Youghiogheny: Appalachian River. Pittsburgh, PA: University of Pittsburgh Press.

Watershed Atlas of Pennsylvania, 1999. (<http://www.watershedatlas.org/>). Pittsburgh, PA: Created by Allegheny Watershed Network.

Way Jr., F., 1942. The Allegheny (Rivers of America Series). New York, Farrar and Rinehart.

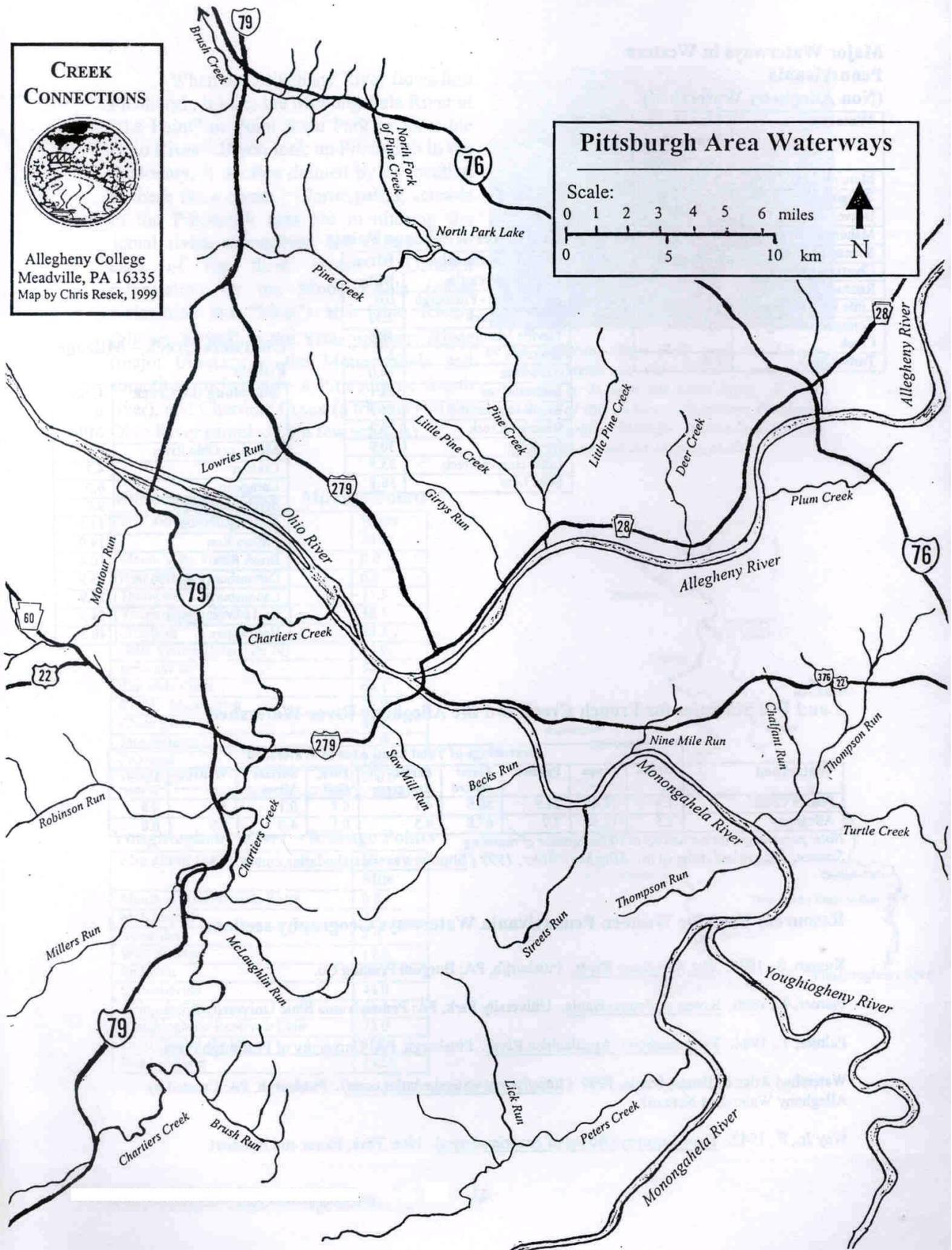
CREEK CONNECTIONS



Allegheny College
 Meadville, PA 16335
 Map by Chris Resek, 1999

Pittsburgh Area Waterways

Scale:
 0 1 2 3 4 5 6 miles
 0 5 10 km

OVERVIEW: SAMPLING WATERWAYS

The purpose of this sheet is to provide an overview of the steps and concerns involved with sampling and analyzing waterways. The precise methodology to be used for specific water quality parameters is given in the Chemical Tests section.

PREPARATION FOR SAMPLING

A minimum of three people is needed for sampling. Some preparation is required before setting out to sample a waterway. Be familiar with all field tests and what they indicate about your waterway before going out to sample. If proper procedures of water quality sampling and analysis are used, the test kits yield very accurate results. Each water sample will be tested for at least nine water quality parameters:

1. Temperature
2. pH
3. Total dissolved solids (TDS)
4. Conductivity
5. Dissolved oxygen (DO)
6. Nitrogen
7. Phosphorus
8. Alkalinity
9. Turbidity

Of these nine tests, the first five **MUST** be done at the site because they are temperature or time dependent; the remaining tests may be done in the field or in the laboratory. If taken back to a lab, water samples should be refrigerated until the time of testing (best completed within 24 hours).

In addition, other optional water quality parameters may also be tested in the laboratory:

1. Ferrous iron *Note: Some schools are doing these tests, but not all.*
2. Contact Creek Connections for additional options

The first step in preparation for sampling is to assemble the necessary equipment used in the field:

- 2 sample bottles (1 labeled "Sample A" and 1 labeled "Sample B")
- bailer for collecting water samples from a bridge, or a shoreline sampling device
- thermometer
- pH pocket meter
- conductivity & total dissolved solids (TDS) pocket meter
- calibration solutions for pH and Cond/TDS meters
- 2 small wide mouth containers for water samples being read by meters
- dissolved oxygen test kit
- distilled water wash bottle
- scissors or nail clippers to open chemical packets in test kits
- test information sheets
- data record sheet and pencil
- waste bottle for used solutions
- other _____

If you plan to do all of the nine basic tests in the field, take the following:

- nitrates test kit
- phosphorus test kit
- alkalinity test kit
- turbidity test kit
- any other test kits you use (ferrous iron, other)
- nitrate test waste – cadmium – container
- other _____

If you plan to do discharge and stage, wading boots may be necessary. If your group needs any other equipment, you should add it to the list.

Before each sampling, the pH and Cond/TDS pocket meters should be checked to ensure the batteries are good. Meters can be calibrated before going to the creek or can be done in the field. Calibration instructions are in the chemical tests section of this handbook.

FIELD SAMPLING AND TESTING

Safety First:

Bridge work: Safety is an important factor in any outdoor or laboratory activity. Extreme caution should be taken when traveling to the sampling sites and while at the site, especially because many sample sites are located on bridges. Bridges with pedestrian sidewalks are best for sampling. If there is no sidewalk, one member of the sampling group should be on lookout for traffic at all times. Always watch out for careless and unsafe drivers: they are all around! Be careful leaning over bridges when obtaining samples. In the winter, be especially careful because bridges can be icier than roadways. If snow has piled up along the sides of the bridge, do not climb on top of the piles to reach over the side to obtain samples.

Creek water: Never go into the water unless a teacher gives you permission. If obtaining water samples creek side, it would be best to use a shoreline water collector rather than wade out into the stream, especially in cold weather. Waterways can be deceptive – even where it is not apparent, they can be very strong and fast. Students should not be in the water from the end of November through mid-March. Sample as the weather permits you to do so safely in the winter. Teachers might want to consider having a blanket or extra sweatshirt on hand when sampling in the winter.

Hunting: If you are testing in a secluded or wooded area where hunters may be near the stream, be careful. Be aware of all hunting seasons (not just traditional buck season). Consider wearing orange vests. These can be purchased for participating classes.

Chemicals: Another facet of safety comes when using the chemicals of the test kits. Each of the chemicals in the kits has explicit safety instructions and lists for possible dangers associated with it. Read, understand, and follow all safety instructions. A teacher may wish for students to wear safety goggles and/or plastic gloves. If working at tables, stand while doing tests so spills don't result in splashes to the face.

Broken glassware: If any equipment becomes broken, please report it to the teacher. DO NOT put it back into the test kit without telling anyone. Take broken glassware back to the classroom (or to Creek Connections staff) for proper disposal.

Wash your hands: When finished with testing, wash hands thoroughly to assure that no reagents/chemicals or creek water remains on your hands.

Sampling:

How many samples? *Two water samples* (A and B) are to be collected on each sample date; all nine water quality tests are to be done for BOTH samples. Before obtaining a water sample, make sure the sample bottles are properly labeled “A” and “B. Replication significantly raises the validity of the data generated by the project participants. If the water quality values of the replicate samples are not similar, the water quality test should be repeated a third time. If all test trials are dissimilar, another water sample should be obtained and fully tested.

Where in the stream to sample? The water quality of a waterway, even at the same general creek location, can be quite variable. The most representative water of a stream is at *mid-depth from the center of the stream*. Samples taken from an especially slow portion of a waterway or right along the shoreline are not likely to be representative of the overall water quality.

Bridge bailing. From the area of the bridge over the center of the stream, lower the bailer into the stream to fill with water. Don’t throw the bailer! Hold onto the rope bundle! Retrieve the bailer and then, with the creek water collected, rinse (or condition) the sample bottles – be sure to rinse ALL of the bottle and the bottle cap to minimize the chance of contaminating the sample. Disregard this rinse water from the bottles and bailers by dumping it on the bridge, not into the creek. Dumping it into the creek may disturb the creek bottom, increasing turbidity for your sample water.

To collect the sample, lower the empty bailer over the bridge again. Try to judge the depth of the bailer so that it collects water from the center of the water column (mid depth). Retrieve the bailer and gently pour the creek water into the 2 “Sample A” plastic sample bottle. Try to fill the bottle up as much as possible. The water sample *should be agitated as little as possible* – significant agitation may artificially increase the amount of dissolved oxygen. With a second (or third...) bail, fill the “Sample B” bottle up as much as possible. Your goal should be to have enough water for all tests and not have to go back and bail for more water later.

Shoreline water collecting: Using a shoreline water collecting device (i.e. a cup on a stick), try to collect the water sample from as far away from the shore as possible, but be careful leaning over the water. Entering the water to collect the sample should be avoided because it may be unsafe and because disturbing the stream bottom can affect some of the water parameters (turbidity, TDS).

Field testing:

Observations: Please fill in the sampling information and stream observations on the data sheet. This information is posted on the database shared with all schools, and this information can assist with the interpretation with the results.

Which tests to do in the field? Perform the tests for temperature, pH, conductivity, TDS, and dissolved oxygen immediately after collecting the water samples. Follow the instructions on the test sheets to complete the tests. Pay particular attention to the dissolved oxygen test procedure. Record all of the test results on the data sheets.

Laboratory Testing:

The remaining water quality tests (alkalinity, nitrates, phosphates, and turbidity, plus any additional tests your class may do) may be done while at the stream or in the laboratory at your school. Refrigerate the samples until it is time to finish the tests in lab; though they should be completed 24 hours from the time of collection. Each of these tests should be done in a clean laboratory setting.

Equipment Clean Up:

Contaminants can get introduced easily from different sources such as dirty glassware. To clean glassware, be sure any cleaning detergents do not contain phosphates (many institutional detergents and dishwasher detergents do as well as tap water) because the residue will alter test results. **All testing equipment should be rinsed in distilled water before use.** Be careful not to mix test tubes or bottles between kits – this may lead to confusion, method error, calculation error, or contamination (see inventory card in each kit).

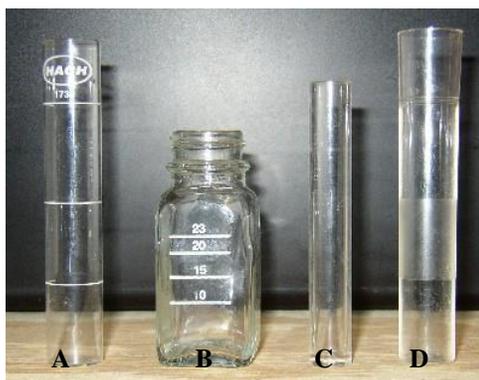
Disposal of Waste:

Each chemical test's instruction sheet has a section regarding what to do with the chemical test waste. All can be flushed down the sink with plenty of water, with the exception of some of the waste generated by the nitrates and ferrous iron tests. They contain a toxic substance that should be kept in a clearly marked (non-beverage) container, and given to Allegheny College at the end of the school year for proper disposal.

Any outdated / expired chemical can also be given to Allegheny College for proper disposal because some should not be thrown in the trash. Check with Allegheny College for questions regarding expired chemicals. Generally all the dry chemicals in the packets are useable beyond the expiration date as long as they have not been exposed to extreme temperatures.

Glassware and Other Equipment Notes:

You were supplied with enough glassware in each test kit to run duplicates (sample A and sample B) at the same time (except for turbidity test). Use them to speed up testing time.



A. Glass Test Tube

May be in older phosphate test kits, or some use plastic

B. Square Mixing Bottle

Used in dissolved oxygen, alkalinity, phosphate kits

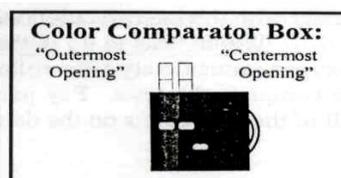
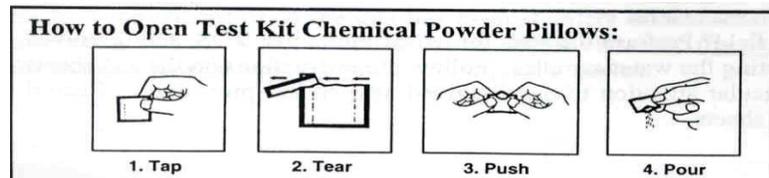
C. Plastic Measuring Tube

Used in dissolved oxygen and alkalinity test kits

D. Plastic Test Tube

Used in nitrate and ferrous iron kits, and in some phosphate kits.

Hach Illustrations





Creek Connections

Data Collection Sheet

Sample Date: ___/___/___ Sampling Site Number: _____ Sampling time ____:____
 Site Name _____ School _____
 Names of Testers / Class _____

Observations: *Creek Appearance (velocity, color, frozen, etc.) _____

*Weather in past 48 hrs (rain, snow, etc.) _____

*Relative Depth (higher/lower than normal, etc.) _____

HYPOTHESIS (optional) _____

FIELD TESTS (To be conducted on-site)

Average

____ °C **TEMPERATURE (Typical Range 0-33°C):**
 Sample A: ____ °C Sample B: ____ °C

____ **pH (Typical Range 6-9):**
 Sample A: ____ Sample B: ____

____ mg/L **TOTAL DISSOLVED SOLIDS (TDS) (Typical Range 68-460 mg/L):**
 Sample A: ____ mg/L Sample B: ____ mg/L

____ μS/cm **CONDUCTIVITY (Typical Range 100-400 μS/cm):**
 Sample A: ____ μS/cm Sample B: ____ μS/cm

____ mg/L **DISSOLVED OXYGEN (DO) (Typical Range 6-14 mg/L):**
 # of drops for A: ____ mg/L # of drops for B: ____ mg/L

LABORATORY TESTS (To be completed within 24 hours)

Average

____ mg/L **NITRATE-NITROGEN (Typical Range 0-3 mg/L):**
 Low Range (0-1 mg/L)
 Reading for A: ____ mg/L Reading for B: ____ mg/L

____ mg/L **TOTAL PHOSPHOROUS (Typical Range 0-0.5 mg/L):**
 Low Range (0-1 mg/L)
 Reading for A: (____ / 150) = ____ mg/L Reading for B: (____ / 150) = ____ mg/L

____ mg/L **TOTAL ALKALINITY (Typical Range 20-170 mg/L):**
 High Range
 # of drops for A: ____ x17 = ____ mg/L # of drops for B: ____ x17 = ____ mg/L

____ JTU **TURBIDITY (Typical Range 0-50 JTU):**
 Low Range (50mL sample)
 # of 0.5 mL additions to A: ____ x5 = ____ JTU # of 0.5 mL additions to B: ____ x5 = ____ JTU

OPTIONAL TESTS

Average

____ mg/L **FERROUS IRON:**

Reading for A: ____ mg/L

Reading for B: ____ mg/L

____ **OTHER TEST:** _____

Sample A: _____

Sample B: _____ (please give units)

SUPPLEMENTAL FIELD TESTS (not mandatory)

____ m **Width**

____ m **Stage**

____ m/s **Flow Rate**

____ m³/s **Discharge**

____ **Riparian, Channel, and Environmental Inventory Score:** Possible scores: 16-360

____ **Pollution Tolerance Index Value (macroinvertebrate sampling)**

Optional: **WATER QUALITY INDEX** – use **average** values of each parameter for calculation

WQI score = 10 + (| pH - 7.5| x 8) + (N x 10) + (P x 15) + (turbidity x 0.2) - (DO x 0.7)

_____ = 10 + (|____ - 7.5| x 8) + (____ x 10) + (____ x 15) + (____ x 0.2) - (____ x 0.7)

Did anything interesting happen when you were out sampling? What else did you do at the waterway besides the chemistry tests? Did you see anything unique? Did any of your results puzzle you?

Let us know below...

TEMPERATURE INFORMATION SHEET

Background

Temperature is the measure of how hot or cold an object is; and is usually recorded in degrees Celsius (preferred in science) or in degrees Fahrenheit. Even though temperature is a simple test to perform on waterways, it is a very important parameter. The temperature characteristics of stream water directly and indirectly influence aquatic ecosystem processes and the biotic (living) composition. Also temperature affects the other water quality parameters.

The sun's energy drives water temperature, and every waterway's temperature will naturally fluctuate from season to season. The more sunlight that hits the water's surface, the warmer the water will get. Narrow, well-shaded headwater streams are often cooler than wider, larger streams that are not fully shaded by **riparian** (streamside) forests. However, temperature change caused by the sun is slow. Water absorbs a lot of heat before it changes temperature, so the water temperature rises slowly as it is warmed by the daily sun or summer heat, and it cools slowly after the sun sets or cooler fall and winter seasons arrive.

In addition to sunlight intensity, the physical dimensions of the waterway will also affect the temperature. Shallow water will fluctuate in temperature faster than deeper water. Running water tends to be cooler than stagnant, still water. Within a stream, the shallow riffles or rapids are often cooler than the slow moving, deep pools. The most downstream stretches of creeks and rivers are often warmer than the upstream sections, and may even have a slight thermal stratification (temperatures differ at various depths) in these deep, slow sections.

The source of water for a stream also influences temperature. If the stream water is predominately from rain and surface runoff, it will have different temperatures than a stream that source of water is from underground (groundwater fed). For instance, rivers and streams fed by melting snow (often near 0°C) will be colder than a same sized stream fed by groundwater warmed by underground layers of soil and rock. Because groundwater maintains a more constant temperature throughout the year, the same groundwater fed stream will be cooler in the summer than a stream filled by warm rain and warmer overland flow.

Temperature affects some of the chemical parameters of water. Probably the most important is dissolved oxygen, which can be found in the spaces between water molecules (H₂O). At lower temperatures, more oxygen can be dissolved in the water because the gas molecules are moving slower and are more compact. At higher temperatures, dissolved oxygen and other gases in water move faster and spread farther apart, including out of the water. Also at higher temperatures, the water molecules may move faster and bump out oxygen. Think of how the gases (carbon dioxide or the fizz) in soda pop eventually escape as it warms up.

A rise in temperature can increase the concentration of total dissolved solids (the ions and particles in the water that you cannot see, such as salt). At higher temperatures, evaporation rates increase and the water vapor leaves behind the total dissolved solids. Concentrations of the dissolved solids will increase, as the body of water becomes shallower. High total dissolved solid concentrations can harm aquatic life. Refer to the Total Dissolved Solids Information Sheet for more information. Increased **turbidity** (cloudiness of water) can also increase the water temperature because the suspended visible particles can absorb the sun's rays.

Temperature influences aquatic life. As water temperature rises, it increases the metabolic rates of fish and aquatic insects. These rates require more oxygen; therefore, dissolved oxygen levels are reduced even further in the water. Temperature also influences another natural stream process. Under warm conditions, the rate of decomposition (break down of plants and animals) speeds up. Decomposition uses oxygen and produces carbon dioxide instead.

There is a natural fluctuation of waterway temperature from season to season, even day and night, and aquatic life can cope with these natural changes. When humans alter the temperature of waterways, it may harm aquatic life; a thermal change of 2°C or more is harmful to stream organisms. All species have a specific range of temperature to which they are adapted. Fishermen know that trout like cold-water streams, while other fish like, carp and bluegills, can tolerate warmer waters. If a stream changes temperature, organisms that cannot tolerate the change are stressed and must either reduce activity, move somewhere else, or in extreme cases, perish. The temperature-induced stress and lower oxygen levels may make aquatic creatures more vulnerable to disease. Many life cycles of fish and aquatic insects are tied to water temperature. Temperature cues are used by these creatures to determine when to spawn, lay eggs, when the eggs will hatch, and when insect larvae will emerge from a stream to fly away. Drastic temperature change can disrupt the timing of the life cycles, possibly causing eggs to hatch before sufficient food resources are available or larva to emerge when it is too cold atmospherically.

Human Impact

Humans can alter natural temperature characteristics of a stream by direct actions to the waterway or indirectly through alterations to the watershed. **Thermal pollution** refers to the unnatural addition of warmer or colder water that causes an unstable jump in the temperature of a waterway. Industries and power plants discharge warm water that was used in the manufacturing process (boilers) or to cool machinery and turbines. When industries and community water authorities withdraw water from a stream, it may decrease the water depth. Since shallower water heats up more readily than deeper water, water withdrawal may increase stream temperatures. Water released from dammed lakes can also alter temperatures because it is often withdrawn from near the lake bottom and is often cooler than the stream temperature in the summer, warmer in the winter. The shock of these rapid temperature changes can be too much for aquatic life to handle.

Humans can alter the land use around a waterway and affect the water temperature. Removing the streamside forests for farming or during timbering eliminates the shade provided to the stream. Sunlight is no longer blocked. The removal of streamside forests and any other actions that promote soil erosion also increase the water temperature as more heat soaking sediment enters the stream. Urbanization is another heat causing pollution source. Rainwater that flows over hot paved surfaces warms up and eventually enters the stream. Many storm drains on roads and parking lots lead directly to the nearest waterway without any type of treatment.

Water Quality Standard

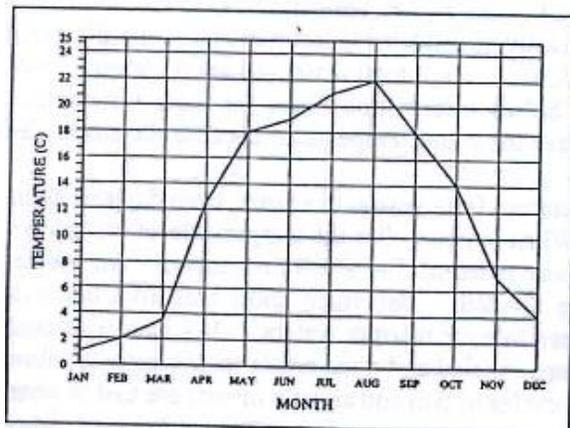
The Environmental Protection Agency (EPA) has established a formula for two important temperature extremes for streams: upper temperature limit and a weekly average. The upper temperature limit, or short term maximum, is set at 30.6°C for the area from the southern shore of Long Island, New York to Cape Hatteras, North Carolina. The weekly maximum is set at 27.8°C for this same area. No regulations are established for the zone containing Western Pennsylvania.

Example Temperature Data – French Creek

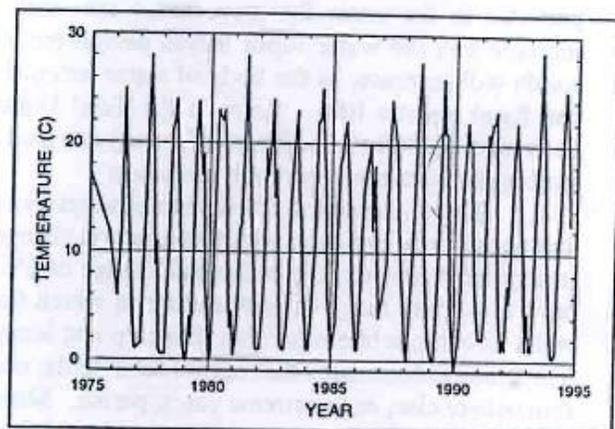
The Department of Environmental Protection (DEP) has systematically collected water quality data from French Creek, at Meadville, since 1973. A summary of these data is below to provide an understanding of past values of temperature and demonstrate trends or relationships of past temperatures.

Average: 11.5 °C **Minimum:** 0.0 °C **Maximum:** 33.0 °C

Graph 1: Monthly temperature variation in French Creek, Meadville, PA in 1985



Graph 2: Temperature in French Creek, Meadville, PA for years 1975 to 1994



Graph 1 shows a trend of increasing temperature from January to August with a seasonal peak in August. The temperature of French Creek decreases from August to January. Graph 2 displays all temperature data from 1975-1994 for French Creek at Meadville. Note that the maximum and minimum temperatures have changed. Changes in temperature are mainly from the natural differences between seasonal weather. Soil erosion, storm drainage, and riparian zone removal may cause some artificial temperature influences. Withdrawal of water for agricultural irrigation and municipal water supplies drop water levels, allowing the shallower stream to heat quicker. Water released from flood controlled reservoirs (Woodcock Lake, Union City) tends to be cooler than natural water, especially during summer months, but these temperature changes would have rebounded before reaching Meadville.

TEMPERATURE FACT SHEET

Definition: A numerical measurement in degrees Celsius (°C) or Fahrenheit (°F) of heat.

$$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32.0)}{1.80}$$

$$^{\circ}\text{F} = (^{\circ}\text{C} \times 1.80) + 32.0$$

Background:

- Many of the physical, chemical, and biological characteristics of a waterway are directly linked to the water temperature.
- The sun provides the energy needed to affect water temperatures, so shading influences temperature.
- The shallower the water, the quicker water temperature will change.
- Moving water (stream, rivers, especially riffles and rapids) is normally cooler than standing water, (ponds, lakes).
- Colder water holds more oxygen, hotter holds less.
- Higher temperatures increase aquatic organisms' metabolic rates... (increase oxygen need).
- Higher temperatures increase plant growth and decomposition rates.
- Different species have specific ideal temperature ranges.

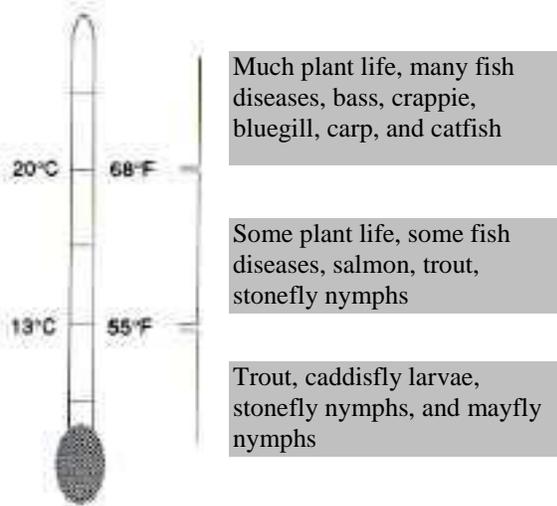
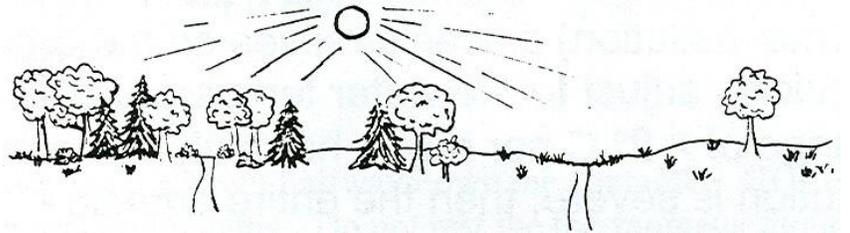


Fig. 1: The temperature tolerances of aquatic life.

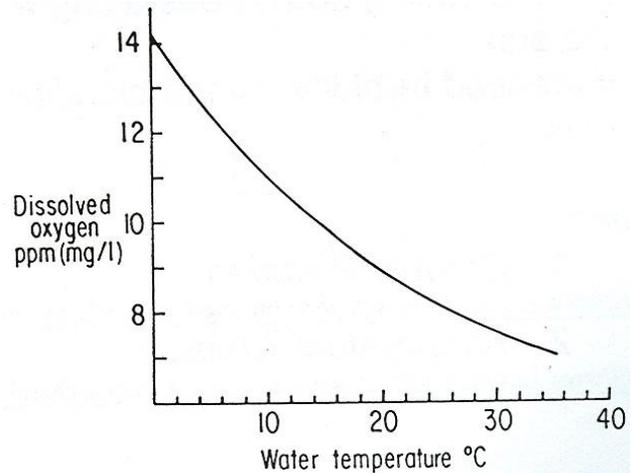


Fig. 2: Relationship between temperature and dissolved oxygen in pure water at sea level pressure.

Sources of figures 1 and 2: From or based upon Caduto, 1985. *Pond and Brook: A Guide to Nature In Freshwater Environments.*

Thermal Pollution

Definition: When relatively warmer or colder water enters a body of water, causing unnatural changes in the temperature of the body of water.

Why is this bad?

An aquatic organism's body temperature is directly linked to water temperature. Thus, the organism needs time to adjust to any change in water temperature. Sudden changes in water temperature (as in thermal pollution) places stresses on the organism too quickly to adjust to the water temperature, (Thermal change of $\geq 2^\circ\text{C}$ per day is harmful). If thermal pollution is severe, then the entire aquatic ecosystem can be destroyed.

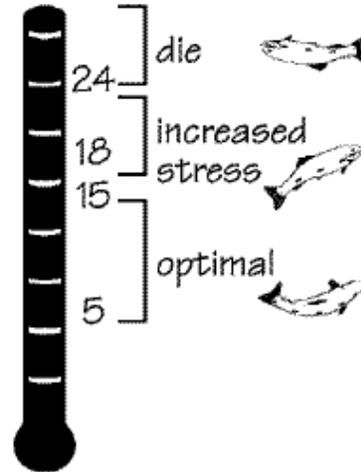


Fig. 3: The stress of increased temperature ($^\circ\text{C}$) on trout and salmon Illustration Source: www.busboy.sped.akons.edu/nkancm/stream/chemical/tempby.shtml

Origins of Thermal Pollution:

- Industries & power plants--- warm discharge water used to cool hot machinery.
- Stormwater---running off of hot urban surfaces such as pavement.
- Cutting of trees along waterways that shade the water from the sun.
- Increased turbidity, (water cloudiness)...Cloudy water absorbs the sun's rays.

Links:

1. Thermal Pollution

<http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Environmental/THERMAL/ttel.html>

2. Temperature Change

<http://eesc.orst.edu/agcomwebfile/edmat/EC1489.pdf>

<http://www.epa.gov/volunteer/stream/vms53.html>

3. Temperature Effects on Fish

http://web.ics.purdue.edu/~jordanb/fish_temperature.htm



How to use...

Thermometer (Temperature Test)

INSTRUCTION SHEET

Test Location - Field

This test must be performed in the field immediately after sample collection.

Materials

Celsius thermometer

Testing Background

For more representative results, take the temperature of two different sample bottles (2 trials). Please note that the longer you hold onto the plastic sample bottles, the more you are changing the temperature of the water inside. The heat from your hands can be transferred to the water if you carry the bottle around too long.

Test Instructions

1. Immerse the thermometer in the water sample about halfway down the container. **HOLD** onto it for at least one minute for an accurate reading. Do not rest the thermometer along the container's edge or bottom. Take the reading with the thermometer in the sample if at all possible. Read the temperature value in degrees Celsius. To check if the reading stabilized, place the thermometer back in the sample and read the value one-minute later.
2. Repeat the procedure for the second sample bottle, 2nd trial. Record both temperatures on the data sheet, and determine the average reading.

Disposal and Clean Up

Make sure you put the thermometer back into its protective case.

Safety Precautions

Use normal safety precautions in handling the thermometer to avoid breaking the equipment. Please inform your teacher immediately if the thermometer breaks.



Photo Source: Fisher Scientific

pH INFORMATION SHEET

Background

The pH of water is very important to water quality because it controls the types and rates of many chemical reactions in water. Aquatic organisms have a specific pH range in which they can live. Water (H₂O) contains both hydrogen ions (H⁺) and hydroxyl ions (OH⁻). pH is a measure of the concentration of free hydrogen ions, which will indicate whether a solution is acidic or basic. Specifically, pH is equal to the negative log of the hydrogen ion concentration (or, $\text{pH} = -\log_{10}[\text{H}^+]$). The numerical value does not have a unit (like mg/L) per se, but must be listed alongside the term pH. The values for pH are arranged on a scale from 0 to 14. A pH of 7 indicates the solution is neutral and the concentration of H⁺ is equal to the concentration of OH⁻. Values of pH less than 7 are considered **acidic** (more H⁺ are present, less OH⁻). Values of pH greater than 7 are considered **basic** (less H⁺ are present, more OH⁻). Because pH is determined based upon a log scale, each unit change in pH indicates a ten-fold difference in the concentration of hydrogen ions. For example, water at pH 5 is ten times more concentrated with H⁺ than water at pH 6.

Natural, uncontaminated rainwater is generally somewhat acidic, with a pH of about 5.6. This acidity is due to the natural dissolving of carbon dioxide (CO₂) in precipitation (H₂O) to form carbonic acid (H₂CO₃). *The extra hydrogen ions are produced when the carbonic acid dissociates (breaks apart) producing H⁺ and bicarbonate HCO₃⁻.*

Once precipitation hits the ground, a variety of organic and inorganic chemical reactions may take place to alter the pH of water. In the upper parts of the soil, infiltrating water commonly reacts with organic matter to form organic acids, and eventually lower the value of pH (more acidic). Reaction with inorganic minerals (in rocks for example) dominate once water infiltrates beneath the soil; most of these reactions will use free hydrogen ions (buffering the solution) and therefore cause an increase in pH (more basic). The geology of a region exerts a strong control on the pH of natural waters. For example, minerals such as calcite (calcium carbonate – CaCO₃), the main component of limestone and the cement that holds sandstone particles together, are especially effective at causing increases in pH. As calcium carbonate dissolves, free hydrogen ions are used. This ability to buffer, or resist the changes in pH, is called **alkalinity**. See the alkalinity information sheet for more background.

Once water enters lakes and streams, aquatic life may affect pH. Respiration by plants and animals and decomposition produce CO₂, allowing it to react with water to form carbonic acid (eventually dissociating to produce H⁺) and the pH levels of a waterway can decrease (more H⁺). However, during daylight hours, plants photosynthesize using CO₂ and keeping it from forming carbonic acid and extra H⁺. Under normal stream conditions, pH levels are usually highest at the end of a day of photosynthesis, lowest after a night of respiration.

All aquatic life has a specific pH range that it can tolerate and to which it is adapted. If the pH changes even slightly, it will stress the creatures and may even kill them. At extremely high (9.6) or low (5.0) pH values, the water becomes unsuitable for most organisms. Immature stages of aquatic insects and young fish are extremely sensitive to a pH below 5. Low pH causes an imbalance in the sodium and chloride ions in aquatic organisms' blood. At low pH, hydrogen ions may be taken into cells while expelling sodium ions. Higher acidity can increase the concentration of toxic metal concentrations in a stream, such as aluminum (Al⁺³) and copper (Cu⁺²). These metals are locked up in mineral matter under neutral pH levels, but become mobile when the pH lowers. Metals can clog fish gills causing breathing complications or cause deformities to young fish. They can also settle on the stream bottom filling in spaces between rocks where insects live or eggs are laid, even smothering the eggs.

Human Impact

Acidic waters have been and continue to be a major environmental concern. Whereas unpolluted precipitation has a pH of about 5.6, the precipitation in most of the Northeast United States has a pH of between 4 and 4.5. Air pollution is the cause. Increased amounts of nitrogen oxide (NO_x) and sulfur dioxide (SO₂) gases, primarily from the burning of fossil fuels by power plants and industry and from car exhaust, react with water and are converted to nitric acid (HNO₃) and sulfuric acid (H₂SO₄) in the atmosphere. Both of these acids can dissociate to produce extra H⁺ and lower the pH of the rain, and the

streams that it falls and drains into. Waterways may not be affected by this acidic rain if the geology in the watershed contains an abundance of acid-neutralizing rocks containing CaCO_3 . A region with this type of geology has high alkalinity (ability to resist changes in pH). However, a region void of this type of rock and low alkalinity can have streams that are damaged by acid rain. For example, the Adirondack region in New York has rocks and streams that are unable to neutralize the acid rain; as a result, widespread fish kills have occurred.

Coal mining operations (current and abandoned) can add acidity to a waterway through acid mine drainage (AMD). The waste material of coal mining is called spoils or overburden and is the discarded soil and crushed rock found above and between coal seams. This waste contains iron pyrite (fool's gold) and when exposed to air and water, it reacts to form iron hydroxide ($\text{Fe}(\text{OH})_3$) and sulfuric acid (H_2SO_4). The acid can dissolve other minerals and metals, and the water can become very acidic (as low as a pH of 2 even) as it enters local streams.

Water Quality Criteria

As in many chemicals, there is no distinct dividing line between safe and harmful pH levels. The drinking water standards set by the Environmental Protection Agency (EPA) calls for a minimum pH of 6.5 and a maximum pH of 8.5. Natural waters should have a pH between 5.0 and 8.5, since lower or higher values are likely to be harmful to fish populations and other aquatic life.

Example pH Data – French Creek

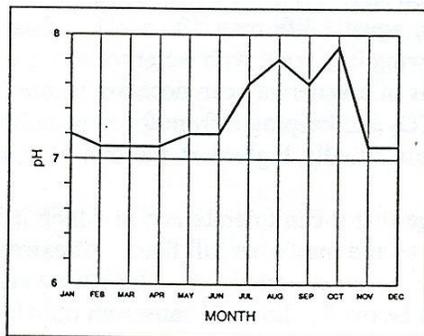
Data on the pH of French Creek were collected by the Pennsylvania Department of Environmental Protection (DEP) for a Meadville site from 1973 to present date. The pH values from Meadville were tabulated and graphed for the time period of 1973-1994 and the average, maximum and minimum values were determined.

Average: pH 7.40

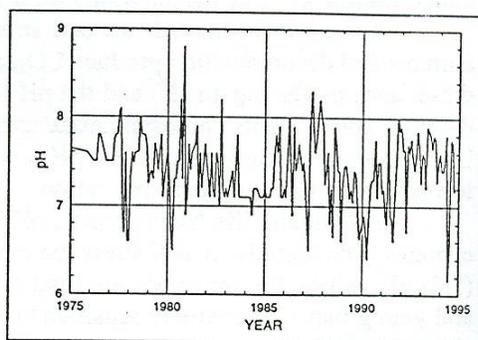
Maximum: pH 8.80

Minimum: pH 6.16

Graph 1: Monthly values of pH in French Creek, Meadville, PA for 1985



Graph 2: Values of pH in French Creek, for years 1975 to 1994, Meadville, PA



The pH trends, for a typical year (1985) in French Creek, shows values between 7 and 8, a range excellent for aquatic life. The pH is relatively low in the late winter through June. This is due to more acid precipitation and snowmelt directly entering the stream before becoming groundwater that is buffered by bedrock and soils. Also in the spring, plants are beginning to grow, respiring more and producing CO_2 that can form carbonic acid. Beginning in June, the pH begins to rise until October (drier season) because the main source of water for the stream is from well-buffered groundwater. After October, another decline occurs as the stream relies less on groundwater flow and plants begin to decompose (producing CO_2).

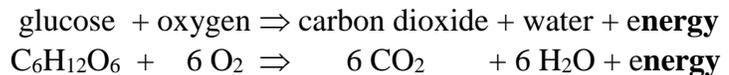
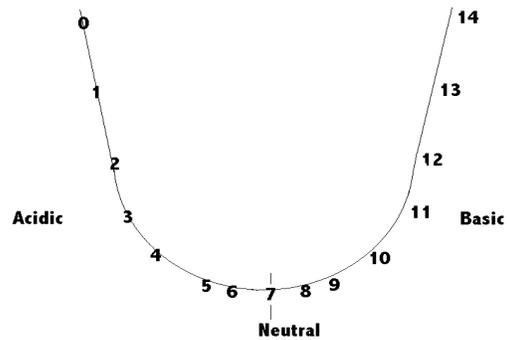
A source of acidity that enters French Creek is acid precipitation (often around pH of 4.5) and organic acids (carbonic acid). However, the French Creek Watershed has the geology (CaCO_3) to buffer acid inputs, thus keeping the stream pH in the basic range. Luckily the watershed has only thin coal seams, therefore no coal mining, and no resulting acid mine drainage has occurred.

pH FACT SHEET

Definition: A measurement of hydrogen ion concentration (H⁺) in liquids and other substances. The amount of H⁺ can determine whether the substance is acidic or basic, (alkaline).

Background:

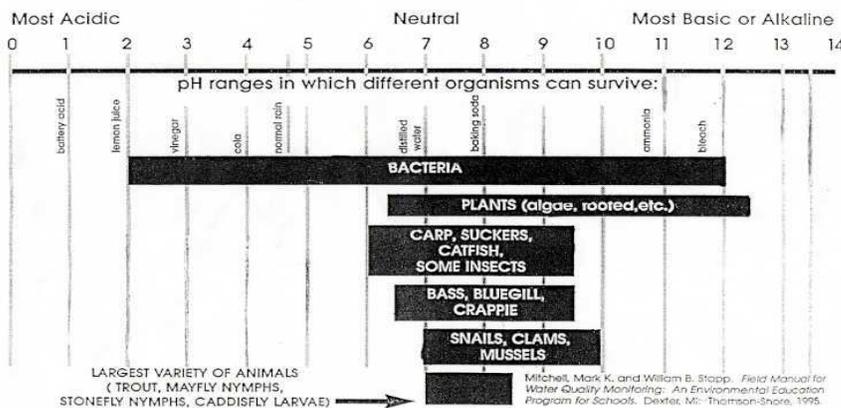
- Water contains both H⁺ (hydrogen) and OH⁻ (hydroxyl) ions.
- Pure distilled water has an equal number of hydrogen and hydroxyl ions...making the water neutral (pH of 7).
- More hydrogen than hydroxyl ions results in an acidic solution, (pH <7).
- More hydroxyl than hydrogen ions results in a basic solution, (pH >7).
- pH is expressed on a Log10 scale from 1-14, thus a pH of 6 is *10 times* more acidic than pH of 7.
- Natural rain has pH of about 5.6, (CO₂ + H₂O forms carbonic acid, which breaks off a H⁺ and makes rain acidic).
- Organic acids in upper soil layer can lower pH by producing extra H⁺.
- Calcium carbonate rocks and soils (CaCO₃), can buffer changes in pH.
- Photosynthesis removes CO₂, (and eventually carbonic acid) making water more basic.
- Respiration/decomposition adds CO₂ (and eventually carbonic acid) making water more acidic.



- *High pH* prevails in summer when waterways are heavily influenced by groundwater flow and buffered by limestone soils and more photosynthesis occurs.
- *Low pH* prevails in late winter and spring when snow melts and precipitation rapidly enters waterways (without contact with calcium carbonate rocks), there is less buffered groundwater influence, and photosynthesis is not occurring.

Environmental Impacts

- Effects of acid rain are worse in those regions that:
 - Are downwind of industrial areas
 - Do not contain calcium carbonate in rocks and soils to reduce acidity.
- Primary cause of acid rain is from nitrogen oxides (NO_x) and sulfur dioxide (SO₂), from automobile and coal-fired power plant emissions, which transform into nitric & sulfuric acid.
- Northeast USA typically receives acidic rain of pH 4.5 or lower.
- Resulting acidic rain precipitates to the ground, rendering waterways too acidic to support aquatic life.
- Average pH of natural creek water in Pennsylvania is between 6.5 and 8.5, except in acid mine drainage streams.
- Most organisms are adapted to live within a specific range of pH, thus, even a slight change may be fatal.



Source: Cuyahoga Valley Environmental Education Center, Peninsula, OH. Student Discovery Book, 5/97 Version

Fig. 4: pH ranges in which different organisms can survive
 Source: Cuyahoga Valley Environmental Education Center, Student of Pennsylvania Discovery Book 5/97 version. Peninsula, OH.

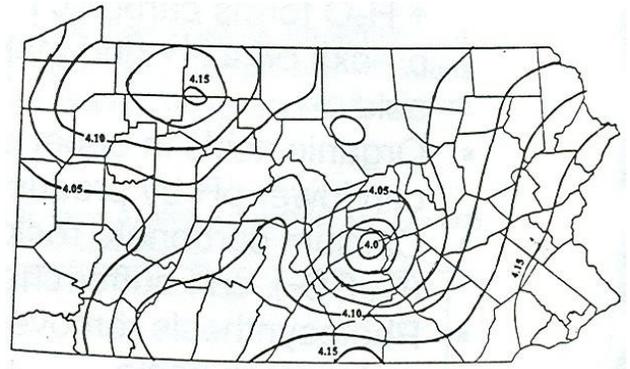


Fig. 5: pH of rain in Pennsylvania
 Based on: Cuff, 1989. Atlas 1997.

- Acid mine drainage, from coal mining and other resource extraction, contains sulfuric acid (H₂SO₄) which can break off an extra H⁺.
- Acidic water (low pH) releases metals, which can harm aquatic life.

Water Quality:

- Natural waters should have a pH between 5-8.5.
- EPA's required pH levels for drinking water is 6.5-8.5.

Links:

1. *Monitoring Water Quality* ~ defines pH and importance to water quality

<http://www.epa.gov/volunteer/stream/vms54.html>

http://www.fisheries.nsw.gov.au/aquaculture/extension_services2/water_quality_monitoring_ph



How to use...

Pocket pH Meter

INSTRUCTION SHEET For Waterproof Oakton pHTestr 1 Double Junction or EcoTestr pH2

Testing Location - Field

This test, using the pH meter, should be performed in the field.

Materials

pHTestr 1 Double Junction (beige with yellow trim) or EcoTestr pH2 (green with gray trim)

Three or four 1.4 or 1.5 volt batteries (probably already in the meter)

Large-mouthed collection container

pH 7 calibration solution (yellow)

Testing Background

There are a variety of ways to test for pH: pH paper, meters, color comparator kits. *If properly taken care of*, the pH meters we have provided will give accurate numerical results in 0.1 increments. There are two models of pH meters being used by our schools; some are using the pH Testr1 from Oakton (beige in color with yellow trim), and others are using the EcoTestr pH2 (green with gray trim). Instructions for both types follow.

Calibration

Should be done before each use



Oakton pHTestr 1 Double Junction

(beige w/ yellow trim)

1. To calibrate, find the pH 7 calibration solution (yellow liquid).
2. Remove the cap from the bottom of the meter. Immerse glass electrode 0.5 to 1 inch (not any deeper) in the pH 7 solution.
3. Press the ON button. Stir once and press the CAL button to enter Calibration (CA) mode. 'CA' flashes on the display. A pH value close to 7.0 will flash repeatedly. If the reading is not near 7.0, rinse the electrode and try again. If the reading is still not near 7.0, read the "trouble shooting" section.
4. After **30 seconds** press the HOLD/CON button to confirm calibration. The display will show 'CO' and then switch to the buffer value reading (7.0).
5. Turn the meter OFF and rinse the electrode with distilled water before proceeding with testing.

Oakton EcoTestr pH2 (green w/gray trim)

1. To calibrate, find the pH 7 calibration solution (yellow liquid).
2. Remove the cap from the bottom of the meter. Immerse the glass electrode 0.5 to 1 inch (not any deeper) in the pH 7 solution.
3. Press the ON button. Stir once and press the CAL button to enter calibration mode. A value will blink during this time. Stir gently and wait for the displayed value to stabilize on one reading. Hopefully this reading is near 7.0; aim for between 6.6 and 7.4. If the meter is not stabilizing near this value, rinse the glass electrode with distilled water and begin the calibration again. If the meter still does not stabilize, read the "trouble shooting" section.
4. When the reading has stabilized, press the HOLD/ENT button to confirm. Turn the meter OFF before removing it from the pH 7 solution. Rinse the glass electrode with distilled water.

Test Instructions for either meter:

1. Pour Sample water into small, wide mouth container that the meter can fit into. You only need about 1 inch of sample water.
2. Remove the cap from the bottom of the meter. Dip the meter's electrode 0.5 to 1 inch in the sample water.
3. Turn the meter ON. Stir once and wait for the display reading to stabilize. The stabilized reading is the pH for the water sample. Record this value.
4. Turn the meter OFF and rinse the electrode. Repeat for Sample B.
5. When finished, make sure the meter is turned OFF. Rinse the glass electrode with distilled water and replace the cap. It is okay to have some moisture inside the cap when putting the meter away – this will actually prolong the life of the electrode.

Disposal and Clean Up

Calibration solution should be replaced after 4 sampling events/dates. Calibration solution can be flushed down the sink with plenty of water. Properly dispose of expired batteries; you can give them to Creek Connections.

Safety Precautions

Normal safety precautions should be taken when handling the water sample, buffer solution and the equipment to avoid breakage.

Trouble Shooting Tips

METER DOES NOT TURN ON

1. Check batteries. Make sure they are installed properly (see Changing Batteries instructions below).
2. If still not working, install new batteries (see Changing Batteries instructions below).
3. If the meter does not work after replacing batteries, recheck the direction of the batteries in the meter. Reversed batteries in meter will result in failure of the meter to work. If the new batteries are in the correct position, check to see if the red or black wires connecting to the battery compartment are broken. If they are broken, *you need to replace your meter.*
4. If the batteries are new and the meter is still not working, the battery contacts may be corroded or dirty. Check the metal contacts that the batteries fit between and look for rust or other oxidation. Clean them with isopropyl alcohol. You may need to carefully scrap away rust or dirt with a flathead screwdriver or pair of scissors. Replace batteries and try again.
5. If the meter still does not turn on, *you need to replace your meter.*

THE NUMBERS ARE FAINT OR DISAPPEAR or there is an ER1 (bAt) Message

1. If the meter is IN a solution, and the readout numbers are faint or disappear while meter is on or there is an ER1 (bAt) Message that is displayed, then the batteries need to be replaced (see Changing Batteries Instructions below).

METER WILL NOT CALIBRATE or there is an ER2 Message

1. Did you take the cap off the meter?
2. Do you have fresh calibration solution?
3. Are you following the directions for calibration correctly? Use the Creek Connections handbook instructions.
4. If the digital reading does not stabilize when calibrating... rinse the glass electrode with distilled water before calibrating. Make sure the meter is in new pH 7 calibration solution (this should be replaced after a 3 or 4 creek trips). For both meters, make sure the meter is actually IN the calibration solution when turning the meter on to calibrate; numbers will go crazy if the meter is on while in the air and not in a solution. Before removing from any solution or sample, turn the meter off.
5. An ER2 Error Message means that the wrong buffer has been used or the buffer is bad. Replace the buffer. This error message could also mean the electrode is failing and needs to be replaced.
6. Are you calibrating to the correct number? The meter will not necessarily blink and stabilize on 7.0 perfectly. The closer to 7.0 the better, but 6.6 - 7.4 is acceptable, just as long as when the "Hold/Con(Ent)" button is pushed, the meter reads 7.0.
7. After addressing these, if the reading still does not stabilize at all, the batteries may need to be replaced (see Changing Batteries Instructions below).

NUMBERS ON METER WILL NOT STABILIZE IN A SAMPLE or there is an ER2 (ERR) Message

1. Did you take the cap off the meter?
2. Do you have fresh calibration solution?
3. Just wait. It takes some time for the meter to stabilize. After a few minutes, if the readout number does not stabilize (it is "jumping around" still), turn off the meter, remove from the sample, and then rinse the meter's glass electrode thoroughly with distilled water and try again.
4. If readout still does not stabilize, the batteries may need to be replaced (see Battery Changing Instructions below).
5. If the batteries are new, installed correctly, the contacts and wiring are in good condition, and the readout still does not stabilize, then the glass electrode may need cleaned more thoroughly. You should soak the glass electrode periodically in tap water for 1-2 hours. This will help remove any buildup on the electrode. Do this then try your sample again later. A consistent ER2 (ERR) error message could mean the electrode is failing and needs to be replaced.

METER STILL NOT WORKING

If you have done all of the above and the meter is still malfunctioning, contact Creek Connections for a replacement meter.

CHANGING BATTERIES

1. For the pHTestr 1 Double Junction (yellow trim), unscrew the battery compartment on the top of the meter. It is held on tightly by a waterproof o-ring and will unscrew with some difficulty. For the EcoTestr pH2, lift up front battery cover and hold in position before lifting two sides of the pocket clip. Remove old batteries (give them to your teacher for proper disposal).
2. Replace the batteries with new ones noting polarity (+ and -) inside the meter and on the batteries. The red wire is the positive (+) side; black wire, negative (-). Make sure the small black cloth or white plastic strip wraps along the bottom of the batteries before inserting them. It is a tug strip to help pop out the batteries. Make sure the tug strip is not placed in between batteries or covers up the metal contacts.
3. When replacing the cap on the pHTestr 1 Double Junction (yellow trim), make sure the seal with the o-ring is waterproof by snugly tightening the cap. Do not over-tighten!

What batteries to use: They are hearing aid batteries often found in pharmacies. Shop for 1.5 or 1.4 volt Eveready EP675E or EP675HP, Duracell DA675, or most any other 1.5 or 1.4 volt brand with the number 675 in its name.

LONG TERM CARE TIPS

1. Make sure the meter is turned off after each use. For both meters, DO NOT have meter turned on unless it is in a solution, having it on when the electrodes are in the air is not good.
2. Use distilled or tap water (not de-ionized water) to rinse the electrode and never store the meter with de-ionized water on the electrode. It is okay to store the meters with some water moisture in the electrode cap. You can even wet a paper towel or small sponge piece and insert it in the cap. This will actually prolong the life of the electrode.
3. To improve meter performance and accuracy, periodically soak the glass electrode in tap water.
4. Do not expose battery compartment to excess moisture. Store in a dry place. Do not drop meter in the creek or leave out in rain.
5. Students should not touch the meter's glass electrode.

This test sheet was adapted from the instructions for the Oakton pHTestr1DoubleJunction and the EcoTestr pH2 and from Creek Connections staff observation.

TOTAL DISSOLVED SOLIDS INFORMATION SHEET

Background

Total dissolved solids (TDS) consist of minerals, organic matter, and nutrients that have dissolved in water – the ions and compounds that you cannot see in the water. Water is known as the universal solvent because of its ability to dissolve, to some degree, most elements and compounds. The major components of TDS in natural waters include: bicarbonate (HCO_3^-), calcium (Ca^{+2}), sulfate (SO_4^{-2}), hydrogen (H^+), silica (SiO_4), chlorine (Cl^-), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), nitrogen (N_2 , NH_3 , NO^{-2} , NO^{-3}), and phosphorus in the form of phosphate (PO_4^{-3}). These components have been listed more or less in order from most concentrated to least concentrated in typical waterways. Bicarbonate can make up 50% of TDS in some streams. Minor constituents that are normally found in trace amounts in streams include: iron (Fe^{+3}), copper (Cu^{+2}), zinc (Zn^+), boron (B^{+3}), manganese (Mn^{+2}), and molybdenum (Mo^+).

A constant level of these total dissolved solids is essential for the maintenance of aquatic life because the density of total solids determines flow of water in and out of an organism's cells (osmosis). Plus the nutrients (nitrogen and phosphorus) are important for organism growth. A sudden or extreme change in TDS can be detrimental to aquatic life. For instance, an increase in salts could kill freshwater species whose bodies are not adapted to live in saltwater.

The natural sources of dissolved solids are rocks, bedrocks, and soils. As water comes in contact with the rocks, minerals will dissolve to some degree. Geologic settings that include limestones (calcium carbonate) and halite (salt, sodium chloride), which readily dissolve in water, generally have waters with high TDS values. Regions underlain by rocks not susceptible to weathering, such as quartz-rich granite, generally have waters with low TDS levels.

The hydrological setting also exerts a strong control on the amount of TDS. Groundwater generally has high TDS values because it moves slowly and comes in contact with lots of rocks and sediment. Conversely, storm water runoff has low TDS because it moves rapidly and has limited contact with rocks and sediments. Because of this relationship, TDS is typically highest in streams flowing during low flow conditions, when groundwater is the primary source of water. During high flow conditions, stream TDS is low because storm runoff is the primary source of water.

The greater the land area that water has to come in contact with soils and rocks, the more likely the TDS levels will be higher. For instance, if TDS levels were analyzed at the mouth of a stream that drained a 60 square mile watershed, they would be higher than a sample taken from the mouth of a stream draining the upper 5 square miles of that same watershed.

The term total dissolved solids is often confused with other types of stream measurement tests. For instance, **total solids** (TS) is the sum of both TDS and visible solids (sediments) that would contribute to the turbidity of water. TDS is also different from **conductivity**, which is a measure of the electrical conductance of water. TDS is a measure of the amount of ions in water, while conductivity is a measurement of those ions' ability to do something – conduct electricity. Distilled water (very low TDS) has little capacity for electron conductivity. The more ions in the water, the higher the electron flow. Usually there is a strong correlation between conductivity and TDS, but there is still a difference between the two. Conductivity is only an approximate predictor of TDS. **Salinity** is also different from TDS. Salinity deals only with salts and is defined as the concentration of all ionic constituents that include halides, bicarbonates, and sodium chloride.

TDS is a complex water quality parameter because it is directly linked to so many chemical and biological processes, and incorporates a number of the other water parameters that we test. The average concentration of TDS for the world's rivers is 100mg/L, while North American rivers average 142.6 mg/L. Each region in the country has a specific, normal TDS level - some high, some low. Ecosystems are adjusted to local conditions; therefore, a large change in TDS concentrations will disrupt the system and increase its overall sensitivity.

Human Impacts

Because TDS is related to so many other chemical parameters and processes, humans can increase TDS levels in a number of ways. Rain will wash additional dissolved solids into a stream. This will occur naturally but we can increase it by encouraging soil erosion through poor farming practices, construction sites, timbering, and removal of riparian zones. Soil can bring in more minerals, nutrients, and metals. Rain will also be more effective at dissolving minerals if it is acidic, and humans have drastically lowered the pH (increased acidity) of rainfall through car exhaust and the burning of fossil fuels. Rain can also wash excess nutrients into a stream if too much fertilizer is placed on cropland or lawns. Since nutrients are a component of TDS, any human practices that contribute nutrients to streams will increase TDS levels. See the Nitrogen and Phosphorus Information Sheets. An easy to understand dissolved solid – salt – is another common artificial source of higher TDS. Road salt used on roads in the winter can wash into waterways.

Water Quality Criteria

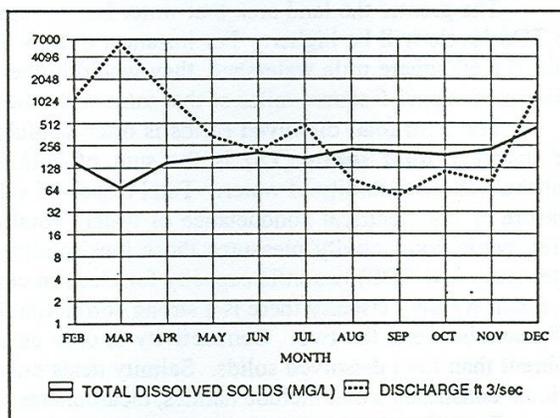
The Environmental Protection Agency (EPA) limits the amount of dissolved solids to 500 mg/L for drinking water. Each component that makes up TDS has a specific water quality limit also. A monthly average of 500 mg/L and a maximum of 750 mg/L for a single event is considered safe for aquatic life.

Example Total Dissolved Solids Data – French Creek

The Pennsylvania Department of Environmental Protection (DEP) has systematically collected water quality data from French Creek, at Meadville since about 1973. A summary of these data is below to provide an understanding of past values of TDS and to demonstrate relationships of past TDS levels with discharge.

Average: 202.00 mg/L
Maximum: 454.00 mg/L
Minimum: 68.00 mg/L

Graph 1: Total Dissolved Solids Concentrations in French Creek, Meadville, PA for 1991



The graph displays a trend of lower concentrations of TDS with high discharges within French Creek. This pattern of high discharges and low concentrations of TDS is most apparent in March. Higher TDS values correlate with times when the discharge of French Creek is low and dominated by TDS-rich groundwater inputs.

Natural sources of dissolved solids that could contribute to the concentrations of TDS in French Creek flow from groundwater into the stream. Groundwater is the primary source of water into French Creek during low-flow conditions. The primary components of TDS in the French Creek watershed are calcium and carbonate.

In addition to natural sources, artificial sources of dissolved matter include runoff from human activities in urban and rural areas. Road salts, placed on roadways in winter, and fertilizers can runoff into French Creek. Acid rain may cause elevated levels of TDS throughout the watershed.

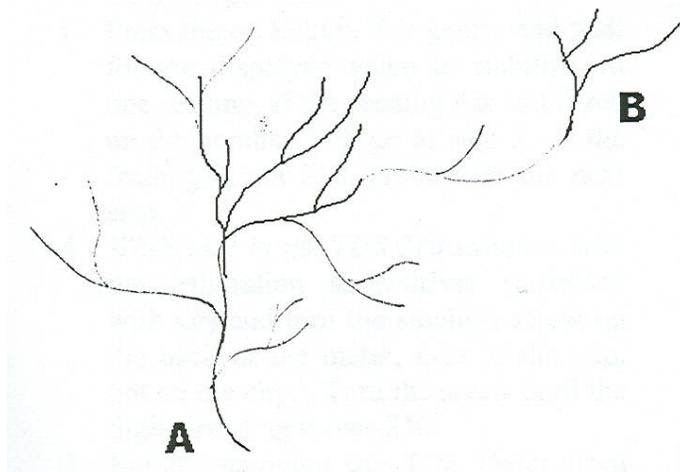
TOTAL DISSOLVED SOLIDS (TDS) FACT SHEET

Definition: The total amount of minerals, organic matter, and nutrients that are dissolved, (not merely suspended) in the water. They are the particles that you can't see in the water.

Dissolved Substances within Water Considered TDS			
<i>Substance</i>	<i>Natural Source</i>	<i>Substance</i>	<i>Natural Source</i>
Calcium (Ca ⁺²)	sed./meta. rock	Bicarbonate (HCO ⁻)	sed./meta. Rock
Magnesium (Mg ⁺²)	sed./ign. rock	Sulfate SO ₄ ⁻²	sed./ign. Rock
Sodium (Na ⁺)	sed./ign. rock	Chlorine (Cl ⁻)	all rocks, sea spray
Potassium (K ⁺)	sed./ign. rock	Silica (Si ⁺⁴)	all rocks
Hydrogen (H ⁺)	sed./ign. rock	Nitrogen (N ₂)	N ₂ fixation, runoff
Phosphorus (PO ₄ ⁻³)	sed. rocks, runoff	Iron, copper, aluminum	sed. rock, runoff

Background:

- TDS helps regulate the process of osmosis (water flow in and out of an organism's cells).
- Majority of dissolved material in water is from weathering rocks & soil erosion.
- Groundwater, (wells, springs, etc), is high in TDS.
- Typically, the greater the land area of a watershed, the higher the TDS.



If a TDS reading was taken at the mouth of the main stream (Site A) in the watershed to the left, it will be higher than a TDS reading taken at Site B. A smaller land area drains into the stream at site B, and the more contact water has with the land, the greater the concentration of TDS. This is because material is naturally dissolving from rocks and soils into the waterway.

Environmental Impacts:

- Each land region has specific, normal TDS levels. Changes can affect stream life and can indicate a disruption in the watershed.
- Higher TDS values can correspond to low flow periods, when waterway is dominated by groundwater inputs.
- More runoff can increase the TDS concentration because of more soil erosion, (the dissolved particles are carried into the soil).
- Road salt runoff can increase TDS to over 1000 mg/L, which is toxic to life.
- Industrial boiler water inputs can increase TDS.
- Abnormally high or low dissolved solids disturb osmotic balance of native species, (like putting freshwater species in saltwater!).

Water Quality:

- For drinking water, 500 mg/L is the limit.
- For aquatic life, a monthly average of 500 mg/L and a max of 750 mg/L.
- Each component that makes up TDS has water quality limits also.

Links:

1. *Understanding TDS in water*

<http://www.epa.gov/volunteer/stream/vms58.html>

<http://waterontheweb.org/under/waterquality/conductivity.html>



How to use...

Pocket TDS Meter

INSTRUCTION SHEET For Waterproof Oakton TDSTestr Low or LaMotte Tracer Conductivity/TDS/Salinity

Testing Location - Field

This test using the TDS instrument should be performed in the field.

Materials

Oakton TDSTestr Low (light brown w/ yellow trim) or LaMotte Tracer (Gray w/ black trim)

TDSTestrLow: Three or four 1.4 volt (or 1.5 volt) batteries

Tracer: SR-44W button batteries

Small wide mouthed sample containers marked A and B

TDSTestrLow: TDS 210 calibration solution (clear)

Tracer: Conductivity 1413 calibration solution (clear)

Testing Background

If properly taken care of, the TDS meters we have provided can quickly give accurate numerical results. Some schools are using the new LaMotte Tracer (gray with black trim), while others have the older Oakton TDSTestr Low (light brown in color with yellow trim).

Calibration Instructions

The meters should be calibrated before each use.) **LaMotte Tracer Conductivity/ Total Dissolved Solids/Salinity** (gray, black trim)



1. Remove the protective cap from the bottom of the meter. Rinse the metal electrodes at the bottom of the meter with distilled water. Immerse the bottom of the meter .5 to 1 inches (not any deeper!) in the TDS 210 calibration, buffer solution (clear).
2. Press the “on” button. Stir gently and wait for the displayed value to stabilize on one reading. If the stabilized reading is 210, go to step 4. If the reading is not 210, proceed to the next step.
3. Unscrew the top of the meter (battery compartment lid). *While still in the TDS 210 solution*, there are two small white buttons that you *gently* press to adjust the reading to 210. One button increases the value, the other decreases. After 3 seconds of not pressing a button the display will flash 3 times, and then show "ENT". When this occurs, the meter accepts the displayed value as the calibration value (it should be 210). You **DO NOT** and should not hit the “hold” button at all.

Continue next page, left column



1. Take off the bottom cap covering the electrodes.
2. Place the meter in 20 mL of 1413 $\mu\text{S}/\text{cm}$ standard calibration solution. Turn the meter on by pressing the ON/OFF button. The meter must be in conductivity mode (“ μS ” will be displayed above the reading; to change modes, press the MODE button until it switches modes).
3. Press and hold the CAL button for ~2 seconds. “CAL” will appear on the bottom of the screen and 1413 will flash on the screen.
4. The device will automatically recognize and calibrate to the conductivity standard. 1413 will stop flashing and the display will briefly read “SA” and “End”. (“SA” will not appear if the calibration fails.)
5. Rinse the meter with distilled water, shake dry, and turn the meter off. Proceed to testing instructions on next page.

4. Turn the meter off before removing it from the solution. Rinse it with distilled water and proceed to testing instructions.

Test Instructions:

Oakton TDSTestr Low (light brown, yellow trim)

1. Pour water sample into a small, wide mouth container that the meter can fit into. You only need 1 inch of sample water.
2. While the meter is OFF, remove the protective cap from the bottom. Immerse the bottom of the meter .5 to 1 inches in water sample, just enough that the metal electrodes at the bottom are submerged.
3. Turn the meter ON. Let the display number stabilize. The stabilized display is the TDS value for the water sample. Record this value.
4. Turn the meter OFF and rinse the electrodes. Repeat steps 1 through 3 for Sample B.
5. When finished, make sure the meter is turned OFF. Rinse the metal electrodes on the bottom with distilled water and replace the cap.

LaMotte Tracer Conductivity/ Total Dissolved Solids/Salinity (gray, black trim)

1. Pour water sample into a small, wide mouth container that the meter can fit into. You only need 1 inch of sample water.
2. While the meter is OFF, remove the protective cap from the bottom. Immerse the bottom of the meter .5 to 1 inches in water sample, just enough that the metal electrodes at the bottom are submerged.
3. Press the **ON/OFF** button to turn on the meter- **SELF CAL** will flash on the display.
4. Press and hold the **MODE** button until you see the **TDS** on the bottom of the display and **ppm** in the top left corner. *(There should not be an "S" above the reading- that is the salinity mode and is not used).*
5. Allow the reading to stabilize, then record the TDS measurement on the data sheet.
6. If you also need a conductivity reading: Check to see that meter is in **CONDUCTIVITY MODE (μS should be displayed above the reading)**. *To change modes, press and hold the **MODE** button until the correct units appear.*
7. Allow the reading to stabilize, then record the **CONDUCTIVITY** on the data sheet.
8. Press **ON/OFF** button to turn off. Rinse the meter with distilled water, shake dry and replace cap.

Disposal and Clean Up

Calibration solution should be replaced after 4 sampling events/dates. Calibration solution can be flushed down the sink with plenty of water. Properly dispose of expired batteries; you can give them to Creek Connections.

Safety Precautions

Normal safety precautions should be taken when handling the water sample, buffer solution and the equipment to

Trouble Shooting Tips

METER DOES NOT TURN ON

1. Check batteries. Make sure they are installed properly (see Changing Batteries instructions below).
2. If still not working, install new batteries (see Changing Batteries instructions below).
3. If the meter does not work after replacing batteries, recheck the direction of the batteries in the meter. Reversed batteries in meter will result in failure of the meter to work. If the new batteries are in the correct position, check to see if the red or black wires connecting to the battery compartment are broken. If they are broken, *your meter needs replaced.*
4. If the batteries are new and the meter is still not working, the battery contacts may be corroded or dirty. Check the metal contacts that the batteries fit between and look for rust or other oxidation. Clean them with isopropyl alcohol. You may need to carefully scrap away rust or dirt with a flathead screwdriver or pair of scissors. Replace batteries and try again.
5. If the meter still does not turn on, *the meter needs replaced.*

THE NUMBERS ARE FAINT OR DISAPPEAR

1. If the readout numbers are faint or disappear while meter is on and while it is IN a solution or if the meter's low battery indicator symbol appears, then the batteries need to be replaced (see Changing Batteries Section below).

METER WILL NOT CALIBRATE

1. Did you take the cap off the meter?
2. For both types of meters, if the digital reading does not stabilize when calibrating... rinse the metal electrodes with distilled water before calibrating. Make sure the meter is in new calibration solution (this should be replaced after a 3 or 4 creek trips). Make sure the meter is actually IN the calibration solution when turning the correct calibration screw on the back; numbers will go crazy if the meter is on while in the air and not in a solution. Before removing from any solution or sample, shut the meter off. After addressing these, if the reading still does not stabilize at all, the batteries may need to be replaced (see Battery Changing Section below).
3. If air bubbles are trapped near electrodes, tap the meter or stir sample to release the air bubbles.

NUMBERS ON METER WILL NOT STABILIZE IN A SAMPLE

1. Did you take the cap off the meter?
2. Do you have fresh calibration solution?
3. Just wait. It takes some time for the meter to stabilize. After a few minutes, if the readout number does not stabilize (it is "jumping around" still), shut off the meter, remove from the sample, and then rinse the meter's metal electrodes thoroughly with distilled water and try again.
4. If readout still does not stabilize, the batteries may need to be replaced (see Changing Batteries Section below).
5. If the batteries are new, installed correctly, the contacts and wiring are in good condition, and the readout still does not stabilize, then the electrodes may need cleaned more thoroughly. Long term care of the meter states that you should soak the stainless steel electrodes periodically in isopropyl alcohol for 10-15 minutes. This will help remove any buildup on the electrodes. Do this, rinse electrodes with water then try your sample again later.

METER STILL NOT WORKING

If you have done all of the above and the meter is still malfunctioning, contact Creek Connections for a replacement meter.

CHANGING BATTERIES

1. Open the top battery compartment lid carefully on top of the meter. Remove old batteries (give them to your teacher for proper disposal).
2. Replace the batteries with new ones noting polarity (+ and -) inside the meter and on the batteries. The red wire is the positive (+) side; black wire, negative (-).

What batteries to use: They are hearing aid batteries often found in pharmacies. Shop for 1.4 volt Eveready EP675E or EP675HP, Duracell DA675, or most any other 1.4 volt (or 1.5 volt) brand with the number 675 in its name. In the TDSTestr LOW, Eveready A76BP are supplied in meter, but the above mentioned batteries should also work. Tracer uses 1 SR-44W button battery.

LONG TERM CARE TIPS

1. Make sure the meter is turned off after each use. DO NOT have meter turned on unless it is in a solution, having it on when the electrodes are in the air is bad.
2. Rinse the electrodes thoroughly with distilled water after each use. It is okay to store the meter with some moisture in the electrode cap.
3. To improve meter performance and accuracy, periodically rinse/soak the metal electrodes in isopropyl alcohol for 10-15 minutes to help clean them.
4. Do not expose meters to excess moisture. Store in a dry place. Do not drop meter in the creek or leave out in rain.
5. Make sure students CAREFULLY calibrate the meter.

This instructions sheet was adapted from the instructions for the Oakton TDS Testr Low Waterproof and LaMotte Tracer as well as from Creek Connections staff observations.

Conductivity Information Sheet

Background:

When considering the composition of a cup of water, one might be fooled into believing that only water molecules can be found inside the cup. That would be true if humans only drank distilled water (otherwise known as pure H₂O). Every body of water (including drinking reservoirs, groundwater, and wells) is full of billions of microscopic chemical structures classified as both inorganic and organic compounds. Inorganic compounds are associated with geological (non-living) systems, opposed to organic molecules, which are viewed as members of biological (living) systems. Common examples of inorganic compounds in the natural world include H₂O (water), NaCl (salt), and SiO₂ (sand and quartz), as opposed to oil, sugars, and alcohols, all examples of organic structures. Gauging the overall abundance of inorganic dissolved ions in a watershed is a method for monitoring stream health, and is studied through the measurement of conductivity. Conductivity pertaining to testing of water quality is defined as the ability for water to spread an electrical current. The standard unit of measuring conductivity in water is the microSiemen (μS), which is measured per centimeter ($\mu\text{S}/\text{cm}$) of water. Inorganic compounds with both positive and negative charges are very strong conductors, giving them the largest role in conductivity measurement. Organic compounds on the other hand are minimally conductive, in fact they have a slightly decreasing effect on conductivity.

Conductivity vs. TDS:

To many people, it would seem that testing conductivity is no different than testing total dissolved solids (TDS), a test that has been included in water chemistry kits for a long time. From some reference points, this isn't totally incorrect. Interestingly enough, TDS measurements are merely a conversion of conductivity that measures only charged particles. Depending on which style of TDS apparatus is being used, there are three common conversion factors in practice; NaCl, KCl, and 442, all of which are assumed concentrations based on the average abundance of NaCl and KCl in water as a base unit. For this reason, TDS is often considered an approximation rather than a calculation of conductivity. What makes conductivity different is that it has the ability to measure any molecule that can carry a charge regardless of whether it is charged or neutral. Hence conductivity is often seen as a generic measurement, yet nonetheless relevant and useful, because it provides a holistic view of particles in a stream.

Natural Influences on Conductivity:

Conductivity measurements usually remain constant within a watershed at normal conditions. The largest natural factor regarding conductivity measurement is rainfall. The amount of dissolved inorganic ions in water remains unchanged in most cases, however the concentration of those molecules varies depending on total volume change after droughts and storms. High water levels and flooding, indicative of seasonal weather from spring into early summer, increase total water volume, decreasing the concentration of dissolved inorganic ions in

the water, and thereby decreasing conductivity. At the same time, conductivity measurements during periods of ice and snow are often inflated by the presence of road salt (NaCl) in runoff water, common in watersheds that are either surrounded or intersected by roads. Likewise, saltwater is much higher in conductivity than most freshwater sources because of its high concentration of salt. During summer and fall months precipitation is usually low, concentrating the inorganic particles and increasing conductivity. Other natural factors leading to a change in conductivity can often be traced back to the composition and origin of the watershed. Some are often sourced by groundwater or have clay beds that contribute to the abundance of inorganic molecules.

Human Impacts:

Even though conductivity will often change naturally within a watershed, humans have an innate ability to disrupt the natural flow of an ecosystem. Sewage output from treatment plants leave behind chloride, phosphate, and nitrate molecules, all of which are inorganic compounds and therefore good conductors. Another means by which conductivity increases is contamination and pollution from industrial companies using waterways as either an output or a coolant for large machinery where exposure to chemicals is inevitable. Other examples of human ignorance leading to conductivity contamination include road salt and other runoff chemicals found on highways, oil and chemical spills, littering and irresponsible waste treatment, and the ongoing issue of agriculture runoff. There is a positive correlation between water conductivity and percent agriculture in the surrounding watershed area. Many farmers use irrigation as a means of maximizing their output of crops. Furthermore, fertilizer (mostly nitrates and phosphates) measured by the ton is spread across irrigated fields for the same purpose. The methodology behind this is that the water and fertilizer mix in the soil, followed by the uptake of water and nutrients by the crops. However, before that process ever occurs, a large portion of the water is evaporated into air. This leads to a lopsided amount of nitrates and phosphates present in the soil in comparison to water. The majority of these chemicals then are washed through a watershed until they reach a waterway. Regardless of the original source, irrigated water increases conductivity in a watershed.

Safety Concerns and Detrimental Impacts on the Environment:

Water that contains irregular concentrations of inorganic molecules can induce major societal issues. It is not uncommon for water with high conductivity to emanate an unpleasant odor or taste. High water conductance often hastens deterioration of pipes and other fixtures specifically designed for water use. Consider the life expectancy of boats and docks in salt water compared to fresh water. The increased concentration of sodium chloride in salt water accelerates the corrosion process on metal, due to its reactive qualities with metal. People can help prevent the increase of conductivity through responsible waste management, which is a fairly simple and affordable task. On the contrary, the reversal process dealing with

contaminated water with high conductivity is very expensive and in the case of watersheds, can take many years to recuperate.

Another important idea to understand is the reciprocal relationship of water conductivity and agricultural success. By increasing conductivity levels in a watershed through irrigation, farmers put both their own agricultural fields and the agricultural fields of other farmers at risk. High levels of conductivity are known to prevent plant growth in two ways. Toxicity of specific ions can exceed tolerable amounts, in effect poisoning the plant. The other growth prevention is a result of increased osmotic pressure in the root system of a plant, making it difficult for plants to absorb water from the soil.

Conductivity as a Determinant of Stream Health

Although conductivity is useful in finding the overall conductance of a watershed, it is rarely used as a sole determinant of water quality. Rather, it is used as a means to find irregularities in dissolved ion abundance. These irregularities can be signs of contamination via chemical spills or runoff. Therefore the measure of conductivity is used mostly as a preventative evaluation, intended to detect oddities and fix the root of the problem before it is able to spread. Along with the aforementioned use, habitual conductivity measurements can be used to determine the composition of a stream. If, for example, a stream has consistently provided high levels of conductivity, it might be deduced that the stream is composed of bedrock and is fed by a groundwater source with high erosion. On the contrary, streams with chronically low measurements of conductivity indicate a precipitation dependent watershed with minimal erosion.

Example Conductivity Data- French Creek:

- Mean: 236 $\mu\text{S}/\text{cm}$
- Maximum: 341 $\mu\text{S}/\text{cm}$
- Minimum: 112 $\mu\text{S}/\text{cm}$

Conductivity Measurements from French Creek and Its Tributaries 2003:

Conductivity (mS/cm)	Spring	0.13	0.18	0.10	0.14	0.15	0.11	0.11	0.12	0.11	0.15	0.10
	Base	0.33	0.37	0.23	0.30	0.33	0.25	0.22	0.30	0.19	0.34	0.20
	Summer	0.21	0.37	0.22	0.26	0.28	0.22	0.21	0.26	0.19	0.31	0.16

	Conneaut	Conneauttee	Cussewago	French Creek	Le Boeuf	Little Sugar	Muddy	South Branch FC	Sugar	West Branch FC	Woodcock
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<http://water.usgs.gov/edu/characteristics.html>

<http://www.dartmouth.edu/~bio31/conductivity.htm>

http://www.paconserve.org/assets/fcsos1_full.pdf

http://www.paconserve.org/assets/FC_plan_full_plan.pdf

CONDUCTIVITY FACT SHEET

Definition: The measure of the ability of water to spread an electrical current. Conductivity is dictated by temperature and inorganic dissolved solids, composed of both anions and cations.

Background:

- Warm water results in increased conductivity levels, therefore conductivity is measured at a standard of 25° C
- Geology of a watershed has a huge impact on conductivity levels
 - Clay soils and groundwater tend to increase conductivity
 - Granite bedrock usually results in low conductivity readings
- Inorganic compounds, such as chloride, nitrate, sodium, and phosphate, are great conductors, and are responsible for conductivity in a watershed
- Organic compounds, such as oil and alcohol, are poor conductors, however still possess the ability to slightly lower conductivity
- Most sewage systems release inorganic compounds, thereby raising conductivity
- Rainfall lowers conductivity (dilution), opposed to droughts which raise conductivity (concentration)
- Each watershed has a typical range of conductivity measurements
- Measured in microSiemens per centimeter($\mu\text{S}/\text{cm}$)

Environmental Impacts:

- Excessive levels of conductivity can wipe out many aquatic plants
- At the same time, all aquatic organisms require at least some ions to survive
- Ranges of different watersheds can be compared to determine relative water quality
- Rapidly increasing levels of conductivity is an indication of pollution

Water Quality:

- Diverse, and therefore healthy fisheries typically have conductivity readings inside the interval of 150-500 $\mu\text{S}/\text{cm}$
- Recordings outside this range could be an indication of an unhealthy watershed
- Industrial waters have recordings upward of 10,000 $\mu\text{S}/\text{cm}$!
- Distilled water is 0-2 $\mu\text{S}/\text{cm}$
- Drinking water ranges from 50-1,500 $\mu\text{S}/\text{cm}$

Sources:

<https://www.gvsu.edu/wri/education/instructor-s-manual-conductivity-11.htm>
<http://water.epa.gov/type/rsl/monitoring/vms59.cfm>
<http://www.uvm.edu/~empact/water/conductivity.php>



**How to use...
Pocket Conductivity Meter
INSTRUCTION SHEET For LaMotte Tracer
Conductivity/TDS/Salinity**

Testing Location - Field

This test using the meter should be performed in the field.

Materials

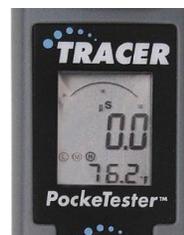
- LaMotte Tracer (Gray w/ black trim)
- SR-44W button batteries
- Small wide mouthed sample containers marked A and B
- Conductivity 1413 calibration solution (clear)

Testing Background

If properly taken care of, the Conductivity meters we have provided can quickly give accurate numerical results.

Calibration Instructions

-LaMotte Tracer Conductivity/ Total Dissolved Solids/Salinity (gray, black trim)



1. Take off the bottom cap covering the electrodes.
2. Place the meter in 20 mL of 1413 $\mu\text{S}/\text{cm}$ standard calibration solution. Turn the meter on by pressing the ON/OFF button. The meter must be in conductivity mode ("µS" will be displayed above the reading; to change modes, press the MODE button until it switches modes).
3. Press and hold the CAL button for ~2 seconds. "CAL" will appear on the bottom of the screen and 1413 will flash on the screen.
4. The device will automatically recognize and calibrate to the conductivity standard. 1413 will stop flashing and the display will briefly read "SA" and "End". ("SA" will not appear if the calibration fails.)
5. Rinse the meter with distilled water, shake dry, and turn the meter off. Proceed to testing instructions on next page.

LaMotte Tracer Conductivity/Total Dissolved Solids/Salinity (gray, black trim)

1. Pour water sample into a small, wide mouth container that the meter can fit into. You only need 1 inch of sample water.
2. While the meter is OFF, remove the protective cap from the bottom. Immerse the bottom of the meter 0.5 to 1 inches in water sample, just enough that the metal electrodes at the bottom are submerged.
3. Press the ON/OFF button to turn on the meter- SELF CAL will flash on the display.
4. Press and hold the MODE button until you see the TDS on the bottom of the display and ppm in the top left corner. (There should not be an “S” above the reading- that is the salinity mode and is not used).
5. Allow the reading to stabilize, then record the TDS measurement on the data sheet.
6. You should also record conductivity: Check to see that meter is in CONDUCTIVITY MODE (μS should be displayed above the reading). To change modes, press and hold the MODE button until the correct units appear.
7. Allow the reading to stabilize, then record the CONDUCTIVITY on the data sheet.
8. Press ON/OFF button to turn off. Rinse the meter with distilled water, shake dry and replace cap.

Disposal and Clean Up

Calibration solution should be replaced after 4 sampling events/dates. Calibration solution can be flushed down the sink with plenty of water. Properly dispose of expired batteries; you can give them to Creek Connections.

Safety Precautions

Normal safety precautions should be taken when handling the water sample, buffer solution and the equipment to avoid breakage.

Trouble Shooting Tips

METER DOES NOT TURN ON

1. Check batteries. Make sure they are installed properly (see Changing Batteries instructions below).
2. If still not working, install new batteries (see Changing Batteries instructions below).
3. If the meter does not work after replacing batteries, recheck the direction of the batteries in the meter. Reversed batteries in meter will result in failure of the meter to work. If the new batteries are in the correct position, check to see if the red or black wires connecting to the battery compartment are broken. If they are broken, *the meter needs to be replaced*.

4. If the batteries are new and the meter is still not working, the battery contacts may be corroded or dirty. Check the metal contacts that the batteries fit between and look for rust or other oxidation. Clean them with isopropyl alcohol. You may need to carefully scrap away rust or dirt with a flathead screwdriver or pair of scissors. Replace batteries and try again.
5. If the meter still does not turn on, *the meter needs to be replaced*.

THE NUMBERS ARE FAINT OR DISAPPEAR

1. If the readout numbers are faint or disappear while meter is on and while it is IN a solution or if the meter's low battery indicator symbol appears, then the batteries need to be replaced (see Changing Batteries Section below).

METER WILL NOT CALIBRATE

1. Did you take the cap off the meter?
2. For both types of meters, if the digital reading does not stabilize when calibrating... rinse the metal electrodes with distilled water before calibrating. Make sure the meter is in new calibration solution (this should be replaced after a 3 or 4 creek trips). Make sure the meter is actually IN the calibration solution when turning the correct calibration screw on the back; numbers will go crazy if the meter is on while in the air and not in a solution. Before removing from any solution or sample, shut the meter off. After addressing these, if the reading still does not stabilize at all, the batteries may need to be replaced (see Battery Changing Section below).
3. If air bubbles are trapped near electrodes, tap the meter or stir sample to release the air bubbles.

NUMBERS ON METER WILL NOT STABILIZE IN A SAMPLE

1. Did you take the cap off the meter?
2. Did you use fresh calibration solution?
3. Just wait. It takes some time for the meter to stabilize. After a few minutes, if the readout number does not stabilize (it is "jumping around" still), shut off the meter, remove from the sample, and then rinse the meter's metal electrodes thoroughly with distilled water and try again.
4. If readout still does not stabilize, the batteries may need to be replaced (see Changing Batteries Section below).
5. If the batteries are new, installed correctly, the contacts and wiring are in good condition, and the readout still does not stabilize, then the electrodes may need cleaned more thoroughly. Long term care of the meter states that you should soak the stainless steel electrodes

periodically in isopropyl alcohol for 10-15 minutes. This will help remove any buildup on the electrodes. Do this, rinse electrodes with water then try your sample again later.

METER STILL NOT WORKING

If you have done all of the above and the meter is still malfunctioning, contact Creek Connections for a replacement meter.

CHANGING BATTERIES

1. Open the top battery compartment lid carefully on top of the meter. Remove old batteries (give them to your teacher for proper disposal).
2. Replace the batteries with new ones noting polarity (+ and -) inside the meter and on the batteries. The red wire is the positive (+) side; black wire, negative (-).

What batteries to use: Tracer uses 1 SR-44W button battery.

LONG TERM CARE TIPS

1. Make sure the meter is turned off after each use. DO NOT have meter turned on unless it is in a solution, having it on when the electrodes are in the air is not good for the meter.
2. Rinse the electrodes thoroughly with distilled water after each use. It is okay to store the meter with some moisture in the electrode cap.
3. To improve meter performance and accuracy, periodically rinse/soak the metal electrodes in isopropyl alcohol for 10-15 minutes to help clean them.
4. Do not expose meters to excess moisture. Store in a dry place. Do not drop meter in the creek or leave out in rain.
5. Make sure students CAREFULLY calibrate the meter.

This instructions sheet was adapted from the instructions for the LaMotte Tracer as well as from Creek Connections staff observations.

DISSOLVED OXYGEN INFORMATION SHEET

Background

An essential gas for healthy maintenance of lakes and rivers, dissolved oxygen (DO) is the soluble microscopic oxygen molecules that are in the air spaces between water molecules (H₂O). Dissolved oxygen can range from 0 mg/L to 20 g/L with higher amounts of DO corresponding to better water quality.

Oxygen from the atmosphere is naturally incorporated into water through surface diffusion and when water tumbles over rocks in rapids and riffles, over waterfalls, and from the waves caused by wind. Higher water flows and turbulence (after storms, snow melts) allow for higher rates of oxygen diffusion.

In addition, photosynthetic aquatic life such as phytoplankton (algae, some protists, and cyanobacteria), and macrophytes (flowering, leafy plants and mosses) produce oxygen during photosynthesis. Sunlight is needed for photosynthesis, so oxygen levels are greatest during the afternoon when there is the most intense light. At night, plants do not photosynthesize and produce oxygen. Instead they respire (respiration), which consumes oxygen. Therefore, DO levels are at their lowest right before dawn.

There is a strong connection between temperature and DO. Any activity that changes the temperature of water is also affecting the DO. Colder water has a higher capacity (can “hold” more) for DO because the gas molecules in water are moving slower and are more compact. At higher temperatures, DO and other gases in water move faster and spread farther apart, including out of the water. Also at higher temperatures, the water molecules may move faster and bump out oxygen. Since water has a high specific heat (it takes a long time to heat up), water temperatures are often highest in the late summer and early fall, after the warmest months of the year.

Higher temperatures affect the dissolved oxygen levels in other ways. With warmth, the metabolic rates (body processes) of fish and aquatic creatures increase, resulting in greater consumption of DO in the water. Higher temperatures also increase the rate of decomposition (another process that is the opposite of photosynthesis), which consumes oxygen, lowering the concentration of DO.

After determining the temperature and DO level (mg/L) of water, the **percent saturation** of oxygen can be determined. This gives a percentage for the amount of oxygen available in the water. For instance, if the temperature is 5°C and a test kit determined there to be 13.0 mg/L of DO, the stream is at 100% saturation, which is the exact, balanced amount expected to be in the stream. At 5°C, if the DO was only 9 mg/L, the stream is only at 70% percent saturation – something (possibly a pollutant) is keeping 30% of the oxygen from being in the water. Rivers and streams below 90% saturation may have an overabundance of oxygen demanding materials and organisms. See the Percent Saturation Chart on the following pages for more information.

Unlike surface waters, groundwater is nearly devoid of oxygen because there is no interaction with the atmosphere and no plant life. When groundwater flows up to the surface from a spring, it may not have DO right away. Because groundwater is usually cold during warm weather months, it is capable of obtaining DO quickly.

Human Impact

Fish and other aquatic organisms need oxygen to survive. When levels are reduced, they must alter their breathing patterns or lower their level of activity. It slows their development, causes reproduction problems (increased egg mortality and defects), or deforms them. Each aquatic organism has a different level of oxygen that it must have to survive. For instance, trout need more oxygen and colder waters than a carp, a warm water fish with a tolerance for low oxygen levels. If the oxygen levels in a stream are reduced long term, an ecological shift can occur involving the replacement of species not tolerant of low oxygen (mayflies nymphs, stonefly nymphs, caddisfly larva, trout) with more tolerant species (worms, midge larva, carp, largemouth bass, and bluegills). In extreme circumstances, oxygen depletion can cause all oxygen dependent species to move elsewhere or perish.

Along with limiting biodiversity and affecting the health of organisms, lack of oxygen makes water taste poor and smell bad. Bacterial breakdown of organic matter under anaerobic (non-oxygenated) conditions forms sulfide, which can have a musty odor at low concentrations, and a “rotten eggs” smell at higher concentrations. Sewage treatment plants remove anaerobic conditions during treatment by aerating the wastewater.

So how can humans affect the levels of DO? Any actions that affect the temperature of the stream (see Temperature Information Sheet) will affect the DO levels. Humans can also disrupt the natural balance of photosynthesis and respiration/decomposition by indirectly adding fertilizers (nutrients) to a stream from agricultural fields and lawns. Extra fertilizers promote excessive plant growth, which at first adds plenty of oxygen to the water. Eventually those extra plants die, and aerobic (oxygen demanding) bacteria decompose them, consuming oxygen in the process. This process is known as **eutrophication**.

In addition to extra dead plants, other organic wastes (anything once part of a living plant or animal) can be added to waterways by humans: sewage, animal waste from farms, organic materials from soil erosion, waste from industry, paper mills, and food processing plants. These organic wastes also need to be broken down by bacteria, using up oxygen. **Biochemical Oxygen Demand (BOD)** is another water test that measures the quantity of oxygen used by microorganisms in the break down of organic matter. High levels of BOD are bad for a stream.

Humans can also add too much oxygen to the water, which can be toxic to aquatic organisms. One common example is turbulent water released from a dam.

Water Quality Criteria

For aesthetic purposes, the Environmental Protection Agency (EPA) requires only enough oxygen needed to maintain aerobic conditions. Specifically, the minimum amount of DO required to prevent negative effects on organisms is at least 5 mg/L in most places. Cold water fish (for example, trout) require at least 6 mg/L; warm water fish, 5 mg/L.

Example Data for Dissolved Oxygen – French Creek

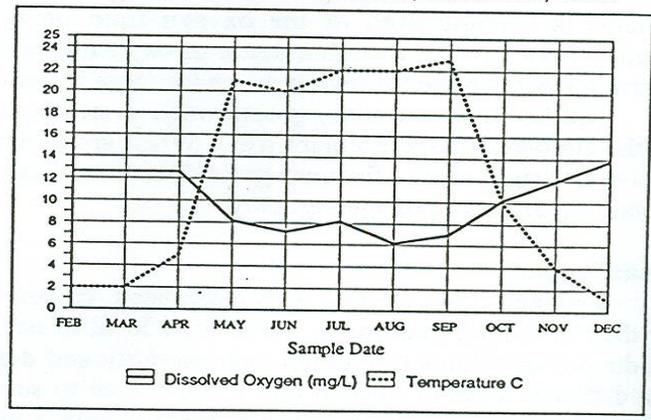
The Pennsylvania Department of Environmental Protection (DEP) has systematically collected water quality data from French Creek, at Meadville since about 1973. A summary of these data is below to provide an understanding of past values of DO and demonstrate relationships of past DO and temperature levels.

Average: 10.05 mg/L
Maximum: 13.80 mg/L
Minimum: 6.2 mg/L

The graph shows a change in the concentration of DO from February through December 1991. The highest DO concentration is in the winter months while the lowest concentrations are in the late summer months of August and September. This change in DO concentration shows an inverse relationship to changes in temperature.

Dissolved oxygen concentrations can be affected by natural as well as human sources. Temperature is a primary factor to the amount of DO contained in the waters of French Creek – water at lower temperatures contains higher concentrations of DO. In addition to the natural variation attributed to temperature, artificial influences of French Creek can cause lower DO concentrations. Inputs of nutrients (phosphates and nitrates) from sewage and fertilizers can cause algae to grow and eventually die. The death and decomposition of the algae use oxygen and lowers DO levels in streams in the watershed.

Graph 1: Dissolved Oxygen concentrations and Temperatures of French Creek, Meadville, 1991



DISSOLVED OXYGEN FACT SHEET

Definition: Microscopic oxygen (O_2) molecules that are mixed within water. Dissolved oxygen is found in the spaces between water (H_2O) molecules.

Background:

- Aquatic animals and aerobic bacteria need O_2 for respiration. *Without* dissolved oxygen, fish would drown!
- Presence of dissolved oxygen is a positive sign, while its absence is a signal of severe pollution.

Physical Influences:

- Temperature: dissolved oxygen is normally greatest during the winter because cold water can hold more O_2 (as temperatures drop, water molecules are spaced farther apart).
- Wet weather or melting snow increases flow, which results in greater mixing of atmospheric oxygen.

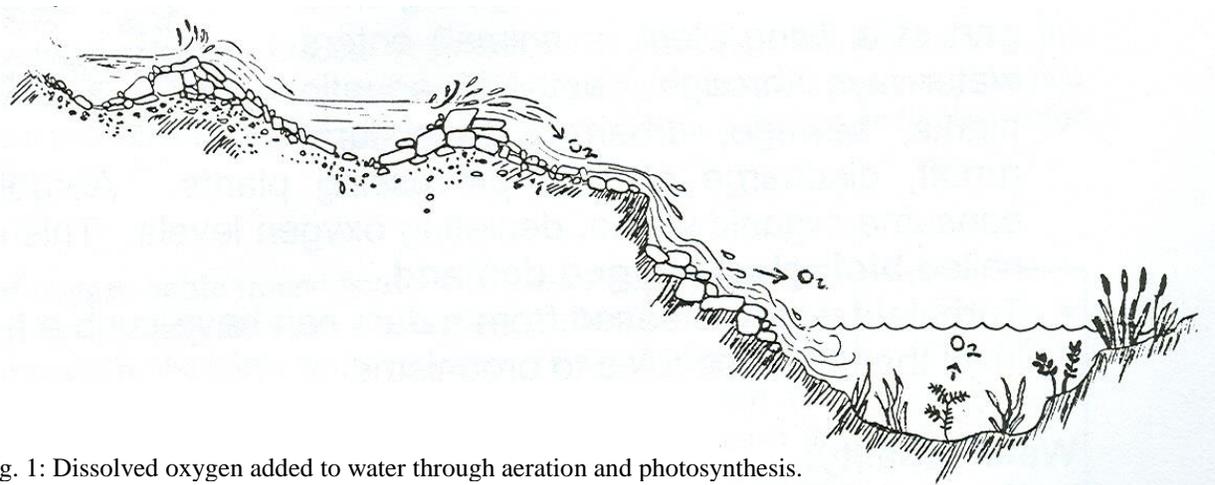


Fig. 1: Dissolved oxygen added to water through aeration and photosynthesis.

Aquatic Life Influences

- Algae and aquatic plants deliver O_2 to water through photosynthesis.
- Respiration/decomposition removes dissolved O_2 .
- During growing seasons, dissolved O_2 is highest in early afternoon when aquatic photosynthesis is maximal.

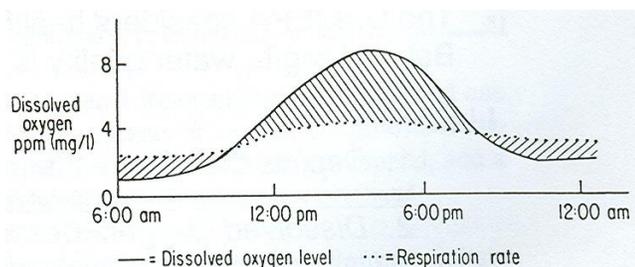
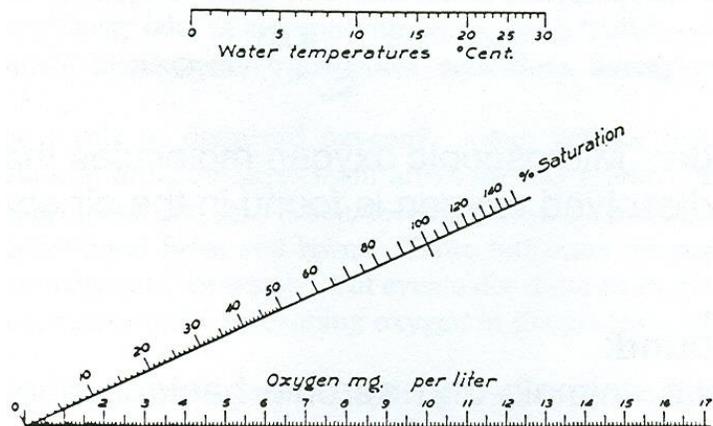


Fig. 2: Dissolved oxygen as it relates to plant respiration (source: Caduto, 1985 – Pond and Brook)

Percent Saturation:

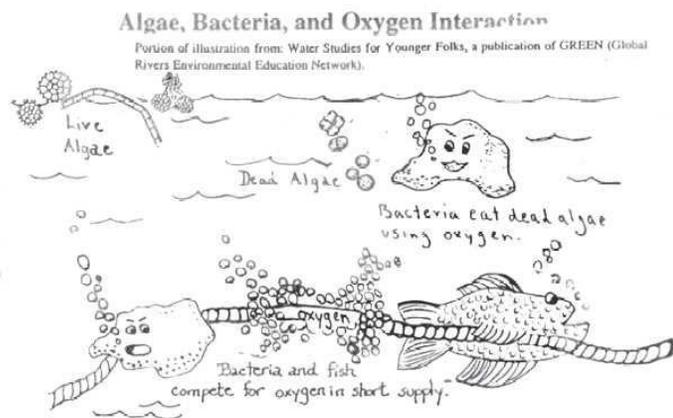
- The percentage of oxygen available in the water.

To determine percent saturation:
Multiply your DO level (mg/L)
by an atmospheric pressure
correction factor
Elev. 542-1094 = .98 factor
Elev. 1094-1688 = .96 factor
Find this corrected DO level on
the bottom horizontal line and
draw a straight line to connect to
the water temperature (top line).



Environmental Impacts:

- Temperature changes - any actions that change the temperature of the stream affect dissolved oxygen.
- Nutrient additions – from fertilizers encourage excessive plant growth (algal blooms), which eventually die and need to be decomposed by aerobic (oxygen using) bacteria. DO levels drop. This is **eutrophication**.
- Organic waste additions (anything once part of a living plant or animal) enter waterways through death of aquatic plants, sewage, urban & agricultural runoff, and discharge of food processing plants. Aerobic bacteria also consume organic waste, depleting oxygen levels. This use of oxygen is called **biological oxygen demand**.
- Turbulent water released from a dam can have such a high DO level that it can be toxic to organisms.



Water Quality:

- The U.S. EPA considers healthy water to have 5 mg/L dissolved oxygen; below 4 mg/L water quality is considered poor.

Links:

1. *Depicts* the effects that decreasing levels of DO have on wildlife
<http://waterontheweb.org/under/waterquality/oxygen.html>
2. *Dissolved Oxygen*~describes why dissolved oxygen is important
<http://www.epa.gov/volunteer/stream/vms52.html>
3. *Dissolved Oxygen in Lake Erie*~Shows DO levels since 1970
<http://www.epa.gov/glnpo/lakeerie/dostory.html>



How to use...

Dissolved Oxygen Kit (Hach Model OX-2P)

INSTRUCTION SHEET



Testing Location - Field

This test must be performed in the field since any sample shaking, temperature change, or extended period of time will promote the release of oxygen, therefore altering the accuracy of the results.

Materials

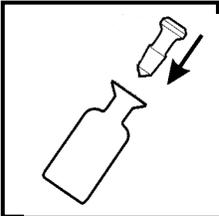
- 2 Glass-stoppered water collection bottle
- Dissolved oxygen 1, 2, & 3 reagent powder
- Clippers or scissors
- 2 Plastic measuring tube
- 2 Square mixing bottle
- Sodium thiosulfate standard solution with eyedropper

Testing Background

The goal of this test to determine the amount of dissolved oxygen in the water, not the amount of atmospheric oxygen that you allow to mix with the water. It is extremely critical to use precise sampling method techniques for this test, as any addition of air in the stages of opening and closing the collection bottle will dramatically affect the results. It is better to add some sample water to the dissolved oxygen bottle if not completely full rather than shaking the bottle with extra air.

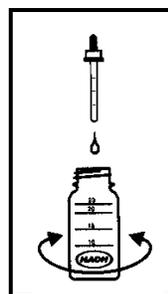
This test involves a titration process – an analytical procedure for determining the reactive capacity of a solution. A titration involves adding a reagent in small portions of known volume (or drops) to a known volume of a solution being tested until a desired end point (color change) has occurred.

Test Instructions

1. Fill the dissolved oxygen bottle (round bottle with glass stopper) with the water to be tested by getting the water level into the neck of the bottle. You want to displace all air space in the bottle with the water. To avoid trapping air bubbles in the bottle, incline the bottle slightly and insert the stopper from an angle. This will force the air bubbles out. Turn the bottle upside down (while holding the stopper in) to check if there are air bubbles. If none, proceed to the next step. If yes, fill the bottle into the neck again and reinsert the stopper again until there are no bubbles. Do all steps for A & B samples at same time.
- 
2. Use the clippers or scissors to open one Dissolved Oxygen 1 Reagent Powder Pillow and one Dissolved Oxygen 2 Reagent Powder Pillow. Add the contents of each of the pillows to the bottle. Stopper the bottle carefully to exclude air bubbles. If air bubbles get trapped, add a little sample water to the bottle and re-stopper until there are no bubbles.
 3. Grip the bottle and stopper firmly; invert repeatedly to mix. A flocculent (floc) precipitate will be formed. If oxygen is present the precipitate will be brownish orange in color. A small amount of powdered reagent may remain stuck to the bottom of the bottle. This will not affect the test results.
 4. Allow the sample to stand until the floc has settled halfway down in the bottle, leaving the upper half of the sample clear. Shake the bottle again. Again let it stand until the upper half of the sample is clear. Note: the floc will not settle in samples with high concentrations of chloride (possibly

drinking water) but interference with the test results will not occur as long as the sample is allowed to stand for four or five minutes.

5. Use the clippers or scissors to open one Dissolved Oxygen 3 Reagent Powder Pillow. Remove the stopper from the bottle and add the contents of the pillow. Carefully re-stopper the bottle and shake to mix. Make sure there is no air bubble. Add the smallest amount of sample water necessary to rid any persistent bubbles. The floc will dissolve and a yellow color will develop if oxygen is present. Note: at this point the amount of DO in the sample is fixed, and if necessary, the sample can be transported back to the classroom for the remaining steps.
6. Fill the plastic measuring tube over the top with the yellow colored solution prepared in steps 1 through 5. Pour this measured out amount into the square-mixing bottle.
Note: Do not discard the leftover sample from the large dissolved oxygen bottle; it may be needed later in the test.
7. It is time to titrate the sample. Using the eyedropper, add Sodium Thiosulfate Standard Solution drop by drop to the mixing bottle, *swirling* to mix after *each* drop. *Hold the dropper vertically (straight up and down – NOT AT AN ANGLE)* above the bottle and count each drop as it is added. Continue to add drops until the sample changes from yellow to colorless. To check to see if the solution truly is colorless, place the square mixing bottle on white paper or the white lid of the Dissolved Oxygen 3 Reagent Powder Pillow container. If not sure, add an additional drop to see if any further change occurred. If not, disregard your last drop. If any mistakes were made during step 7, go back to step 6.
8. Each drop used to bring about the color change in step 7 is equal to 1 mg/L of dissolved oxygen (DO). Record this value on the data sheet. Rinse all glassware with distilled water.



If the results were less than or equal to 3 mg/L: A more sensitive test must be conducted.

1. Take the prepared sample from step 5 and slowly and carefully pour it out until it reaches the white line midway on the dissolved oxygen bottle (30 mL line).
2. Add Sodium Thiosulfate Standard Solution drop by drop to this bottle. Hold the dropper vertically, counting each drop and swirling between each drop. Continue to add drops until the sample changes from yellow to colorless. Make sure it is colorless.
3. Each drop of Sodium Thiosulfate Standard Solution used to bring about a color change in the above step is equal to 0.2 mg/L dissolved oxygen (multiply the number of drops by 0.2). Record this value on your data sheet. Rinse all glassware with distilled water.

Disposal and Clean-up

Empty remaining sample and titration into a waste container to take back to the classroom. The waste from this test can be flushed down the sink with plenty of water. Rinse all dissolved oxygen glassware with distilled water.

Safety Precautions:

The chemicals can cause eye and skin irritation and are harmful if ingested. Aside from taking normal precautions when handling the bottles, read the labels on the packaging before beginning the test. Be sure to wash your hands after using the chemicals

This test sheet was adapted from the HACH Company (Loveland, Colorado) Dissolved Oxygen Test Kit Model OX-2P.

NITROGEN INFORMATION SHEET

Background

Nitrogen gas (N_2) makes up 79% of the atmosphere; however, this form is of no use to plants and animals. In order to use this source of nutrients, nitrogen must be converted to other forms called ammonia (NH_3) and nitrates (NO_3^-). The process by which this is completed is called the **nitrogen cycle**.

In the first step of the nitrogen cycle, called **nitrogen fixation**, bacteria, blue green algae, and lightning convert nitrogen to ammonia (NH_3). Some plants can use ammonia directly as a nitrogen source, some cannot. So bacteria can convert the ammonia first into nitrites (NO_2^-) then into nitrates (NO_3^-). Plant roots pick up nitrates to use for protein, DNA, and RNA synthesis. Herbivorous animals obtain the desired amount of nitrates by eating plants, while carnivores obtain nitrates by eating the herbivores. Nitrogen can be reused when it is returned to the soil through animal urine, feces, carcass decay, and plant decay. Bacteria break down the nitrogenous compounds in organic matter (dead plants and animals or waste products) into ammonia, which then can be oxidized (combined with oxygen) by other bacteria to form nitrites and nitrates again. There are even bacteria that convert nitrates from dead plants and animals directly back to nitrogen gas (N_2) in a process called **denitrification**. The whole cycle can start again.

Nitrate levels in nature can sometimes limit plant and animal growth. In freshwater ecosystems, the limiting nutrient for growth is usually phosphorus, not nitrates. See the phosphorus information sheet to learn more about that nutrient. Our test kits measure for the amount of nitrates (NO_3^-) or the specific amount of nitrogen (N) within those nitrates.

Human Impact

The nitrogen cycle can supply all the necessary nitrates to a locally adapted, undisturbed ecosystem. However, humans can alter the nitrogen cycle by disrupting the ecosystem or adding excessive nitrogen to the system. Repeated planting and harvesting of crops can deplete nutrients. For instance, if a nutrient rich wheat field is harvested and that wheat is shipped to the other side of the country, we have removed the opportunity for some of those nitrates to return to that field. A completely closed nitrogen cycle in this case would include leaving all wheat plant remains on the field, having the farmer eat the wheat, return the resulting human manure to the field, and eventually having the farmer die and decompose on the field. That would keep the nitrogen in the same location. Society doesn't work that way. Instead, crops are sent everywhere on earth. People eat them and then human waste is sent to a wastewater treatment plant. There it is treated to remove bacteria and the remaining nutrient rich sludge is usually sent to a landfill instead of back to farmers' fields. In some cases, the sewage treatment systems fail or are overloaded (often in rainstorms) and sewage (full of nutrients) is dumped into a stream heading downstream far from the farmer's field.

To replace all the missing nitrates from the cycle, farmers must add fertilizers to their fields. If more is added than the plants need, extra nitrates and ammonia can be washed into waterways by rain. Nitrates can also wash off over-fertilized lawns or pastures where animal waste has accumulated. Any practices that promote soil erosion (improper tilling practices on farms, removal of riparian zones, deforestation, and construction) can contribute nitrates to a waterway as nutrient rich soil washes into the water. Extra nitrates in our waterways from over-fertilization, soil erosion, and sewage inputs can disrupt the stream ecosystem.

Even though phosphorus is usually the growth-limiting nutrient for plants, extra nitrogen to a stream can cause excessive growth by photosynthetic aquatic life such as phytoplankton (algae, some protists, and cyanobacteria), and macrophytes (flowering, leafy plants and mosses). Algal blooms (excessive growth) can create a soupy green stream. Aquatic weeds can clog waterways making boating and swimming difficult. Most importantly, these plants cannot live forever. Eventually they die and are decomposed by bacteria, a process that pulls oxygen out of the water. This process is called **eutrophication**. Lower oxygen levels can stress fish and aquatic insects, possibly even causing pollution sensitive creatures to leave or die. See the dissolved oxygen information sheet to learn more about the importance of oxygen in a stream.

Excretions of aquatic organisms can be very rich in ammonia, but unless a stream is overpopulated with organisms, the levels of ammonia in a stream will not rise. Some lakes and ponds have large ammonia loads added from the excrement of large goose and duck populations, whose natural predators may have been eliminated by man.

In some areas with high nitrate contents in drinking water, cases of infant methemoglobinemia or “blue baby syndrome” have occurred. The nitrates interfere with the blood’s (red blood cells’) ability to carry oxygen. Cattle also can have a similar response when drinking nitrate contaminated water. Fish can suffer from a condition called “brown blood disease”.

Water Quality Criteria

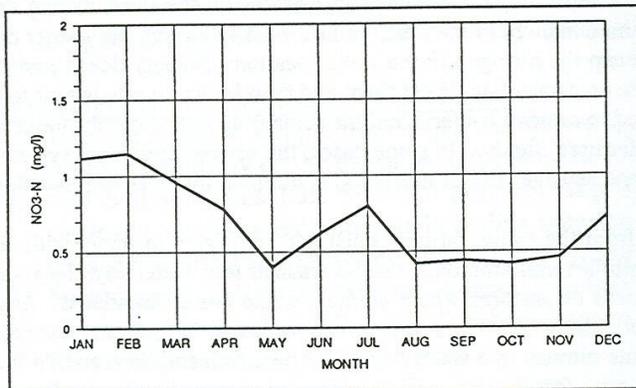
The Environmental Protection Agency (EPA) limits the amount of nitrates to 10 mg/L for domestic water supplies for health reasons. Although there are no set criteria for nitrate concentrations in fresh waters, to protect ecological habitats, a maximum of 5 mg/L of nitrates has been recommended.

Example Nitrates Data – French Creek

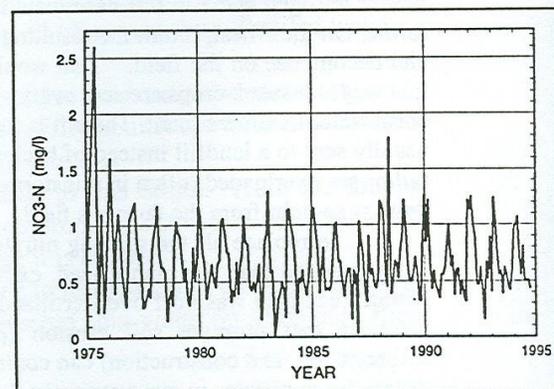
The Department of Environmental Protection (DEP) has systematically collected water quality data from French Creek, at Meadville, since 1973. A summary of these data is below to provide an understanding of past values of nitrates and demonstrate trends or relationships of past total nitrate concentrations.

Average: 0.64 mg/L
Maximum: 2.60 mg/L
Minimum: 0.00 mg/L

Graph 1: Monthly Nitrate-Nitrogen Concentrations in French Creek, Meadville, PA -- 1985



Graph 2: Nitrate-Nitrogen Concentration for year 1975-1994, French Creek, Meadville, PA



The graphs show a seasonal trend of higher concentrations present within the winter months of December to March and, in general, lower concentrations of nitrates in the summer months. In most years, however, there is a secondary nitrate peak in mid summer (Graph 1). This cyclic pattern of increasing concentrations of nitrates in the fall and decreasing amounts of nitrates in the summer is apparent in the Graph 2 of the DEP data from 1975-1994.

Some natural sources of nitrates that could contribute to concentrations of nitrates into French Creek are decay of vegetative litter such as leaves and decay of human and animal wastes. In addition to natural sources and causes of variation of nitrate concentrations, artificial sources of nitrates within the French Creek watershed include runoff from fertilizers placed on croplands and lawns, runoff from pastureland, and sewage effluent. Each of these sources can contribute to raised concentration of nitrates within French Creek.

NITRATES (NO₃) FACT SHEET

Definition: An important nutrient for plants and animals used in the building of proteins, DNA, and RNA. It is found naturally in waterways but, excessive amounts cause problems.

Background:

- Nitrogen is a very common element found in many forms throughout the environment (occurs in waters as nitrate (NO₃), nitrite (NO₂), and ammonia (NH₃)).
- Bacteria and blue-green algae convert atmospheric N₂ into forms (ammonia & nitrate), which plants can absorb through their roots. This process is called **nitrogen fixation**.
- Aquatic animals obtain nitrogen by either consuming aquatic plants or consuming those animals that consume the plants.
- Nitrates can be returned to the soil from animal urine, feces, carcass decay and plant decay.

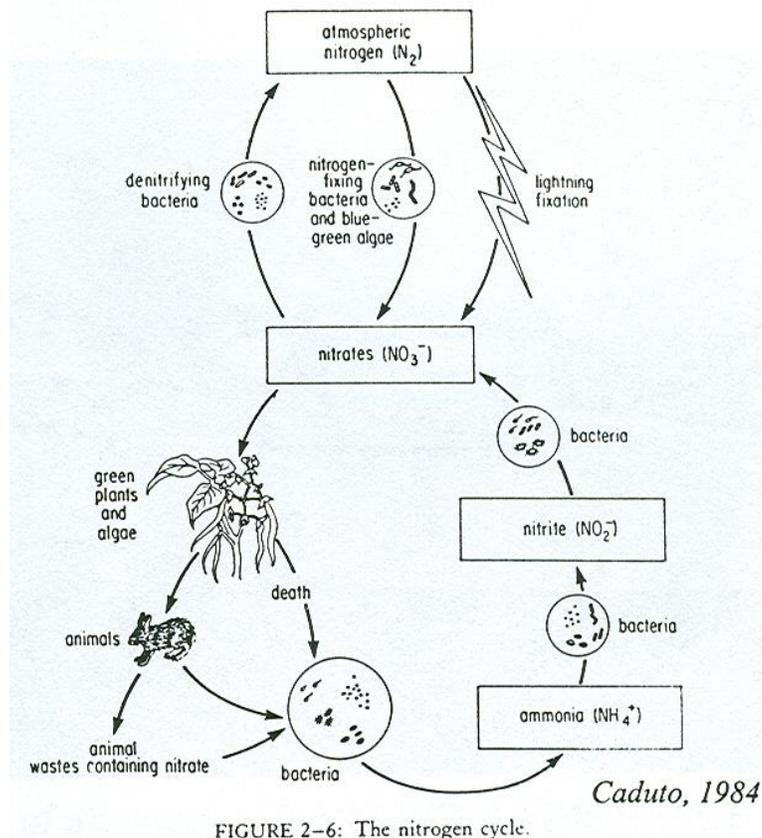
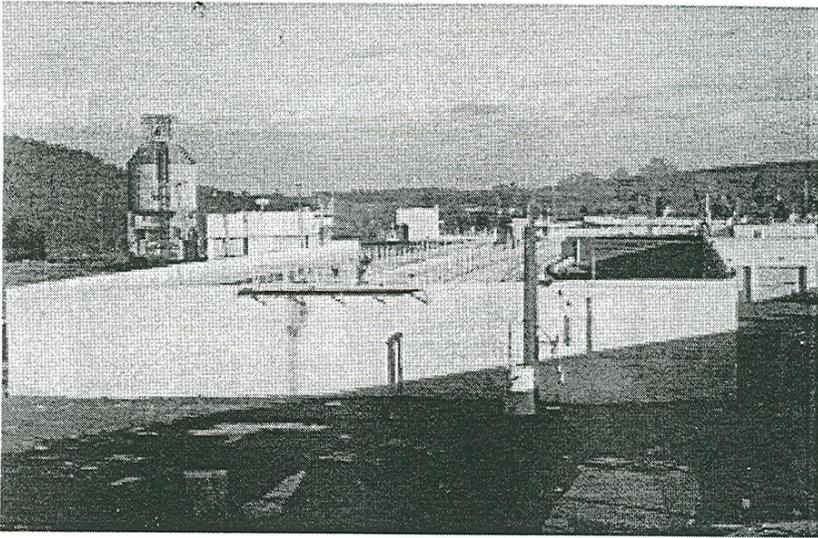


FIGURE 2-6: The nitrogen cycle.

Environmental Consequences:

- Oversupply of nitrates and ammonia leads to **eutrophication**. High levels of nitrates or phosphates stimulate algae and aquatic plant growth. Aerobic bacteria populations then increase because of the large amounts of organic matter now available in the water. The resulting elevated bacteria populations deplete much of the dissolved oxygen found in the water.
- Excessive algal growth creates a soupy green stream, which can be visually displeasing.
- Excessive aquatic weed (macrophytes) growth can make boating and swimming difficult.
- Humans add large quantities of nitrates into waterways through sewage (treatment plants and septic tanks), fertilizers (from farms and lawns), nutrient rich runoff from cattle feedlots, dairies, and barnyards and nutrient rich soils washed in from a deforested area.





Sewage is a major source of waterway nitrates. It can enter from outdated wastewater treatment plants, faulty septic tanks, and illegal sewage connections. There is a new Meadville Wastewater Treatment plant (left) that has eliminated releasing untreated sewage to French Creek. Photo source for above: Cunningham and Saigo, 1999.

- Nitrates can produce a serious condition in fish called "brown blood disease."
- Nitrates also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. This destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age.

Water Quality:

- Unpolluted waters have a Nitrate level of below 1 mg/L.

Links:

1. NO_3 ~ General overview of Nitrates in streams
http://www.heinzctr.org/ecosystems/forest/nitr_strms.shtml
2. *Testing for Nitrates* ~ Describes what nitrates are, and how to test for them in water
<http://www.epa.gov/volunteer/stream/vms57.html>



How to use...

Nitrate Nitrogen Kit (Hach Model NI-14)

INSTRUCTION SHEET



Test Location – Field or Laboratory

If the water sample is taken back to the laboratory or classroom, the nitrate nitrogen test should be conducted within 24 hours for best results.

Testing Background

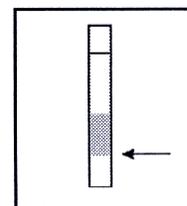
Which range to use? This test kit has two ranges that can be tested: low range (0-1 mg/L) or high range (1-10 mg/L). In most cases, all schools will use the low range test. If the results of this test using the low range instructions are 1 mg/L or greater, you will need to do the high range test for a more accurate result. Below are instructions for both the low range test (0-1 mg/L) and the high range test (1-10 mg/L).

Materials

- NitraVer 6 Nitrate Powder Pillow
- NitriVer 3 Nitrite Powder Pillow
- 3 test tubes with stoppers
- black comparator box with red shaded color disc
- distilled, demineralized or deionized water (for high range test)
- dropper (for high range test)

Testing Instructions - Low Range Test (0-1 mg/L of nitrates) - START WITH THIS RANGE

1. Rinse each of the test tubes twice with the water sample to be tested by stoppering the tube and shaking vigorously. After rinsed, fill the tube to the bottom mark or line (5 mL) with the water sample.
2. Add the contents of one NitraVer 6 Nitrate Reagent Powder Pillow to each A & B sample. Stopper the tubes and shake for three minutes. Then allow the samples to stand undisturbed for 30 seconds. Unoxidized particles of cadmium metal may form; if they do, they will remain in the sample and settle to the bottom of the tube. If no particles form – skip to step 5.
3. If cadmium particles are present, pour the prepared sample into a second viewing tube carefully so that the cadmium particles remain in the first tube. It is okay if a few drops of water containing the cadmium are left over in the first tube.
4. Rinse out the leftover cadmium metal particles from the bottom of the test tube from step 3, but place this waste in the specially marked cadmium waste container specified by your teacher. If no particles are on the bottom of the tube – then there is no hazardous cadmium waste = no need to put it in the special container.



5. Add the contents of one NitraVer 3 Nitrite Reagent Powder Pillow to the samples. Stopper the tubes and shake for 30 seconds. A reddish color will develop if nitrate is present. Allow the test tubes to sit for at least 10 minutes, but no longer than 20 minutes before using the color comparator (black box). While waiting, do the next two steps.
6. Fill a clean test tube to the 5 mL mark (bottom line on test tube) with some new, untreated water sample. Place this tube in the outermost opening of the color comparator. If not already done, insert the color disc into the comparator. The numbers should be readable through the open slit on the comparator.
7. After waiting 10 to 20 minutes, insert the prepared sample (possibly pink in color) into the centermost opening of the color comparator. Hold the comparator up to a light source (i.e. the sky, window, or lamp) and view through the openings in front. *Note: BOTH test tubes either have to be capped or uncapped, not one capped and one uncapped.* Rotate the disc to obtain a color match, then read the mg/L nitrate nitrogen (N) value through the scale window. Record this value on the data sheet. If this value was higher than 1 mg/L of nitrogen (N) or greater, the results are not accurate enough and proceed to the high range (1-10 mg/L nitrate, NO₃) test instructions.

Testing Instructions – High Range (1-10 mg/L of nitrates)

Requires distilled, demineralized, or deionized water and dropper.

8. Rinse each test tube twice with demineralized water (Note: distilled water can be used).
9. Rinse the eye dropper with the water sample then fill to the 0.5 mL mark of the dropper with the water sample. Add the contents of the dropper to the test tube. Add demineralized (distilled) water to the test tube until the level reaches the bottom line (5mL). Do this for both the A & B samples.

****Now follow steps 2 through 6 above. Then proceed to Step 10 below.**

10. After waiting 10 to 20 minutes, insert the prepared sample (possibly pink in color) into the centermost opening of the color comparator. Hold the comparator up to a light source and rotate the disc to obtain a color match. Read the value through the scale window and *multiply by 10* to obtain the mg/L nitrate nitrogen present in the sample. Record this value on the data sheet.

Disposal and Clean Up

If *cadmium* has been produced after adding NitraVer 6 Nitrate Reagent Powder Pillow to the water sample, this cadmium should be placed in a specially marked container. Cadmium is a metal that should not be dumped down a sink. Teachers can give Allegheny College their cadmium waste at the end of the school year. Do **not** store the waste in a beverage container.

The *other waste* from this test should be placed in a general waste container and taken back to the classroom and flushed down the sink with plenty of water. Rinse all glassware with distilled water.

Safety Precautions

The chemicals in this kit may be hazardous to the health and safety of the user if inappropriately handled. Please read all warnings on the packages before performing the test. Use appropriate safety equipment and normal safety precautions.

Test sheet was adapted from the HACH Company (Loveland, Colorado) Low Range Nitrate Test Kit Model NI-14.

PHOSPHORUS INFORMATION SHEET

Background

Phosphorus is an essential element for the growth and metabolism of plants and animals. It is a major component of nucleic acids and cell membranes. Despite its importance, in most streams phosphorus is found in low concentrations, therefore becoming the limiting factor for aquatic plant growth. The amount in water is generally no more than 0.1 mg/L.

Phosphorus occurs in two forms: organic and inorganic phosphates (PO_4). Organic phosphates are derived from living plants, animals, their by-products, and remains. Inorganic phosphates (also known as orthophosphates, free phosphates, or reactive phosphates) naturally occur and are bonded to soil particles. In streams, plants and algae readily absorb inorganic phosphates, which cause them to grow rapidly. Our test kits determine the concentration of inorganic phosphate only.

Inputs of phosphorus into streams are derived from natural and unnatural sources. Phosphorus tends to bind to soil and sediment particles and can be washed into streams when soil erodes. Soil erosion can be a natural process during rain events, especially in regions where the geologic conditions include erodible sediment or bedrock and fast flowing waters. These areas can have high phosphorus concentrations. When humans alter the land in ways that increase soil erosion (deforestation, removal of riparian zones, construction sites, improper agricultural tilling practices), an overabundance of phosphorus can enter a waterway.

Some other unnatural sources of phosphorus inputs into streams include human wastes, industrial wastes, inputs from fertilizer runoff, and the drainage of wetlands. Old, outdated sewage treatment plants can contribute to increased phosphorus levels in streams, especially in heavy precipitation events. This is because many storm drains are connected to sewage lines causing the sewage treatment plants to overflow and release untreated sewage to a stream. Rural households with faulty septic tanks can also add phosphorus. Human waste is not the only culprit; animal waste contributes, especially from livestock that graze near or even in a stream.

Industries can add phosphorus when they add any organic wastes (food waste from processing plants), cleaning detergents that contain phosphates, and phosphoric acid industrial strength cleaners. Fertilizers that are placed onto lawns and crops usually contain phosphorus. If applied in excess, the phosphorus from the fertilizers is washed into streams from rain events.

Phosphorus is often locked up at the bottom of lakes and wetlands, bound to the bottom sediments or metal ions that have sunk to the bottom (see the Ferrous Iron Information Sheet). The phosphorus is naturally reintroduced to a lake's water column during fall and spring overturns, caused by temperature inversions in the water. Any human disturbance of a wetland or lake bottom can also release this locked up phosphorus. Completely draining wetlands for development or farmland is a disturbance that can add phosphorus to streams. By bringing the organic matter and soil/sediment bound phosphorus that were locked up in wetland bottoms to a land surface; storms can then erode this newly exposed soil into local waterways.

Human Impact

Alteration of the concentrations of phosphorus in natural systems by humans' influence usually results in drastic changes in the ecology of the stream. Because levels of phosphates in nature are usually low and are the limiting factor in the growth of plants in most naturally controlled systems, too much phosphorus can unbalance the system.

Excessive phosphorus causes rapid growth in photosynthetic aquatic life such as phytoplankton (algae, some protists, and cyanobacteria), and macrophytes (flowering, leafy plants and mosses). As little as 0.03 mg/L phosphates can stimulate excessive plant growth. Resulting algal blooms, or an explosive growth in algae, can give the water a soupy green appearance. The extra plant life adds plenty of oxygen to the water, which is temporarily a good thing, but eventually those extra plants die, and aerobic (oxygen demanding) bacteria decompose them, consuming oxygen in the process. This process is known as **eutrophication**. The resulting reduction in the available amount of dissolved oxygen in the water harms

aquatic life, disrupting their ability to breathe, reproduce, and remain active. For instance, streams with high amounts of dissolved oxygen are able to support pollution sensitive fish such as trout, while streams with lower dissolved oxygen levels are only able to support more tolerant fish such as carp. If oxygen depletion is extreme, aquatic life must move or perish. See the dissolved oxygen information sheet for more information.

One major problem with phosphate pollution of streams is that there is no biological process that removes dissolved phosphates from streams. The phosphates are simply cycled into plants then back into the water when the plants die - to be reused by other plants later.

Water Quality Criteria

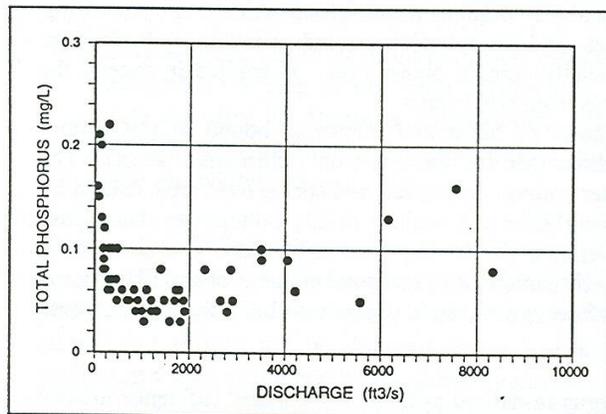
According to the Environmental Protection Agency (EPA) the concentration of phosphorus in sewage waste should be less than 1 mg/L. Currently there is no established value of phosphorus for drinking water.

Example Data for Phosphorus - French Creek

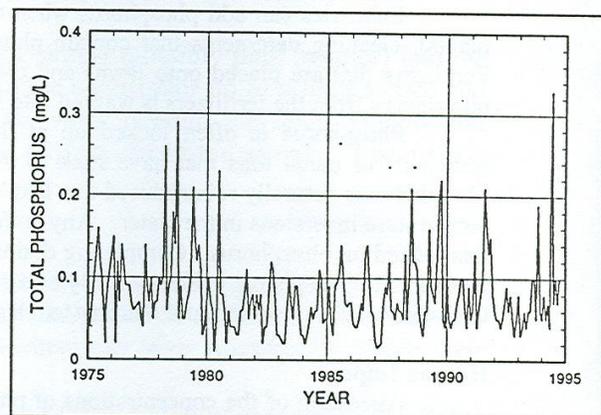
The Department of Environmental Protection (DEP) has systematically collected water quality data from French Creek, at Meadville, since 1973. A summary of these data is below to provide an understanding of past values of phosphorus and demonstrate trends or relationships of past total phosphorus concentrations.

Average: 0.082 mg/L
Maximum: 0.430 mg/L
Minimum: 0.010 mg/L

Graph 1: Total Phosphorus versus discharge in French Creek, Meadville, PA for years 1989-1993.



Graph 2: Total Phosphorus for years 1975-1994, French Creek, Meadville, PA.



Graph 1 shows, in general, a trend of higher phosphorus concentrations at low discharges and high discharges in French Creek. At low flow, increased phosphorus is probably caused by man-made additions. At high flow, the increased phosphorus is probably from soil erosion caused by storm events. The concentrations of phosphorus are lowest between discharges of 500 ft³/s to 2000 ft³/s.

Graph 2 shows the annual patterns of concentrations of phosphorus as well as the long-term trend for 1975-1994. Some of this variation in phosphorus is probably explained naturally by faster flows, associated with higher discharges, causing more soil and sediment erosion throughout the watershed. One unnatural source of phosphates that could contribute to phosphates into the French Creek watershed include runoff from fertilizers placed upon crops and lawns, industrial wastes, sewage effluent, and disturbances of land by humans.

PHOSPHORUS FACT SHEET

Definition: An essential nutrient that is fundamental to the development of nucleic acids and cell membranes of plants and animals.

Background:

- Phosphorus occurs in several forms:
 - *organic phosphates* from plant-animal matter, waste
 - *inorganic (also called orthophosphate, free phosphates, reactive phosphates)* naturally occur and bind to soil particles.
- It is often a limiting nutrient for freshwater phytoplankton & plants.
- It naturally enters surface waters from organic decay & soil weathering.

Environmental Impacts:

- Excess Phosphorus comes from sewage treatment plants, fertilizer runoff, farm manure piles, detergents and phosphoric acid industrial cleaners.

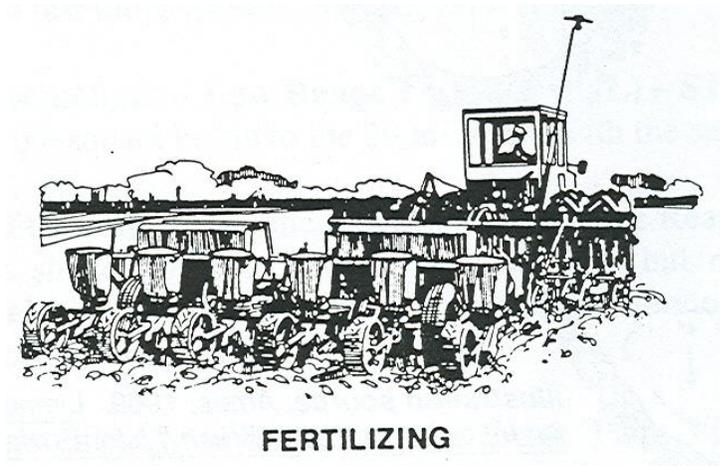
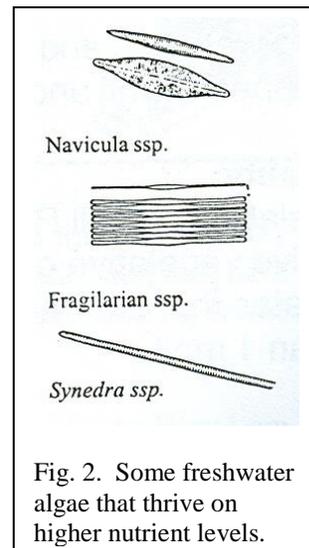


Fig. 1: One of the major contributors to high levels of phosphates in waterways today is from fertilizers. Rainfall carries fertilizers into nearby creeks and lakes, therefore unnaturally increasing nutrient levels. Too much phosphate can help cause algal blooms and other excessive plant growth.

- Excessive phosphate levels cause an overabundance of plant growth – algae and aquatic weeds (macrophytes).
- When resulting algal blooms die, their decomposition from aerobic bacteria removes dissolved oxygen from water (process known as **eutrophication**).
- Lack of oxygen can hurt aquatic life, causing fish kills.
- Algal blooms also choke out rooted vegetation by blocking light penetration.
- The majority of algal blooms are the result of human interference, although algal blooms do occur naturally, their occurrence is insignificant in comparison to human produced algal blooms.
- Phosphorus in lakes can be stored in sediment and resuspended in water columns with spring and fall overturns.



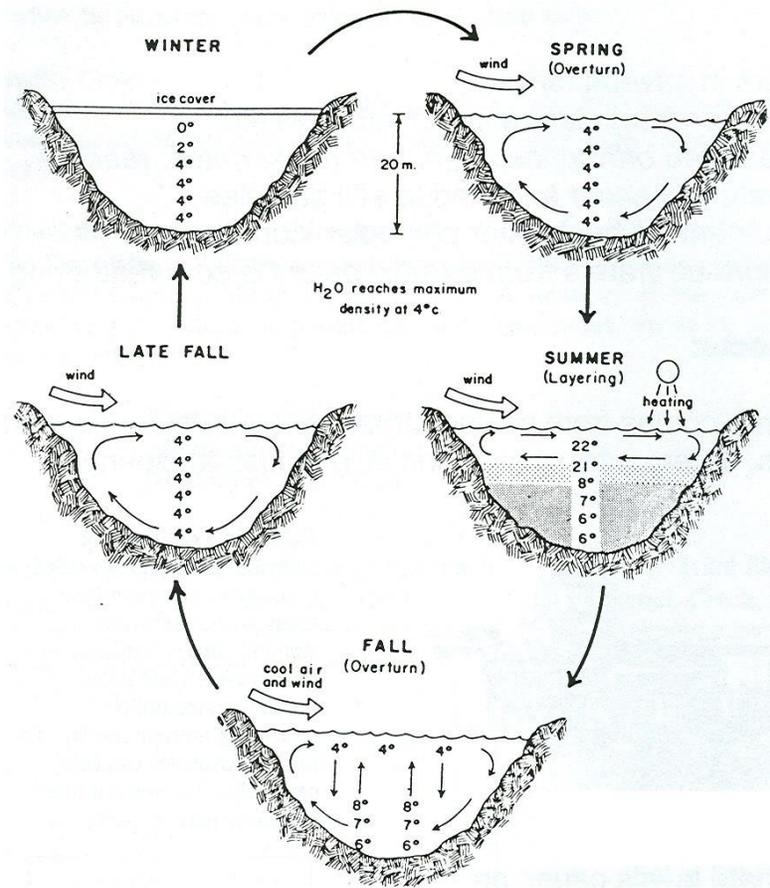


Illustration source: Amos, 1969. Limnology: An Introduction to the Fresh Water Environment

- Draining wetlands and clearing vegetation can liberate phosphorus that was trapped in soil and organic matter.

Water Quality:

- Even relatively small Phosphorus inputs, (<0.03mg/L), can stimulate excessive vegetative growth.
- The EPA states that the Phosphorus concentration in sewage waste should be less than 1 mg/L.

Links:

1. Phosphates~General overview on phosphates
<http://www.state.ky.us/nrepc/water/wcftp.htm>
<http://www.water-research.net/phosphate.htm>
2. PO₄~More background information
<http://www.epa.gov/volunteer/stream/vms56.html>



How to use...

Orthophosphate Kit (Hach Model PO-19)

INSTRUCTION SHEET



Testing Location – Field or Laboratory

If the water sample is taken back to the laboratory or classroom, the phosphate test should be conducted within 24 hours for best results. Store samples in the refrigerator until testing.

Testing Background

Phosphorus occurs in two forms: organic and inorganic phosphates (PO_4^-). Our tests kits measure for inorganic phosphate (also known as orthophosphate, reactive phosphate, or free phosphate). Total phosphates (both inorganic and organic) are available, however, they are expensive and require using a heating apparatus.

For our test kit, there is a low range (0-1 mg/L), mid-range (0-5 mg/L; best for 1-5 mg/L), and high range (0-50 mg/L; best for 5-50 mg/L). Most schools will use the low range test and should start with those instructions below. If the high range test is needed, refer to the instructions found at www.hach.com.

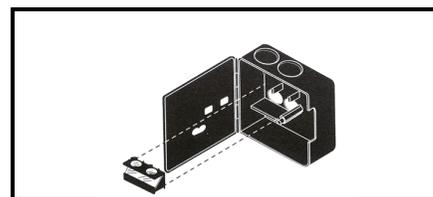
Materials

- PhosVer 3 Phosphate Reagent Powder Pillows
- Color comparator with viewing adapter (mirror) and blue shaded color disc
- 2 square mixing bottles
- 4 test tubes (plastic or glass) with stoppers

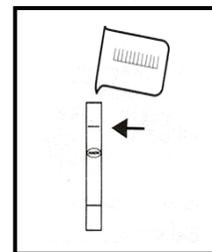
Test Instructions – Low Range Test (0-1 mg/L) – START WITH THIS TEST RANGE

1. For both Sample A and Sample B: Fill the square bottle to the 20 mL mark with the sample water.
2. Add the contents of one PhosVer 3 Phosphate Reagent Powder pillow to the bottle and swirl (not shake) to mix. Allow at least eight but no more than ten minutes for full color development. If phosphate is present, a blue-violet color will develop. While you wait, proceed to step 3 and 4.

3. If not already done, place the Long Path Viewing Adapter (the little mirror holder) onto the shelf in the black comparator box with the mirror angled outward. Also insert the blue shaded color disk so that you can read the numbers through the slit on the front of the black comparator box.



4. With untreated sample water, fill a clean test tube to the top line (1 cm below the top). If it is a glass test tube, the line is labeled 1730; plastic test tubes have no label. Place this tube (with no stopper) in the outermost opening of the color comparator.
5. After eight minutes has elapsed, fill an empty test tube to the highest line (1 cm below the top) with the prepared sample from the square bottle. Place this tube (with no stopper) in the central opening of the viewing comparator. Hold the comparator up to a light source (sky, window, or lamp) being careful not to spill the samples. View the test tubes through the openings on the front of the comparator box. Rotate the disc to obtain a color match.



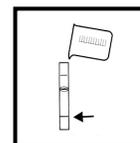
Note: The color may be very faint or nonexistent. So if you are sure you followed the directions correctly, there just may not be any phosphate in the sample or the amount is too small for this test kit to detect.

6. Read the concentration of the measured parameter through the scale window. Divide this number by 50 to obtain the mg/L phosphate (PO_4^{3-}). Divide the phosphate value by 3 to obtain the value as mg/L phosphorus (P). [Total division is by 150 like done on the data sheet]. Record this value on the data sheet. Rinse all glassware with distilled water.

Note: If the color developed is so dark as to be off the high end of the scale (greater than 1 mg/L phosphate or 0.33 mg/L phosphorus), proceed to the mid-range (0-5 mg/L) test instructions.

Test Instructions – Mid-Range (0-5 mg/L; best used for 1-5 mg/L)

1. Remove the Long Path Viewing Adapter (mirror) from the color comparator box.
 2. With sample water, fill a clean *test tube* to the first line (5 mL) at the bottom.
 3. Add the contents of one PhosVer 3 Phosphate Reagent Powder Pillow to the test tube. Swirl to mix. Wait at least one minute for full color development (blue-violet). You must make the color comparison within 5 minutes. This test tube (no stoppers) goes in the central opening of the color comparator box.
 4. With untreated sample water, fill another clean test tube to the first line (5 mL) at the bottom. Place this test tube (no stoppers) in the outermost opening in the color comparator.
 5. Hold the comparator up to a light source (sky, window, or lamp) being careful not to spill the samples. View the test tubes through the openings on the front of the comparator box. Rotate the disc to obtain a color match.
 6. Read the concentration of the measured parameter through the scale window. Divide this number by 10 to obtain the mg/L phosphate (PO_4^{3-}). Divide the phosphate value by 3 to obtain the value as mg/L phosphorus (P). [Total division is by 30 like done on the data sheet]. Record this value on the data sheet. Rinse all glassware with distilled water.
- Note: If the color developed is so dark as to be off the high end of the scale (greater than 5 mg/L phosphates or 1.66 mg/L phosphorus), use the high range (0-50 mg/L) test instructions in booklet supplied by Hach in the test kit.*



Disposal and Clean Up

Empty remaining sample into a waste container to take back to the classroom. At school, the waste from this test can be flushed down the sink with plenty of water. Rinse all glassware with distilled water.

Safety Precautions:

The chemical in this kit may be hazardous to the health and safety of the user if inappropriately handled. Please read the warning on the package before performing the test. Use appropriate safety equipment and normal precautions.

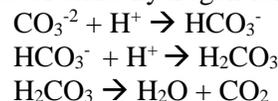
This test sheet was adapted from the HACH Company (Loveland, Colorado) Orthophosphate Test Kit Model PO-19/PO-19A.

ALKALINITY INFORMATION SHEET

Background

Alkalinity is a measure of the ability of a water system to resist changes in pH** when acid is added to water. A stream that has a high alkalinity is well buffered so that large inputs of acid (from acid rain for instance) can be made with little affect on the stream pH. A stream that has a low alkalinity is poorly buffered and may undergo large, sudden drops in pH in response to acid inputs.

The amount of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) in water helps to determine its alkalinity. The more of these present, the better chance the water has to resist a change in pH (alkalinity). Carbonate (CO_3^{2-}) will react with a free hydrogen ion (H^+) to form bicarbonate (HCO_3^-). Bicarbonate will react with free hydrogen ions to create carbonic acid (H_2CO_3), which then can dissociate (break down further) into water (H_2O) and carbon dioxide (CO_2). During this process, free hydrogen ions have been locked up, thus keeping the pH from lowering (keep in mind, a low pH has lots of extra hydrogen ions present). The formula for the above reactions follows:



This reaction process can also *reverse* itself. In other words, water and carbon dioxide can combine to form carbonic acid. Carbonic acid can dissociate (break down) into bicarbonate and hydrogen, and the bicarbonate can dissociate into carbonate and hydrogen. The reaction is balanced and is able to deal with the free hydrogen ions that are present before they make the pH level drop. A problem occurs when additional free hydrogen ions are added to this balanced system.

Acids such as sulfuric acid (H_2SO_4) and nitric acid (HNO_3) (components of acid rain) provide extra hydrogen ions when they dissociate. For instance, sulfuric acid will eventually break down yielding 2 hydrogen ions ($\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{2-}$).

To combat these additional hydrogen ions, which would lower the pH if left alone, additional bicarbonate and carbonate need to be added to the water. Carbonic acid (H_2CO_3) does this. Carbonic acid (H_2CO_3) does not have to dissociate into water and carbon dioxide; instead it can react with carbonate based rocks such as sandstones, limestones, and dolomite as part of the rock's weathering process. Calcium carbonate (CaCO_3) makes up limestone and the cement that holds sandstone together, while magnesium carbonate (MgCO_3) makes up dolomite. Both can react with carbonic acid yielding either calcium bicarbonate $\text{Ca}(\text{HCO}_3^-)_2$ or magnesium bicarbonate $\text{Mg}(\text{HCO}_3^-)_2$ [$\text{H}_2\text{CO}_3 + \text{CaCO}_3 \rightarrow \text{Ca}(\text{HCO}_3^-)_2$]. The calcium (Ca^{+2}) and magnesium (Mg^{+2}) drop off as a solid to the stream bottom while 2 bicarbonates (HCO_3^-) remain, each able to react with one free hydrogen (thus maintaining the pH). This reaction yields carbonic acid again ($\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$).

Watersheds with high alkalinity have the sandstones, limestones, and dolomites and the corresponding calcium carbonates/magnesium carbonates needed to help buffer a stream. They are able to handle additions of extra hydrogen ions. These rock types exist in Western Pennsylvania. Watersheds where the bedrock does not consist of sandstones and limestones, but instead have igneous rocks like granite and basalt, are unable to provide the needed calcium/magnesium carbonate that rid acidity. Streams in those areas have low alkalinity and a pH below 5.4 (extra hydrogen ions present). An artificial source of alkalinity is lime (calcium carbonate), used to neutralize a stream or even treat acid mine drainage (with lots of extra hydrogen ions). Lime is also used as a soil amendment to rid acidity in cropland, gardens, and lawns.

Because of its contact with bedrock and soils containing calcium/magnesium carbonate, groundwater usually has a higher alkalinity than surface water. Acid rain does not directly come in contact with groundwater, but instead, surface stream water has to use some of its alkalinity to buffer the acidic storm runoff (that never reached the groundwater table).

**pH is a measure of the concentration of free hydrogen ions (H^+) and indicates whether a solution is acidic or basic. Specifically, pH is equal to the negative log of the hydrogen ion concentration (or, $\text{pH} = -\log_{10}[\text{H}^+]$). A pH of 7 indicates the solution is neutral and that the concentration of the H^+ is equal to the concentration of OH^- . Values of pH less than 7 are considered acidic; values greater than 7 are considered basic.

Plants can also contribute to lowering alkalinity in a stream. Plants use carbon dioxide in water during photosynthesis to produce oxygen. Less carbon dioxide reduces the capability for the reaction between water and carbon dioxide to produce carbonic acid. Less carbonic acid means less dissociation to bicarbonate and less reaction with calcium carbonate. The reduced alkalinity of the stream leaves the stream more susceptible to sudden additions of hydrogen and resulting changes in pH.

Human Impact

Alkalinity is an important measure of a stream's ability to absorb inputs of acid. Acid rain and acid mine drainage from coal mining causes a considerable drop in pH of stream water. A decrease in pH of a stream can disturb the natural equilibrium and destroy many habitats for aquatic life, especially for species intolerant of pH changes.

Rapid seasonal changes in pH often occur in the spring and fall. Increased organic matter in the fall can cause greater inputs of organic acids from decaying organic matter (remember organic acids can dissociate forming extra hydrogen ions). To address these increased hydrogen ions from the organic acids, bicarbonate and carbonate must be used, removing their availability to react with hydrogen supplied by acid rain. During the spring, heavy rains and melting snow can result in a large, sudden input of acid into hydrologic systems, too much to buffer, causing a rapid drop in pH. In some cases, such an "acid spike" results in fish kills as the pH drops below acceptable levels for supporting aquatic life.

Water Quality Criteria

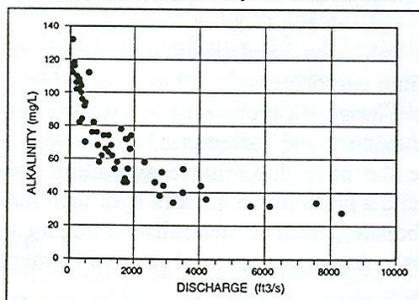
The Environmental Protection Agency (EPA) has suggested a minimum of 20mg/L of CaCO_3 for freshwater aquatic life except where natural concentrations are less. Although this criterion has been established, many problems exist in streams that are acidic or streams that suffer changes in alkalinity through the year.

Example Alkalinity Data – French Creek

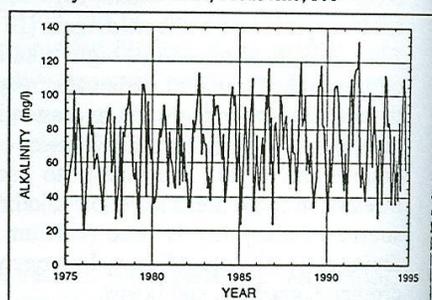
Alkalinity concentrations in French Creek have been recorded by the Pennsylvania Department of Environmental Protection (DEP) for sites in Meadville from 1973 to present date. The alkalinity concentrations from Meadville were tabulated and graphed for 1973-1994 and the average, maximum and minimum values were determined.

Average: 70mg/L
Maximum: 132mg/L
Minimum: 20mg/L

Graph 1: Alkalinity versus Discharge of French Creek, Meadville, PA for years 1989 to 1994.



Graph 2: Alkalinity Concentrations of French Creek for years 1973- 1994, Meadville, PA



The values of alkalinity in French Creek, in general, are inversely related to discharge (stream flow rate). A likely explanation for this is that at lower flow rates, a large portion of the flow is fed by groundwater rather than storm related runoff. Groundwater, because it moves at slow rates over long distances, becomes chemically enriched as it flows through sediments and rocks. Sediments deposited by glaciers and glacial rivers, which blanket all of northwestern Pennsylvania, contain significant amounts of calcium carbonate, commonly in the form of particles of limestone. Graph 2 shows that alkalinity varies seasonally, likely due to seasonal variations in stream discharges, photosynthesis rates, and acid rain inputs.

ALKALINITY FACT SHEET

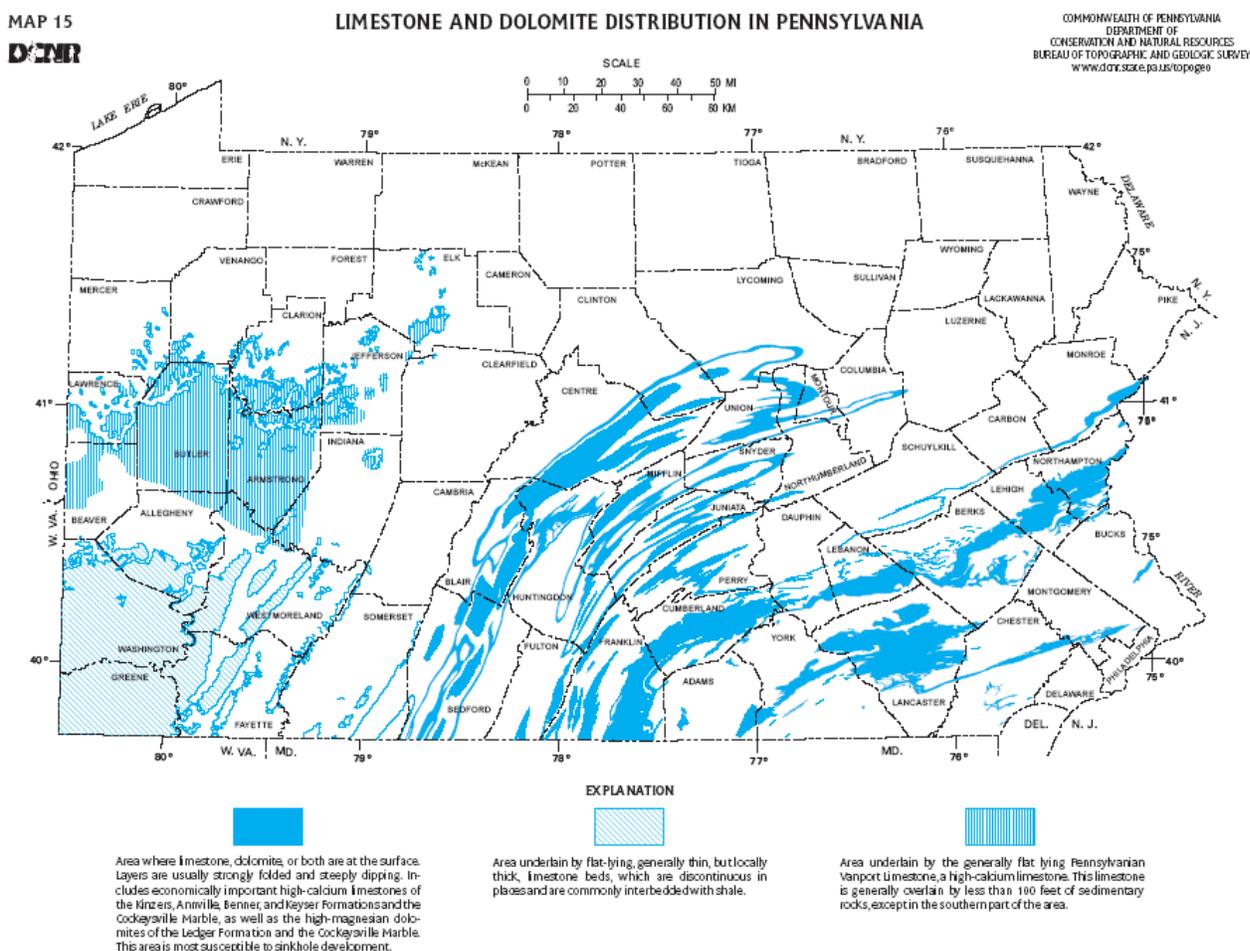
Definition: Measure of ability to "*resist change*" in **pH** or the number of hydrogen ions (H⁺). Measure of acid neutralizing capacity and the ability to buffer.

Background:

- Without this acid-neutralizing capacity, acid added to a stream would cause an immediate change in pH - amount of free hydrogen ions (H⁺) in water. Extra hydrogen ions make water acidic.
- Amounts of **carbonates** (CO₃⁻²) and **bicarbonates** (HCO₃⁻) help determine alkalinity. They react with the free hydrogen ions, maintaining pH levels.
- Extra carbonate and bicarbonate provided by the interaction between **calcium carbonate** (CaCO₃ - a component in limestones and sandstones) and **carbonic acid** (H₂CO₃ - a natural acid that forms from water and carbon dioxide [H₂O + CO₂ → H₂CO₃]).

Alkalinity is influenced by:

- Rocks and soils – if an area’s geology contains calcium carbonate, the stream will have higher alkalinity.



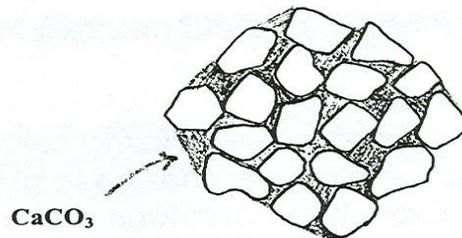
➤ Addition of lime (CaCO_3) – soil amendment (correction) often used to decrease acidity.

➤ Groundwater is well buffered after coming in contact with calcium carbonate rocks.

➤ Stormwater runoff does not have the chance to react with rocks to become buffered.

➤ Photosynthesis - removes CO_2 , thus lowering the chance to form carbonic acid, which reacts with calcium carbonate.

➤ Decomposition / respiration – adds CO_2 , increasing the chance to form carbonic acid, which reacts with calcium carbonate.



Sand particles held together by calcium carbonate to form a sandstone.

Carbon dioxide + water + **solar energy** → glucose + oxygen

Glucose + oxygen → carbon dioxide + water + **energy**

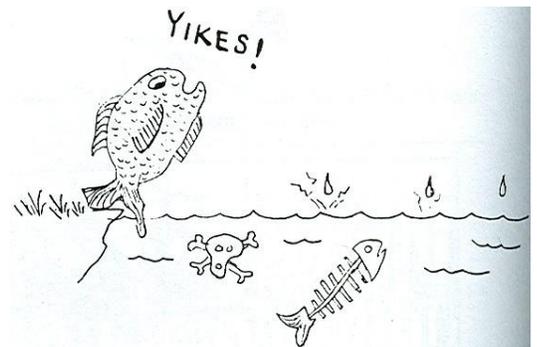


Environmental Impacts:

- Water with low alkalinity is at risk of being affected by increased acidity (hydrogen ions)
- Acid rain can increase acidity if a stream has low alkalinity (New York's Adirondacks & Eastern Canada Lakes).
- Aquatic life cannot tolerate large changes in pH (level of acidity).
- Acid rain, if not buffered, can cause fish kills.

Water Quality:

The EPA considers 20 mg/L alkalinity a minimum for healthy aquatic life.



Link:

Monitoring Water Quality~General overview of alkalinity, and how to test for alkalinity.
<http://www.epa.gov/volunteer/stream/vms510.html>



How to use...

Alkalinity Kit (Hach Model AL-AP)

INSTRUCTION SHEET



Testing Location – Field or Laboratory

If the sample is kept to conduct the test later in the laboratory, be sure to refrigerate the sample. It is best to conduct the test within 24 hours of collecting the water.

Testing Background

Which range to use? There are two ranges for this alkalinity test: high range (more than two drops of Sulfuric Acid needed) and low range (less than two drops of Sulfuric Acid needed). For most sampling, the high range test will be used. Start with it first. Both sets of instructions follow.

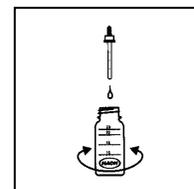
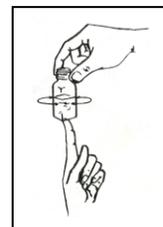
This test involves a titration process – an analytical procedure for determining the reactive capacity of a solution. A titration involves adding a reagent in small portions of known volume (or drops) to a known volume of a solution being tested until a desired end point (color change) has occurred.

Materials

- Phenolphthalein Indicator Powder Pillow
- Bromcresol Green-Methyl Red Indicator Powder Pillow
- Sulfuric Acid Standard Solution
- 2 plastic measuring tubes
- 2 square glass mixing bottles

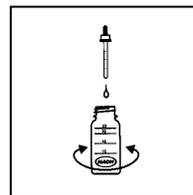
Test Instructions – High Range Test – START WITH THIS TEST RANGE

1. Fill the plastic measuring tube (not test tube) completely full with the water sample and pour into the square glass mixing bottle.
2. Add the contents of one Phenolphthalein Indicator Powder Pillow to the mixing bottle. Swirl to mix by placing one finger under the bottle and rotating the bottle back and forth with the other hand.
3. If the water remains colorless after the addition of phenolphthalein, the phenolphthalein alkalinity is zero. Proceed to step 6. If the water becomes slightly pink with the addition of phenolphthalein, proceed to step 4.
4. Add Sulfuric Acid Standard Solution drop-by-drop, holding the eyedropper straight up and down, to the pink mixing bottle. Swirl to mix after each drop, until the water becomes colorless. To make sure it is colorless, place it in front of a white background. Count and record the number of drops for later calculations.
5. The number of drops of sulfuric acid used is equal to the phenolphthalein alkalinity in grains per gallon as calcium carbonate (CaCO_3). To convert the grains per gallon (g/g) to milligrams per liter (mg/L) multiply the g/g value by 17. Proceed to step 6.



6. Now add the contents of one Bromcresol Green-Methyl Red Indicator Powder Pillow to the mixing bottle and swirl to mix. The color will change to blue-green.

7. Add Sulfuric Acid Standard Solution drop-by-drop, holding the eyedropper straight up and down, to the blue-green colored mixing bottle. Swirl to mix after each drop, until the water changes to a red/pink color. Make sure you swirl each time. Add drops until the SHADE of red/pink no longer changes. If you think the last drop added was not needed to complete the color change, disregard it. Count the number of drops that were needed to complete the color change to red/pink.



8. The green-methyl alkalinity in grains per gallon (g/g) as calcium carbonate (CaCO_3) is equal to the total number of drops of sulfuric acid used in step 7. To convert to mg/L (or ppm), multiply the g/g value by 17. Add this alkalinity value to the alkalinity calculated in step 5 (if performed) to find the total (methyl-orange) alkalinity of the water sample. Record this value on the data sheet. *NOTE: If very few (1 or 2) drops of sulfuric acid were used in the titration, follow the procedure (steps 9-17) for the low range test. This will make the low total alkalinity more accurate.*

Test Instructions – Low Range Test

9. Fill a CLEAN mixing bottle to the 15 mL mark with the water to be tested.

10. Add the contents of one Phenolphthalein Indicator Powder Pillow and swirl to mix by placing one finger under the bottle and rotating the bottle back and forth with the other hand.

11. If the water remains colorless, the phenolphthalein alkalinity is zero. Proceed to step 14. If the water becomes pink with the phenolphthalein, proceed to step 12.

12. Add Sulfuric Acid Standard Solution by the drop-count method (drop-by-drop, holding the eyedropper straight up and down, to the pink mixing bottle) swirling to mix after each drop. Continue adding and counting the drops until the water becomes colorless. Check to make sure it is colorless!

13. The phenolphthalein alkalinity in grains per gallon (g/g) as calcium carbonate (CaCO_3) is found by dividing the number of drops of sulfuric acid used in step 12 by 2.5. To convert to milligrams per liter (mg/L) alkalinity, multiply the g/g value by 17 [this is the same as multiplying the drops by 6.8 like done on the data sheet]. Proceed to step 14.

14. Add the contents of one Bromcresol Green-Methyl Red Indicator Powder Pillow to the mixing bottle and swirl to mix. The color will change to blue-green.

15. Add Sulfuric Acid Standard Solution drop-by-drop, holding the eyedropper straight up and down, to the blue-green colored mixing bottle. Swirl to mix after each drop, until the water changes to a red/pink color. Make sure you swirl each time. Add drops until the SHADE of red/pink no longer changes. If you think the last drop added was not needed to complete the

color change, disregard it. This method is highly encouraged and guarantees accurate results. Count the number of drops that were needed to complete the color change to red/pink.

16. The green-methyl alkalinity is g/g as CaCO_3 can be found by dividing the number of drops in step 15 by 2.5. Convert this value to mg/L (ppm) by multiplying the g/g value by 17 [this is the same as multiplying the drops by 6.8 like done on the data sheet.] Add this to the alkalinity calculated in step 13 (if performed) to find the total (methyl-orange) alkalinity of the water sample. Record this value on the data sheet.

Disposal and Clean Up

Dispose of sample waste in a waste container to take back to the classroom. Once there, these wastes can be flushed down the sink with plenty of water. All glassware must be rinsed thoroughly with distilled water before using them again.

Safety Precautions:

Sulfuric Acid Standard Solution may cause a serious skin irritation; wash your skin immediately if contacted. If swallowed, Sulfuric Acid can cause blindness or be fatal. Do not inhale; vapors may cause respiratory tract irritation. The other chemicals in this kit may be hazardous to the user if inappropriately handled. Read all warning labels on the materials before use. Always use normal safety precautions.

This test sheet and illustrations were adapted from the HACH Company (Loveland, Colorado) Alkalinity Test Kit Model AL-AP.

TURBIDITY INFORMATION SHEET

Background

Turbidity measures the cloudiness of water: the higher the turbidity, the cloudier the water. The numerical measurement is given in Jackson Turbidity Units (JTUs). Turbidity is caused by suspended organic (living or once living) and inorganic (non-living) particulate matter – the things you can see in the water. Erosion provides the clay (very small) and silt (a little bigger) sized particles that are suspended in water. Phytoplankton (algae, some protists, and cyanobacteria), fine particulate organic matter (FPOM, small pieces of dead plant and animal parts), and animal waste can also contribute to turbidity levels.

Turbidity caused by phytoplankton is usually highest in late summer, which is the prime-growing season. Turbidity caused by mineral matter is highest when discharge of the river is high; when strong flows scour the waterway channel. Water containing sediment acts like sandpaper against the edges of a stream channel, scraping away more sediment. In addition, heavy rainstorms can increase soil and sediment erosion into the stream. These particles will settle out of the water column after flow conditions slow down, and they will become deposited on the stream bottom. This process is called **sedimentation**.

Cloudy water can complicate the lives of aquatic organisms. Turbidity directly affects the amount of light transmitted through water, possibly blocking out sun needed for algae and plant growth. Photosynthesis may decline, reducing the amount of oxygen provided to streams. High turbidity levels reduce visibility, making it difficult for predators (such as fish) to find their food. Suspended sediments further harm fish by clogging their gills, causing breathing difficulties. Clear water is needed by filter feeding organisms that siphon water through body parts to obtain food. Sediments in turbid water that eventually settle on the stream bottom can fill in the spaces between rocks where insects are supposed to live. It can also smother insect and fish eggs. Abundant bottom feeding fish like carp can kick up these settled sediments as they search for food, increasing the cloudiness of the water again.

Cloudy water also does something else to disturb aquatic life – it absorbs heat. The increased suspended solids absorb heat energy from the sun, raising the temperature of the stream. With a rise in temperature comes a decrease in dissolved oxygen. Aquatic life may not be able to tolerate the change in temperature and dissolved oxygen levels and may become inactive, unhealthy, or even die. Review the Temperature and Dissolved Oxygen Information Sheets for more information about how those parameters affect aquatic life.

Cloudy water can frustrate another animal – humans. When it comes to drinking water, we prefer sparkling clear water. Water authorities have an easier job of disinfecting and providing us with clear water if the source of water was clear to begin with. If the source water is turbid, water engineers must begin treatment with removing the fine solids. Then they can disinfect it and send it to our faucets. Humans also find clear bodies of water more aesthetically pleasing for recreation, vacationing, and wildlife viewing.

Some turbidity is from natural soil erosion, a main source of suspended inorganic matter and some organic matter. Geology of a watershed greatly influences turbidity. Regions with steep slopes composed of fine-grained sediments are most prone to erosion and contributing particles to the stream. In Western Pennsylvania, shale is a rock type that easily erodes compared to sandstone and limestone. Human impact on the geology and land in a watershed also attributes to higher turbidity.

Human Impact

In watersheds disturbed by people, improper land use practices can increase soil erosion into a stream. Removing streamside (**riparian**) vegetation for farming, construction, and timbering can increase erosion because plant roots are no longer holding the soil in place. Riparian zones also slow the flow of storm runoff before it enters a stream, and actually traps some of the soil that the storm water was carrying. Maintaining a healthy **riparian buffer zone** along a waterway's edge can effectively prevent soil erosion and help trap sediments.

Farmers can further contribute to high turbidity when they choose inappropriate tilling methods (not contour plowing). Late spring is a sensitive period because fields have been plowed and seeded, but crops have not yet emerged or are too small to provide much resistance to heavy rains and runoff. A heavy rain on an open field can carry away a valuable soil resource and wash it into the stream, especially if the farmer has not left any riparian zones intact.

Some land uses may result in a decrease in erosion and turbidity. This would not appear to be a problem, except if aquatic life had adapted to living in turbid water. Dams trap sediments on their upstream side, so that water flowing out of them is unnaturally clear. Along the Colorado River – a river that is naturally very turbid – dams have caused major changes in aquatic species. Perhaps an insect larva that used to thrive in the turbid water can no longer exist in the clear water because its predators (fish) are easily able to see them and eat them. In regions that are very heavily urbanized, covered with pavement, there may be less soil erosion than normal.

Water Quality Criteria

The Environmental Protection Agency (EPA) has set a general water quality standard that suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonably established norm for aquatic life. For drinking water, the turbidity should not exceed 5 JTU (Jackson Turbidity Units) for two consecutive days or have a monthly average more than 1 JTU.

Example Turbidity Data – French Creek

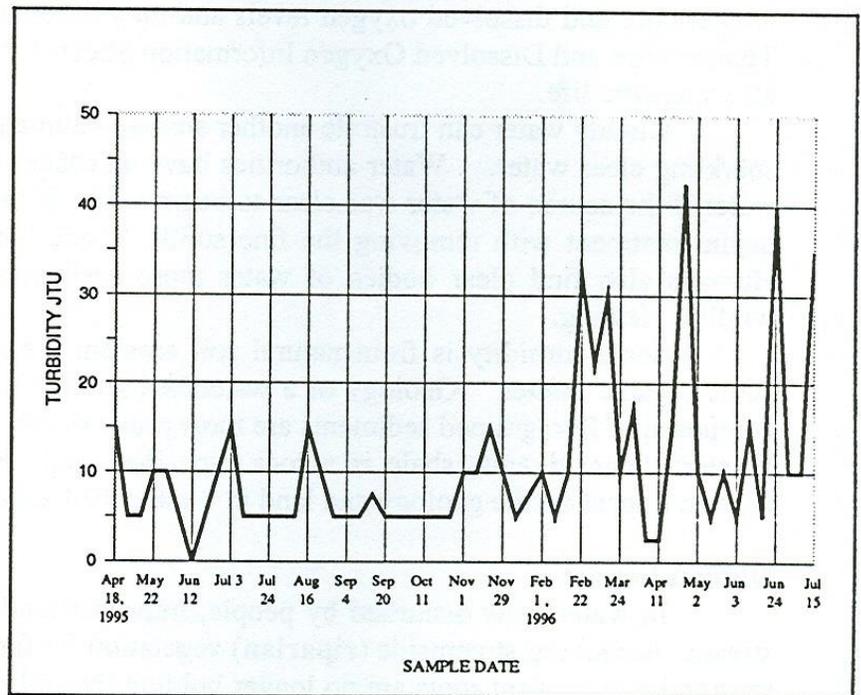
The Department of Environmental Protection (DEP) has collected water quality data for many water quality parameters since 1973; however, no information is readily available on turbidity in French Creek. Allegheny College, from April 1995 through July 1996, collected turbidity data for French Creek from a Meadville site. A summary of the data is below.

Average: 13 JTU
Maximum: 42 JTU
Minimum: 0 JTU

The graph shows, in general, higher turbidity values since October 1995; this time coincides with wetter, higher discharges since the dry spell prior to that date.

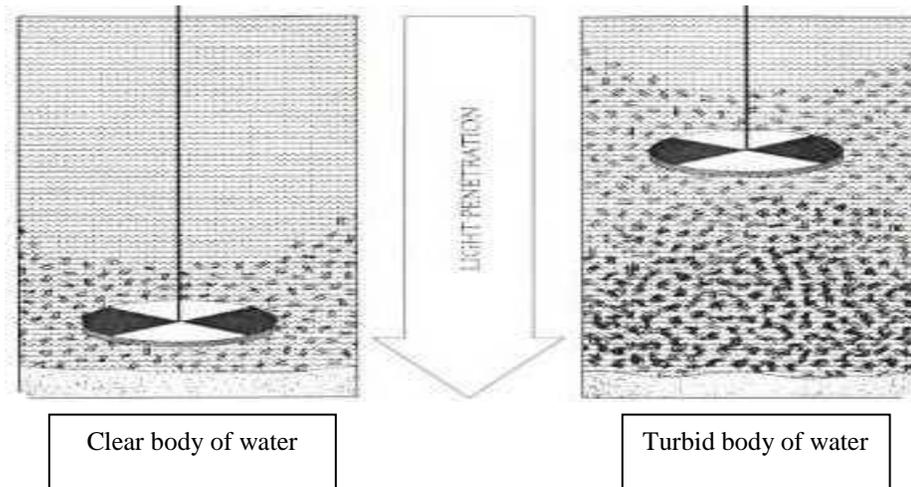
Some sources of turbidity within the stream are the growth of algae and increased feeding by fish (which can disturb bottom sediments). Turbidity can also be increased by large inputs of rain in a short period of time such as a summer thunderstorm. High inputs of sediment are most likely in areas of cropland without buffers along streams. Cropland is especially prone to erosion during planting time and after fall harvest.

**Graph 1: Turbidity in French Creek, Meadville, PA
 April 1995 to July 1996.**



TURBIDITY FACT SHEET

Definition: Cloudiness of the water, caused by suspended materials that can be seen and scatter the light, which passes through the water (Turbid waters are those in which you cannot see your feet in knee deep water).



Background:

Causes of Turbidity:

- Soil Erosion
- Waste Discharge
- Urban Runoff
- Bottom feeders, such as carp, kick up sediment as they search for food on the bottom of the waterway
- Algal growth

Soil erosion and urban runoff in a suburb of Pittsburgh. Creek Connections photo.



Consequences of Turbidity:

- As turbidity increases, water loses its ability to support diverse aquatic organisms
- It warms water by absorbing heat
- It blocks photosynthesis
- It irritates and clogs gills of fish

- It irritates filter feeding insects and mussels
- It smothers egg masses & nest sites
- It carries nutrients and pesticides
- It decreases visibility for predators and prey

Water Quality:

- The EPA states that drinking water should not exceed 5 JTU for two consecutive days or have a monthly average of 1 JTU.
- Should not reduce photosynthetic activity any more than 10% of normal.

Links:

Turbidity~Additional background info on turbidity

<http://www.epa.gov/volunteer/stream/vms55.html>

<http://waterontheweb.org/under/waterquality/turbidity.html>



How to use...

Turbidity Kit (LaMotte Turbidity Kit Model TTM) INSTRUCTION SHEET

Testing Location – Field or Laboratory

It is not necessary to do this experiment in the field; however if time and conditions permit, it is always advised. If stored in the classroom, shake the water sample before doing this test.

Testing Background

The turbidity test compares the cloudiness of a measured amount of sample with an identical amount of a clear sample. The readings are made by looking down through the column of liquid at a black dot. If turbidity is present, it will interfere with the passage of light through the column and cause blurring or cloudiness. Any color present should be disregarded. The turbidity analysis only determines the cloudiness of the sample.

Materials

- Standard Turbidity Reagent
- 2 Turbidity Columns
- Plastic Pipette (eyedropper), with a 0.5 mL measurement line
- Plastic stirring rod
- Distilled water

Testing Instructions

Caution: Due to the personal subjectivity of this test, more than one person should help with this test to ensure that all readings are consistent.

1. If the sample has been stored in the classroom for a long period of time, shake the sample to remix the particles in the water. Do not do this if the turbidity test is being conducted in the field because the sample bottle's dissolved oxygen may need to be tested still. Shaking affects dissolved oxygen levels.
2. Fill one Turbidity Column to the 50 mL line with the sample water. If the black dot on the bottom of the tube is not visible when looking down through the column of liquid, pour out a sufficient amount of the test sample so that the tube is filled to the 25 mL line. Hopefully you can now see the dot.
3. Fill the second Turbidity Column with distilled water (as an alternative, clear tap water can be used) to the same level as the first Turbidity Column.
4. Place the two tubes side by side and note the difference in clarity. Compare the cloudiness of the black dot, and how crisp the dot's edge is. If the black dot is equally clear in both tubes, the turbidity is zero. If the black dot in the sample water tube is cloudy, proceed with the instructions.

- Shake the Turbidity Reagent vigorously. Fill the pipette (eyedropper) to the 0.5 mL. Add ALL (not drops) of this 0.5 mL to the “clear water” (the distilled water, not creek water) tube. You are trying to cloud up the clear water to match your creek water sample.



- Using the stirring rod, which sometimes slips down beside the foam in the bottom of the test kit container, stir contents of both tubes to distribute the particles. Check for the amount of turbidity by looking through the solution at the black dot. If the turbidity of the sample water is greater than that of the “clear water,” continue to add the reagent in 0.5 mL increments to the “clear water.” Mix carefully after each addition. Continue to add reagent until the turbidity of the “clear water” equals that of the sample. Record the total times you added reagent.
- Each 0.5 mL addition to the 50 mL size sample amount is equal to 5 Jackson Turbidity Units (JTUs). If a 25 mL sample amount was used, each 0.5 mL addition of reagent is equal to 10 Jackson Turbidity Units.

TURBIDITY TEST RESULTS			
Number of Measured Additions	Amount in mL	50 mL Graduation	25 mL Graduation
1	0.5	5 JTU	10 JTU
2	1.0	10 JTU	20 JTU
3	1.5	15 JTU	30 JTU
4	2.0	20 JTU	40 JTU
5	2.5	25 JTU	50 JTU
6	3.0	30 JTU	60 JTU
7	3.5	35 JTU	70 JTU
8	4.0	40 JTU	80 JTU
9	4.5	45 JTU	90 JTU
10	5.0	50 JTU	100 JTU
15	7.5	75 JTU	150 JTU
20	10.0	100 JTU	200 JTU

- Rinse both tubes after each test. Make sure you did this test once with sample A and once with sample B.

Disposal and Clean Up

The samples from the Turbidity Columns can be emptied into the waste container to be dumped down the classroom sink. Clean the Turbidity Columns with distilled water.

Safety Precautions

Normal safety precautions should be taken when handling the water sample, solution and the equipment to avoid breakage.

This test sheet was adapted from the LaMotte Company (Chestertown, Maryland) Turbidity Test Kit Model TTM, Code Number 7519.

IRON INFORMATION SHEET

Background

Iron is the most abundant metal on Earth. Iron is a metal extracted from iron ore, and is hardly ever found in the free (elemental) state. In order to obtain elemental iron, the impurities must be removed by chemical reduction. Iron is used in the production of steel, which is not an element but an alloy, a solution of different metals (and some non-metals, particularly carbon). Iron is the most used of all the metals, comprising 95 percent of all the metal tonnage produced worldwide. Its combination of low cost and high strength make it indispensable, especially in applications like automobiles and building materials.

Iron is one of the most troublesome elements in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater, as it infiltrates the soil and underlying geologic formations, dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 mg/L (or ppm). However, as little as 0.3 mg/l can cause water to turn a reddish brown color.

Iron as a water contaminant can take two major forms. The water-soluble form is known as the ferrous state. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. Soluble iron can be removed by processes that induce an ion exchange. When exposed to air in the pressure tank or atmosphere, water containing ferrous iron can turn cloudy and a reddish brown substance may begin to form. This sediment is the oxidized, or ferric, form of iron that will not dissolve in water. While soluble iron can be found in deep wells, it may be converted into the more troublesome insoluble iron by running through tanks or leaky pump seals that allow the water to mix with air. The water-insoluble form is known as the ferric state. Sources of insoluble iron are aerated well waters, surface sources, and iron scale from unlined pipes and tanks.

Human Impact

Iron is not considered hazardous to human health. In fact, iron is essential for good health because it transports oxygen in the bloodstream. In the United States, most tap water probably supplies less than 5 percent of the dietary requirement for iron. Under Department of Natural Resources rules, iron is considered a secondary or "aesthetic" contaminant. The present recommended limit for iron in water, 0.3 mg/L, is based on taste and appearance rather than on any detrimental health effect. Private water supplies are not subject to the rules, but the guidelines can be used to evaluate water quality.

For instance, when the level of iron in water exceeds the 0.3 mg/L limit, a red, brown, or yellow staining of household assets, such as laundry, dishes, and/or sinks is often observed. The water may also have a metallic taste or offensive odor. Water system piping and fixtures can also become restricted or clogged.

As noted above, iron is generally divided into two main categories: soluble and insoluble. Soluble, "clear water" iron, is the most common form and the one that creates the most complaints by water users. This type of iron can be identified in a glass of cold, clear, tap water. If allowed to stand for a few minutes, reddish brown particles will appear in the glass and eventually settle to the bottom.

However when insoluble iron, or "red water" iron, is poured into a glass, it appears rusty or has a red or yellow color. Although not very common in water wells, insoluble iron can create serious taste and appearance problems for water users. Because iron combines with different naturally occurring acids, it may also exist as an organic compound. A combination of acid and iron can be found in shallow wells and surface water. Although this kind of iron can be colorless, it is usually yellow or brown. Finally, when iron exists along with certain kinds of

bacteria, problems can become even worse. Iron bacteria consume iron to survive and leave a reddish brown or yellow slime that can clog plumbing and cause an offensive odor.

Water Quality Criteria

National Secondary Drinking Water Regulations, or secondary standards, are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards. The EPA mandated Secondary Drinking Water Regulation for ferrous iron is 0.3mg/L.

Acid Mine Drainage (AMD)

AMD is characterized by drainage flowing from or caused by surface mining, deep mining or coal refuse piles that are typically highly acidic with elevated levels of dissolved metals. The formation of AMD is primarily a function of the geology, hydrology and mining technology employed on a mine site. AMD is formed by a series of complex geo-chemical and microbial reactions that occur when water comes in contact with pyrite (iron disulfide minerals) in coal, refuse or the overburden of a mine operation. The resulting water is usually high in acidity and dissolved metals. The metals stay dissolved in solution until the pH rises to a level where precipitation occurs.

The sediments produced by AMD can cause damage by discoloring stream substrates, clogging the gills of aquatic organisms, and increasing the levels of toxic metals. However, the most damaging component of AMD is the production of sulfuric acid, which is acutely toxic to all aquatic organisms.

In western and north central Pennsylvania alone, coal reserves total up to an estimated 7.1 billion tons. Because of the abundance of these rich coal resources, intensive mining has riddled the landscape of Pennsylvania for over one hundred years. As a result of resource extraction and subsequent exhaustion of reserves at various sites, abandoned mine drainage remains the single biggest source of surface water impairment in the Commonwealth. Drainage flowing from abandoned mine sites often decreases the pH of streams and rivers affected by the drainage. Additionally, it can elevate concentrations of heavy metals and suspended solids within impacted waterways. Between five to fifteen billion dollars will be required for the complete reclamation of abandoned mine lands in western and north central Pennsylvania.

Over the past twenty years, remediation of waters and reclamation of abandoned mine sites have been actively pursued. Although reclamation and remediation technology is constantly evolving, the most recent methods to treat abandoned mine drainage can be lumped into two general categories: active and passive. Active treatment requires more consistent maintenance, often through applications of hydrated lime or crushed limestone in order to reduce acidity and decrease the accumulation of iron and other metals. Active treatment of mine drainage is typically very expensive to construct and operate. Along with this, active treatment is considered a “band-aid” method because drainage cannot be permanently treated with this technology. On the other hand, passive control of abandoned mine drainage entails the construction of a more permanent treatment system that requires less maintenance. Passive treatment systems vary greatly. Some basic options include open limestone channels, drainage diversion through wetland systems or other settling structures, and alkaline recharge of groundwater.

FERROUS IRON (Fe²⁺) FACT SHEET

Definition

A positively charged metal in water that can easily combine with other compounds.

Background

- Most waters contain some iron.
- The presence of large amounts of iron in water is usually caused by acid mine drainage.
- Large deposits of iron leach into waterways at iron mining sites.
- Iron solids (precipitates) form a reddish-yellow to yellowish-brown coating on rocks.



If a stream has a yellowish-red color, it is indicative of a high iron concentration. Sometimes the streams are nicknamed “yellow boys.”

Image Source: National Mine Land Reclamation Center

Pyrite

- Pyrite is a solid compound of ferrous iron and sulfur, FeS₂(S).
- Pyrite is usually found in coal mining overburden or spoils (the rock and soil that was removed to get to the coal seam).
- When pyrite is exposed to air and water, it becomes oxidized and hydrogen ions are produced which reduces the pH of the water (make it more acidic).

Oxidation of pyrite:



- Bacteria called *Thiobacillus* can catalyze the oxidation reaction by producing enzymes if CO₂, O₂, Fe and small amounts of N and P are present in the water.

Iron Ore Tailings

- 98-99% of what is mined is useless waste low in iron concentration.
- The generated waste product is called iron ore tailings.
- Tailings are disposed of in tailing ponds such as the one below.



One of the main problems with tailings ponds is that they often overflow due to flooding or poor construction. When a leak or overflow occurs, streams nearby can become heavily polluted by the high concentration of iron.

Image source: National Mine Land Reclamation Center

Water Quality:

- The EPA drinking water standard requires ferrous iron to be less than 0.3 mg/L.

Links:

General information about Iron and Water Quality

<http://www.kywater.org/ww/ramp/rmfe.htm>

<http://www.state.ky.us/nrepc/water/wcpfe.htm>



How to use...

Ferrous Iron Kit (Hach Model IR-18C)

INSTRUCTION SHEET



**Optional Test

Testing Location – Field or Laboratory

Refrigerate the sample if not completely immediately. It is best to conduct the test within 24 hours of collecting the water.

Materials

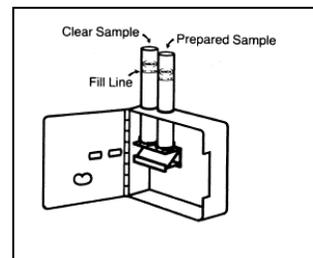
- Ferrous Iron Reagent Powder Pillows
- 2 plastic test tubes
- black color comparator box with orange shaded color disk
- 1 plastic 25 mL measuring vial
- clippers or scissors

Testing Background

This test is an optional test for classes participating in the project. In this test, the 1,10 phenanthroline indicator in the Ferrous Iron Reagent reacts with the ferrous iron in the sample to form an orange color in proportion to the ferrous iron concentration.

Testing Instructions

1. Fill the plastic measuring vial, not test tube, to the 25 mL mark with sample water.
2. Add the contents of one Ferrous Iron Reagent Powder Pillow to the measuring vial. Swirl, not shake, to mix. Allow three minutes to pass for full color development. An orange color will appear if ferrous iron is present. While waiting, proceed to step 3.
3. Fill a clean test tube to the bottom (5 mL) line with sample water. Place this tube in the outermost opening in the black color comparator box (make sure the orange color disk is in).
4. After 3 minutes, fill another test tube with the prepared sample (possibly orange in color) to the bottom (5 mL) line. Place this tube in the centermost opening in the comparator box.
5. Hold the comparator up to a light source (sky, window, or lamp). Look through the openings on the front and rotate disk until the color matches in the two openings. *Note: BOTH test tubes either have to be capped or uncapped, not one capped and one uncapped.* Read the numerical value through the slit on the front. This is the amount of ferrous iron (mg/L) in the sample. Record this value on the data sheet. If there was no orange color and you are sure you have followed the instructions correctly, it can be concluded that there



was either no ferrous iron present or the amount was too small to be detected with this test kit.

Disposal and Clean Up

The waste from this test should be collected in a waste container to take back to the classroom. Once there, it can be flushed down the sink with plenty of water. Clean all equipment thoroughly with distilled water

Safety Precautions

The chemical in this kit may be hazardous to the health and safety of the user if inappropriately handled. Please read the warning on the package before performing the test. Use appropriate safety equipment and normal precautions.

Test instructions adapted from Hach Company (Loveland, CO) instructions for Ferrous Iron Test Kit IR-18C.



How to use...

Ferrous Iron Kit (Hach Model IR-24)

INSTRUCTION SHEET



**Optional Test

Testing Location – Field or Laboratory

If the sample is kept to conduct the test later in the laboratory, be sure to refrigerate the sample. It is best to conduct the test within 24 hours of collecting the water.

Materials

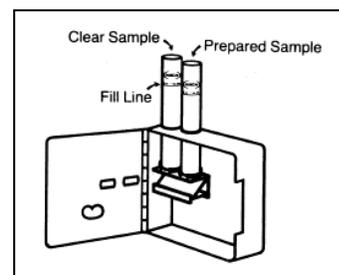
- FerroZine Iron Reagent Solution Pillows
- 2 plastic or glass test tubes
- black color comparator box with violet shaded color disk
- 1 plastic 25 mL measuring vial
- clippers or scissors

Testing Background

This test is an optional test for classes participating in the project to do. In this test, the 1,10 phenanthroline indicator in the Ferrous Iron Reagent reacts with the ferrous iron in the sample to form a violet color in proportion to the ferrous iron concentration.

Testing Instructions - Low Range Test (0-0.2 mg/L) - START WITH THIS TEST RANGE

1. Fill the plastic measuring vial, not test tube, to the 25 mL mark with sample water.
2. Add the contents of one FerroZine Iron Reagent Solution Pillow to the measuring vial. Swirl, not shake, to mix. Allow five minutes to pass for full color development. A violet color will appear if ferrous iron is present. While waiting, proceed to step 3.
3. Fill a clean test tube to the top line (under "No. 1730") with untreated **sample** water. Place this tube in the outermost opening in the black color comparator box (make sure the violet color disk is in it).
4. After 5 minutes, fill another test tube with the prepared sample (possibly violet in color) to the top line (under "No. 1730"). Place this tube in the centermost opening in the comparator box.
5. Hold the comparator up to a light source (sky, window, or lamp). Look through the openings on the front and rotate disk until the color matches in the two openings. *Note: BOTH test tubes either have to be capped or uncapped, not one capped and one uncapped.* Read the numerical value through the slit on the front on the "**end view**" scale. This is the amount of ferrous iron (mg/L) in the sample. Record this

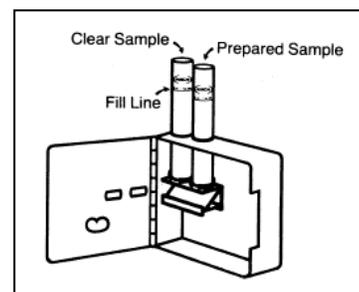


value on the data sheet. If there was no violet color and you are sure you have followed the instructions correctly, it can be concluded that there was either no ferrous iron present or the amount was too small to be detected with this test kit.

Note: If the color developed is so dark as to be off the high end of the scale, proceed to the high range (0-1.0 mg/L) test instructions.

Testing Instructions - High Range Test (0-1.0 mg/L)

1. Fill the plastic measuring vial, not test tube, to the 25 mL mark with sample water.
2. Add the contents of one FerroZine Iron Reagent Solution Pillow to the measuring vial. Swirl, not shake, to mix. Allow five minutes to pass for full color development. A violet color will appear if ferrous iron is present. While waiting, proceed to step 3.
3. Fill a clean test tube to the bottom (5 mL) line with untreated **sample** water. Place this tube in the outermost opening in the black color comparator box (make sure the violet color disk is in it).
4. After 5 minutes, fill another test tube with the prepared sample (possibly violet in color) to the bottom (5 mL) line. Place this tube in the centermost opening in the comparator box.
5. Hold the comparator up to a light source (sky, window, or lamp). Look through the openings on the front and rotate disk until the color matches in the two openings. *Note: BOTH test tubes either have to be capped or uncapped, not one capped and one uncapped.* Read the numerical value through the slit on the front on the "**side view**" scale. This is the amount of ferrous iron (mg/L) in the sample. Record this value on the data sheet. If there was no violet color and you are sure you have followed the instructions correctly, it can be concluded that the amount was too small to be detected with this test kit.



Disposal and Clean Up

The waste from this test should be collected in a waste container to take back to the classroom. Once there, it can be flushed down the sink with plenty of water. Clean all equipment thoroughly with distilled water

Safety Precautions

The chemical in this kit may be hazardous to the health and safety of the user if inappropriately handled. Please read the warning on the package before performing the test. Use appropriate safety equipment and normal precautions.

Test instructions adapted from Hach Company (Loveland, CO) instructions for Ferrous Iron Test Kit IR-24.

References Used for Chemical Testing Section:

- Allan, J.D., 1995. Stream Ecology: Structure and Function of Running Waters. London: Chapman and Hall.
- Amos, W.H., 1969. Limnology: An Introduction to the Freshwater Environment. Chestertown, MD: LaMotte Company.
- Andrews, William A., 1987. Investigating Aquatic Ecosystems. Scarborough, Ontario: Prentice-Hall.
- Arway, J.A., 1997. Water Pollution. Harrisburg: Pennsylvania Fish and Boat Commission.
- Becker, C.D., and D.A. Neitzel (ed), 1992. Water Quality in North American River Systems. Columbus, OH: Battelle Press
- Berner, E.K., and R.A. Berner, 1987. The Global Water Cycle: Geochemistry and Environment. Englewood Cliffs, NJ: Prentice Hall, Inc.
- Cauduto, Michael. (1985). Pond and Brook - A Guide to Nature Study in Freshwater Environments. (2nd Ed.). New Jersey: Prentice-Hall.
- Cuff, D.J, W.J. Young, E.K. Muller, W. Zelinsky, R.F.Abler (editors), 1987. Atlas of Pennsylvania. Philadelphia: Temple University Press.
- Cunningham, W. P. and B. W. Saigo, 1999. Environmental Science: A Global Concern, 5th edition. Boston: WCB McGraw-Hill.
- Deming, H.G., 1975. Water: The Fountain of Opportunity. New York: Oxford University Press.
- Department of Environmental Protection, 1998. Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Harrisburg, PA: Department of Environmental Protection.
- Drever, J.I., 1982. The Geochemistry of Natural Waters. Englewood Cliffs, NJ: Prentice Hall Inc.
- Eblen, R.A, and W. R. Eblen (eds.), 1994. The Encyclopedia of the Environment. Boston: Houghton Mifflin Company.
- Kimmel, W.G., 1983. The impact of acid mine drainage on the stream ecosystem. In: Pennsylvania Coal: Resources, Technology and Utilization, (S.K. Majumdar and W.W. Miller, eds.), The PA Academy of Science Publication, p.424-437.
- Laws, Edward A., 1993. Aquatic Pollution: An Introductory Text, 2nd edition. New York: John Wiley & Sons, Inc.
- Leopold, L. B. and K.S. Davis, 1980. Water. Alexandria, VA: Time Life Books.
- Mason, C.F., 1991. Biology of Freshwater Pollution, 2nd edition. Essex, England: Longman Scientific and Technical (Longman Group UK Ltd).
- Miller Jr., G.T., 1994. Living in the Environment: Principles, Connections, and Solutions, 8th edition. Belmont, CA: Wadsworth Publishing Company.
- Mitchell, Mark K., & Stapp, William B., 1990. Field Manual for Water Quality Monitoring (4th Ed.). Dexter, MI: Thomson-Shore, Inc.
- Needham, J. G., & Needham, P.R., 1962. A Guide to the Study of Freshwater Biology. San Francisco: Holden-Day.

- Newson, M., 1994. Hydrology and the River Environment. Oxford: Clarendon Press.
- Novak, J.M. and W. H. Woodwell, Jr., 1998. A Watershed Primer for Pennsylvania: A Collection of Essays on Watershed Issues. Pittsburgh, PA: Pennsylvania Environmental Council.
- Pennsylvania Fish and Boat Commission, 1995. Acid Precipitation. Harrisburg, PA: Pennsylvania Fish and Boat Commission.
- Pielou, E.C., 1998. Fresh Water. Chicago: University of Chicago Press.
- Press, F. and R. Siever, 1994. Understanding EARTH. New York: W.H. Freeman and Company.
- Renn, C. E., 1968. A Study of Water Quality. Chestertown, MD: LaMotte Company.
- Renn, C. E., 1969. Our Environment Battles Water Pollution. Chestertown, MD: LaMotte Chemical Products Company.
- Renn, C. E., 1970. Investigating Water Problems: A Water Analysis Handbook. Chestertown, MD: LaMotte Company.
- Renn, C. E., 1996. Turbidity: Its Meaning and Measurement. Chestertown, MD: LaMotte Chemical Products Company
- Swenson, H.A., and H.L. Baldwin, 1965. A Primer on Water Quality. Washington, DC: United States Printing Office (USGS).
- Watercourse and Council for Environmental Education, 1995. Project WET: Curriculum and Activity Guide. Bozeman MT: The Watercourse.
- Waters, T.F., 1995. Sediments in Streams: Sources, Biological Effects, and Control. Bethesda, MD: American Fisheries Society.

STAGE / FLOW RATE / DISCHARGE INFORMATION SHEET

Background

Water can enter a stream in a number of ways. If it rains, surface runoff (the water that does not seep into the ground) will flow directly into the stream. The more intense the storm, usually the more surface runoff occurs. Human alteration of land can also influence the amount of surface runoff (paving over soil keeps water from seeping in). Rain also falls directly into the body of water. The other main source of water to a stream is from groundwater. Groundwater flow occurs from water infiltrating into the ground during rain events and then flowing underground, in general, from higher elevations to low elevations. It can enter the stream in valley bottoms (lowlands).

Stage, flow rate, and discharge determine the amount of water in a stream. Frequency and duration of precipitation events and inputs from groundwater control these physical parameters of a stream. The stage of a stream (the relative height (meters) of the water surface or the depth of the water column) is largely dependent upon the amount of precipitation that has fallen. If no rain has fallen recently, then the stream is considered to be at base flow stage. At base flow stage, the stream is fed by groundwater flow into the channel bottom and sides.

The flow rate or velocity of water is the distance traveled by water over a given period of time, often recorded in meters per second (m/s). The flow rate tends to increase in a stream with increased precipitation and the resulting volume of water.

The discharge is the volume of water per unit time that moves through a given cross-section of a stream channel. Discharge is equal to the flow rate (velocity) of the stream multiplied by the stream channel width multiplied by the average depth; often recorded in meters cubed per second (m^3/s). This is an important measure of the amount of water moving through the stream channel at a specific velocity. With increased precipitation there is an increase in the discharge of the stream.

Because a stream can be flowing with water primarily from surface runoff or from groundwater inputs depending on rain events, the amount of water in the stream fluctuates and chemical parameters can fluctuate as well. Many chemical characteristics of streams are related to stream stage, flow rate, and discharge. For instance, groundwater has chemical differences from the precipitation that falls. Groundwater generally tends to have a higher pH, more total dissolved solids and less dissolved oxygen because it has flowed slowly through the ground and reacted with mineral and organic matter. So under dry conditions, a stream fed primarily by groundwater and with a low discharge will have a different chemistry than storm event water with high stream discharge. So, stream discharge is strongly correlated with many water quality parameters, thus an understanding of the hydrogeologic setting of a region is important for the study of natural water chemistry.

Large downpours, extended precipitation events, or snow melt can cause a stream to rapidly receive large amounts of overland flow which may cause the stream to overflow its banks. Large rainfalls are seasonal and usually occur in the spring and fall because of changes in weather patterns. In summer, most rain is received from thunderstorms which tend to be short, high intensity events - such events may result in flash floods. Runoff from storms is also responsible for most soil erosion.

Human Impacts

Human actions can have direct as well as indirect effects on discharge of a stream. Damming of streams for hydroelectric power or flood control has dramatic effects on the flow characteristics of streams. For example, dams along the Colorado River have dramatically altered the discharge of the river and as a result, habitats of fish and other aquatic life have been destroyed.

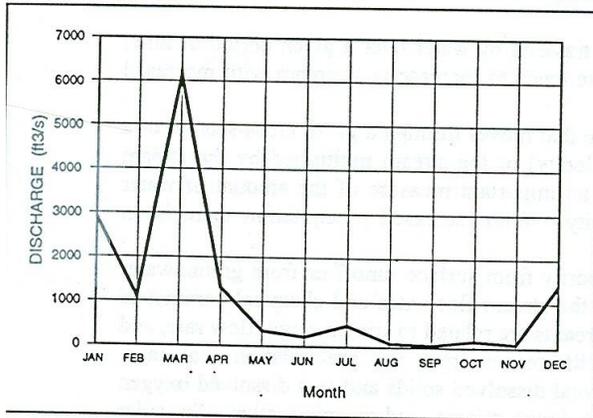
Another direct impact on streams is withdrawal of water, usually for irrigation. Large water withdrawals may cause harm to aquatic life and disrupt the transport of stream sediment. Any change of land use within a watershed can alter stream discharge. The loss of forested land, either to agriculture or urbanization, decreases the ability of the land to "soak up" water; this, in turn, leads to increased storm runoff with larger floods as well as a decrease in groundwater recharge. The increase in storm runoff may also lead to an increase in soil erosion. As the eroded soil is transported into the stream, it can cause excessive deposition within the stream and decrease the clarity of the water.

Example Discharge Data – French Creek

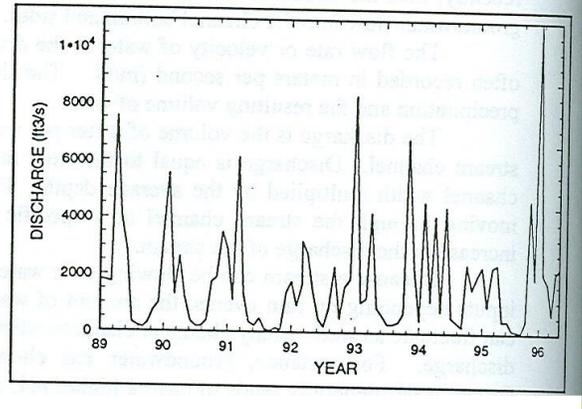
The United States Geological Survey (USGS) has systematically collected water flow data from French Creek, at Meadville and Franklin, for decades. A summary of these data is found in the tables below to provide an understanding of past values of discharge and demonstrate relationships of past discharges.

Average: ~1638 ft³/s
Maximum: ~11,000 ft³/s
Minimum: ~54 ft³/s

Graph 1: Monthly Discharge in French Creek, Meadville, PA for 1991



Graph 2: Discharge in French Creek, Meadville, PA, for years 1989 to 1996



Graph 1 shows a general seasonal pattern in French Creek of higher discharges in the winter and spring months with lower discharges in the summer and fall. Higher temperatures and water use by plants are the primary reason for the lower summer discharges. March is commonly the month of high discharge, probably reflecting the combined effects of snowmelt and precipitation.

The seasonal patterns of discharge are also apparent in longer-term data on French Creek flow (Graph 2). Note the sharp peak in discharge in January 1996; this flood was caused by snowmelt coupled with rain. The abundant groundwater resources, underlying many of the valleys in the French Creek watershed, are the primary source of water for French Creek and its tributaries during low flow (i.e. base flow) conditions. At these times, the creek water has a high percent of dissolved material (e.g. total dissolved solids, alkalinity) because the groundwater flow into the stream is not diluted with surface flow.

Flooding is a hazard in portions of the French Creek watershed. French Creek is most likely to flood in late winter as snow is melting and ice jams may form. Flash floods on smaller tributaries are most likely during high-intensity, long duration thunderstorms. Because of the importance of flooding, the USGS continuously monitors the water level of French Creek and some tributaries at several points within the watershed. Some of these data are available via the internet.



How to measure...

Stream Stage

INSTRUCTION SHEET

Location - Field

Materials

Rod about 2 meters long that is marked off in 5 or 10 cm intervals (to remain at stream)
OR Meter stick

Background

The United States Geological Survey (USGS) has set up many gauging stations in Western Pennsylvania to record the stage (relative height of the water level) of creeks and rivers. This information is available on their website (<http://waterdata.usgs.gov/pa/nwis/current?type=flow>). You can check to see if your waterway has any USGS data points along it.

The stage is best measured by fixing a rod at a permanent place in your local waterway. It should be marked in 5 or 10 cm intervals. The rod should be placed at a site where it can be visually read without having to go into the water. Moreover, it should be secured at a place where people or the current will not remove it. A bridge support is a good place because it is unlikely to be washed away with heavy storm currents (be sure to get permission from the bridge owner before attaching a rod). Some bridges are already marked with stage indicators – if this is the case, just use the existing stage indicator. A permanent measuring rod is nice to install because stage readings can be taken even in high, fast water, and in the winter.

Entering the stream to measure stage should be done with extreme care and should not be done unless a teacher permits it. See safety section below. A meter stick can be used to measure depth when in the stream.

Instructions

1. Once the rod stage indicator is established, simply read and record the water level each time the waterway is sampled.
2. For small streams that are safe to enter, stage can be determined using a meter stick. Either determine the depth in the center of the stream, or you can measure the depth at various spots along a cross section of the stream and then determine the average depth. You will need to do the latter if you are going to determine the discharge later.

Safety Precautions

When taking a rod's stage measurement, be careful not to slip or fall into the water. As stated earlier, the measurement should be made from a distance that will eliminate the danger of falling into the water. There is no need to go into the water to take a reading from a rod, except when the stage station is first established.

To measure stage with a meter stick by getting into the waterway, only enter the waterway if the teacher gives permission. Do not enter a stream if it is flowing faster than normal; currents can be misleading, powerful and cause you to lose balance. Water should not be entered in the winter (late November – March), even if you are wearing hip waders, because of the threat of hypothermia.



How to measure...

Flow Rate (Velocity)

INSTRUCTION SHEET

Location - Field

Materials

Tape measure (ideally 10 meters long)
Something that floats: a small stick, fishing bobber, plastic ball, orange, etc.
Stopwatch

Background

Flow rate can be determined using the following method or by using a flow rate meter, which is an expensive scientific device. A flow rate meter automatically calculates the flow rate and gives you a readout result. Allegheny College does own a few flow rate meters and measurements can be completed with one with Allegheny assistance.

Using a field calculation technique like the one below requires at least two people, but a third person is helpful to be the timekeeper. Flow rate can be calculated using the English measurement or metric system. Scientists usually use metric. The units are m/s.

Entering the stream to measure the flow rate should be done with extreme care and should not be done unless a teacher permits it. See safety section below.

Instructions

1. Carefully enter the stream and estimate the center of the stream (width wise) in the main part of the flow.
2. In the center of the stream, measure out a 10-meter section upstream to downstream (not side to side), with one person stationed at an upstream end, and one person at a downstream end.
3. Have the upstream person drop the floating object at the 0-meter mark while the stopwatch is started. Record the amount of time (in seconds) it takes the object to float past the 10-meter mark. Catch the object.
4. Divide 10 meters by the recorded time (seconds) to obtain the flow rate (meters/second, m/s).
5. Repeat this procedure at least two more times, recording the flow rate each trial, then calculate the average of all trials.
6. The flow rate can be determined at other points along the stream for comparisons, but the center of the stream is usually of most interest for data recording.

Safety Precautions

Only enter the waterway if the teacher gives permission. Do not enter a stream if it is flowing faster than normal; currents can be misleading, powerful and cause you to lose balance. Water should not be entered in the winter (late November –March), even if you are wearing hip waders, because of the threat of hypothermia. Be careful not to slip or fall on rocks in the creek.



How to measure...

Stream Discharge

INSTRUCTION SHEET

Location - Field

Materials

- Tape measure (as long as possible)
- Something that floats: a small stick, fishing bobber, plastic ball, orange, etc.
- Stopwatch
- Calculator (optional)

Background

In order to measure discharge, you need to determine the average stage (depth) and average flow rate (velocity). Using a field technique to determine discharge like the one below requires at least two people, but a third person is helpful to be the timekeeper. Discharge can be calculated using the English measurement or metric system. Scientists usually use metric. The units are m^3/s .

Entering the stream to measure the discharge should be done with extreme care and should not be done unless a teacher permits it. See safety section below.

Instructions

1. Determine the average stage (depth) and average flow rate (velocity) using the instructions on the previous pages.
2. Measure the width of the stream at the location where you have determined the stage and flow rate.
3. Now plug your numbers into the following equation:

$$\text{Discharge (m}^3\text{/s)} = \text{Stream Width (m)} \times \text{Average Depth (m)} \times \text{Flow Rate (m/s)} \times \text{Constant}$$

The constant = .8 for gravel or rocky bottom streams
The constant = .9 for sandy or muddy bottom streams

Note: a sufficient discharge calculation can be obtained without the constant, but include it when possible.

Safety Precautions

Only enter the waterway if the teacher gives permission. Do not enter a stream if it is flowing faster than normal; currents can be misleading, powerful and cause you to lose balance. Water should not be entered in the winter (late November –March), even if you are wearing hip waders, because of the threat of hypothermia. Be careful not to slip or fall on rocks in the creek.

Riparian, Channel and Environmental Inventory, RCE

The Riparian, Channel and Environmental Inventory (RCE) (Petersen 1992) was developed to quickly assess the physical and biological conditions of small streams in lowland, agricultural landscapes in temperate regions that have been physically modified. We have modified the inventory some to better reflect conditions within the Western Pennsylvania watersheds. We encourage each participating school to complete this inventory for their primary sampling site. The site descriptions and inventory results for each school will be posted on the Creek Connections web site. Please send a picture of your sample site also so that it can be posted on our website.

The inventory only characterizes a small stretch of a stream (about 100 m); conclusions about a watershed cannot be made from one site. Remember that the quality of a stream water sample is a function of the entire upstream watershed--not just characteristics at the sampling site. Furthermore, the inventory was developed to assess physical disruption of the channel and riparian zone. Importantly, it does not assess the impact of point sources of pollution such as storm drainpipe discharges. This inventory would be best used in conjunction with chemical and/or biological testing.

Using the RCE inventory: The inventory is used by estimating the values for sixteen characteristics over a selected length of the stream (100 meters is suggested). The highest score for each characteristic varies from 15-30 depending on the value of the characteristic to the overall index. The highest total RCE score possible is 360; the lowest possible score is 16.

The sixteen characteristics included in the inventory all directly or indirectly relate to the biotic health of a stream. For example, several characteristics of the physical structure of the stream are extremely important to the quality of habitat for aquatic life. A channel undergoing a lot of erosion typically has an unstable bed and low diversity of habitat types.

This inventory will be helpful to develop an overall story for your sample site, and could assist with interpreting the chemical data you collect. Over the years, the inventory numbers can be compared to see if changes in land use, riparian zones, stream physical parameters, or biota have occurred.

References

- Petersen, Robert. 1992. The RCE: a riparian, channel, and environmental inventory for small streams in the agricultural landscape. *Freshwater Biology*. Volume 27, pages 295-306.
- Norris, Marian. 1997. Adaption of the riparian, channel and environmental inventory for use by high school students and for use on small streams of the French Creek Watershed. Senior Thesis. Allegheny College.

Glossary

- bars (gravel or channel):** areas of sediment/gravel deposition (fall out) in the stream channel.
- channel:** the physical structure that contains the stream; water only fills the entire channel when flooding.
- darters:** small, colorful fish that “dart” along stream bottoms; generally indicators of good water quality.
- debris dam:** a collection of fallen trees, logs, and twigs that have gotten wedged in the stream channel.
- detritus:** broken-down organic, particulate matter: ex. partially decomposed leaves, twigs; organic muck.
- pool:** deeper, usually calm area of stream, commonly on the outside river bend.
- riffle:** shallow, fast-flowing area, commonly on straight streams sections between bends.
- riparian zone:** area on the stream bank and next to stream bank.
- sculpins:** spiny, large-headed, broad-mouthed fish often scaleless; generally indicators of good water quality.
- substrate:** the material at the bottom of the stream channel, can be rocky, sandy, muddy, etc.
- stream:** the flowing water within the channel; we hope you didn't need to look this up.

RIPARIAN, CHANNEL, AND ENVIRONMENTAL INVENTORY
 modified from Petersen, 1992 by FCEEP for FCEEP, 1997 (now Creek Connections)

BASIC DATA

Stream name: _____ Site #: _____ Date: _____ Time: _____

EXACT Location: _____

Observers: _____

Stream width: _____ m Stream depth: _____ m Stream length examined: _____ m

Stream flow condition: high medium low very low Days since last significant rain: 0 1 2 3 4-7 8+

INVENTORY

Determine the condition of the stream CHANNEL and RIPARIAN ZONE at which you are standing and up to **50 m upstream and downstream (100 m total)**. Estimate the average condition over that distance and select ONE of the four scores for each characteristic.

I: LAND USE

1. Land-use pattern beyond the immediate riparian zone
 - Undisturbed, consisting of forest and/or natural wetlands 30 _____
 - Permanent pasture mixed with woodlots and wetlands; few buildings and roads 20 _____
 - Mixed row crops and pasture, or mixed grass lawn and homes 10 _____
 - Mainly row crops, or mostly streets, pavement, buildings, and parking lots 1 _____
2. Width of riparian zone from stream edge to field
 - Marshy or woody riparian zone >30 m wide 30 _____
 - Marshy or woody riparian zone varying from 5 to 30 m 20 _____
 - Marshy or woody riparian zone 1-5m 5 _____
 - Marshy or woody riparian zone absent 1 _____
3. Completeness of riparian zone
 - Riparian zone intact without breaks in vegetation along entire 100 meter zone you are evaluating 30 _____
 - Areas without vegetation occur at intervals of > 50 m 20 _____
 - Areas without vegetation frequent with some erosion (gullies and scars) every 50 m 5 _____
 - Many areas without vegetation, erosion occurring (gullies, scars) along entire length; or no vegetation 1 _____
4. Vegetation of riparian zone within 10 m of the channel
 - >90% plant density of mature trees or shrubs, or native marsh plants 25 _____
 - Mixed young tree species along channel and mature trees behind 15 _____
 - Vegetation of mixed grasses and sparse young tree or shrub species 5 _____
 - Vegetation consisting mostly of grasses, few trees and shrubs; low plant density; or no vegetation 1 _____

II. PHYSICAL STRUCTURE OF STREAM

5. Debris dams (a natural collection of fallen trees, logs, limbs, and rock material that have gotten wedged in or along channel)
 - Channel with old debris dams - old logs and rocks firmly set in place 15 _____
 - Logs and rocks present but back filled with some sediment 10 _____
 - Debris dams loose, probably moving with floods 5 _____
 - Debris dams sparse, easily moved; or debris dams absent 1 _____
6. Channel (NOT OF WATER ITSELF) width to depth ratio (ability to contain high flows)
 - Divide: if answer is <7; ample for present and annual peak flows 15 _____
 - Channel Width if answer is 8-15; adequate, overbank flows rare 10 _____
 - Channel Depth if answer is 15-25; barely contains common high flows 5 _____
 - if answer is >25 or stream is artificially channelized; overbank flow common 1 _____
7. Channel bars
 - Little or no channel width enlargement (bank erosion, undercutting); coarse-grained bars present 15 _____
 - Some gravel bars, pore spaces between rocks well washed with little silt present 10 _____
 - Sediment bars of rocks, sand, and silt common 5 _____
 - Channel divided into braids around sediment bars; or stream is channelized 1 _____

8. Stream-bank stability	
Banks stable, of rock and soil held firmly by grasses, shrubs, and tree roots	25 _____
Banks firm but loosely held by grass and shrubs	15 _____
Banks loose, held by a sparse layer of grass and shrubs	5 _____
Banks unstable, of loose soil or sand easily disturbed	1 _____
9. Bank undercutting	
Little or none evident or restricted to areas with tree root support	20 _____
Bank undercutting only on curves or narrow channel areas	15 _____
Bank undercutting common, some banks falling in	5 _____
Severe bank undercutting along channel, banks falling in	1 _____
10. Stony substrate; feel and appearance	
Stones clean, rounded without sharp edges (smooth pebbles, cobbles); may have blackened color	25 _____
Stones without sharp edges and with slight gritty feel	15 _____
Some stones with sharp edges, obvious gritty feel	5 _____
Stones bright; silt and grit covering them, sharp edges common	1 _____
11. Stream Bottom	
Various sized rocks, gravel, and sand mixture; open spaces common between rocks	25 _____
Loose stony bottom with some silt having settled in spaces between rocks	15 _____
Mixture of silt, sand, and gravel; open spaces between rocks sparse; bottom firm in places	5 _____
Uniform bottom of sand and silt held loosely together, easily moved, very little or no stony substrate	1 _____
12. Riffles and pools	
Riffles distinct, occurring at intervals of 5-7 times the <u>stream</u> width (not channel width)	25 _____
Riffles and pools irregularly spaced	20 _____
Long pools separating short riffles	10 _____
Riffles and pools absent or stream channelized	1 _____
III. BIOTA	
13. Aquatic vegetation	
When present consists of moss and patches of algae	15 _____
Algae dominant in pools, larger plants along edge, some in center	10 _____
Algal mats present, some larger plants, few mosses	5 _____
Algal mats cover bottom, larger plants dominate the channel	1 _____
14. Fish	
Darters and sculpins present in most riffles	20 _____
Darters and sculpins scarce and difficult to locate	15 _____
No darters or sculpins, other species in riffles	5 _____
Fish absent or scarce	1 _____
15. Detritus	
Mainly consisting of leaves and wood without sediment covering it	25 _____
Leaves and wood scarce; fine organic debris without sediment	10 _____
No leaves or woody debris; coarse and fine organic matter with sediment	5 _____
Fine organic sediment - black in color and foul odor (anaerobic)	1 _____
16. Bottom-dwelling aquatic insects	
Many species present in riffles and pools, on rocks and sand/gravel	20 _____
Many species but only in riffles and on rocks	15 _____
Few species present in riffles and pools, on rocks and sand/gravel	5 _____
Few if any species and only in riffles and pools, on rocks and sand/gravel	1 _____

TOTAL: _____

RESULTS

<u>Class</u>	<u>Score</u>	<u>Evaluation</u>
I	293-360	Excellent
II	224-292	Very good
III	154-223	Good
IV	86-153	Fair
V	16-85	Poor

POLLUTION TOLERANCE INDEX (PTI)

(Adapted from *Volunteer Stream Monitoring: A Methods Manual*, United States Environmental Protection Agency, Office of Water, Draft Document #EPA 841-B-97-003, November 1997 AND Mitchell and Stapp, *Field Manual for Water Quality Monitoring*, 1996.)

This Pollution Tolerance Index (PTI) is currently used by all Pennsylvania volunteer citizen monitoring groups and the Department of Environmental Protection for their stream organism sampling. It is based on the concept of indicator organisms and tolerance levels. The procedures are designed to be done quickly and easily; they provide a rapid means of sampling riffle and other shallow areas to detect moderate to severe stream quality degradation.

The advantages of the PTI are that it provides a relatively rapid means of assessing stream quality, it is useful in developing an information base, and it develops concepts of tolerance ranges of organisms. However, to determine the true health of a stream you should also conduct chemical tests and perform a land use/habitat assessment.

Organisms are collected and identified by comparing them with the drawing on the attached chart or by using a key. They are then divided into three groups based on their tolerance for pollution. Each of the three groups is given an index value, with the least tolerant group having the highest value. The general abundance of each kind of organism is also noted and factored into the index.

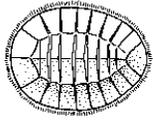
Procedure

1. Choose a 1-meter by 1-meter area that is representative of the riffle or shallow area being sampled. Use the kick screen method to sample this area.
2. Three samples (each 1m x 1m) should be taken at a site to be sure a representative sample is collected. Samples may also be taken from different microhabitats at the site, such as rocks, in slow-moving water, or near banks; different organisms may be found in these microhabitats.
3. Samples can be placed in containers of 70 percent alcohol solution for later identification. Be sure to pick clinging organisms off the kick net. If you do not want to preserve the organisms, and if time allows, you may be able to identify and release the macroinvertebrates at the site.
4. Using the attached data sheet, record the number and kind of each organism collected in the kick samples. Data from the three trials may be pooled on this data sheet.
5. After all organisms have been recorded, assign each type of organism an abundance code as follows:
 - R (Rare) = 1 to 9 organisms found in the sample
 - C (Common) = 10 to 99 organisms found in the sample
 - D (Dominant) = 100 or more organisms found in the sampleRecord the code next to the actual count on the data sheet.
6. Note that the data sheet divides the macroinvertebrates into three groups based on their ability to tolerate pollution. The three tolerance groups are:
 - Group I – Organisms that are sensitive to pollution and are typically found in good quality water.
 - Group II – Organisms that are somewhat sensitive to pollution and are typically found in fair quality water.
 - Group III – Organisms that are tolerant of pollution and are typically found in poor quality water.
7. Follow the instructions on the data sheet to calculate the stream water quality rating.

Macroinvertebrates Grouped by Level of Pollution Tolerance

(Adapted from EASI and the Senior Environmental Corps, *Volunteer Water Quality Monitoring Field Manual*.
 Images from McCafferty, *Aquatic Entomology*, 1981 AND Kellogg, *Monitor's Guide to Aquatic Macroinvertebrates*, 1994.)

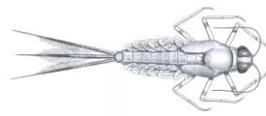
Group I: Generally sensitive to pollution. Large numbers of these types of organisms normally indicate GOOD WATER QUALITY.



Water Penny Beetle Larva



Riffle Beetle Adult



Mayfly Nymph



Stonefly Nymph



Gilled Snail
(has a thin, hornv plate to seal shell opening)



Hellgrammite & Fishfly
Larva



Non-Net-Spinning Caddisfly Larva



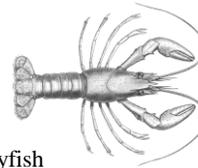
Group II: Can exist under a wide range of water quality conditions. Large numbers of these organisms, in the absence of Group I organisms, normally indicate MODERATE



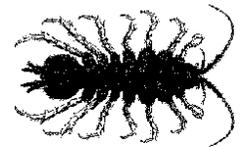
Damselfly Nymph



Cranefly Larva



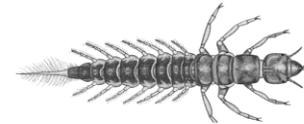
Crayfish



Aquatic Sowbug



Scud



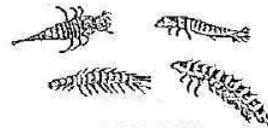
Alderfly Larva



Net-spinning Caddisfly Larva



Clams & Mussels



Beetle Larvae

Group III: Generally tolerant of pollution. Large numbers of these types of organisms normally, in the absence of Group I and Group II organisms, indicate POOR WATER QUALITY.



Blackfly Larva



Midge Larva



Leech



Aquatic Worms



Other Snails (Not Gilled)

NOTE: These organisms are the only macroinvertebrates used to calculate the PTI. Other organisms will be found; to identify them, refer to other macroinvertebrate identification sheets in this section of the handbook.



DATA SHEET : POLLUTION TOLERANCE INDEX

Sample Date: ___/___/___

Sampling time ____:____

Site Name _____

School _____

Names of Testers / Class _____

Observations: *Creek Appearance (velocity, color, frozen, etc.) _____

*Weather in past 24 hours (rain, snow, clear, etc.) _____

*Relative Depth (higher/lower than normal, etc.) _____

Macroinvertebrate Count

Identify the macroinvertebrates (to order) in your sample using the identification sheet. We are only concerned with organisms that appear on the identification sheet. Record the number of organisms below and then assign each organisms an abundance code:

R (rare) = 1-9 organisms; C (common) = 10-99 organisms; or D (dominant) = 100 or more organisms

Example: 20 (C) *Water Penny Larvae*

GROUP I – SENSITIVE

- | | |
|---|--|
| _____ () Gilled Snails | _____ () Riffle Beetle Adults |
| _____ () Mayfly Nymphs | _____ () Stonefly Nymphs |
| _____ () Non-Net-Spinning Caddisfly Larvae | _____ () Water Penny Larvae |
| | _____ () Hellgrammites & Fishfly Larvae |

GROUP II –SOMEWHAT SENSITIVE

- | | |
|----------------------------|---|
| _____ () Alderfly Larvae | _____ () Damselfly Nymphs |
| _____ () Aquatic Sowbugs | _____ () Scuds |
| _____ () Beetle Larvae | _____ () Net-Spinning Caddisfly Larvae |
| _____ () Clams & Mussels | |
| _____ () Crane-fly Larvae | |
| _____ () Crayfish | |

GROUP III – TOLERANT

- | | |
|---------------------------|------------------------|
| _____ () Aquatic Worms | _____ () Midge Larvae |
| _____ () Blackfly Larvae | _____ () Snails |
| _____ () Leeches | |

Based on PTI form n the Volunteer Water Quality Monitoring Field Manual developed for the Senior Environmental Corps and the Environmental Alliance for Senior Involvement in Pennsylvania, 1998.

Water Quality Rating

To calculate the index value, add the number of **letters** (not numbers of macros) found in the three groups on the other side and multiply by the indicated weighing factor.

Group I – Sensitive

$$(\# \text{ of R's}) \times 5.0 = \underline{\hspace{2cm}}$$

$$(\# \text{ of C's}) \times 5.6 = \underline{\hspace{2cm}}$$

$$(\# \text{ of D's}) \times 5.3 = \underline{\hspace{2cm}}$$

$$\text{Sum of Index Value for Group I} = \underline{\hspace{2cm}}$$

Group II – Somewhat Sensitive

$$(\# \text{ of R's}) \times 3.2 = \underline{\hspace{2cm}}$$

$$(\# \text{ of C's}) \times 3.4 = \underline{\hspace{2cm}}$$

$$(\# \text{ of D's}) \times 3.0 = \underline{\hspace{2cm}}$$

$$\text{Sum of Index Value for Group II} = \underline{\hspace{2cm}}$$

Group III – Tolerant

$$(\# \text{ of R's}) \times 1.2 = \underline{\hspace{2cm}}$$

$$(\# \text{ of C's}) \times 1.1 = \underline{\hspace{2cm}}$$

$$(\# \text{ of D's}) \times 1.0 = \underline{\hspace{2cm}}$$

$$\text{Sum of Index Value for Group III} = \underline{\hspace{2cm}}$$

To calculate the water quality score for the stream site, add together the index values for each pollution tolerance group. The sum of these values equals the water quality score.

$$\text{Water Quality Score} = \underline{\hspace{2cm}}$$

Compare this score to the following number ranges to determine the quality of your stream site:

Good > 40

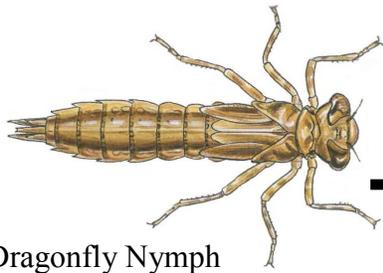
Fair 20 – 40

Poor < 20

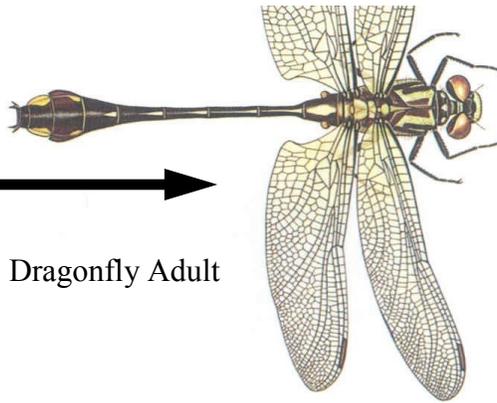
Note: The tolerance groupings (Group I, II, III) and the water quality rating categories were developed for streams in the Mid-Atlantic states.

Macroinvertebrates

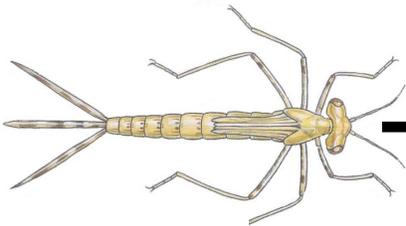
Page numbers correspond with A Golden Guide to Pond Life



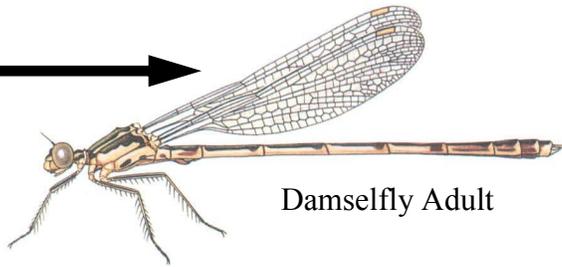
Dragonfly Nymph
(Darter) p.98



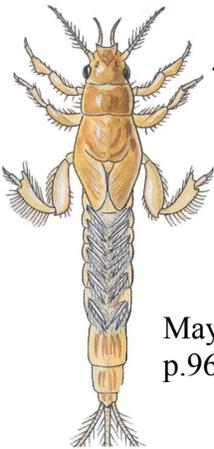
Dragonfly Adult



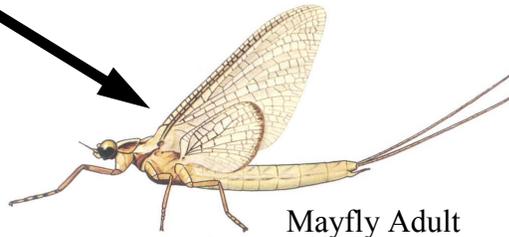
Damselfly Nymph
p.99



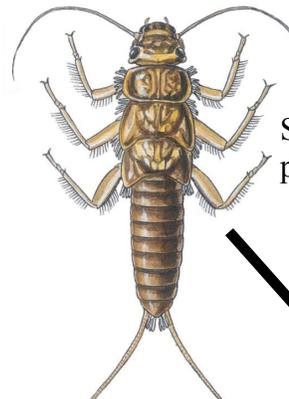
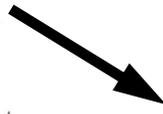
Damselfly Adult



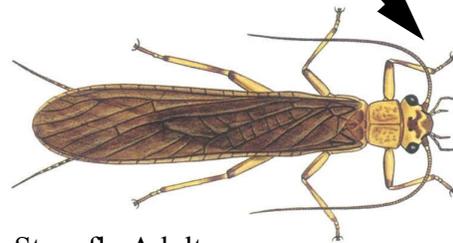
Mayfly Nymph
p.96



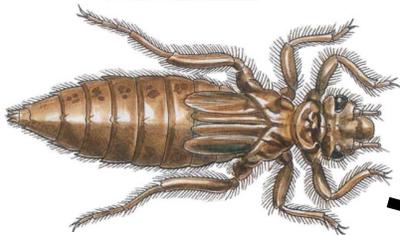
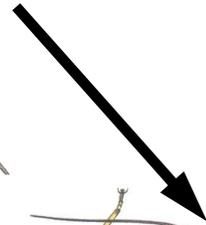
Mayfly Adult



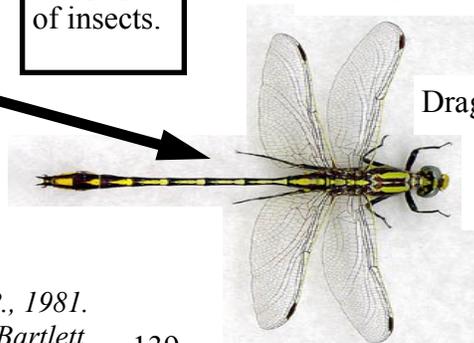
Stonefly Nymph
p.100



Stonefly Adult



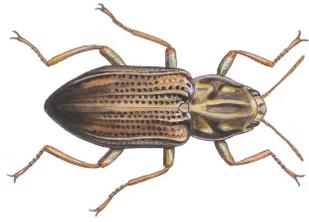
Dragonfly Nymph
(Clubtail) p.98



Dragonfly Adult



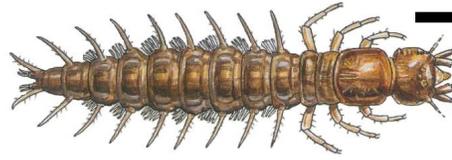
NOTE the TAILS
This is an important differing characteristic of this page of insects.



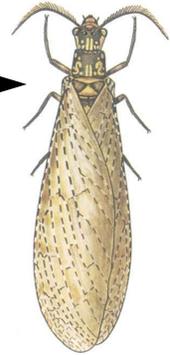
Riffle Beetle Adult p.105



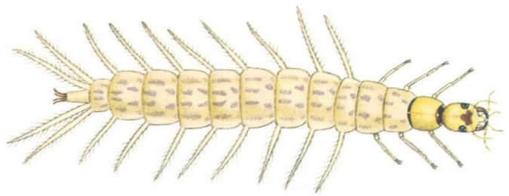
Backswimmer
p. 104



Dobsonfly Larva p.101



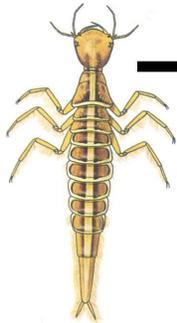
Dobsonfly Adult p.101



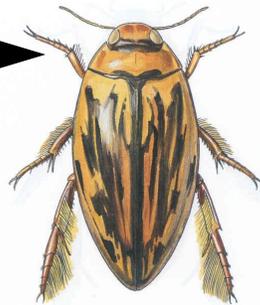
Whirligig Beetle Larva p.105



Whirligig Beetle Adult p.105



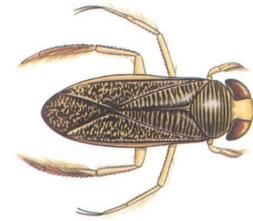
Predaceous Diving
Beetle Larva p.105



Predaceous Diving
Beetle Adult p.105



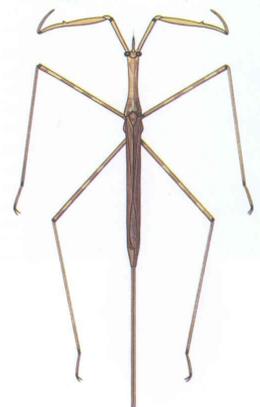
Giant Water Bug p.103



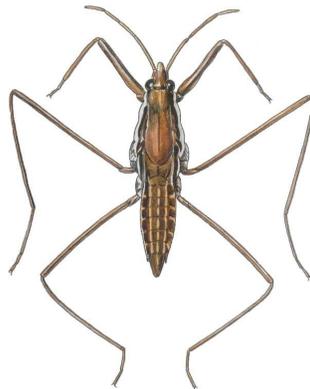
Water Boatman p.103

Live on Top of the Water

Water Scorpion p.103

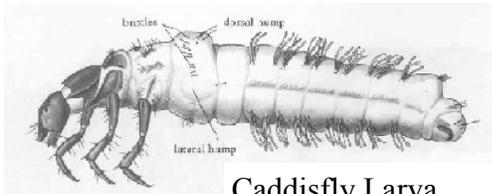


Water Strider p.102

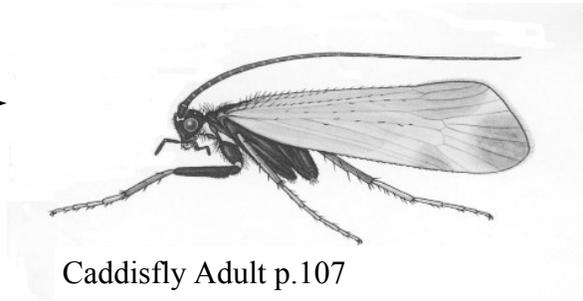


Fishing Spider p.113





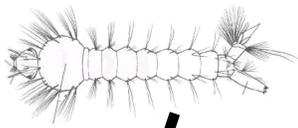
Caddisfly Larva
(case-maker) p.107



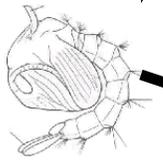
Caddisfly Adult p.107

Worm-Like Creatures

Larva



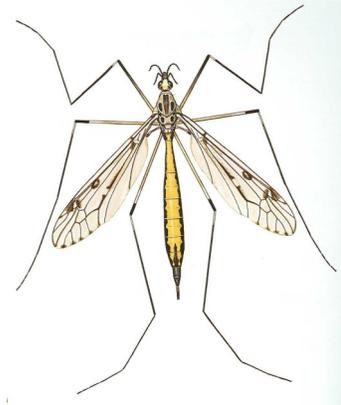
Mosquito
p.108, 109



Pupa

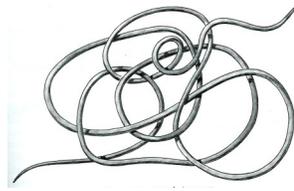
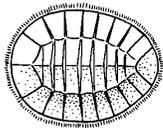


Crane Fly
P. 110



Larva

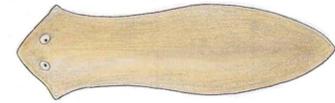
Water Penny



Horsehair Worms p.119



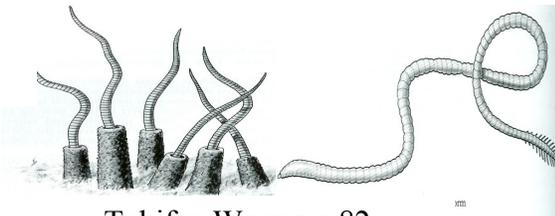
Nematode p.118



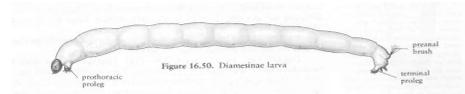
Flatworm p.84



Leeches p.83



Tubifex Worms p.82



Midge (Chironomid) p.111



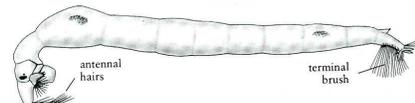
Midge (Bloodworm)



Black Fly Larva p. 111



Black Fly
Adult p.111



Phantom Midge Larva p.108,109



Orb Snail p.115



Pointed Winkle p.115



Hairy Wheel Snail p.115

Little Pond Snail p.115

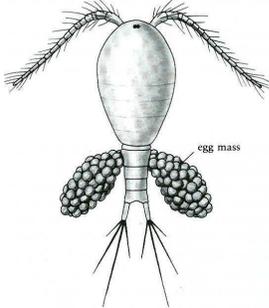


Pouch Snail p.115

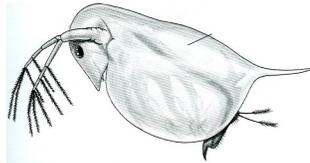
Images from Golden Guide to Pond Life

Very Small Creatures (Dots in the water)

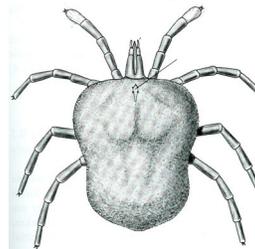
Copepod p.90



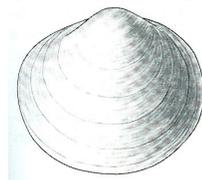
Water Flea p.88



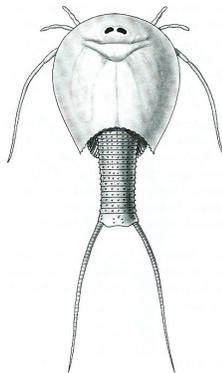
Water Mite p.113



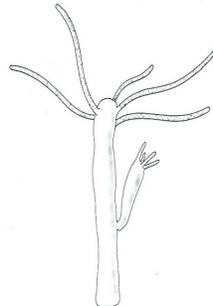
Fingernail Clam p.117



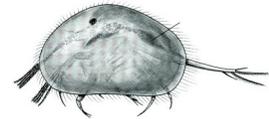
Tadpole Shrimp p.88



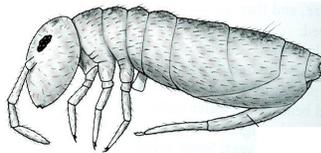
Hydra p.78,79



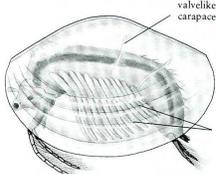
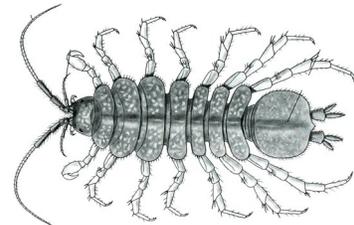
Seed Shrimp p.87



Springtail p.100,101

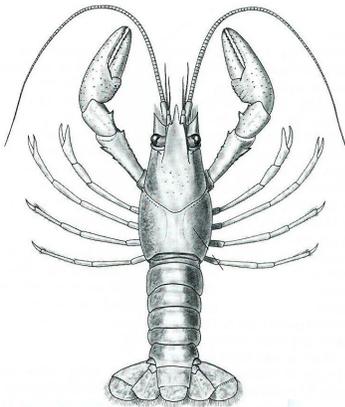


Isopod p.91



Clam Shrimp p.88

Others



Crayfish p.92



Spotted & Mud Salamanders p.131

Image from Golden Guide to Pond Life

Red Spotted Newt p.131

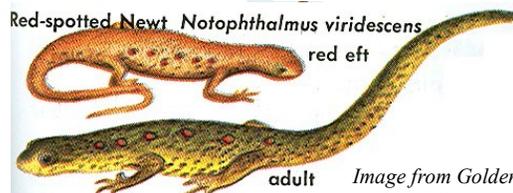


Image from Golden Guide to Pond Life

Tadpoles p.133

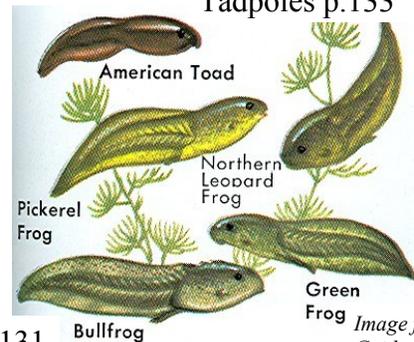
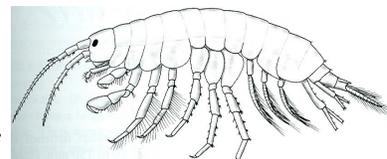


Image from Golden Guide to Pond Life

Scud (Sideswimmer) p.91



Illustrations courtesy of McCafferty, W.P., 1981. Aquatic Entomology. Boston: Jones and Bartlett Publishers unless otherwise noted.

Macroinvertebrate Sampling Equipment

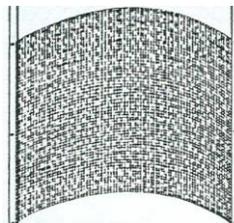
Why are there so many different types of sampling methods and equipment? Different techniques are used depending on the sampling site location and what the monitors are searching for.

Qualitative vs. Quantitative Sampling

Qualitative sampling determines *the different variety of organisms* that are present at a location. It gives general overall data for a site. Although qualitative samples can be compared over time, they are not designed to evaluate a community. During qualitative sampling a number of areas at a site can be sampled to obtain the greatest variety.

On the contrary, quantitative sampling is done to determine *the number of organisms* of each type that are present in a very specific location. This type of sample can be compared among sites and can also provide data for community evaluation. A measured area is sampled, keeping all variables the same between sites. Therefore, a quantitative sample is consistent between samples and numerical data can be easily compared.

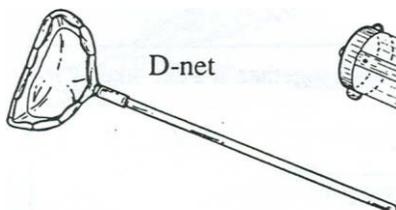
Kick nets are used to sample shallow areas of moving water. The base of the net is held against the bottom of a stream. . Rocks in front of the kick net are brushed off allowing this debris to flow into the net. Then, the area upstream is kicked so organisms drift into the net with the current. Kick net may be used qualitatively or quantitatively. If an unmeasured area is sampled, the results are qualitative. But, if only a certain area in front of the net is kicked then this data is considered quantitative.



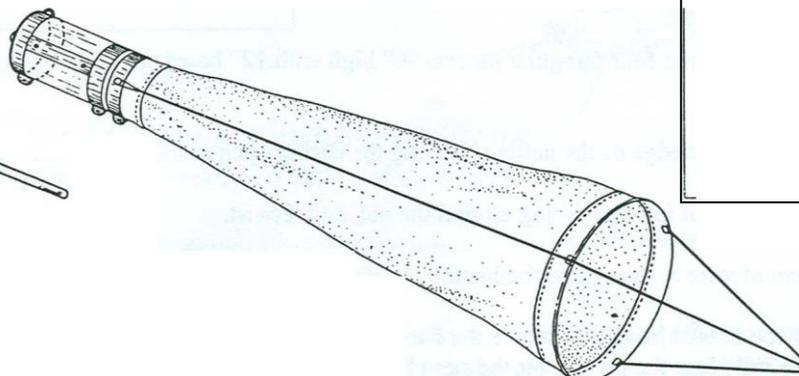
Kick net

Qualitative Sampling Methods

D-nets are effective for sampling in vegetation, on banks, and on muddy waterway bottoms. They can be swiped through plant-filled waters, knocking organisms into the net. Moreover, they have one flat side which can be placed against a bank or bottom, scooping up organisms present there.



D-net



plankton tow

into the water from shore and pulled back.

How to Make an Economical Kick Net

Materials:

- Roll of window/insect screen-silver or gray preferably. (Comes in rolls 100 ft' long, but may be cut to length in store.)
- Lath strips (cheap wood)
- Staple gun and staples
- Drywall screws - coarse thread (1^{5/8}")
- Drill with screwdriver bit
- Pliers
- Scissors

Cut the screen with scissors to any size you want, but in Pennsylvania they may be no wider than 4 ft. (Ours are approximately one square meter.)

Attach the screen to a lath strip one half inch up from one end. This end will go down into the water. Use the staple gun to secure it onto the lath strip snugly. Do this to both lath strips.

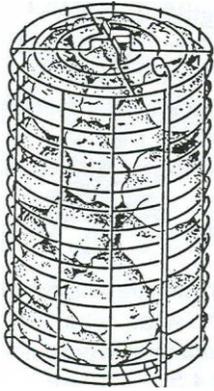
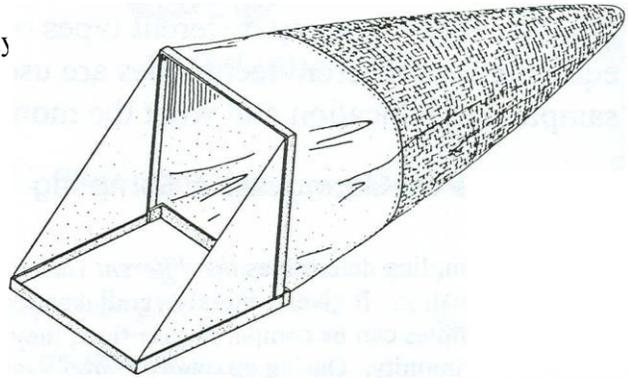
Place a new lath strip on top of the lath strip with the screen stapled to it. With a drill, screw the two lath strips together with 6-8 drywall screws. The screen should be sandwiched between the two strips. The dry wall screws will go through both strips and stick out the other side, so drill them over grass.

Remove the sharp points of the head screws with pliers. Trim any remaining sharp

economical kick net!!

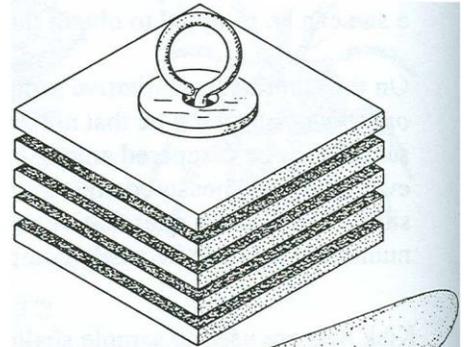
Quantitative Sampling Methods

Surbers are used in shallow, moving water. They sample only a specifically measured area of water. The empty frame is placed on the bottom of the waterway with the net trailing downstream. The area within the frame is disturbed with the hands of the monitor and the organisms drift into the net.

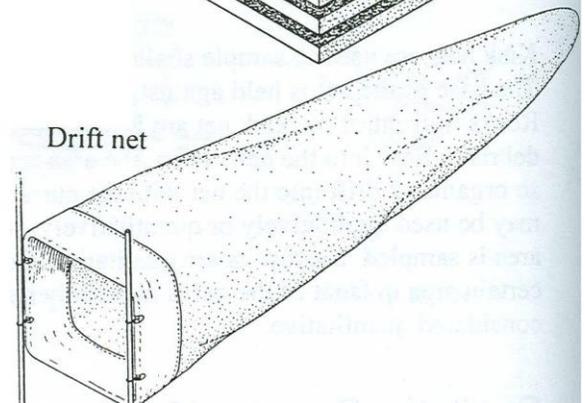


Basket-type artificial substrate sampler

Artificial substrate samplers can be employed at a specific site. This type of sampler includes Hester leaf pack bags. These are left in the water for several weeks so organisms have time to colonize them. They are then removed and examined to identify the organisms.



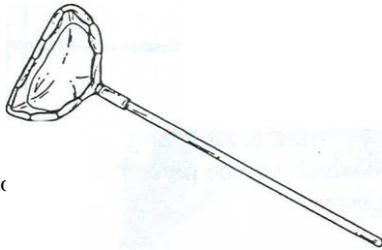
Drift nets are used to sample flowing water in shallow areas. The net is secured in the water and can be left there unattended until removed. This type of net collects drifting organisms.



How to Make a D-net

Materials:

- 4 pieces of nylon netting
- 10" X 12", preferably 1/25" mesh
- 40" of 1" fabric casing
- thread
- scissors
- sewing machine
- wire coat hanger
- drill with 1/4" wood bit
- 4' long broom handle or dowel
- pliers
- duct tape



Begin by cutting the netting into four triangular pieces, 10" high with 12" bases, and sew them together in a cup-like fashion.

Sew the 40" fabric strip to the edge of the netting, leaving the casing open to insert the wire frame.

Untwist the coat hanger, slip it into the casing around the net, and twist back together.

Leave about a 2" stem of wire to insert into the handle. Drill a hole into the broom handle and then insert the wire stem.

Use the remaining piece of coat hanger to secure the handle by bending it into a U-shaped piece. Drill two more holes in the side of the handle and place the piece over the stem base and into the holes. Finally, wrap with duct tape to secure.

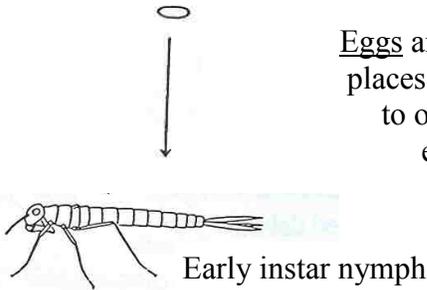
Congrats! A low-cost D-net!

Life Cycles of Aquatic Insects

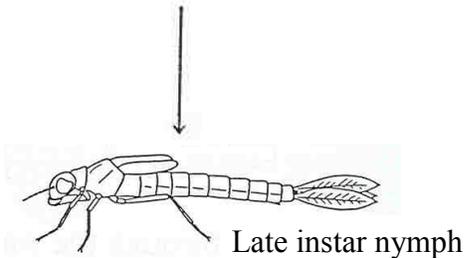
Remember that many of the insects that you find in the water are not adults. The adult form of most aquatic insects is land-dwelling or terrestrial (though some adults are aquatic, too). In order to fulfill their adult functions, insects must go through a change in appearance known as metamorphosis.

Damselfly undergoing INCOMPLETE METAMORPHOSIS

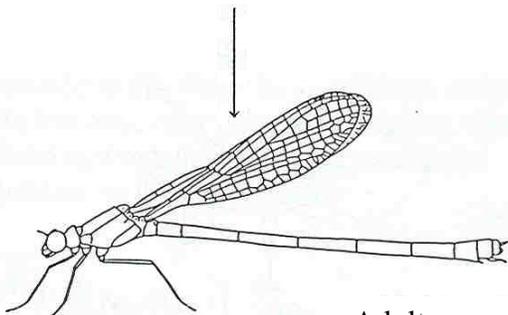
Insects that undergo incomplete metamorphosis go through three main life stages: egg, nymph (sometimes called larva), and adult.



The nymph life stage is similar in appearance to the adult and occurs through a series of molts (processes wherein the skin is shed).



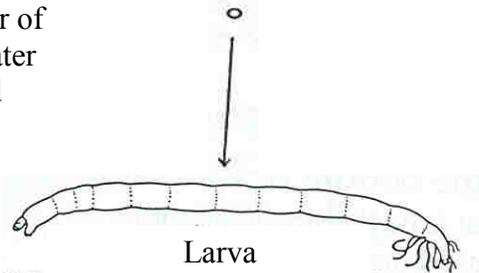
Between molts, the nymph goes through a number of growing stages and is referred to as an instar.



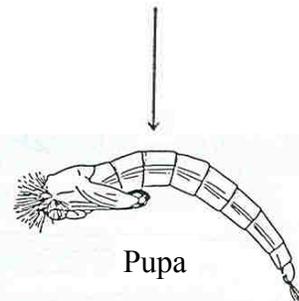
Adults emerge with full capability for reproduction, ready to start the cycle over again.

Midge undergoing COMPLETE METAMORPHOSIS

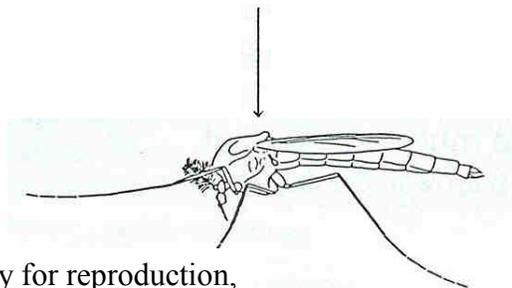
Four main life stages are included in the life cycle of an aquatic insect that undergoes complete metamorphosis. These stages are: egg, larva, pupa, and adult.



The larva (plural: larvae) is very different in form from the adult. It consists of a number of instars between molts.



The pupa (plural: pupae) may live in a cocoon or be free-living. Both internal and external changes occur during the pupal stage to ready the organism for emergence as an adult.

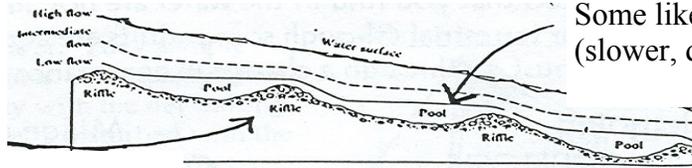


Pictures from McCafferty, 1981

<p>Insects that undergo incomplete metamorphosis:</p> <ul style="list-style-type: none"> Mayflies Damselflies Stoneflies Dragonflies True bugs 	<p>Insects that undergo complete metamorphosis:</p> <ul style="list-style-type: none"> Dobsonflies Beetles Caddisflies Fishflies Alderflies True Flies
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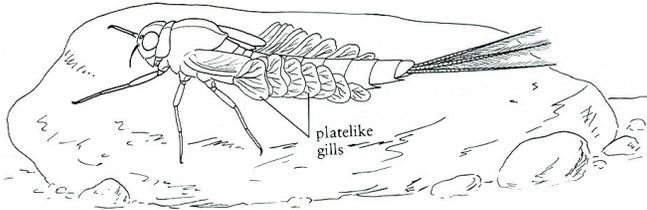
Where do Macroinvertebrates Live?

Most like **riffles**
(where the stream water tumbles
over rocks and is fast moving)

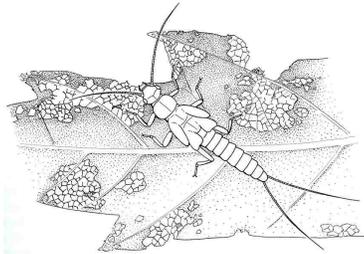


Some like the **pools**
(slower, deeper spots in a stream)

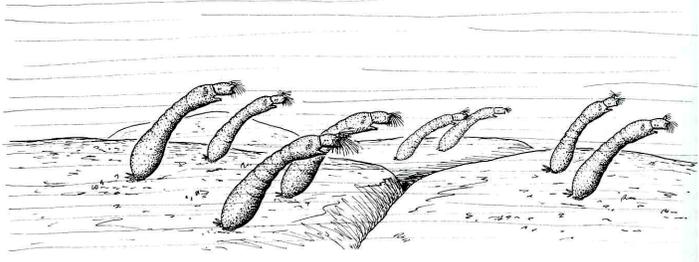
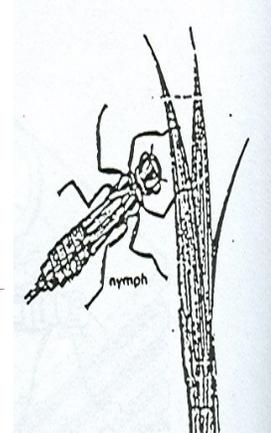
(Dunne & Leopold, 1978)



On or under the rocks in the
bottom of a stream.
What is on the stream bottom
is called the **substrate**

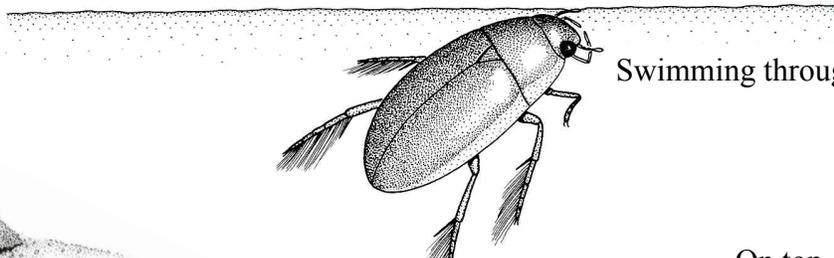


On leaves and twigs
This is called **debris**



Black fly larva attach to the top of rocks

On live plants in the water
Some will cling to vegetation to keep
from floating downstream

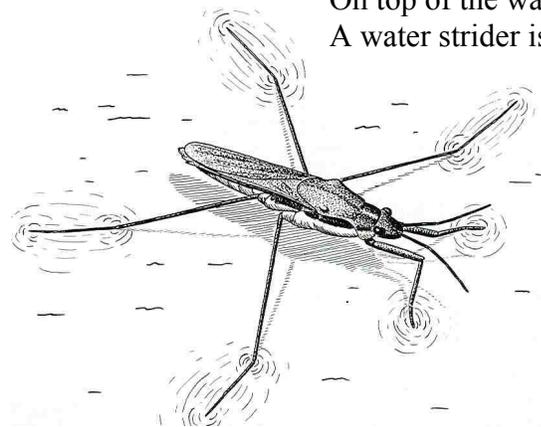


Swimming through the water

On top of the water
A water strider is a good example



In the mud or sediment
Some burrow under the substrate

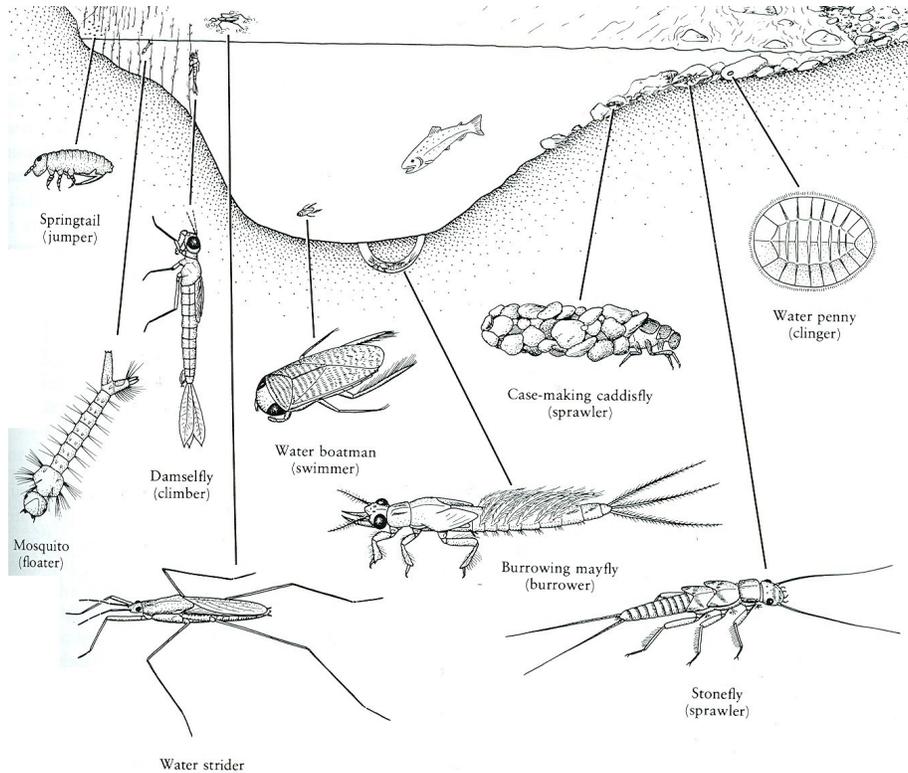


In **CLEAN, UNPOLLUTED WATER**, however, different
insects can tolerate different levels of polluted water

- ~ Clean water only insects are called Group 1 insects
- ~ Moderate quality water insects are called Group 2 insects
- ~ Poor, polluted water insects are called Group 3 insects

Illustrations courtesy of McCafferty, W.P.,
1981. Aquatic Entomology. Boston: Jones
and Barlett Publishers, unless otherwise
noted.

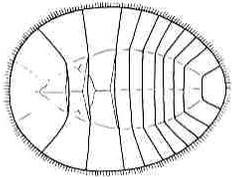
How do Aquatic Macroinvertebrates Move?



Clinger: Grasps onto rocks in strong flowing waters. Aquatic macroinvertebrates have evolved different strategies for adhering to substrates:

Burrower: Generally live in soft bottomed waterbeds. Burrowers bury themselves under the surface of the waterbed to hide from potential predators.

water penny

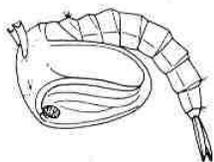


The water penny's suction-cup like body helps the insect attach itself onto rocks.

A second type of clinger is the riffle beetle. Riffle beetles have strong grasping claws to allow it to clamp down onto rocks.



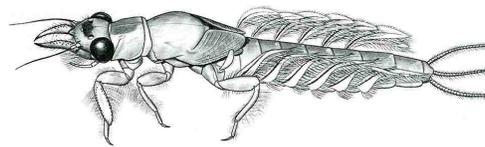
Floaters: Most floaters live at or near the surface of the water for respiratory purposes. To increase their buoyancy, floaters either have hydrostatic organs, or swallow air bubbles to float easier.



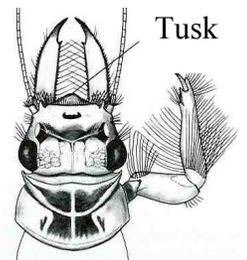
mosquito larva

Mosquito larvae are typical floaters. They stay in close contact with the surface of the water to maximize their respiratory horn from which they breathe. When disturbed, the larva dive with a jerking motion of their bodies.

burrowing mayfly



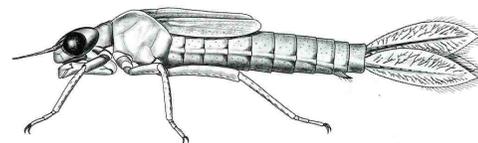
The burrowing mayfly's broadened fore legs and shovel-like tusks help it to dig



Tusk

Climber: Usually inhabit heavily vegetated waters. These aquatic insects climb upon the plant stems, algae, root systems, and mosses of the waterway.

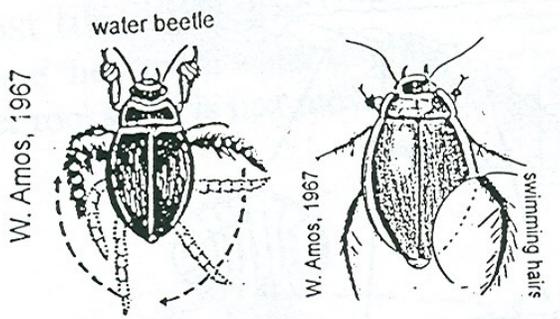
damselfly



The damselfly uses its long appendages and clawed "feet" to effectively climb

Illustrations courtesy of McCafferty, W.P., 1981. Aquatic Entomology. Boston: Jones and Barlett Publishers, unless otherwise noted.

How do aquatic macroinvertebrates move?

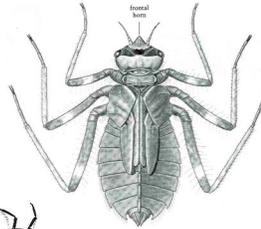


Swimmer: Bodies of water beetle and water bugs have adapted to efficiently swim underwater. Their bodies are streamlined to pierce through the water, and their appendages are oar-like, covered with “swimming hairs” to increase the surface area of the oar.

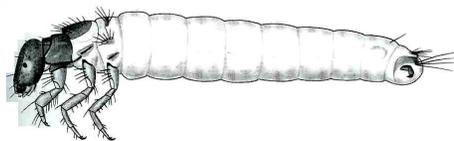
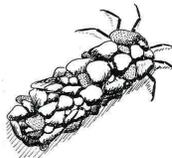
Sprawler: Crawl about freely in still or slightly moving water, often residing on the underside of rocks.

The case building caddisfly is a sprawler that drags its home (or case) with it.

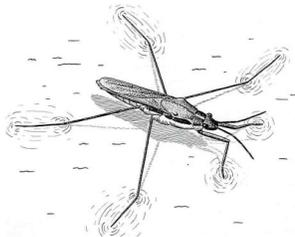
Dragonfly larva



The dragonfly larva is a unique sprawler, because it’s able to quickly propel itself forward by a forceful explosion of water from its rectal chamber, or “hind end.”



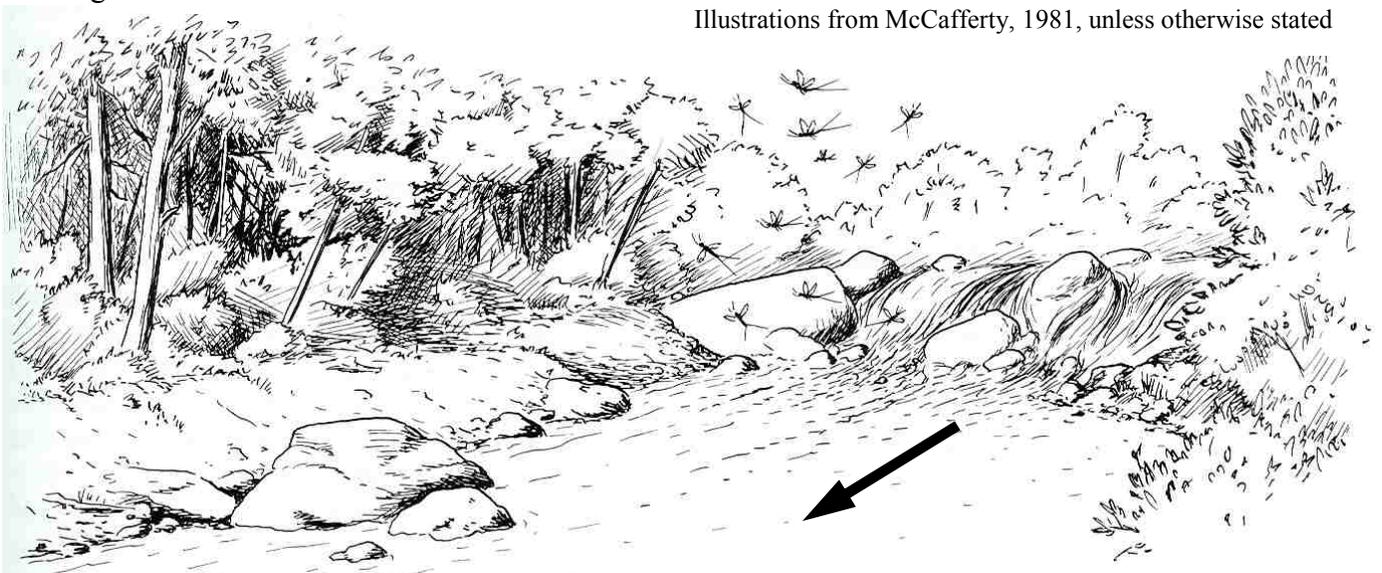
“Naked” Netspinning Caddisfly



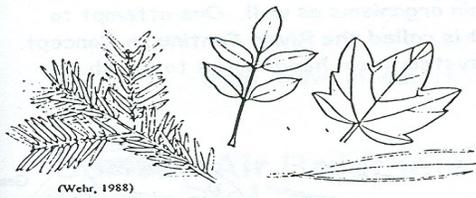
Skater: Water striders and shortlegged striders skate upon the surface of the water. Most skaters found in calm, placid waters. Skaters have skinny, elongated appendages to help balance the insect’s body weight.

Drift: Insects that are temporarily carried downstream by the current are known together as “drift.” When the insects drift, they usually only travel a few meters downstream. Insects drift downstream due to catastrophic events, such as pollution and severe lowering of the water. Insects also commonly drift under normal water conditions, called periodic drifting. It is unclear why insects periodically drift. Some theories include: to optimize carrying capacity of the habitat, because of enhanced predator presence, or simply to migrate downstream.

Illustrations from McCafferty, 1981, unless otherwise stated



What do macroinvertebrates eat?

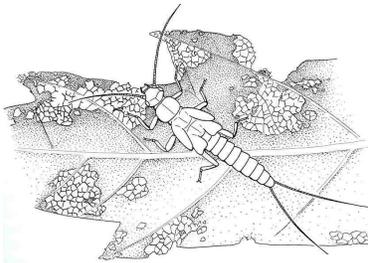


(Wehr, 1988)

1. Leaves, needles and other large organic matter known as **CPOM** or **Course Particulate Organic Matter**.

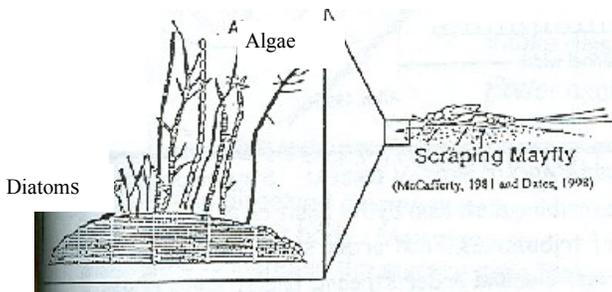
The macroinvertebrates that eat these items are known as **shredders** and include:

- Cranefly larvae
- Case-building caddisfly larvae
- Small stonefly nymphs
- Scuds
- Aquatic Sowbugs



(McCafferty, 1981)

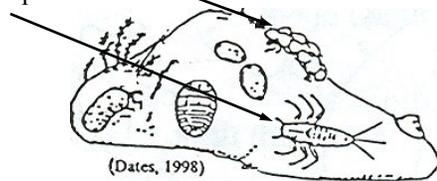
2. Diatoms and algae collectively are called **periphyton**.



(McCafferty, 1981 and Dates, 1998)

The macroinvertebrates that dine on periphyton are called **grazers** or **scrapers**. Among these are:

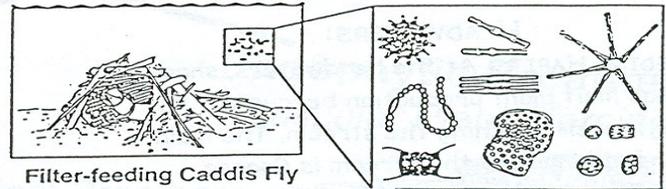
- Caddisfly larvae
- Water penny beetle larvae
- Some mayfly nymphs
- Snails



(Dates, 1998)

5. Some macroinvertebrates belong in a combination of the above categories due to their varies feeding habits

3. Broken down CPOM, soil and wastes and remains of other small macroinvertebrates called **FPOM** or **Fine Particulate Organic Matter**.

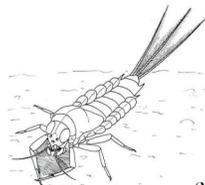


Filter-feeding Caddis Fly

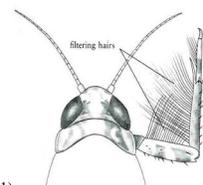
(McCafferty, 1981 and Dates, 1998)

The macroinvertebrates that feast on FPOM are known as **collectors**.

A. **Filtering collectors** obtain their food from bits and pieces floating in the water. Examples are:

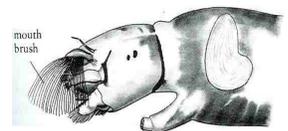


(McCafferty, 1981)



filtering hairs

- Some mayfly nymphs
- Blackfly larvae
- Mussels
- Worms
- Some midge larvae
- Net-spinning caddisfly larvae



mouth brush

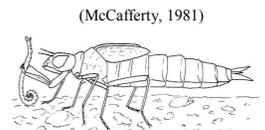
B. **Gathering collectors** get their food from the stream bottom. These include:

- Some mayfly nymphs
- Some caddisfly larvae
- Some midge larvae

4. Other macroinvertebrates.

Macroinvertebrates that eat animals are called **predators**. Some predators are:

- Damselfly and dragonfly nymphs
- Water striders
- Water bugs
- Crayfish
- Larger stoneflies
- Beetles, both larvae and adults
- Hellgrammites



(McCafferty, 1981)



(McCafferty, 1981)

The River Continuum Concept

Although pollution tolerance has a lot to do with what macroinvertebrates you find at a given site, other factors determine the presence or absence of certain organisms as well. One attempt to predict what macroinvertebrates are where arises from what is called the **River Continuum Concept**. This theory describes the gradual changes in a stream system from headwaters to mouth.

HEADWATERS:

FEEDING HABITS: At the headwaters, shade areas limit plant production because of low light levels reaching the stream. The main food input to the stream is Coarse Particulate Organic Matter (CPOM) from leaf litter and plant parts on the shores. Therefore, **shredders** are abundant. The CPOM broken down by the shredders creates Fine Particulate Organic Matter (FPOM) for **collectors** to feast on.

MOVEMENT: At the headwaters, the substrate is generally rocky. Therefore, **clingers** and **sprawlers** dominate this area

MID-ORDER:

FEEDING HABITS: Because mid-order streams are wider, they are shaded less by overhanging trees. Therefore enough sunlight enters the streams to support a sizable periphyton community. **Grazers** dine upon this periphyton and are therefore common in the types of streams. FPOM from upstream areas nourished **collectors** here.

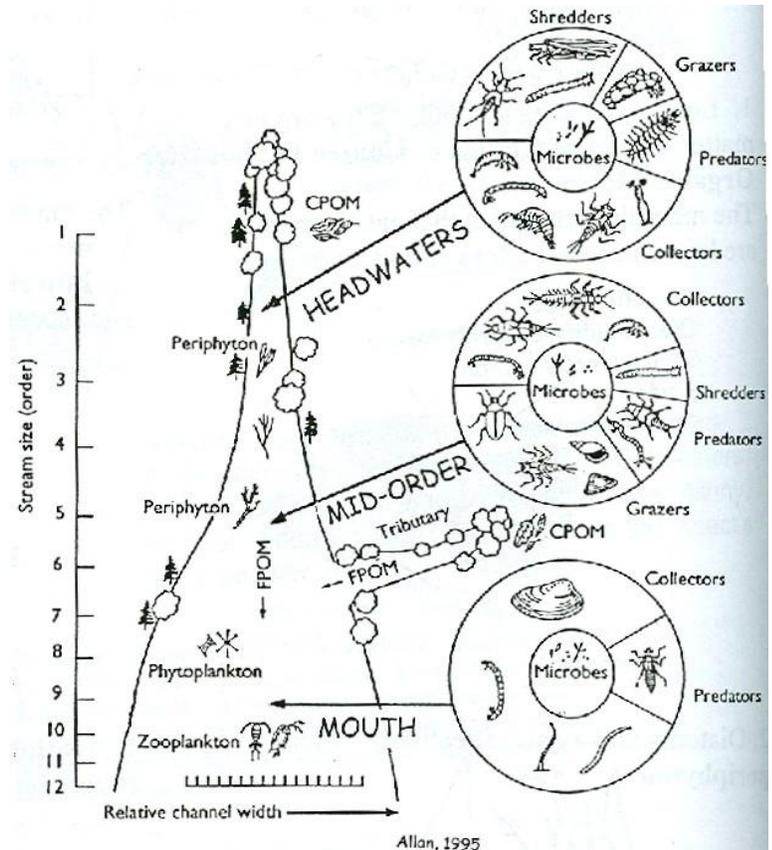
MOVEMENT: Mid-order streams have a bottom that is transitional between rocky and muddy. As a result, organisms with a wide variety of different movement habits are present.

MOUTH:

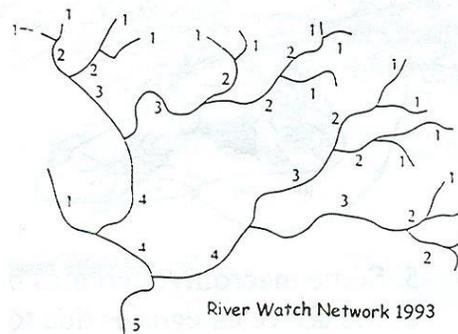
FEEDING HABITS: The mouth area of the river is widest. In it, periphyton production is limited by turbidity (cloudiness) in the water, not by tree shading. The accumulated FPOM from upstream encourages **collector** communities.

MOVEMENT: At the mouth, the bottom is covered with sand, silt, or mud. These conditions make it the perfect habitat for the burrowers that are common here.

Predators are present throughout, eating whatever animals exist in their area.



A FEW WORDS ABOUT STREAM ORDER: Stream order is a way of describing a stream by its position in the hierarchy of tributaries. First order streams have no tributaries. Second order streams are streams whose tributaries are only first order streams. A stream that is third order has only first and second order streams as its tributaries and so on.



How do macroinvertebrates Breathe?

Aeropneustic Insects

“Air Breathing”

Able to live in waters with low dissolved oxygen, (usually indicative of pollution)

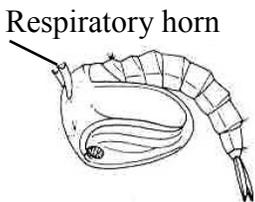
Surface Air Breathers

Endophytic Breathers

“Vascular Plant Piercing”

Tube Breathers

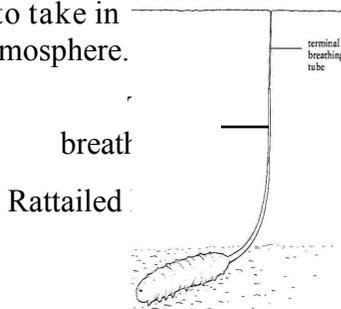
“Snorkel System” approach, using their **terminal breathing tube** as a snorkel to take in oxygen from the atmosphere.



Mosquito Larva

Periodic-Contact Breathers

“SCUBA System” approach, by filling their **underwing chamber** with an oxygen rich air bubble.

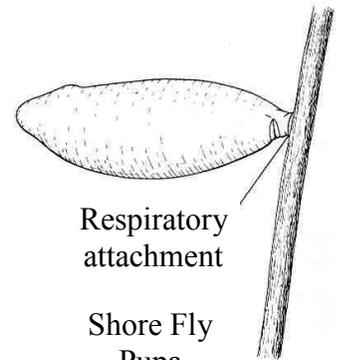


Diving Beetle

Other examples: few species of beetle larvae



Leaf Beetle



Respiratory attachment

Shore Fly Pupa

“Parasitic” approach, these insects tap aquatic plant stems & roots for oxygen. Other examples: few species of mosquito larvae & pupae

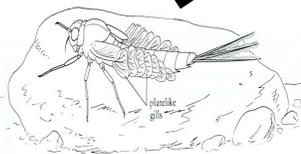
Hydroneustic Insects

“Water Breathing”

Intake dissolved oxygen found in water
Prefer habitats rich in dissolved oxygen

Cutaneous Respiration

Intake dissolved oxygen directly through their body. May also use **gills** to increase the surface area that the oxygen is absorbed through.



Platelike gills

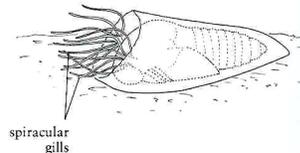


Midge Larva

Midge Larva absorb oxygen directly through their skin

Surface Air Breathers

Have **spiracle gills** that absorb dissolved oxygen. A **plastron**, (layer of air surrounding the spiracle), regulates dissolved oxygen absorption.



Black Fly Pupa

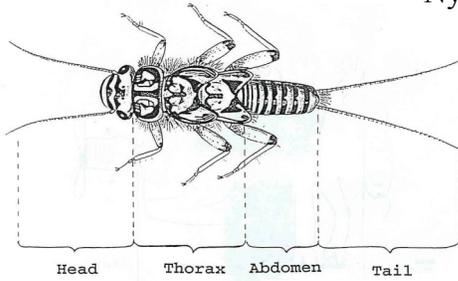
Other examples: midge pupae & crane flies

The mayfly is an example of an aquatic insect that respire through its gills

Pictures from McCafferty, 1981

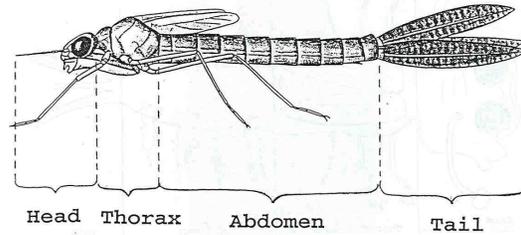
Macroinvertebrate External Anatomy

Anterior ← → Posterior Stonefly Nymph



(McCafferty, 1981)

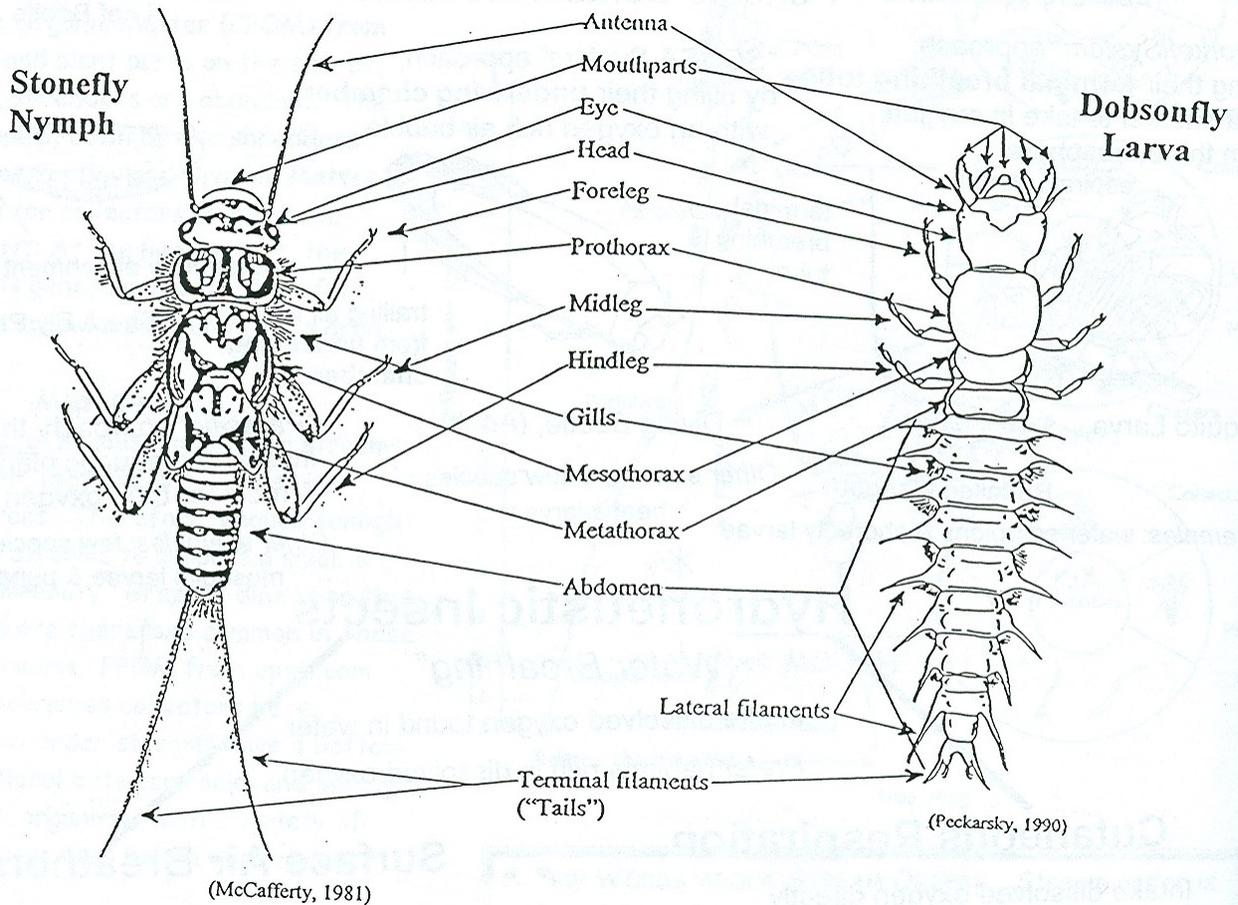
Damselfly Nymph



(McCafferty, 1981)

Dorsal
↑
↓
Ventral

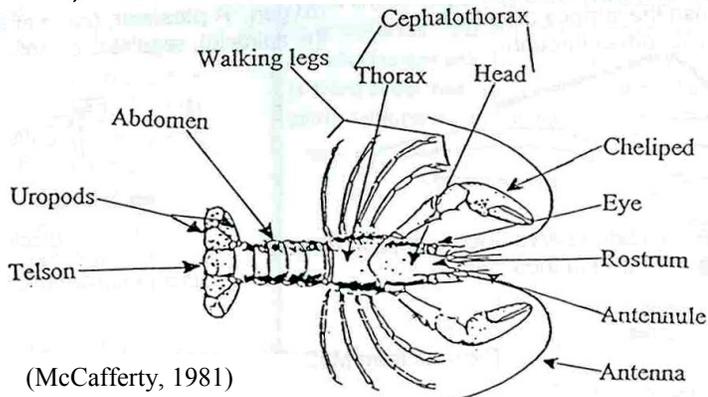
All insects have three main body parts: head, thorax and abdomen. In addition, many also have tails.



(McCafferty, 1981)

(Peckarsky, 1990)

Crayfish



(McCafferty, 1981)

RESOURCES USED FOR BIOLOGICAL SAMPLING SECTION

- Andrews, William A. (1987). Investigating Aquatic Ecosystems. Scarborough, Ontario: Prentice-Hall.
- Britton, L. and P. Greeson. (1988). Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. Denver, CO. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter 4A.
- Cauduto, Michael. (1985). Pond and Brook - A Guide to Nature Study in Freshwater Environments. (2nd Ed.). New Jersey: Prentice-Hall.
- Cuffney, T., M. Gurtz, and M. Meador. (1993). Methods for Collecting Benthic Invertebrate Samples as Part of the National Water-Quality Assessment Program. Denver, CO. U.S. Geological Survey Open-File Report 93-407.
- Cummins, Kenneth W., & Wilzbach, Margaret A. (1985). Field Procedures for analysis of Functional Feeding Groups of Stream Macroinvertebrates. Frostburg, MD. University of Maryland, Appalachian Environmental Laboratory.
- Hynes, H.V.N. (1970). The Ecology of Running Waters. Ontario, Canada: University of Toronto Press.
- Isaak Walton League of America, Inc. Save Our Streams, A Citizen Action Program. Arlington, VA.
- Klemm, Donald J. (1985). A Guide to Freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta, and Hirudinea) of North America. Dubuque, IA: Kendall/Hunt Publishing Company.
- Lehmkuhl, Dennis. (1979). How to Know the Aquatic Insects. Dubuque, IA: W.C. Brown Co.
- Mitchell, Mark K., & Stapp, William B. (1990). Field Manual for Water Quality Monitoring (4th Ed.). Dexter, MI: Thomson-Shore, Inc.
- McCafferty, P.W. (1981 and 1998). Aquatic Entomology: The Fisherman's and Ecologist's Guide to Insects and their Relatives. CA: Jones and Bartlett Publishers, Inc.
- McDonald, B., Borden, W., & Lathorp, J. (1990). Citizen Stream Monitoring: A Manual for Illinois. Springfield, IL: Illinois Department of Energy and Natural Resources.
- Meador, M.R., T. Cuffney, and M. Gurtz. (1993). Methods for Sampling Fish Communities as Part of the National Water-Quality Assessment Program. Denver, CO. U.S. Geological Survey Open-File Report 93-408.
- Merritt, Richard W., & Cummins, Kenneth W. (Eds.). (1994). An Introduction to the Aquatic Insects of North America. (2nd Ed.). Dubuque, IA: Kendall/Hunt.
- Murdoch, Tom, K. O'Laughlin, and M. Cheo. (1994). The Streamkeeper's Field Guide. Everett, WA: The Adopt-A-Stream Foundation.
- Needham, James G., & Needham, Paul R. (1992). A Guide to the Study of Freshwater Biology. San Francisco: Holden-Day.
- Page, Lawrence. (1985). The Crayfishes and Shrimps (Decapoda) of Illinois. Springfield, IL: Illinois State Museum Popular Science Series.
- Palmer, C.M. (1977). Algae and Water Pollution. Cincinnati, OH USEPA Office of Research and Development. EPA-600/9-77-036.
- Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, D.J. Conklin, Jr. (1990). Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, New York.
- Porter, S., T. Cuffney, M. Gurtz, and M. Meador. (1993). Methods for Collecting Algal Samples as Part of the National Water-Quality Assessment Program. Denver, CO: U.S. Geological Survey Open-File Report 93-409.
- Reid, George K. (1967). Pond Life - A Golden Guide. New York: Golden Press.
- Richards, Carl, Swisher, D., & Arbona, F. Jr., (1980). Stoneflies. New York: Benn Brothers.
- River Watch Network. (1993). Guide to Macroinvertebrate Sampling. Montpelier, VT: River Watch Network.
- Sloat, Sharon, & Ziel, Carol. (1992). The Use of Indicator Organisms to Assess Public Water Safety. Loveland, CO: Hach Company.
- Terrell, Charles R., & Bytnar Perfetti, Patricia. (1988). Water Quality Indicators Guide: Surface Waters. Washington, DC: U.S. Department of Agriculture, Soil and Water Conservation Service.

INTRODUCTION TO WATER QUALITY DATA ANALYSIS

Overview

One of the hardest parts of science, but commonly the most important is analyzing data collected for a research project. The sheer volume of data generated is commonly daunting and can leave someone totally confused on how to approach a vast data set. The Creek Connections schools will generate over 1000 water quality data values during this school year! The key to lifting the fog off the large data set is simply to have a question -- a question that can be answered by analyzing a part of the data set. The question can be simple: "Do phosphorus concentrations change throughout the year?"; or more complex: "Do downstream areas buffer acid rain inputs better than upstream areas during times of high stream discharge?". Once a question is chosen, decide on 1) what data to look at to answer the question, and 2) how to look at the data selected. For example, to see if phosphorus concentrations change throughout the year, it would be logical to construct a graph of phosphorus versus time (e.g. date of sample). Is there a pattern to the graph? To add confidence to any interpretation, more data should be viewed; in this case, a graph of phosphorus versus time should be constructed for several sites within the watershed.

Tentative explanations or hypotheses should be made once patterns are recognized. To develop an explanation, more research usually must be done. This research may involve looking at other data, rereading appropriate portions of this handbook, reviewing class notes and texts, finding good resources at your library, devising and conducting an additional experiment, talking with your teachers (is a statistician in the building?) or other experts in the field, or writing to or emailing Creek Connections for some advice (creek@allegheny.edu).

It is important not to be intimidated by the size of the data set; just take one step at a time. There is no need to analyze the entire data set at once or try to develop one, all-purpose explanation for a pattern. It is highly unlikely that all the data generated by Creek Connections is relevant to any single person. Select a subset of data to analyze that will enable a question to be answered. Also recall that water quality is multivariate (i.e. there are many independent controls on water quality), so that no single explanation will fully explain a pattern in the water quality data.

In summary...

1. CHOOSE A QUESTION that can be answered with the data set.
2. SELECT A PORTION OF THE DATA SET TO ANALYZE to begin to answer the question.
3. CONSTRUCT A SIMPLE GRAPH or a table that will permit you to view the data set in a logical way to answer your question.
4. LOOK FOR PATTERNS in the data.
5. ANALYZE OTHER SIMILAR DATA SETS to determine if a pattern is common.
6. DEVELOP AN EXPLANATION for the pattern.
7. TEST THE EXPLANATION by analyzing other data, by research, or by experiment.
8. ENJOY THE EXCITEMENT OF SCIENTIFIC DISCOVERY. Don't be intimidated by the large amount of data or about venturing into new topics.

Methods of Viewing Data

There are three basic ways to analyze water quality data to determine what controls or influences the values and patterns of different parameters. Water quality parameters may be analyzed:

- Parameter vs. time,
- Parameter vs. space, or
- Parameter vs. parameter.

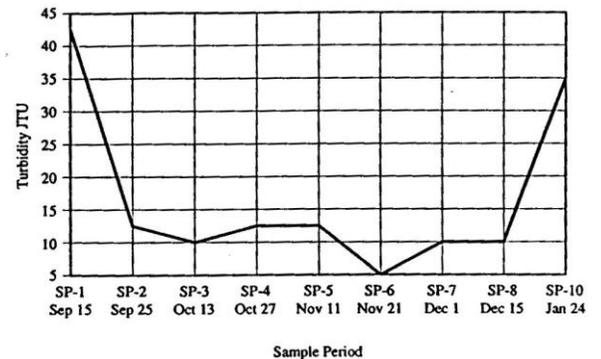
Water Quality Parameter vs. Time (sample date, season, year)

Graphing the value of a parameter versus the date of sampling (time) is one of the most basic and beneficial methods to view data. You can see how the data from one of your water tests changed throughout the school year at your field site. You can also graph a parameter over the course of a few years. Data from your field site from past years may also be available on the Creek Connections website (<http://creekconnections.alleghey.edu/DataFiles/Data.html>) This depends on how long your school has been monitoring with FCEEP. Since 1998-1999 has been a drought year, it might be worth investigating if the drought conditions affected water quality compared to non-drought years. Graphing water quality parameters vs. time can also help you decide if water quality is affected by the season of the year (summer, spring, etc.). To find out how the seasons affect water quality, you'll have to do some research. Use the FCEEP handbook and *Field Manual for Water Quality Monitoring* (by Mitchell and Stapp) to start.

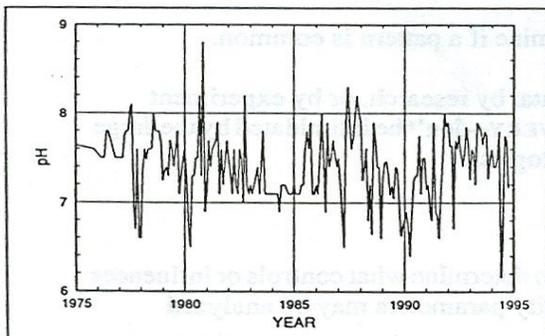
What is a **Parameter**? Any set of information that is used to describe something. The parameters of water quality would be the water tests you complete when sampling. For example, nitrates and temperature are two parameters of water quality

Example of graph displaying one site's data throughout the year.

Cambridge Springs Turbidity



Graph 2: Values of pH in French Creek for years 1975 to 1994, Meadville, PA



This graph shows fluctuations in pH for 19 years.



How would you show changes in parameters during the different seasons? What caused these changes?

Water Quality Parameter vs. Space

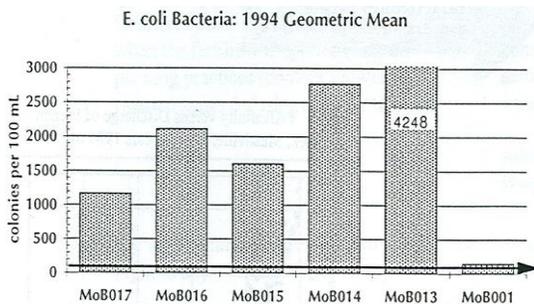
(different parts of watershed, distance along stream, different watersheds i.e. urban vs. rural)

Evaluating parameters vs. space helps reveal a story about how the land may be affecting the water quality. If your site (your space) is located next to an industrial waste dump, your water quality parameter should be influenced by it. Your site's data will be different than another school's data on the other side of the watershed because the things that affect water quality are different at each location. Maybe your site is in a forest and another school's site is in a farmer's field. The data might be different because the farmer's field is adding things to the water that are not entering the water as much in a forest.

There are MANY things that could account for differences in data between sites, so it is not easy to point to one cause. You need to address and learn about each potential component that affects water quality at a site. Because of this, drawing conclusions is more challenging. See the section on "What Affects Water Quality", then read your Creek Connections handbook and the *Field Manual for Water Quality Monitoring* (by Mitchell and Stapp) for more detailed information. Do some research.

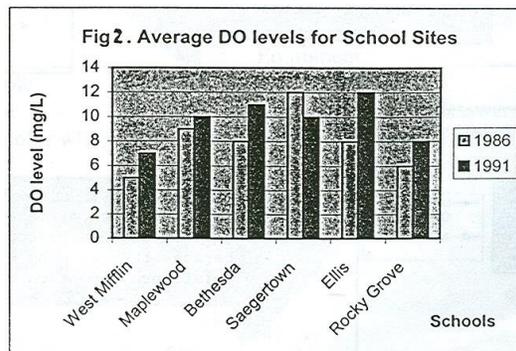
Graphs of parameters vs. space (locations within a watershed) can also reveal natural trends within a watershed. For instance, plotting the total dissolved solids at each site as water travels from the source (beginning) of a creek to the mouth (end) can show how there is a natural, chemical evolution (development) of water as it moves downstream within a watershed. Graphing data from sites on the same creek will allow you to look for upstream and downstream trends.

Comparing graphed data from two completely different regions and watersheds will also reveal some water quality stories about effects on water quality in each area. For instance, you might want to check out if the TDS levels are different between the French Creek Watershed and the Pittsburgh area schools. If so, why might this be?



This graph shows average bacteria levels at 6 different sites along the same stream.

Comparing dissolved oxygen between two different years and between 6 different sites.



- List of sites from upstream to downstream:**
- FRENCH CREEK (main stem)**
- Site 9 – Sherman
 - Site 19 – Clymer
 - Site 20* – Ft. Lebo.
 - Site 4 – C. Springs
 - Site 5* – Venango
 - Site 6 – Saegertown
 - Site 27 – Allegheny
 - Site 7 – Meadville
 - Site 21 – Cochranon
 - Site 8 – Franklin
 - Site 109 – Pittsburgh and Allegheny River
- * indicates former sites not used during 98-99

Water Quality Parameter vs. Parameter

If you create a line graph for one water quality parameter (such as temperature) and then graph the line of the second different parameter (such as dissolved oxygen) on the same graph, you might be able to interpret similar trends and patterns between the parameters. From this you can develop an explanation for the interaction between the two parameters. Be careful though, your data have to be related to one another. For the above-mentioned graph, the data needs to be from the same sampling dates and location. It would be worthless to graph 1995 dissolved oxygen data with 1998 temperature data.

If you have a large data set, a scatter (XY) graph will allow you to plot one parameter (x-axis) directly versus another parameter (y-axis). This type of graph (Fig.1 below) represents the data with dots and can represent the trend with a line.

After, you graph two water quality parameters together, look for trends and relationships between the two. If one goes up, does the other go down (*inverse relationship*), or they may both have the same increasing/decreasing pattern (*direct relationship*). Make an educated guess on why this may have happened, then do research. Look for background information and other data that had similar results. You need to conclude if the two parameters really do have a relationship with each other or if your graphed pattern is just a coincidence like Fig. 2 below. Read the this handbook and *Field Manual for Water Quality Monitoring* (by Mitchell and Stapp) to discover how different water quality parameters may affect each other.

Graph 1: Dissolved Oxygen concentrations and Temperatures of French Creek, Meadville, PA for the year 1991

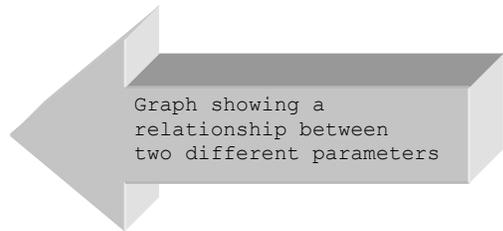
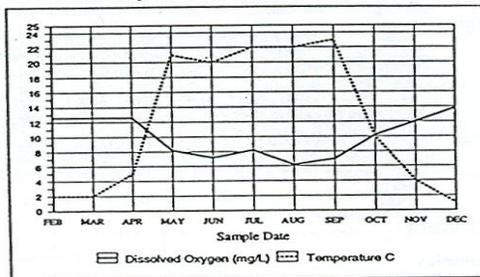
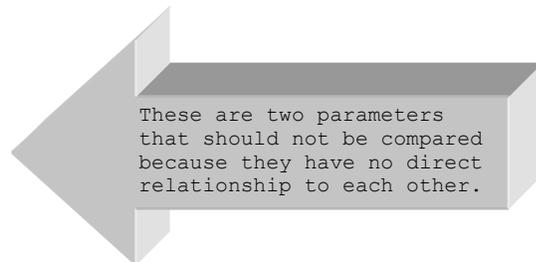
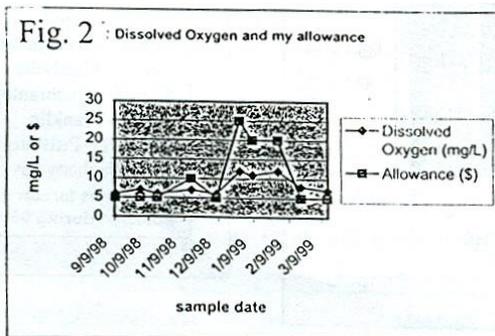
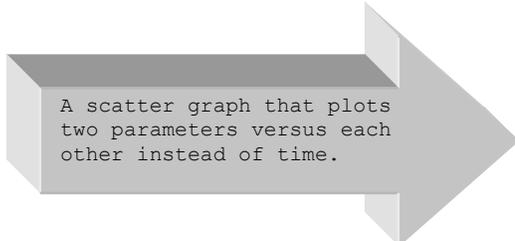
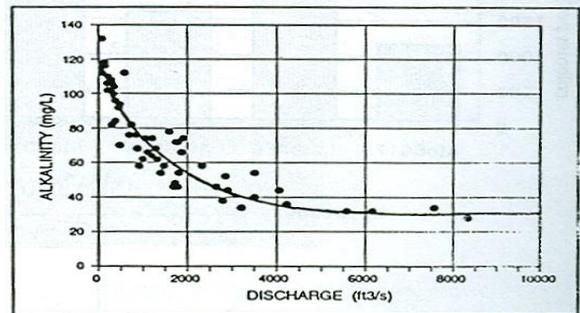
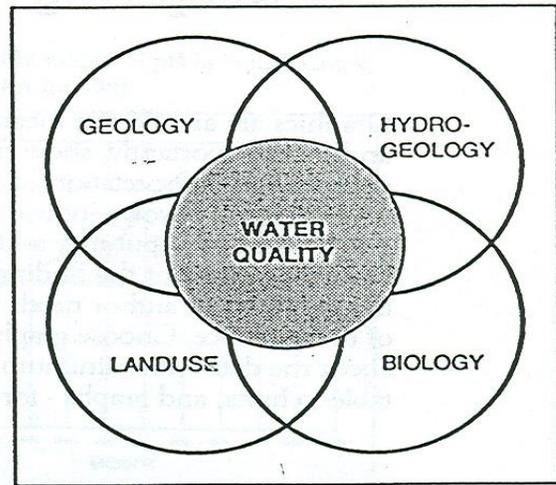


Fig. 1 : Alkalinity versus Discharge of French Creek, Meadville, PA for years 1989 to 1994.



Effects on Water Quality

The primary effects on water quality parameters tested by Creek Connections students are described in some detail in the this handbook Information Sheets for each test. The changes in water quality parameters are a function of many different natural and artificial controls, with some of the major ones listed below.



NATURAL

<u>Biological</u>	<u>Geological / Geography</u>	<u>Hydrogeological</u>
temperature	rock/ bedrock type	precipitation
streamside land plants/ types/ amount	soil/sediment type	stream discharge
aquatic plant life/ types/ amount	rock folds, fractures	groundwater influence
aquatic animal life / types/ amount	topography (flat or hills)	infiltration rates of rain
seasonal cycles of the above	drainage basin size	aquifer characteristics
day/night cycles of the above	location in watershed	

ARTIFICIAL – Land Use

<u>Agricultural</u>	<u>Urbanization</u>	<u>Industrial</u>
type of farm (animal, crops)	sewer, waste water system	point source pollution
type of crop or animal	storm runoff	water usage (taking from the stream)
fertilizer / chemical / pesticide use	pavement runoff	thermal water pollution
when the fertilizer is applied (season)	construction	acid rain
plowing practices (contour plowing?)	acid rain	industrial waste storage
riparian zones (missing or maintained?)	water usage (taking from stream)	
	salting or roads	
	lawn fertilizers, pesticides	

TIME (the above natural and artificial affects can change through time)

night to day	day to day	season to season	year to year
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SPACE (the natural and artificial affects can change from place to place)

site to site	creek to creek	watershed to watershed
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ERRORS

<u>You the Sampler</u>	<u>Equipment</u>
contaminating the sample	malfunction
mishandling the sample	dirty equipment / glassware
misjudging the result (color wheel)	limit to the range of detecting parameter
calculation mistake	
test method error	
variability is always going to happen (we are human)	

Graphing: Showing off Your Data

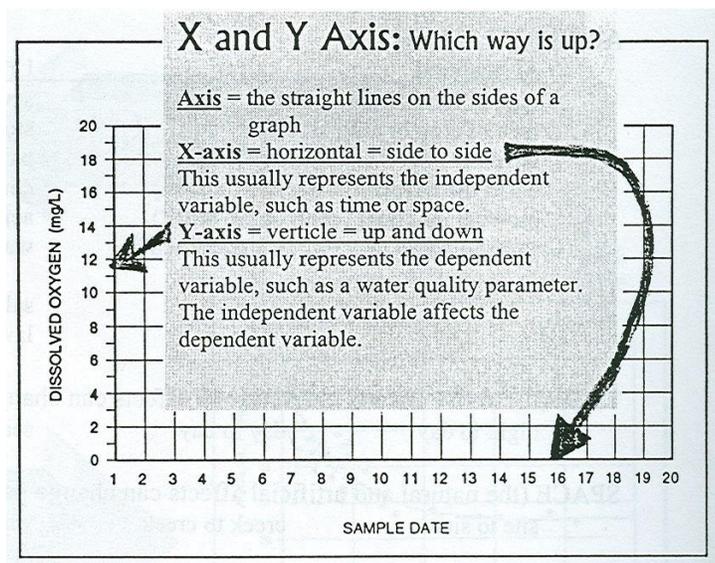
Graphics are an effective means of presenting data. Graphics clarify, reinforce, summarize and most importantly, show trends and relationships (Houp, 1988). Graphics enhance the analysis and interpretation of data, highlight text in written reports and reinforce oral presentations. Involve individuals from different segments of the program in designing graphics. Their input may add new perspectives on the data relationships and determine the best way to present the findings. Along with understanding the relationship of the numbers, the presenter or author needs to know the meeting or report objectives and the composition of the audience. Choose graphics that provide a clear picture to the viewer and tell a story about the data with minimum verbiage. Choose the right medium – photographs, maps, tables, charts, and graphs – for the message.

Table, Graph, or Text?

Clear graphs and concise, intelligible tables are as important as clear, concise writing. If your manual has not specified how you are to present your data, and you cannot state the results simply in a sentence, you must choose a table or graph – but not both for the same data. Graphs are generally more easily understood; any data that show a trend should be graphed. If there is no trend, or if exact numbers are more important, use a table.

Table 1: Drainage areas and river miles for points along French Creek

	River Mile	Drainage Area (mi ²)
Sherman, NY	89	16
Wattsburg, PA (includes West Branch French Ck)	71	193
Le Boeuf Creek	59	399
Cambridge Springs	47	577
Saegertown	38	670
Meadville (includes Cussewago Creek)	31	701
Conneaut Lake Outlet	23	926
Cochranton (includes Little Sugar Creek)	16	1027
Franklin	0	1235



Tables

Tables are a good way to organize large sets of data and categories of information that would be obscured if displayed in chart or graph form. Tables are best used in written reports rather than in speaker presentations. Readable type, logical data placement, clear concise column and row headings, and minimum use of dividing lines produce an effective display of large volumes of information.

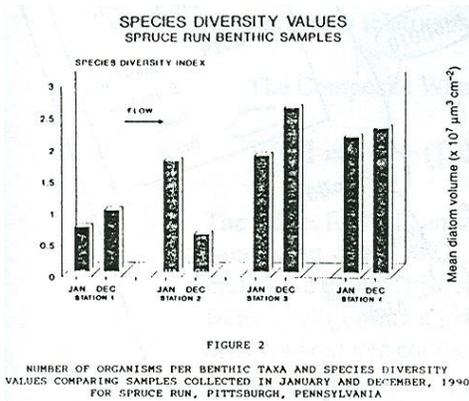
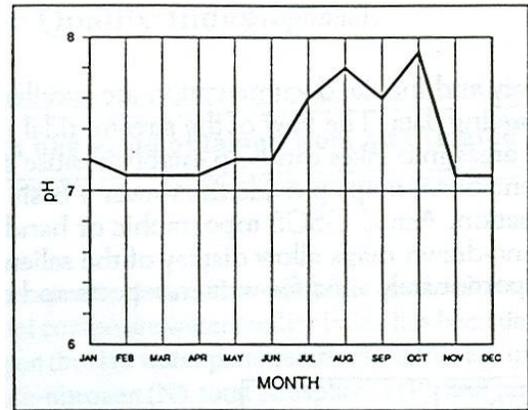
Which Type of Graph do I Use?



Line Graphs

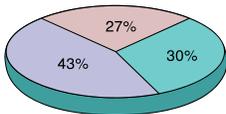
A line graph is a good way to display scientific data in order to reveal relationships and trends of parameters over time. A line graph with only one parameter line is easy to interpret, but it gives you limited information. A line graph with more than one line can be helpful with interpreting relationships between parameter data. During a sampling school year, the two lines could represent two different water tests (DO and temperature) or two different sites with the same test (DO at Cambridge Springs and Franklin). Be careful though, too many lines on a single graph can get confusing.

Graph 1: Monthly values of pH in French Creek, Meadville, PA for 1985.



Bar Graphs

Bar graphs are easily constructed and interpreted by most audiences. They compare two or more parameters (items) from place to place or over different time periods. Categories are along the x-axis (horizontal), and data values are along the y-axis (vertical). Single bar graphs for each category are the simplest, with multiple bars and divided bars portraying several comparisons at once. Pictograms use “pictures” or symbols instead of bars.



Pie Charts

Pie charts show the proportional size (%) of items that make up a data series to the total sum of the items (100%). These charts are good ways to summarize data visually when percentages would tell the story better than numbers. Pie charts can be difficult to interpret if there are numerous pie pieces, especially small pie pieces. To conquer this, graphs can be created that have a smaller whole pie representing a piece of the larger pie (see Fig 1).

PTI Analysis of Spring Creek

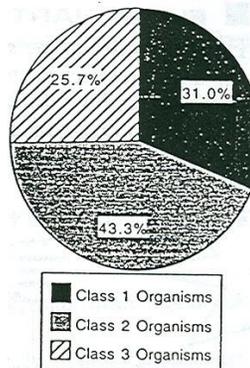
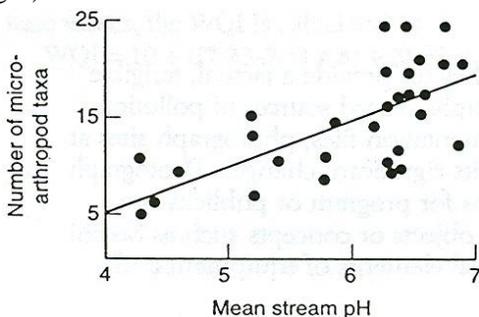
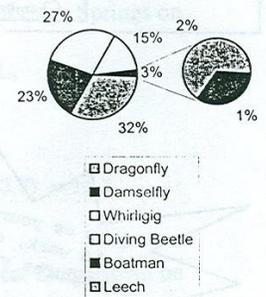


Fig.1: Bugs found in our Pond



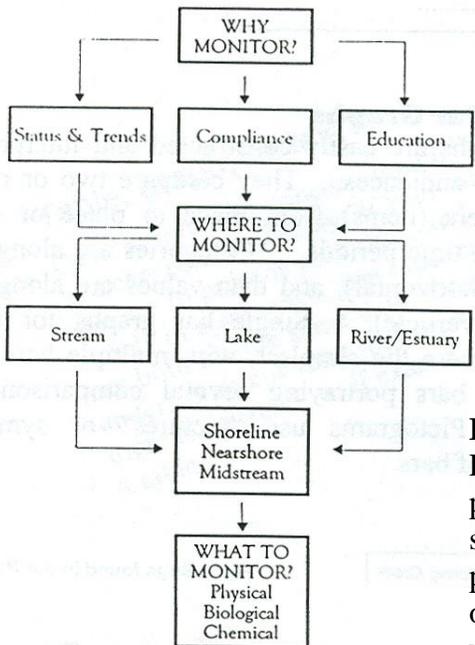
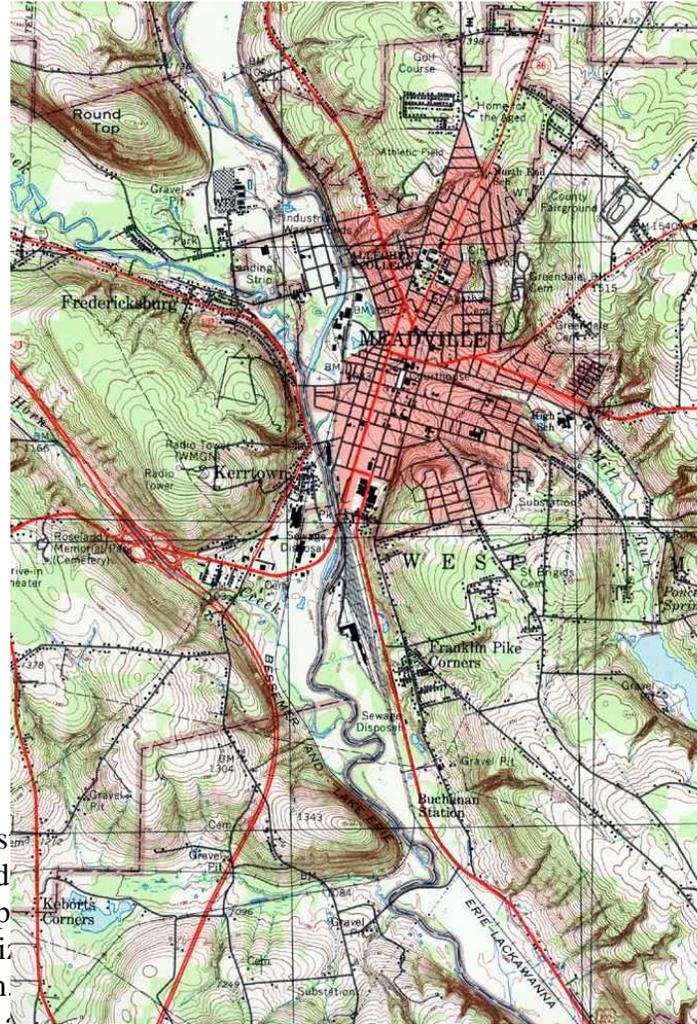
Scatter (XY) Graph

A scatter graph can be helpful to display numeric values from several data series or to plot two different parameters against each other. The specific time intervals between sampling dates are less important in these graphs and won't show up on the graph. Data is represented by dots on the graph, and the average trend, if determined, can be represented by a line.

Other Ways to Tell Your Data Story

Maps

Maps used in the survey and for site documentation are excellent visual resources when interpreting data. The flow of the stream, tidal influences in rivers and drainage areas into lakes can help establish cause and effect relationships. In presentations, maps provide the viewer a basis for understanding the situation. Actual USGS topographic or hand-drawn maps can be used. Hand-drawn maps allow display of the salient points and can be proportionately sized for written reports and oral presentations.



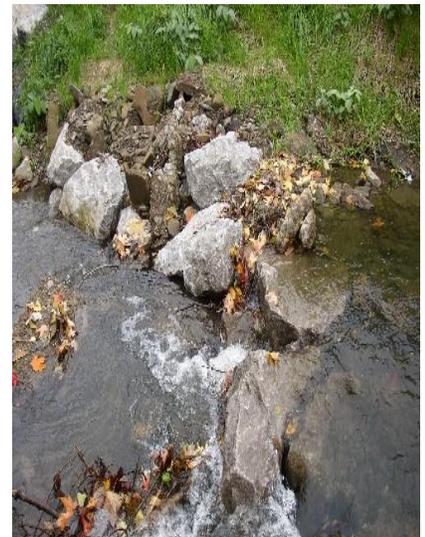
Flow Charts

Flowcharts depict the system process, such as the drainage process, stormwater runoff, sampling procedures for the organization of a monitoring program. They are useful for both technical and non-technical audiences.



Photographs and Drawings

Photographs, in themselves, do not show data. However, they do provide a factual, tangible medium to document conditions at specific times. Photographs record sources of pollution and the results of successful restoration projects. For documentation files, photograph sites at the beginning of the project, and at any time the site exhibits significant changes. Photograph monitoring equipment, the volunteers, and stream cleanups for program or publicity use. Photographs, together with drawings, can accurately depict objects or concepts such as Secchi disk measurement or watershed boundaries. Drawings reveal elements of equipment and processes not normally seen and understood.



What is what “WQI Value” on the Data Table?

Composite Water Quality Index (*optional*)

A way to sum up the water quality story with one value obtained from a calculated equation

To easily evaluate the water quality data collected by Creek Connections participants, an optional composite water quality index has been developed. The Composite Water Quality Index (WQI) is based upon the five water parameters tested that are most indicative of water quality: pH, dissolved oxygen (DO), nitrate-nitrogen (N), total phosphorus (P), and turbidity (turb). The other parameters being tested in this project, although not directly indicative of water quality, exert direct and indirect control on water quality.

Higher values of WQI indicate poorer water quality and lower values indicate better water quality. The WQI is only a relative indicator of water quality – it is not an absolute indicator of water quality.

The Composite Water Quality Index is:

$$\text{WQI} = 10 + ([\text{pH} - 7.5] \times 8) + (\text{N} \times 10) + (\text{P} \times 15) + (\text{turb.} \times 0.2) - (\text{DO} \times 0.7)$$

The values for N, P, and DO should be in mg/L; the values for turbidity should be JTU. Note that for the pH component of the WQI, the absolute value of the difference between the tested value of pH and 7.5 is multiplied by 8. This relationship is used because pH values greater than OR less than 7.5 indicate poorer water quality (thus a pH value of 6 is equivalent to a pH value of 9 with this WQI). Also note that the dissolved oxygen component of the WQI is subtracted from the equation, rather than added, because higher values of dissolved oxygen indicate better water quality (for the other components, higher values indicate poorer water quality). The purpose of the multiplication factors in the WQI expression is to equate the effect of the different ranges of values likely for the different water quality parameters tested.

Example 1:

The following values were obtained for a sample of water from French Creek in Cambridge Springs on June 6, 2005.

pH: 7.93, Nitrate-Nitrogen: 0.03 mg/L, Total Phosphorous: 0.1 mg/L,
Turbidity: 30 JTU, Dissolved Oxygen: 7.1 mg/L

For these values, the WQI is calculated as:

$$\text{WQI} = 10 + ([7.93 - 7.5] \times 8) + (0.03 \times 10) + (0.1 \times 15) + (30 \times 0.2) - (7.1 \times 0.7) = 16.3$$

Example 2:

The following values were obtained from a sample of water from Woodcock Creek near Saegertown on June 6, 2005.

pH: 7.23, Nitrate-Nitrogen: 0.03 mg/L, Total Phosphorous: 0.44 mg/L,
Turbidity: 5 JTU, Dissolved Oxygen: 7.0 mg/L

For these values, the WQI is calculated as:

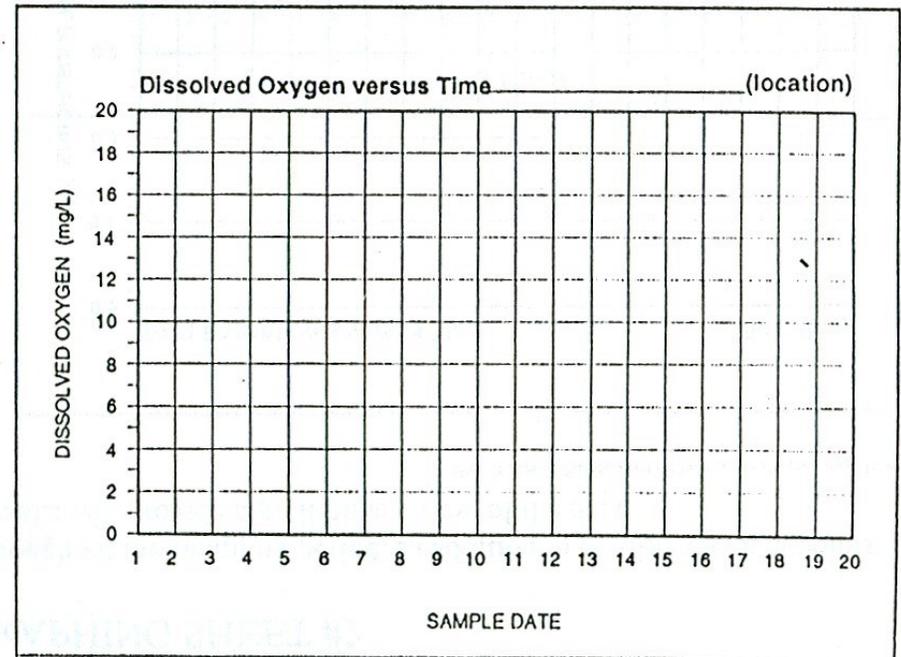
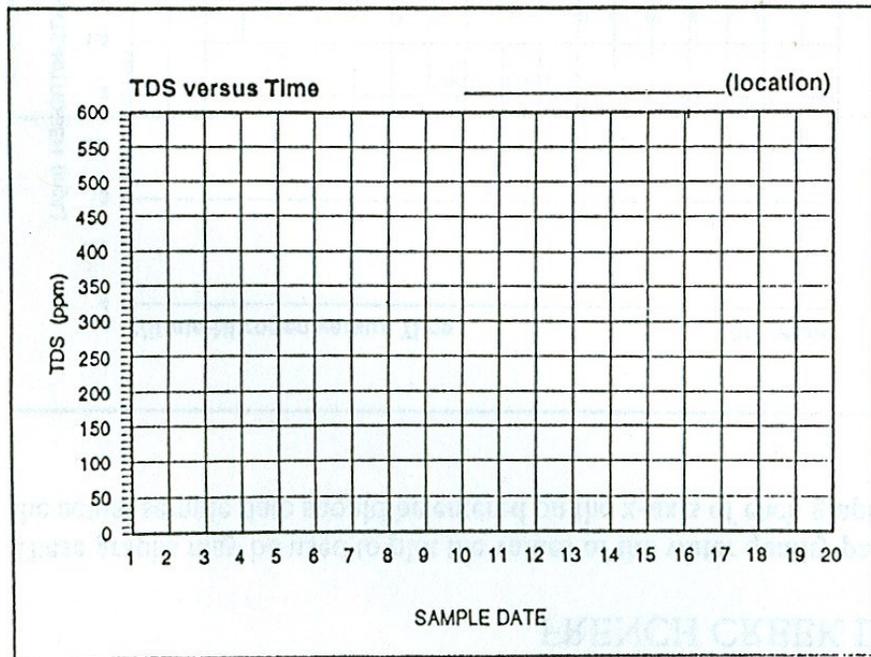
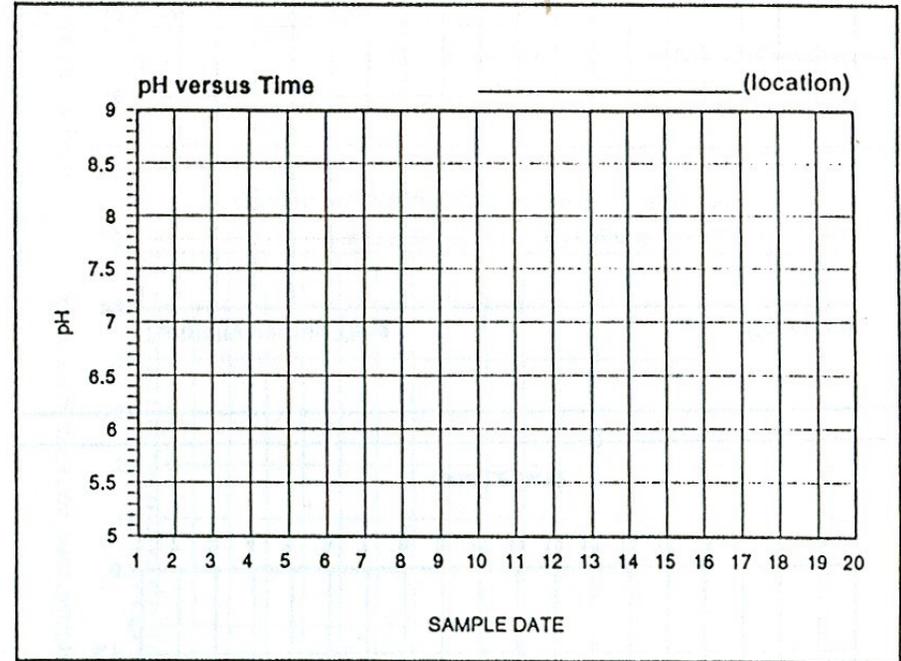
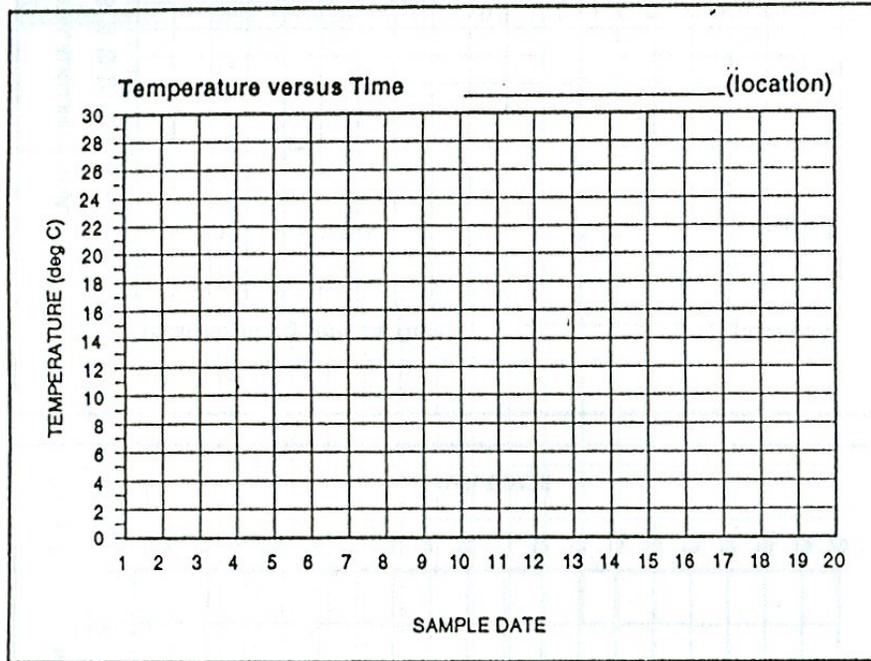
$$\text{WQI} = 10 + ([7.23 - 7.5] \times 8) + (0.03 \times 10) + (0.44 \times 15) + (5 \times 0.2) - (7.0 \times 0.7) = \mathbf{15.2}$$

Sample ID: Date, Time, & Location	Water Quality DATA RECORD Sheet												
	Field Tests					Laboratory Tests				Optional Tests			
	TEMP.	pH.	TDS	DO	STAGE	NITRATE- NITROGEN	TOTAL PHOS.	TOTAL ALK.	TURBIDIT Y	SULFATE	FERROUS IRON	WQI	Other -----
	Degrees Celsius		mg/L	mg/L	m	mg/L	mg/L	mg/L	JTU	mg/L	mg/L	--	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

* This DATA RECORD sheet should be used to record the average value calculated for each water quality parameter tested - this should be taken directly from the CREEK CONNECTIONS DATA SHEET

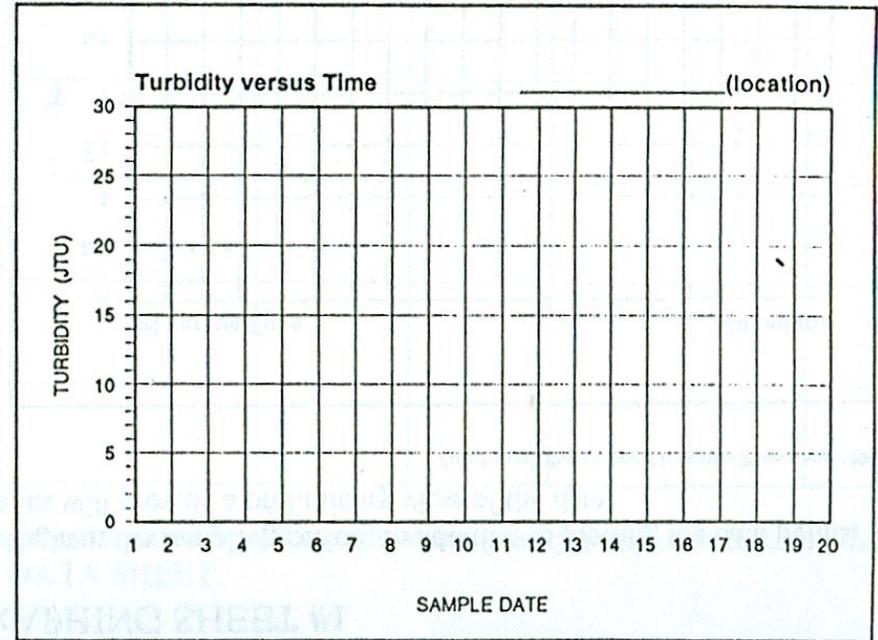
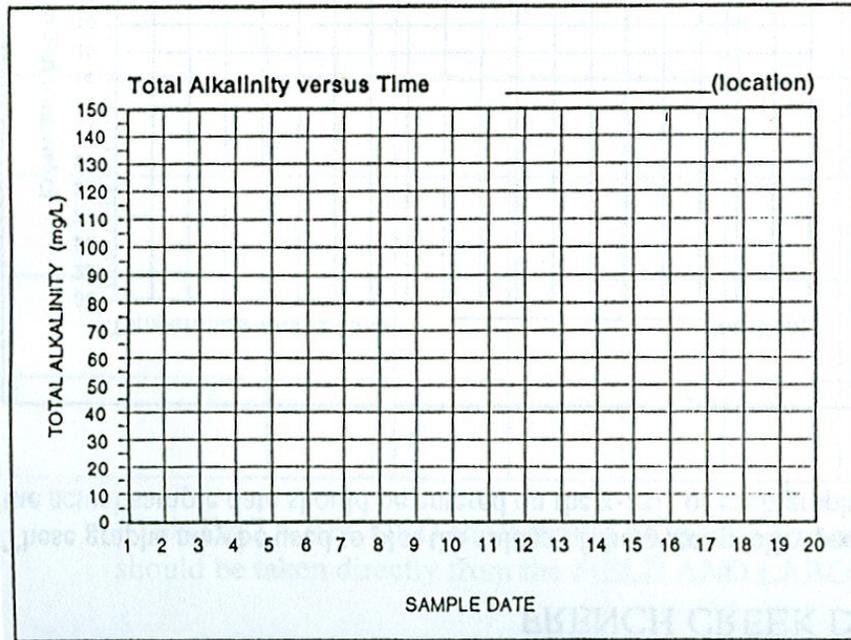
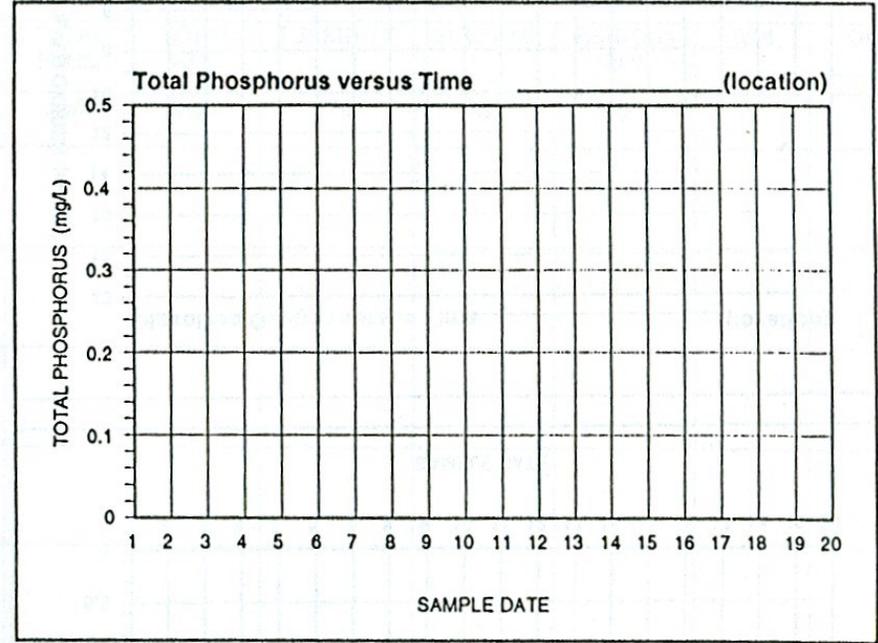
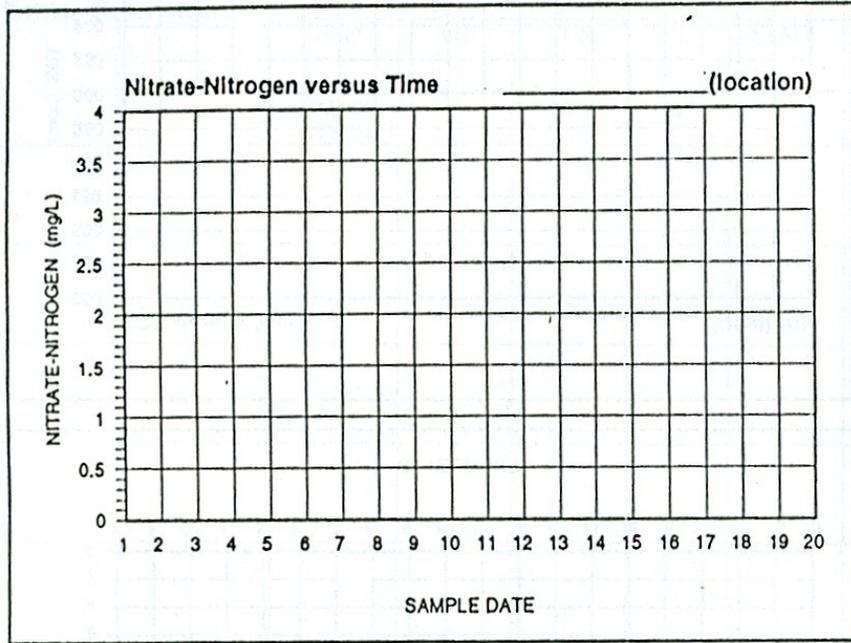
CREEK DATA GRAPHING SHEET #1

These graphs may be used to plot the values of the water quality parameters throughout the sampling period. In addition to plotting the data points, the actual sample date should be entered on the x-axis of each graph. These graphs will provide an preliminary view of the data.



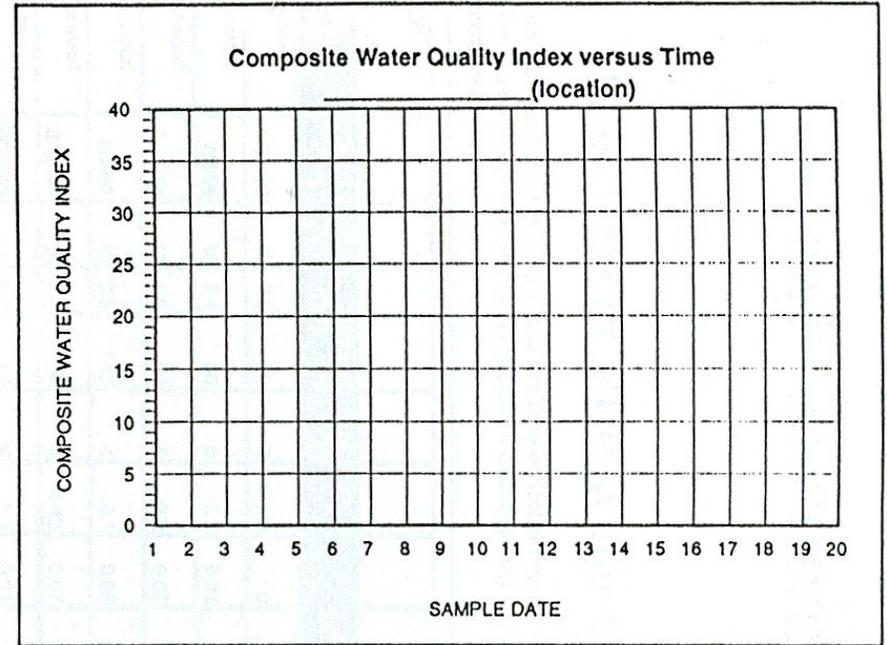
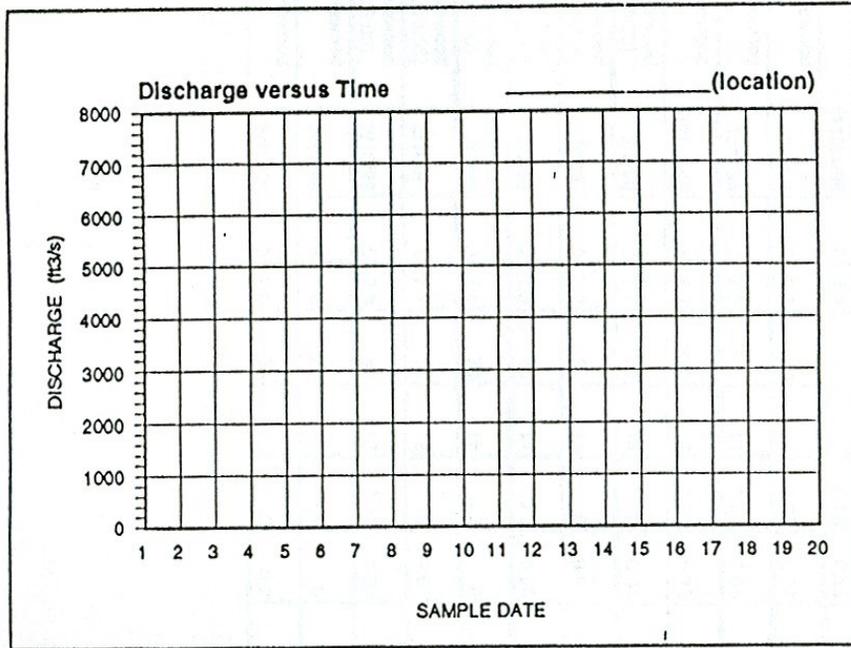
CREEK DATA GRAPHING SHEET #2

These graphs may be used to plot the values of the water quality parameters throughout the sampling period. In addition to plotting the data points, the actual sample date should be entered on the x-axis of each graph. These graphs will provide an preliminary view of the data.



CREEK DATA GRAPHING SHEET #3

These graphs may be used to plot the values of the water quality parameters throughout the sampling period. In addition to plotting the data points, the actual sample date should be entered on the x-axis of each graph. These graphs will provide an preliminary view of the data.



IDEAS FOR STUDENT DESIGNED INDEPENDENT RESEARCH PROJECTS

We encourage teachers to discuss possible independent projects with students and choose an idea(s) that meets classroom needs and interests. It's our hope that any equipment and materials purchased for the independent projects will be useful not only for Creek Connections activities but also in other classes and clubs. As with the routine water quality testing, we encourage looking for patterns and explanations of those patterns in any data collected. The topics listed below are intended to give you some ideas, but please do not feel constrained by this list. Remember, we would be happy to discuss any ideas--listed or unlisted.

Water Chemistry Studies

- ❑ Running vs. standing water - characterize differences in water quality parameters between fast-moving, slow-moving and/or standing water.
- ❑ Effect of tributary on water quality in your Stream - measure water quality parameters in French Creek upstream and downstream from a tributary, as well as in the tributary itself.
- ❑ Effect of a missing riparian buffer zone on water quality.
- ❑ Compare two tributaries with distinct land use differences.
- ❑ Compare the upstream and downstream sites of a potential pollution source (farm, sewage plant, parking lot, etc.).
- ❑ Water quality characteristics of surface water versus groundwater or versus precipitation.
- ❑ Analysis of bacterial coliform at selected sites (seasonal or between sites).
- ❑ Effect of storms on water quality characteristics - analyze water samples taken at 3 to 6 hour intervals before during and after a major precipitation event.
- ❑ Collect groundwater (well water) samples from the homes of students in the class that have wells, then determine water quality characteristics and plot trends on a map locating the sample sites.
- ❑ Research the effect that drought has on the water chemistry of your stream.
- ❑ Explore water quality parameters besides the 8 required for project testing.



Biological Studies

- You can study macroinvertebrates, crustaceans, amphibians, reptiles, fish, mussels, algae, plankton/phytoplankton, bacteria, streamside creatures, or waterway birds.
- Explore biological diversity seasonally or between sites using d-net, kick-net, Hester-Dendy samplers, Surber samplers, plankton nets or sediment grab sample.
- Compare the macroinvertebrate diversity results obtained from various sampling techniques.
- Correlate macroinvertebrates with water quality parameters and stream health.
- Compare aquatic life between two streams or two regions.
- Correlate plankton samples with season and/or water quality parameters.
- Ecological study of selected taxonomic group such as mussels, mayflies, stoneflies, etc. (characterize their distribution and abundance at your field site).
- Develop laboratory aquaria or stream tanks for the culture and study of macroinvertebrates or fish.
- Study streamside creatures and their interaction with the stream.
- Create identification guides, field guides, or a video documentary for your stream organisms.



Geological / Geographical / Land Use Studies

- ◆ Construct a 3-D topographical model of your portion of the watershed and determine its boundaries on topographical maps.
- ◆ Use a groundwater simulator and conduct/ prepare activities to illustrate groundwater principles that relate to the watershed.
- ◆ Characterize the geological substrates in your stream at your field site or other sites, identify the rocks, determine the average size of substrate, and conduct a pebble count.
- ◆ Research the geological history of the watershed and explain how different geological regions affect water quality.
- ◆ Effect of channel geomorphology on flow characteristics – map portions of different stream channels (for channel shape and pattern) and correlate with flow characteristics that are measured in the field.
- ◆ Effect of flow rate on bed material – map a reach of a stream for its channel bed materials (ex. particle size, sorting, etc.) to determine the relationship between flow rates and bed material size.
- ◆ Map your stream; include stream dynamics (riffle, run, pool, debris dams), land uses, elevations, vegetation cover, soil type, animal life, etc.
- ◆ Study the riparian zones along your waterway, the roles they play, the habitats they provide.
- ◆ Compare sites by using the Riparian, Channel, and Environmental Inventory.



Educational / Informational / Other

- ❖ Prepare photographed and drawn field guides of your field site and or portion of the watershed (including taxonomic keys).
- ❖ Prepare a video that describes the unique history, geology and/or biology of your watershed.
- ❖ Construct a calendar with informative images of your watershed and dates of ecological events witnessed.
- ❖ Prepare brochures to inform your community about the waterway resources near you.
- ❖ Dramatic performance - prepare an educational program about your waterway that your class presents to other classes or grades not participating in Creek Connections.
- ❖ Study the history of your waterway, interview elders in the community about your creek's past.
- ❖ Create a presentation about the variety of bridges that cross your waterways.
- ❖ Create educational posters, write a story or song about your waterway, or design a mural to display in your community.



Creek Connections

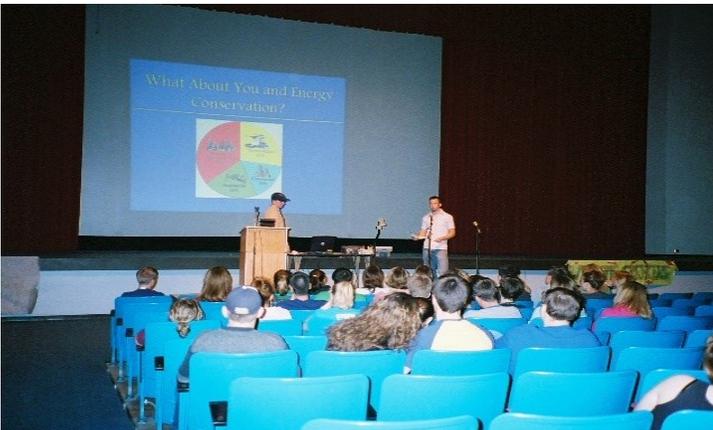
Student Research Symposia



Each April, participating schools from northwestern PA and southern NY join together at the Allegheny College Campus Center to share their research and to compare their work with others in the watershed.



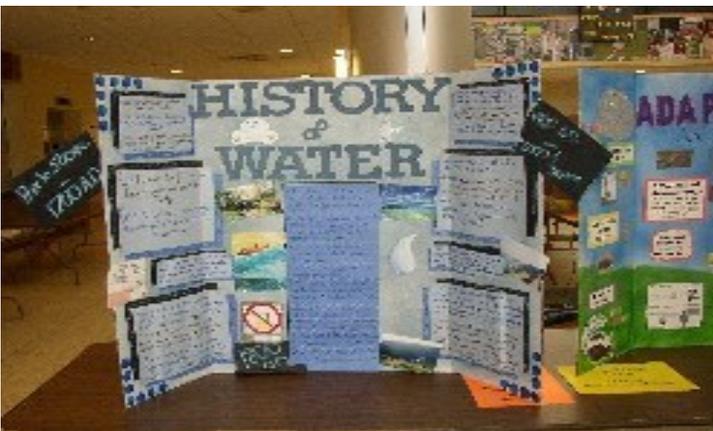
Participating Pittsburgh area schools have their own gathering at Camp Kon-O-Kwee where they can showcase what they've learned throughout the year.



Students can present their work in numerous ways: some give oral presentations which can include slideshows, videos, Power Point presentations and much more.



The students aren't limited, they can do pretty much anything their teacher approves. Here some students got creative and turned their presentation into a "fear factor" episode.



Many visual displays and poster presentations are set up to showcase the research that the schools have completed.



These visual aids allow the students to see what other classes have studied, ask questions, and compare results.



Environmental organizations are also invited to the symposium to set up educational displays. Here Tamarack Wildlife Rehabilitation Center brought some of their feathered friends to help them out for the day.



Hopefully the weather is nice because students could get an opportunity to head outside for their focus group activities.



Focus group activities provide hands on field and laboratory excursions dealing with watershed topics.



Each focus group activity is different and they all cover a wide range of topics.



Students always seem to enjoy the focus group activities, especially if they get to get a little wet!

You Know You Are Involved In CREEK CONNECTIONS When You...

ALLEGHENY COLLEGE



- ☼ Identify so many macroinvertebrates that you can see them in your sleep
- ☼ Know what eutrophication is but can't pronounce it
- ☼ See the Project Director do the mysterious riffle dance
- ☼ Know that a Hach Kit is not used to help cough up a hair ball
- ☼ Think the fish electroshocker looks like a ghost busters back pack
- ☼ Get water down your waders and it's the biggest thrill of your day
- ☼ Get to ride in the creek
- ☼ Connections minivan from sample site to site
- ☼ Tell your parents they are not disposing motor oil properly
- ☼ Question the physics behind why those tri-fold display boards never seem to fall down
- ☼ 700 students one day in April - no problem
- ☼ Lose your water analysis handbook on a weekly basis
- ☼ Refuse to eat seafood because it may be related to an endangered species in French
- ☼ Count caddisfly larva instead of sheep to fall asleep
- ☼ Get competitive when comparing water quality data with other schools
- ☼ Do extra research about the life of phytoplankton
- ☼ Realize that the nitrogen cycle is not just a fancy bike
- ☼ Learn the pickled scud is not an appetizer at Red Lobster
- ☼ Willingly write poems about environmental science
- ☼ Fight over who can do the dissolved oxygen test
- ☼ Know that riparian is not a foreign language
- ☼ Know that planarian is not an infectious disease
- ☼ Know that a mudpuppy is not a dirty dog
- ☼ Know that local foods isn't your closest grocery store
- ☼ If you risk life and limb to get a water sample from a lake
- ☼ Know a bailer isn't someone who gets you out of jail
- ☼ Learn that pickling isn't just something you do with food
- ☼ Take a class photo in hip waders

Creek Connections

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