FIELD BINDER

Based on Conference Field Binder
from the proceedings of the
Abandoned Mine Reclamation Conference - June 12, 2004 Indiana, PA

Updated November 2, 2011

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What's In Your Water? Abandoned Mine Drainage in Local Watersheds: An Education Module
Station Information (adapted from PA DEP Bureau of Water Standards Form 3800-FM-WSFR0086 Rev. 12/2008)

Date-Time-Initials: __________ - ________ - ________ Station ID: ____________________________

Location (ex. Latitude/Longitude, directions, landmarks...): ____________________________________________


County: ____________ Municipality: ____________ Topo Quad: ______________

Survey Type (see below): _____ Ch. 93 Use: ____________ Weather - Current: ____________ - Past Week: ____________


Physical Conditions (adapted from WV SOS Level one Survey Datasheet 18373 Rev. 11/2009) (circle one or more):

Water Clarity: clear, murky, milky, muddy, other       Water Color: none, brown, black, orange/red, gray/white, green
Streambed Color: brown, black, green, white/gray, orange/red       Surface Foam: none, slight, moderate, high
Water Odor: none, fishy, musky, rotten egg, sewage, chemical       Algae Abundance: none, scattered, moderate, heavy
Algae Growth Habit: even coating, hairy, matted, floating       Algae Color: light green, dark green, brown, other

Field Chemistry (adapted from WV SOS Level one Survey Datasheet 18373 Rev. 11/2009)

<table>
<thead>
<tr>
<th>Result</th>
<th>Unit</th>
<th>Result</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Temperature</td>
<td></td>
<td>Total Alkalinity</td>
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<tr>
<td>Total Iron</td>
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<td>Total Acidity</td>
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<tr>
<td>pH</td>
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<td>Dissolved Oxygen</td>
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</tbody>
</table>

Additional tests (describe and record results):

Flow Calculation (adapted from WV SOS Level one Survey Datasheet 18373 Rev. 11/2009) Channel Width/Pipe Diameter(ft):

Method Used (circle one): flow meter, float, pipe, velocity head rod (VHR)

<table>
<thead>
<tr>
<th>Tape distance (ft)</th>
<th>Depth (ft)</th>
<th>Velocity (ft/sec)</th>
<th>Float (sec)</th>
<th>VHR (Rise-inches)</th>
<th>Discharge (cfs)</th>
<th>Rise</th>
<th>Velocity</th>
<th>Rise</th>
<th>Velocity</th>
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</thead>
<tbody>
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<td>1</td>
<td>2.3</td>
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<td>4.6</td>
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<td>5</td>
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<td>1 ¼</td>
<td>2.6</td>
<td>4 ¼</td>
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<td>6</td>
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<td>1 ½</td>
<td>2.8</td>
<td>4 ½</td>
<td>4.9</td>
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<td>3.1</td>
<td>4 ¾</td>
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<td>8</td>
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<td>2</td>
<td>3.3</td>
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<td>9</td>
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<td>2 ¼</td>
<td>3.5</td>
<td>5 ¼</td>
<td>5.3</td>
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<td>10</td>
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<td>2 ½</td>
<td>3.7</td>
<td>5 ½</td>
<td>5.4</td>
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<td>Totals/Averages</td>
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<td>2 ¾</td>
<td>3.8</td>
<td>5 ¾</td>
<td>5.5</td>
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</table>

Basic Calculation: Discharge (cfs) = Width (ft) x Avg. Depth(ft) x Avg. Velocity (ft/sec.)

If you use the “float method” record your float distance here _____ (ft) and multiply by the time (recorded above) to get velocity.
If you use the “VHR method” record the rise in inches and select velocity in the chart to the right. 1 cfs = 448.83 gpm
Particle Size Descriptors: Silt (slick feel), Sand (grainy feel), Gravel (> pea), Cobble (> tennis ball), Boulder (> basketball), and Bedrock (> car).

<table>
<thead>
<tr>
<th>Habitat Parameter</th>
<th>Optimal</th>
<th>Suboptimal</th>
<th>Marginal</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Instream Cover</td>
<td>Greater than 50% mix of boulder, cobble, sub-merged logs, undercut banks, or other stable habitat.</td>
<td>30-50% mix of boulder, cobble, or other stable habitat; adequate habitat.</td>
<td>10-30% mix of boulder, cobble, or other stable habitat; habitat availability less than desirable.</td>
<td>Less than 10% mix of boulder, cobble, or other stable habitat; lack of habitat is obvious.</td>
</tr>
</tbody>
</table>

**Score: ______**

2. Epifaunal Substrate

|                        | Well developed riffle and run, riffle is as wide as stream and length extends two times the width of stream; abundance of cobble. | Riffle is as wide as stream but length is less than two times width; abundance of cobble; boulders and gravel common. | Run area may be lacking; riffle not as wide as stream and its length is less than two times the stream width; gravel or large boulders and bedrock prevalent; some cobble present. | Riffles or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking. |

**Score: ______**

3. Embeddedness

|                        | Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment (silt=slick or sand=grainy feel). | Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment. | Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment. | Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. |

**Score: ______**

4. Velocity/Depth Regimes

|                        | All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). | Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes). | Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score lower than if missing other regimes). | Dominated by 1 velocity/depth regime (usually slow-deep). |

**Score: ______**

5. Channel Alteration

|                        | No channelization or dredging present. | Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present. | New embankments present on both banks; and 40-80% of stream reach channelized and disrupted. | Banks shored gabion or cement; over 80% of the stream reach channelized and disrupted. |

**Score: ______**

6. Sediment Deposition

|                        | Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. | Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools. | Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstruction, constriction, and bends; moderate deposition of pools prevalent. | Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition. |

**Score: ______**

Total Part 1 ______
<table>
<thead>
<tr>
<th>Habitat Parameter</th>
<th>Optimal</th>
<th>Suboptimal</th>
<th>Marginal</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Frequency of Riffles</td>
<td>Occurrence of riffles relatively frequent; distance between riffles divided by the width of the stream equals 5 to 7; variety of habitat.</td>
<td>Occurrence of riffles infrequent; distance between riffles divided by the width of the stream equals 7 to 15.</td>
<td>Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of stream is between 15 to 25.</td>
<td>Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is between ratio &gt;25.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>8. Channel Flow Status</td>
<td>Water reaches base of both lower banks and minimal amount of channel substrate is exposed.</td>
<td>Water fills &gt;75% of the available channel; or &lt;25% of channel substrate is exposed.</td>
<td>Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.</td>
<td>Very little water in channel and mostly present as standing pools.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>9. Condition of Banks</td>
<td>Banks stable; no evidence of erosion or bank failure.</td>
<td>Moderately stable; infrequent, small areas of erosion mostly healed over.</td>
<td>Moderately unstable; up to 60% of banks in reach have areas of erosion.</td>
<td>Unstable; many eroded areas; “raw” areas frequent along straight sections and bends; on side slopes, 60-100% of bank has erosional scars.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>10. Bank Vegetative Protection</td>
<td>More than 90% of the streambank surface covered by vegetation.</td>
<td>70-90% of the streambank surface covered by vegetation.</td>
<td>50-70% of the streambank surfaces covered by vegetation.</td>
<td>Less than 50% of the streambank surface covered by vegetation.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>11. Grazing or Other Disruptive Pressure</td>
<td>Vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.</td>
<td>Disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.</td>
<td>Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.</td>
<td>Disruption of vegetation is very high; vegetation has been removed to 2 inches or less in average stubble height.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>12. Riparian Vegetative Zone Width</td>
<td>Width of riparian zone &gt;18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.</td>
<td>Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.</td>
<td>Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.</td>
<td>Width of riparian zone &lt;6 meters; little or no riparian vegetation due to human activities.</td>
</tr>
<tr>
<td>SCOREx (Score)</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
</tr>
</tbody>
</table>

Total Part 2 =

Total Score If < 140 for forested, cold water & high gradient (<120 for warm water low gradient), then generally impaired

Impairment Thresholds
#3 Embeddedness + #6 Sediment Deposition: _______ If < 24 (<20 for warm water low gradient), then impaired by sediment
#9 Condition of Banks + #10 Bank Vegetation: _______ If < 24 (<20 for warm water low gradient), then impaired by bank erosion

Land Use
Residential: _______ % Commercial: _______ % Industrial: _______ % Cropland: _______ % Pasture: _______ % Abd. Mining: _______ %
Old Fields: _______ % Forest: _______ % Other: _______ %
Canopy cover: open partly shaded mostly shaded fully shaded

Habitat Comments: 

Aquatic life observed or collected (other than Macro-invertebrate tally): 

_________________________
### Benthic Macro-invertebrates

(adapted from WV SOS Level One Survey Datasheet 18373)

Number after name indicates Pollution Tolerance Level: Low (1) to High (10). Use the dot dash tally method.

**Sampling Method Used?** (circle one): Std. Kick Screen, D-Frame Net, Surber Sampler, Other

**Record:** # of kinds - indicates groups where multiple kinds (families) are possible & **Abundance** - (A) > 50, (C) 5 – 50 and (R) < 5.

<table>
<thead>
<tr>
<th>Benthic Macro-invertebrates</th>
<th># of kinds</th>
<th># of kinds</th>
<th># of kinds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoneflies (2)</td>
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<tr>
<td>Mayflies (3)</td>
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<tr>
<td>Caddisflies (3)</td>
<td></td>
<td></td>
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<tr>
<td>Dragonflies (4)</td>
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<tr>
<td>Caddisflies (5)</td>
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<tr>
<td>Damselflies (7)</td>
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<tr>
<td>Hellgrammite (3)</td>
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<tr>
<td>Riffle beetle (4)</td>
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<tr>
<td>Water penny (3)</td>
<td></td>
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<tr>
<td>Rat-Tailed Maggots / Midges (8)</td>
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<tr>
<td>Watersnipe fly (3)</td>
<td></td>
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<tr>
<td>Clams (6)</td>
<td></td>
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<td></td>
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<tr>
<td>Mussel (4)</td>
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<tr>
<td>Scud/Sideswimmer (5)</td>
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<tr>
<td>Operculate snails (5) - have lid</td>
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<tr>
<td>Non-operculate snails (7) - no lid</td>
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<tr>
<td>Aquatic worm (10)</td>
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<tr>
<td>Aquatic sowbug (7)</td>
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</table>

**Total # of Kinds:**

**Date-Time-Initials:**

**Station ID:**
PASSIVE TREATMENT SYSTEM O&M INSPECTION (General)

Inspection Date: ______________________________________  Project Name:_______________________________________________________

Inspected by:________________________________________  Municipality:______________________________________________________

Organization:________________________________________  County: _________________________________________________________  State: _______

Time Start: ____________    End: _____________   Project Coordinates:  ______° _______’ _______” Lat, ______° _______’ _______” Long

Receiving Stream:________________________  Sub-watershed: ____________  Watershed: __________________________

Weather (circle one):  Snow, Heavy Rain, Rain, Light Rain, Overcast, Fair/Sunny  Ambient Temp(°F): ______

Is maintenance required? Yes/No If yes, provide explanation: _____________________________________________________________

____________________________________________________________________________________________________________________________________

INSPECTION SUMMARY

A. Site Vegetation (Uplands and Associated Slopes)
Overall condition of vegetation on site: 0 1 2 3 4 5 (0=poor, 5=excellent, circle one) (See instructions.)
Is any reseeding required? Yes/No If yes, describe area size and identify location:

____________________________________________________________________________________________________________________________________

B. Site Access and Parking
Is the access road passable for operation and monitoring? Yes/No Does vegetation hinder monitoring? Yes/No
Does the access road need maintenance? Yes/No
Describe maintenance performed and remaining (Identify location):  _____________________________________________________

____________________________________________________________________________________________________________________________________

C. Vandalism and “Housekeeping”
Is there litter around or in the passive system? Yes/No If yes, was the litter picked up? Yes/No
Is there litter that may be considered hazardous or dangerous that requires special disposal? Yes/No
Is there evidence of vandalism to the passive system? Yes/No
Additional comments: __________________________________________________________________________________________________________

D. Ditches, Channels, Spillways

<table>
<thead>
<tr>
<th>Channel Identification</th>
<th>Erosion Rills (Y/N)</th>
<th>Debris Present (Y/N)</th>
<th>Maintenance Performed (Y/N)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
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<td>In</td>
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<td>Out</td>
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</tbody>
</table>
E. Passive Treatment System Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Erosion Rills (Y/N)</th>
<th>Berms Stable (Y/N)</th>
<th>Vegetation Successful (Y/N)</th>
<th>Siltation Significant (Y/N)</th>
<th>Water Level Change (Y/N)</th>
<th>Valves Operable (Y/N)</th>
<th>Maintenance Performed and Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake</td>
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<td>Outlet</td>
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</table>

Is the intake system functioning properly? Yes/No  Does it need cleaning? Yes/No  Was it cleaned? Yes/No?
Is any flowing over the spill dam? Yes/No  Is the dam in good condition? Yes/No  Does the dam need repair? Yes/No
Are any of the pipes broken? Yes/No  Are the pipes or components free of metals buildup? Yes/No
If no, what ___% blocked?  Was the piping flushed (If possible)? Yes/No  Additional Comments: ________________
Other maintenance conducted or needed (erosion, ponds overflowing, etc): ______________________________________________________

F. Wildlife Utilization
Animals sighted or tracks observed: ________________________________________________________________
Invasive plants observed: __________________________________________________________
Describe any damage caused to by wildlife (especially muskrats) and required maintenance: ________________

G. Field Water Monitoring and Sample Collection - For passive components sample effluent. Loading requires a flow for calculation.

<table>
<thead>
<tr>
<th>Sampling Point</th>
<th>Flow (gal/min)</th>
<th>pH</th>
<th>Temp. (°F)</th>
<th>Acidity (mg/L)</th>
<th>Alkalinity (mg/L)</th>
<th>Diss. O² (mg/L)</th>
<th>Iron (mg/L)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>In</td>
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</table>

Field monitored? Yes/No  Sent to Lab? Yes/No
CHEMISTRY
Water Temperature:
1. Place thermometer in water on the edge of stream in flowing water, but away from direct current for approximately 10 minutes to obtain an accurate measurement.

Dissolved Oxygen:
1. Allow the glass-stoppered bottle to overflow for two or three minutes with the water to be tested. Fill the bottle, tilt the bottle and place the stopper such that you do not trap any air in the bottle. Air bubbles will stray results substantially.
2. Remove stopper. Use the clippers to open one pillow packet each of Dissolved Oxygen Reagent 1 and Dissolved Oxygen Reagent 2 and add both to the bottle. Tilt the bottle and replace the stopper such that you do not trap any air in the bottle. Grip the bottle and shake vigorously for approximately 30 seconds. A flocculent precipitate will form. If oxygen is present a Brownish-Orange precipitate will form. A small amount of powdered reagent may still exist at the bottom and will not affect results.
3. Allow the sample to stand until the floc has settled half way and the upper half is clear (Approximately 10 minutes). Then shake again and let settle.
4. Remove stopper and add the contents of one Dissolved Oxygen Reagent 3, carefully replace the stopper and shake to mix. The floc will dissolve and a yellow color will develop in the presence of oxygen. This is the prepared sample.
5. Fill the plastic measuring tube level-full with the prepared sample. Pour the contents of the tube into the mixing bottle.
6. Add Sodium Thiosulfate Standard Solution drop by drop to the contents of the mixing bottle. Hold the dropper vertically above the top of the bottle and swirl the bottle constantly while dispensing drops as shown in Figures 2 and 4. Count each drop as the color changes from yellow to colorless. Each drop used to bring about the color change is equal to 1 mg/L Dissolved Oxygen.

pH Test:
1. Thoroughly rinse the two plastic viewing tubes with the water sample to be tested. Viewing tubes looking from the bottom of the tube to the top there is a cloudy area etched into the middle of the tube. From the bottom of the tube to the bottom of the cloudy area is 5 mL. Fill both tubes with the water sample to the 5 mL mark.
2. Unscrew the dropper from the bottle of Wide Range 4 pH Indicator Solution. Take the dropper out from the Wide Range 4 pH Indicator Solution and hold the dropper vertically above one of the plastic viewing tubes and add 6 drops directly into the water sample as shown in Figure 2. Try not to allow the drops to drip down the sides of the plastic viewing tube. Swirl to mix.
3. Insert the prepared water sample viewing tube into the right top opening of the color comparator as shown in Figure 3.
4. Insert the untreated sample water sample viewing tube into the left top opening of the color comparator as shown in Figure 3.
5. Open the color comparator from left to right and slide the pH color disc onto the center axis with the numeric pH scale facing towards you and then close the color comparator.
6. Hold the color comparator up to a light source, such as the sky, and rotate the disc with your pointer finger until you obtain a color match in both windows viewable from the front of the color comparator. Read the pH through the scale window located in the center of the color comparator.

Free Acidity Test:
[Avoid excessive agitation of all of your water samples.]

A. High Range
1. Fill your water sample level with the top of the plastic measuring tube (~5mL). Pour your water sample from the plastic measuring tube into the mixing bottle.
2. Open a Bromcresol Green-Methyl Red Indicator Powder Pillow as shown in Figure 1. Add the contents to the mixing bottle. Stir to mix as shown in Figure 2.
   a. IF the water sample turns gray-blue or green, the Free Acidity is zero.
   b. IF the water sample turns pink, titrate with Sodium Hydroxide Standard Solution. Unscrew the dropper from the bottle of Sodium Hydroxide Standard Solution and squeeze the dropper bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the mixing bottle and begin to count
the drops you will add to the water sample, swirling the bottle after each drop, until the sample just begins to turn gray-blue.

3. Calculate the Free Acidity results of the water sample in mg/L, by multiplying the number of drops counted in Step 2b needed to bring about the color change by 17.1

**B. Low Range**

1. Fill the mixing bottle to the 15 mL mark with your water sample.
2. Open a Bromcresol Green-Methyl Red Indicator Powder Pillow as shown in Figure 1. Add the contents to the mixing bottle. Swirl to mix as shown in Figure 2.
   a. IF the water sample turns gray-blue or green, the Free Acidity is zero.
   b. IF the water sample turns pink, titrate with Sodium Hydroxide Standard Solution. Unscrew the dropper from the bottle of Sodium Hydroxide Standard Solution and squeeze the dropper bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the mixing bottle and begin to count the drops you will add to the water sample, swirling the bottle after each drop, until the sample just begins to turn gray-blue.

3. Calculate the Free Acidity results of the water sample in mg/L, by multiplying the number of drops counted in Step 2b needed to bring about the color change by 6.84

**Total Acidity Test:**
The directions for the Total Acidity Test are the same as those for Free Acidity, except use a Phenolphthalein Indicator Powder Pillow instead of a Bromcresol Green-Methyl Red Powder Pillow. The titration is carried from colorless until a light pink color forms and persists for 30 seconds in the water sample. IF the water sample turns pink upon the addition of the Phenolphthalein Indicator Powder, the Total Acidity is zero.

**Alkalinity Test:**

**A. High Range**

1. Fill your water sample level with the top of the plastic measuring tube (~5mL). Pour your water sample from the plastic measuring tube into the mixing bottle.
2. Open a Phenolphthalein Indicator Powder Pillow as shown in Figure 1. Add the contents to the mixing bottle. Swirl to mix as shown in Figure 2.
   a. IF the water sample remains colorless after the addition of the Phenolphthalein Indicator Powder Pillow, the Phenolphthalein Alkalinity is zero. If this is the case, proceed to Step 4.
   b. IF the water sample turns pink after the addition of the Phenolphthalein Indicator Powder Pillow titrate with Sulfuric Acid Standard Solution. Unscrew the dropper from the bottle of Sulfuric Acid Standard Solution and squeeze the dropper inside of the bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the mixing bottle and begin to count the drops you will add to the water sample, swirling the bottle after each drop, until the sample becomes colorless.

3. Calculate the Phenolphthalein Alkalinity results of the water sample in mg/L, by multiplying the number of drops counted in Step 2b needed to bring about the color change by 17.1
4. Add the contents of a Bromcresol Green-Methyl Red Indicator Powder Pillow to the mixing bottle. Swirl to mix as shown in Figure 2.
5. Titrate with Sulfuric Acid Standard Solution. Unscrew the dropper from the bottle of Sulfuric Acid Standard Solution and squeeze the dropper inside of the bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the mixing bottle and begin to count the drops you will add to the water sample, swirling the bottle after each drop, until the color changes from blue-green to pink.
6. Calculate the Total Methyl Orange Alkalinity results of the water sample in mg/L, by multiplying the number of drops counted in Step 5 needed to bring about the color change by 17.1

**B. Low Range**

1. Fill the mixing bottle to the 15 mL mark with your water sample.
2. Open a Phenolphthalein Indicator Powder Pillow as shown in Figure 1. Add the contents to the mixing bottle. Swirl to mix as shown in Figure 2.
   a. IF the water sample remains colorless, after the addition of the Phenolphthalein Indicator Powder Pillow, the Phenolphthalein Alkalinity is zero. If this is the case, proceed to Step 4.
   b. IF the water sample turns pink after the addition of the Phenolphthalein Indicator Powder Pillow, titrate with Sulfuric Acid Standard Solution. Unscrew the dropper from the bottle and squeeze the dropper inside of the bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the
mixing bottle and begin to count the drops you will add to the water sample, swirling the bottle after each drop, until the sample becomes colorless.

3. Calculate the Phenolphthalein Alkalinity results of the water sample in mg/L, by multiplying the number of drops counted in Step 2b needed to bring about the color change by 6.84.

4. Add the contents of a Bromcresol Green-Methyl Red Indicator Powder Pillow to the mixing bottle. Swirl to mix as shown in Figure 2.

5. Titrate with Sulfuric Acid Standard Solution. Unscrew the dropper from the bottle of Sulfuric Acid Standard Solution and squeeze the dropper inside of the bottle until the dropper is full. Take the dropper out from the bottle and hold the dropper vertically above the mixing bottle. Drop the solution into the mixing bottle and begin to count the drops you will add to the water sample, swirling the bottle after each drop, until the color changes from blue-green to pink.

6. Calculate the Total Methyl Orange Alkalinity results of the water sample in mg/L, by multiplying the number of drops counted in Step 5 needed to bring about the color change by 6.84.

Iron (Fe) Test:
1. Thoroughly rinse the two plastic viewing tubes with the water sample to be tested. Fill both tubes with the water sample to the 5 mL mark etched onto the plastic viewing tubes looking from the bottom of the tube to the top (bottom of the cloudy area). Open a FerroVer® Iron Reagent Pillow as shown in Figure 1 and add the contents to one of the plastic viewing tubes. Place a stopper in the prepared sample and shake the plastic viewing tube between your thumb and pointer finger. IF Iron is present, an orange color will develop. Wait at least 2 minutes for full color development before completing Step 5.

2. Place the plastic viewing tube of the prepared sample in the right top opening of the color comparator as shown in Figure 3.

3. Insert the untreated sample water sample viewing tube into the left top opening of the color comparator as shown in Figure 3.

4. Open the color comparator from left to right and slide the Iron color disc onto the center axis with the numeric scale facing towards you and then close the color comparator.

5. Hold the color comparator up to a light source, such as the sky, and rotate the disc with your pointer finger until you obtain a color tint match in both windows viewable from the front of the color comparator. Read the Iron results in mg/L through the scale window located in the center of the color comparator.

Iron Test Dilution Procedure: (For sites containing over 10 mg/L of Iron)
1. If your qualitative test result shows that there are 9 mg/L or more it may be necessary to verify the result with a dilution. Begin by adding 5 mL distilled demineralized water (not sample water) to the vile containing the sample and indicator from the previous test. Viewing tubes from the bottom of the tube to the top there is a cloudy area etched into the middle of the tube. From the bottom of the tube to the bottom of the cloudy area is 5 mL. The cloudy area is a second 5mL capacity.

2. Re-read the test using the Iron color wheel in the colorimeter and multiply this result by 2 to get the correct reading. (ex. After adding a second 5mL of water, the wheel now reads 8 mg/L multiply by 2 and the real result will be 16 mg/L)

3. If needed, this dilution can be done again by pouring out 5 mL of the sample and indicator water and adding another 5 mL of distilled water to make a total of 10 mL of fluids in the vile. Again, multiply your result by 2 to get the correct reading.

4. Repeat the dilution as many times as necessary to qualitatively describe the color best represented in the color wheel at the time of the dilution.

Acidification of a Sample to PA DEP:
1. Take one large sample (500 mL) and one “acidified” small sample (250 mL).
2. Mark a large red “A” on the lid of the smaller bottle with permanent marker.
3. Dip the bottles into the creek or discharge, cap and rinse several times with this water, then fill each bottle.
4. In the smaller bottle, add 3 drops of HNO3 (or another recommended acid).
5. Cap both bottles and keep in a cooler on ice until dropping them at the appropriate pick-up point.
6. Make sure you mark and have a record of which sample corresponds with which monitoring station.

Where to get test kits:

AMD Field Water Chemistry Worksheet

Date-Year: __________ Month/Day: __________ Hour/Minute: __________ Site ID: __________

Watershed Name: __________________________ Stream Name: __________________________

Site Description (Landmark?): _______________________________________________________

________________________________________________________________________________

________________________________________________________________________________

Water Temperature: __________ Dissolved Oxygen: __________ Iron: __________

Alkalinity: ______________________ pH: __________ Acidity: ______________________

Weather in past 24 hours: __________ Current Weather: __________ Air Temp. __________

Figures: Use these pictures to aide in the preparation of the tests
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FLOW
Measure and Calculate Flows

Important Equations
Flow in Cubic Feet per Second (cfs) = Cross Sectional Area (csa) X Water Velocity (v)
Cross Sectional Area (csa) = Stream Width (w) X Average Stream Depth (d)
Flow in Gallons per Minute (gpm) = Flow in Cubic Feet per Second (cfs) X 448.8

Small Streams / Discharges (< 5 ft across):

Step 1. Measure the stream’s width in feet (water’s edge to water’s edge).

Step 2. Measure the stream’s average depth by taking a depth (in feet) at every foot interval and averaging.

Step 3. Measure the stream’s velocity with either a flow probe a little more than ½ way down from the surface. No flow Meter? Use bobber and stopwatch technique (detailed below).

Step 4. Calculate \[ w \text{ (ft)} \times d \text{ (ft)} \times v \text{ (ft/sec)} = f \text{ (cfs)} \]
Example: 5’ w X 1’ d X 0.733’/s v = 3.66 cfs

Bobber and Stopwatch Technique
1. Lay out a tape measure along bank to a selected length (in this example 5 ft)
2. Time how quickly a bobber (or an orange works great too) takes to flow those 5 ft at every 1 ft interval across the stream and then average.
   \[ v = \frac{5ft}{10sec} = 0.5 \text{ cfs} \]
Measure and Calculate Flows

Head Rod Flow Estimates (*WV SOS*)

*Only works for Small Streams and Discharges < 5 ft across and 1"<18" deep:

**Important Equations**

Flow in Cubic Feet per Second (cfs) = Square Root of the Rise (ft) X 8 X Stream Width (ft)

Square Root of the Rise (ft) = Height of the "Wave" in front of the stick (n)

**Step 1. Measure the stream’s width in feet and select a point of about average depth.**

**Step 2. Measure the "Wave" in feet.**

Use a 4' long X 2" wide X 1/8" thick architect’s ruler and measure the depth on the downstream end of the ruler with the ruler placed parallel to the flow. Then turn the ruler 90 degrees so it is perpendicular to the flow and measure the height of the wave that forms in front of the upstream end of the ruler.

**Step 3. Calculate the sq. rt. of n (ft) X 8 X w (ft) = estimated flow (cfs)**

**Larger Streams / Discharges (> 5 ft across)**

Very similar to how you calculate flow in a small stream, except you may want to be more precise by taking a velocity and depth at every 1-3 ft intervals across the stream.

**Total width in feet should equal the number of stations**
Measure and Calculate Flows

Example 1:
10 ft wide stream – take width and depth at every foot interval across stream then add every cfs.

<table>
<thead>
<tr>
<th>Station</th>
<th>Velocity</th>
<th>Depth</th>
<th>cfs (1 w X v X d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1'</td>
<td>0.43</td>
<td>0.56</td>
<td>0.2408</td>
</tr>
<tr>
<td>2'</td>
<td>0.52</td>
<td>0.43</td>
<td>0.2236</td>
</tr>
<tr>
<td>3'</td>
<td>0.71</td>
<td>1.70</td>
<td>1.207</td>
</tr>
<tr>
<td>4'</td>
<td>0.86</td>
<td>0.56</td>
<td>0.4816</td>
</tr>
<tr>
<td>5'</td>
<td>0.34</td>
<td>0.43</td>
<td>0.1462</td>
</tr>
<tr>
<td>6'</td>
<td>0.90</td>
<td>0.89</td>
<td>0.801</td>
</tr>
<tr>
<td>7'</td>
<td>0.49</td>
<td>0.78</td>
<td>0.3822</td>
</tr>
<tr>
<td>8'</td>
<td>0.50</td>
<td>0.53</td>
<td>0.265</td>
</tr>
<tr>
<td>9'</td>
<td>0.87</td>
<td>0.45</td>
<td>0.3915</td>
</tr>
<tr>
<td>10'</td>
<td>0.23</td>
<td>0.23</td>
<td>0.0529</td>
</tr>
<tr>
<td><strong>Total cfs</strong></td>
<td></td>
<td></td>
<td><strong>4.1918</strong></td>
</tr>
<tr>
<td><strong>Total gpm</strong></td>
<td></td>
<td></td>
<td><strong>1881.28</strong></td>
</tr>
</tbody>
</table>

Example 2:
30 ft wide stream – take width and depth at every three foot interval across stream then add every cfs.

<table>
<thead>
<tr>
<th>Station</th>
<th>Velocity</th>
<th>Depth</th>
<th>cfs (1 w X v X d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3'</td>
<td>0.43</td>
<td>0.56</td>
<td>0.7224</td>
</tr>
<tr>
<td>6'</td>
<td>0.52</td>
<td>0.43</td>
<td>0.6708</td>
</tr>
<tr>
<td>9'</td>
<td>0.71</td>
<td>1.70</td>
<td>3.621</td>
</tr>
<tr>
<td>12'</td>
<td>0.86</td>
<td>0.56</td>
<td>1.4448</td>
</tr>
<tr>
<td>15'</td>
<td>0.34</td>
<td>0.43</td>
<td>0.4386</td>
</tr>
<tr>
<td>18'</td>
<td>0.90</td>
<td>0.89</td>
<td>2.403</td>
</tr>
<tr>
<td>21'</td>
<td>0.49</td>
<td>0.78</td>
<td>1.1466</td>
</tr>
<tr>
<td>24'</td>
<td>0.50</td>
<td>0.53</td>
<td>0.795</td>
</tr>
<tr>
<td>27'</td>
<td>0.87</td>
<td>0.45</td>
<td>1.1745</td>
</tr>
<tr>
<td>30'</td>
<td>0.23</td>
<td>0.23</td>
<td>0.1587</td>
</tr>
<tr>
<td><strong>Total cfs</strong></td>
<td></td>
<td></td>
<td><strong>4.1918</strong></td>
</tr>
<tr>
<td><strong>Total gpm</strong></td>
<td></td>
<td></td>
<td><strong>1881.28</strong></td>
</tr>
</tbody>
</table>

Weirs:
90° or 2 ft and 4 ft rectangular weirs

Step 1. Measure height of water over notch in inches or feet and use chart to figure out flow.
### Measure and Calculate Flows

<table>
<thead>
<tr>
<th>Water Height (in)</th>
<th>Water Height (ft)</th>
<th>90o cfs</th>
<th>90o gpm</th>
<th>2' cfs</th>
<th>2' gpm</th>
<th>4' cfs</th>
<th>4' gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.04</td>
<td>0.001</td>
<td>0.54</td>
<td>0.056</td>
<td>25.32</td>
<td>0.113</td>
<td>50.74</td>
</tr>
<tr>
<td>0.6</td>
<td>0.05</td>
<td>0.002</td>
<td>0.85</td>
<td>0.074</td>
<td>33.25</td>
<td>0.149</td>
<td>66.67</td>
</tr>
<tr>
<td>0.7</td>
<td>0.06</td>
<td>0.003</td>
<td>1.24</td>
<td>0.093</td>
<td>41.87</td>
<td>0.187</td>
<td>83.98</td>
</tr>
<tr>
<td>0.8</td>
<td>0.07</td>
<td>0.004</td>
<td>1.72</td>
<td>0.114</td>
<td>51.11</td>
<td>0.229</td>
<td>102.56</td>
</tr>
<tr>
<td>0.9</td>
<td>0.08</td>
<td>0.005</td>
<td>2.30</td>
<td>0.136</td>
<td>60.93</td>
<td>0.273</td>
<td>122.33</td>
</tr>
<tr>
<td>1.0</td>
<td>0.08</td>
<td>0.007</td>
<td>2.99</td>
<td>0.159</td>
<td>71.31</td>
<td>0.319</td>
<td>143.21</td>
</tr>
<tr>
<td>1.1</td>
<td>0.09</td>
<td>0.008</td>
<td>3.78</td>
<td>0.183</td>
<td>82.19</td>
<td>0.368</td>
<td>165.15</td>
</tr>
<tr>
<td>1.2</td>
<td>0.10</td>
<td>0.010</td>
<td>4.68</td>
<td>0.209</td>
<td>93.58</td>
<td>0.419</td>
<td>188.10</td>
</tr>
<tr>
<td>1.3</td>
<td>0.11</td>
<td>0.013</td>
<td>5.71</td>
<td>0.235</td>
<td>106.42</td>
<td>0.472</td>
<td>212.00</td>
</tr>
<tr>
<td>1.4</td>
<td>0.12</td>
<td>0.015</td>
<td>6.85</td>
<td>0.262</td>
<td>117.72</td>
<td>0.528</td>
<td>236.83</td>
</tr>
<tr>
<td>1.5</td>
<td>0.13</td>
<td>0.018</td>
<td>8.12</td>
<td>0.291</td>
<td>130.45</td>
<td>0.585</td>
<td>262.54</td>
</tr>
<tr>
<td>1.6</td>
<td>0.13</td>
<td>0.021</td>
<td>9.52</td>
<td>0.320</td>
<td>143.58</td>
<td>0.644</td>
<td>288.11</td>
</tr>
<tr>
<td>1.7</td>
<td>0.14</td>
<td>0.025</td>
<td>11.06</td>
<td>0.350</td>
<td>157.12</td>
<td>0.705</td>
<td>315.60</td>
</tr>
<tr>
<td>1.8</td>
<td>0.15</td>
<td>0.028</td>
<td>12.73</td>
<td>0.381</td>
<td>171.04</td>
<td>0.768</td>
<td>344.69</td>
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<tr>
<td>1.9</td>
<td>0.16</td>
<td>0.032</td>
<td>14.55</td>
<td>0.413</td>
<td>185.35</td>
<td>0.833</td>
<td>373.65</td>
</tr>
</tbody>
</table>

90° Reference Temperature
STREAM ORGANISM COLLECTION
TECHNIQUES

ROCK FLIPPING
Have a partner close at hand with a basin. Pick-up a rock (rocks should be 3-8 inches in diameter, in flowing water works best) and flip it over the basin. Some stream invertebrates will quickly move off the rock and others seem permanently attached. Flush and brush as many organisms as possible into the basin and transfer to a sorting tray.

LEAF-PACK PICKING
Have a partner close at hand with a basin. Pick-up a leaf pack and quickly transfer it to a net. Rinse the net in the stream and empty into a basin. Flush and brush each leaf individually to remove all attached and free-swimming organisms and transfer to a sorting tray.

KICK-NET
Have a partner stand about 1 foot downstream from you. The partner holds a D-Frame net or a cloth stretched between two poles. You will kick the substrate and/or disturb it with your hands to cause organisms to float downstream and get caught in the net. Work within a defined area for a set amount of time and then transfer the contents of the net into a sorting tray. Note whether you are in a riffle zone (i.e. where water flows over rocks), deposition area (i.e. where water flows more slowly and small particles accumulate), or some other part of the stream.
Macroinvertebrate Sampling

Preparing to collect:

Because macroinvertebrates have adapted to survive in a variety of stream conditions, all habitats need to be sampled. *The preservative in the sample collection jars is rubbing alcohol.*

Where possible, three samples from at least three different (preferably all) habitats listed below need to be collected. The total site will be counted as one composite sample, so all the macroinvertebrates can be put into the same jar, regardless of where you found them.

<table>
<thead>
<tr>
<th>Most Diverse Habitat</th>
<th>Least Diverse Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riffles Leaf</td>
<td>Sediments</td>
</tr>
<tr>
<td>packs</td>
<td></td>
</tr>
<tr>
<td>Tree roots, snags, and submerged logs</td>
<td></td>
</tr>
<tr>
<td>Undercut banks (overhanging vegetation)</td>
<td></td>
</tr>
<tr>
<td>Submerged macrophytes (aquatic plants)</td>
<td></td>
</tr>
</tbody>
</table>

Crayfish, *live* clams, and *live* snails need only be counted and released. **DO NOT preserve** them in the alcohol! Empty shells tell us nothing about the current stream condition (we don't know when they died), so they are not counted.

A sample bottle and forceps should be carried by the volunteers in the stream to facilitate collecting fast moving organisms.

1. Survey a 300 foot stream stretch. If it is at a road crossing, sample upstream of the road.
2. Determine a plan of attack for collection sites based upon the above habitat chart.
3. Start at the downstream-most point, and work upstream so you always work into undisturbed water.
4. To make collection easier, the order of sampling sites may be mixed and collected in the same net load. For example: undercut bank, riffle, macrophyte, empty net, riffle, etc. Remember that everything is going into the same batch, so order doesn't matter. Do what is easiest for you.

**Keys to easier "picking" are**
- Patience!
- Look for movement
Riffles

1. Select the fastest and slowest moving areas of the riffle. Organisms collected from both these sites will constitute one riffle sample.

2. Begin at the downstream end of the reach to be sampled and work upstream. This keeps the working area undisturbed.

3. With the net opening facing upstream, place the bottom of the net flush on the stream bottom immediately downstream from the riffle. Position the handle perpendicular to the stream flow.

4. While the first volunteer ("netter") holds the net, the second ("collector") picks up large rocks (2 inch or greater diameter) within a 1 foot by 1 foot area directly in front of the net opening and gently rubs them in the net opening to remove any clinging organisms. Be sure to hold the rock under water in front of the net.

5. Gently place the cleaned rocks outside the sampling area.

6. When all the stones (or as many as possible) are removed from the sample area, the "collector" stands approximately one foot upstream of the net opening and kicks the stream bed vigorously to dislodge any remaining organisms into the net.

7. Kick down approximately two inches (approximately one to two minutes) while moving toward the net.

8. When done kicking, the "netter" sweeps the net in an upward fashion to collect the organisms.

Note: If the net is relatively empty after sampling at the first station, steps 9 - 12 may be skipped and the net emptied (according to steps 9 - 12) only as necessary.

9. Carry the net to the shoreline.

10. While the "collector" holds the sampling pan, the "netter" empties the net's contents into the tray.

11. Using the squirt bottle filled with stream water, rinse the inside of the net into the tray to collect all the organisms.

12. Remove any clinging organisms and place them directly into a sampling jar.

13. Collect a total of three riffle samples by repeating steps 1 - 12.
Leaf Pack

1. Look for leaves that are about four to six months old. These old leaf packs are dark brown and slightly decomposed. Only a handful of leaves is necessary.

2. Begin at the downstream end of the reach to be sampled and work upstream. This keeps the working area undisturbed.

3. With the net opening facing upstream, place the bottom of the net flush on the stream bottom immediately downstream from the leaf pack. Position the handle perpendicular to the stream flow.

4. Gently shake the leaf pack in the water to release some of the organisms, then quickly scoop up the net, capturing both organisms and the leaf pack in the net.

Note: If the net is relatively empty after sampling at the first station, steps 5 - 8 may be skipped and the net emptied (according to steps 5 - 8) only as necessary.

5. Carry the net to the shoreline.

6. While the "collector" holds the sampling pan, the "netter" empties the net's contents into the tray.

7. Using the squirt bottle filled with stream water, rinse the inside of the net into the tray to collect all the organisms.

8. Remove any clinging organisms and place them directly into a sampling jar.

9. Collect a total of three leaf pack samples by repeating steps 1 - 8.
Tree Roots, Snags, and Submerged Logs

Snags are accumulations of debris caught or "snagged" by logs or boulders lodged in the stream current. Caddisflies, stoneflies, riffle beetles, and midges commonly inhabit these areas.

1. Select an area on the tree roots, snag, or submerged logs which is approximately 3 feet by 3 feet in size.

2. Begin at the downstream end of the reach to be sampled and work upstream. This keeps the working area undisturbed.

3. Scrape the surface of the tree roots, logs, or other debris with the net while on the downstream side of the snag. You can also disturb such surfaces by scraping them with your foot or large stick, or by pulling off some of the bark to get at the organisms hiding underneath. In all cases, be sure that the net is positioned downstream from the snag, so that dislodged material floats into the net.

4. You may remove a log from the water to better sample from it, but be sure to replace it when you are done.

Note: If the net is relatively empty after sampling at the first station, steps 5 - 8 may be skipped and the net emptied (according to steps 5 - 8) only as necessary.

5. Carry the net to the shoreline.

6. While the "collector" holds the sampling pan, the "netter" empties the net's contents into the tray.

7. Using the squirt bottle filled with stream water, rinse the inside of the net into the tray to collect all the organisms.

8. Remove any clinging organisms and place them directly into a sampling jar.

9. Collect a total of three tree root samples by repeating steps 1 - 8.
Undercut Bank and Overhanging Vegetation

Undercut banks are areas where moving water has cut out vertical or nearly vertical banks, just below the surface of the water. In such areas you will find overhanging vegetation and submerged root mats that harbor dragonflies, damselflies, and crayfish. Note: Do not collect crayfish in sample jars, simply note their presence and number.

1. Place the net below the surface under the overhanging vegetation.

2. Move the net in a bottom-up motion, jabbing at the bank five times in a row to loosen organisms.

Note: If the net is relatively empty after sampling at the first station, steps 3 - 6 may be skipped and the net emptied (according to steps 3 - 6) only as necessary.

3. Carry the net to the shoreline.

4. While the "collector" holds the sampling pan, the "netter" empties the net's contents into the tray.

5. Using the squirt bottle filled with stream water, rinse the inside of the net into the tray to collect all the organisms.

6. Remove any clinging organisms and place them directly into a sampling jar.

7. Collect a total of three undercut bank samples by repeating steps 1 - 6.
Sediments

Areas of mostly sand and / or mud can usually be found on the edges of the stream, where water flows more slowly.

1. A netter stands downstream of the sediment area with the dip net resting on the bottom. A collector disturbs the sediment to a depth of about two inches as he or she approaches the net.

2. The netter sweeps the net upward to collect the organisms as the kicker approaches.

3. Keeping the opening of the net at least an inch or two above the surface of the water, wash out the sediment from the net by gently moving the net back and forth in the water of the stream.

Note: If the net is relatively empty after sampling at the first station, steps 4 - 7 may be skipped and the net emptied (according to steps 4 - 7) only as necessary.

4. Carry the net to the shoreline.

5. While the "collector" holds the sampling pan, the "netter" empties the net's content into the tray.

6. Using the squirt bottle filled with stream water, rinse the inside of the net into the tray to collect all the organisms.

7. Remove any clinging organisms and place them directly into a sampling jar.

8. Collect a total of three sediment samples by repeating steps 1 - 7.
## Virginia Save Our Streams Macroinvertebrate Tally Sheet

<table>
<thead>
<tr>
<th>Macroinvertebrates</th>
<th>Tally</th>
<th>Count</th>
<th>Macroinvertebrates</th>
<th>Tally</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worms</td>
<td></td>
<td></td>
<td>Common Netspiders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat-Worms</td>
<td></td>
<td></td>
<td>Most Caddisflies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leeches</td>
<td></td>
<td></td>
<td>Beetles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crayfishes</td>
<td></td>
<td></td>
<td>Midges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sowbugs</td>
<td></td>
<td></td>
<td>Black Flies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scuds</td>
<td></td>
<td></td>
<td>Most True Flies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stoneflies</td>
<td></td>
<td></td>
<td>Gilled Snails</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mayflies</td>
<td></td>
<td></td>
<td>Lunged Snails</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dragonflies and Damselflies</td>
<td></td>
<td></td>
<td>Clams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hellgrammites, Fishflies, and Alderflies</td>
<td></td>
<td></td>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total number of organisms in the sample


Fig. 3. New field sheets developed for use in the modified Virginia Save-Our-Streams protocol. (A) Sheet for identifying macroinvertebrates and recording counts.
### Individual Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Number</th>
<th>Total number of organisms in the sample</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayflies + Stoneflies + Most Caddisflies</td>
<td>Divide by</td>
<td>Multiply by 100</td>
<td></td>
</tr>
<tr>
<td>Common Netspinners</td>
<td>Divide by</td>
<td>Multiply by 100</td>
<td></td>
</tr>
<tr>
<td>Lunged Snails</td>
<td>Divide by</td>
<td>Multiply by 100</td>
<td></td>
</tr>
<tr>
<td>Beetles</td>
<td>Divide by</td>
<td>Multiply by 100</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3. (B) Sheet for calculating individual metrics.**

### Save Our Streams Multimetric Index

Determine whether each metric should get a score of 2, 1, or 0. Write your metric value from the previous page in the 2nd column (Your Metric Value). Put a check in the appropriate boxes for 2, 1, or 0. Then calculate the subtotals and Save Our Streams Multimetric Index score and determine whether the site has acceptable or unacceptable ecological condition.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Your Metric Value</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Mayflies + Stoneflies + Most Caddisflies</td>
<td>Greater than 32.2</td>
<td>16.1 - 32.2</td>
<td>Less than 16.1</td>
<td></td>
</tr>
<tr>
<td>% Common Netspinners</td>
<td>Less than 19.7</td>
<td>19.7 - 34.5</td>
<td>Greater than 34.5</td>
<td></td>
</tr>
<tr>
<td>% Lunged Snails</td>
<td>Less than 0.3</td>
<td>0.3 - 1.5</td>
<td>Greater than 1.5</td>
<td></td>
</tr>
<tr>
<td>% Beetles</td>
<td>Greater than 6.4</td>
<td>3.2 - 6.4</td>
<td>Less than 3.2</td>
<td></td>
</tr>
<tr>
<td>% Tolerant</td>
<td>Less than 46.7</td>
<td>46.7 - 61.5</td>
<td>Greater than 61.5</td>
<td></td>
</tr>
<tr>
<td>% Non-Insects</td>
<td>Less than 5.4</td>
<td>5.4 - 20.8</td>
<td>Greater than 20.8</td>
<td></td>
</tr>
</tbody>
</table>

Now add the 3 subtotals to get the Save Our Streams Multimetric Index score:

- Acceptable ecological condition (7 to 12)
- Unacceptable ecological condition (0 to 6)

**Fig. 3. (C) Sheet for calculating new Virginia (USA) Save-Our-Streams multimetric index and determining the category of ecological condition.**
KEYS TO THE FAMILIES OF AQUATIC INSECTS

Keys extracted from

Aquatic Entomology

Written by
W.P. McCafferty

Illustrations by
A.V. Provonsa
MAYFLIES

Figure 7.5. MATURE EPHEMEROPTERA LARVAE

THORAX ROBUST WITH NOTUM FUSED BETWEEN FORE WING PADS FOR AT LEAST HALF LENGTH OF PADS; GILLS ON ABDOMINAL SEGMENT 2 EITHER ABSENT, CONCEALED, OR OPERCULATE

THORACIC NOTUM CARAPACELIKE AND COVERING MUCH OF ABDOMEN

Baetiscidae (p. 122)

GILLS ON ABDOMINAL SEGMENT 2 ROUNDED OR TRIANGULAR

Tricorythidae (p. 119)

THORACIC NOTUM NOT COVERING MOST OF ABDOMEN

GILLS ON ABDOMINAL SEGMENT 2 ABSENT

Ephemerellidae (p. 118)

GILLS ON ABDOMINAL SEGMENT 2 PRESENT AND OPERCULATE

GILLS ON ABDOMINAL SEGMENT 2 QUADRATE

TUSKS WITH NO SPINES IN DISTAL HALF

Ephemeridae (p. 115)

ABDOMINAL GILLS 2–7 DOUBLE, ELONGATE, WITH FRINGED MARGINS

ABDOMINAL GILLS 2–7 NEVER DOUBLE, ELONGATE, AND FRINGED IN COMBINATION

HEAD WITHOUT TUSKS

Behningiidae (p. 112)

HEAD WITH ANTERIORLY PROJECTING TUSKS

GILLS ON ABDOMINAL SEGMENT 2 NOT FUSED BUT OVERLAPPING

Caenidae (p. 121)

FORE WING PADS FREE, SEPARATE FOR HALF THEIR LENGTH OR MORE; GILLS ON ABDOMINAL SEGMENT 2 PRESENT, VARIABLE, BUT NEVER OPERCULATE
GILLS ON ABDOMINAL SEGMENTS 2–5 FORKED OR DOUBLE AND ELONGATE OR WITH FINGERLIKE PROJECTIONS OR IN CLUSTERS OF FILAMENTS, AND NEVER VENTRAL

Leptophlebiidae
(p. 110)

GILLS ON ABDOMINAL SEGMENTS 2–5 USUALLY PLATELIKE AND OFTEN WITH BASAL GILL TUFTS OR FLAPS, ONLY RARELY POINTED

FORE LEGS WITH 2 ROWS OF LONG HAIRS

Oligoneuriidae
(p. 105)

FORE LEGS WITHOUT 2 ROWS OF LONG HAIRS

DISTINCTLY FLATTENED BODIES WITH HORIZONTAL HEADS AND OUTSPREAD LEGS

BODY ELONGATE, STREAM-LINED; HEAD VERTICAL

FORE LEG CLAWS DIFFERENT FROM MIDDLE AND HIND LEG CLAWS

Hepageniidae
(p. 106)

TUSKS WITH OUTER KEEL AND OUTCURVED TIPS

Palingeniidae
(p. 116)

TUSKS WITH SCATTERED OR INNER SPINES AND DOWNWARD-INWARD CURVED TIPS

FORE LEG CLAWS CLEFT

Foreleg Claws Simple, with Bristles

Metretopodidae
(p. 101)

Ametropodidae
(p. 102)

TUSKS WITH OUTER KEEL AND OUTCURVED TIPS

ForeLeg Claws CLEFT

FORE LEG CLAWS SIMPLE, WITH BRISTLES

Metretopodidae
(p. 101)

Ametropodidae
(p. 102)

CLAWS ON ALL LEGS SIMILAR

WITH 2 OR 3 WELL-DEVELOPED TAILS; IF 3 TAILS PRESENT, THEN ANTENNAE 2 × TO 3 × HEAD WIDTH

Baeotidae
(p. 102)

LEGS AND GILLS OUTSPREAD LATERALLY

Potamanthidae
(p. 112)

LEGS ROBUST; GILLS DORSAL

Polymitarcyidae
(p. 113)

WITH 3 WELL-DEVELOPED TAILS; ANTENNAE SHORTER THAN 2 × HEAD WIDTH

Siphlonuridae
(p. 100)
STONEFLIES

Figure 9.2. MATURE PLECOPTERA LARVAE

NOT ROACHLIKE, THORAX NOT GREATLY ENLARGED

ROACHLIKE; THORAX WITH LARGE SHIELDLIKE PLATES COVERING BASES OF HEAD, LEGS AND ABDOMEN, AND WITH OVERLAPPING PLATES VENTRALLY

NO BRANCING GILLS BEHIND BASES OF LEGS

BRANCING GILLS BEHIND BASES OF LEGS

BODY OF LABIUM COMPACT WITH 3 NOTCHES ALONG OUTER MARGIN, PALPS THICK

BODY OF LABIUM DIVIDED FROM THE OUTER MARGIN INTO ONLY 2 PARTS, PALPS SLENDER

SOME BRANCING GILLS ORIGINATING FROM BASAL ABDOMINAL SEGMENTS

BRANCING GILLS NEVER ORIGINATING FROM BASAL ABDOMINAL SEGMENTS

Pteronarcyidae (p. 159)

Peplid (p. 160)

CHLOROPERLIIDAE (p. 164)

Perlodidae (p. 163)

WING PADS PARALLEL; TAILS USUALLY SHORTER THAN ABDOMEN

WING PADS DIVERGENT; TAILS LONG

THORAX CYLINDRICAL-SLINDER WITH PARALLEL WING PADS

THORAX ROBUST WITH DIVERGENT WING PADS

TARSAL SEGMENTS 1 AND 2 ABOUT THE SAME LENGTH

TARSAL SEGMENT 2 MUCH SHORTER THAN 1

LATERAL LONGITUDINAL FOLD OF ABDOMEN NOT EXTENDING BEYOND SEGMENT 7

LATERAL LONGITUDINAL FOLD OF ABDOMEN EXTENDING THROUGH SEGMENT 8

Taeniopyrgidae (p. 154)

Nemouridae (p. 153)

Capniidae (p. 156)

Leuctridae (p. 158)
DRAGONFLIES AND DAMSELFLIES

Figure 8.2. MATURE ODONATA LARVAE

- Abdomen ending in caudal lamellae
  - Abdomen without caudal lamellae
    - Segment 1 of antennae very long
    - Labium without a long, narrow base
      - Caudal lamellae leaflike, never strongly divided
        - Coenagrionidae (p. 134)
      - Labium without large and narrow
        - Lateral lobes of labium with very slight indentations
          - Libellulidae (p. 144)
    - All segments of antennae about equal
    - Lateral lobes of labium without large and jagged teeth
      - Lateral spines of abdominal segment 8 absent or shorter than midlength of segment 9
        - Corduliidae (p. 143)
      - Lateral lobes of labium with very slight indentations
    - Lateral lobes of labium with moderate indentations
      - Cordulegastridae (p. 140)
    - Labium spoon-shaped
      - Antennae 4-segmented, segment 3 very large
        - Gomphidae (p. 137)
      - Terminal antennal segments slender
        - Antennal segments thick and with hairs
          - Pterostictidae (p. 136)
    - Labium elongate and narrow
      - Labium flat

- Antennae with 6 or 7 short segments
  - Lateral lobes of labium with large, irregular, jagged teeth
    - Lateral spines of abdominal segment 8 as long or longer than midlength of segment 9
      - Cordulidae (p. 143)
Figure 13.1. AQUATIC COLEOPTERA ADULTS

WITH LARGE COXAL PLATES COVERING BASES OF HIND LEGS AND ABDOMEN

WITH ONE PAIR OF UNDIVIDED EYES

HEAD WITHOUT SNOUS

BODY STREAMLINED; DORSAL AND LATERAL LINE OF PRONOTUM AND ELyTRA USUALLY FORMING SIMILAR CONTINUOUS CURVE; HIND LEGS WITH SWIMMING HAIRS

BODY NOT ESPECIALLY STREAMLINED; HIND LEGS WITHOUT SWIMMING HAIRS (NON-SWIMMING)

ANTENNAE NOT CLUBBED

SCUTELLUM CONCEALED

SIZE VARIABLE, WITH SWIMMING HAIRS ON HIND LEGS

FORE TIBIA WITH CURVED PROJECTION OR SPUR AT Apex; 2-6 MM

FORE TIBIA WITHOUT CURVED PROJECTION OR SPUR AT TIP; SIZE VARIABLE

HALIPHIDAE (p. 213)

CURCULIONIDAE (p. 234)

HYDROPHILIDAE (p. 221)

Gyrinidae (p. 219)

Hydrophilidae (p. 221)

Dytiscidae (p. 214)

Dytiscidae (p. 214)

Noteridae (p. 218)

Noteridae (p. 218)

Noteridae (p. 218)
Figure 13.2. AQUATIC COLEOPTERA LARVAE

BODY DISCLIKE WITH DORSAL PLATES COVERING HEAD AND LEGS

*Psephenidae* (p. 226)

THORACIC LEGS PRESENT

NO LEGS
Curculionidae  
(p. 234)

See also: Shore-Dwelling  
Hydrophilidae, Chap. 17

LEGS 6-SEGMENTED  
(INCLUDING CLAW AS SEGMENT)

LEGS 5-SEGMENTED  
(INCLUDING CLAW)

ABDOMEN 8-SEGMENTED

ABDOMEN 9- TO 10-SEGMENTED

BODY WITH LATERALLY EXPANDED PLATES

*Amphizoidae*  
(p. 213)

BODY WITHOUT LATERALLY EXPANDED PLATES

LEG CLAWS DOUBLE  
*Gyrinidae*  
(p. 219)

LEG CLAWS SINGLE  
*Haliplidae*  
(p. 213)

BODY ELONGATE, PARALLEL SIDED WITH SHORT THICK LEGS

*Dytiscidae*  
(p. 214)

BODY USUALLY TAPERED AT ENDS, WITH SLENDER LEGS; OFTEN WITH VARIOUS ABDOMINAL FILAMENTS AND SICKLE-SHAPED MANDIBLES

*Noteridae*  
(p. 218)
TRUE BUGS

Figure 10.1. UNDERWATER AND SURFACE HEMIPTERA

ANTENNAE SHORTER THAN HEAD

BEAK SHORT, TRIANGULAR, AND NOT SEGMENTED

BEAK SEGMENTED AND VARIABLY CYLINDRICAL

HIND LEGS GARLIKE, ELONGATE-FLATTENED, WITHOUT CLAWS

HIND LEGS VARIABLY SHAPED, WITH PAIR OF CLAWS

Notonectidae
(p. 173)

CLAWS OF FORE LEGS PREAPICAL

CLAWS OF ALL LEGS APICAL

ABDOMEN WITHOUT CYLINDRICAL BREATHING TUBE

Corixidae
(p. 179)

ABDOMEN WITH TERMINAL ELONGATE BREATHING TUBE

Nepidae
(p. 175)

BODY SOMewhat FLATTENED, USUALLY GREATER THAN 3 MM

BODY HIGHLY CONVEX, LESS THAN 3 MM

Veliidae
(p. 183)

Gerridae
(p. 181)

HIND FEMORA NOT REACHING OR REACHING ONLY SLIGHTLY BEYOND TIP OF ABDOMEN

HIND FEMORA REACHING WELL BEYOND TIP OF ABDOMEN

Pleidae
(p. 174)

Body NOT STICKLIKE, WITH A SHORT HEAD

STICKLIKE BODY; WITH ELONGATE HEAD

Belostomatidae
(p. 178)

MEMBRANE OF FORE WING VEINED

MEMBRANE OF FORE WING NOT VEINED

Belostomatidae
(p. 178)

Nautoridae
(p. 176)

WITHOUT PAIR OF DORSAL ABDOMINAL SCENT GLANDS

Mesoveliidae
(p. 185)

WITH PAIR OF DORSAL ABDOMINAL SCENT GLANDS

Herbridae
(p. 185)

Legs WITHOUT SCATTERED BLACK SPINES

Hydrometridae
(p. 184)

Legs WITH SCATTERED BLACK SPINES (AT LEAST 1 OR 2 ON FEMORA)
CADDISFLIES

Figure 14.1. MATURE TRICHOPTERA LARVAE

3 THORACIC SEGMENTS COVERED DORSALLY WITH WELL-DEVELOPED PLATES

THORACIC SEGMENT 3 MOSTLY FLESHY DORSALLY OR WITH SMALL SEPARATED PLATES ONLY

ABDOMEN WITHOUT GILLS; SMALL
Hydropsychidae (p. 255)

ABDOMEN WITH BRANCHED GILLS AND SCATTERED HAIRS

DORSAL THORACIC SEGMENT 2 FLESHY OR WITH SMALL SEPARATED PLATES ONLY

Hydropsychidae (p. 249)

ABDOMINAL SEGMENT 1 WITH HUMPS; USUALLY LARGE WITH STRIPED HEAD
Phryganeidae (p. 257)

ABDOMINAL SEGMENT 1 WITHOUT HUMPS; BODY GENERALLY CURVED

BASAL HALF OF ANAL PROLEGS BROADLY JOINED TO ABDOMINAL SEGMENT 9
Glossosomatidae (p. 254)

MOST OF ANAL PROLEGS FREE AND WELL DEVELOPED

ABDOMINAL SEGMENT 9 WITH DORSAL PLATE

Helicopsychidae (p. 267)

ABDOMINAL SEGMENT 9 WITHOUT DORSAL PLATE

LABRUM MEMBRANOUS AND T-SHAPED
Philopotamidae (p. 244)

LABRUM NOT HIGHLY MODIFIED

Rhyacophilidae (p. 252)

TROCHANTIN BROAD AT APEX

Psychomyiidae (p. 247)

TROCHANTIN POINTED AT APEX
Polycentropodidae (p. 247)
Figure 16.1. AQUATIC DIPTERA IMMATURES

BODY WITH DEVELOPING WINGS; 3 PAIRS OF THORACIC LEGS APPARENT (MAY BE FUSED TO BODY)

DEVELOPING ANTENNAE ELONGATE AND LYING OVER EYES

Nematocera Pupae
(See Family Discussions)

DEVELOPING ANTENNAE NOT LYING OVER EYES, NOT REACHING BEYOND WING BASES

Brachycera Pupae

BODY WITHOUT 3 PAIRS OF THORACIC LEGS AND WITHOUT DEVELOPING WINGS (ALL AQUATIC FLY LARVAE AND PUPARIA)

BODY DORSOVENTRALLY FLATTENED WITH 6 DEEP LATERAL CONSTRUCTIONS; 6 REGIONS WITH VENTRAL ATTACHMENT DISCS

Blephariceridae
(p. 300)

HEAD FULLY FORMED, HEADLIKE, AND DISTINCT FROM THORAX

PROTHORAX WITH PROLEG(S)

DISTAL THIRD OF ABDOMEN SWOLLEN

Simuliidae
(p. 314)

DISTAL THIRD OF ABDOMEN NOT SWOLLEN

PROTHORAX WITHOUT PROLEGS

FLESHY PROCESSES OR BRISTLES DORSALLY ALONG BODY

Ceratopogonidae
(p. 307)

HEAD INCONSPICUOUS, INCOMPLETELY FORMED, OFTEN REPRESENTED BY A MERE TIP OF ANTERIORLY TAPERED BODY, AND/OR RETRACTED INTO THORAX

BODY MORE-OR-LESS CYLINDRICAL, NOT LEATHERY

THORACIC SEGMENTS DISTINCT, NOT WIDER THAN ABDOMEN

Stratiomyidae
(p. 316)

BODY SOMEWHAT DORSOVENTRALLY FLATTENED AND LEATHERY

THORACIC SEGMENTS FUSED, USUALLY SWOLLEN BUT NOT ALWAYS

ANTENNAE WITH SHORT HAIRS ONLY

Culicidae
(p. 305)

ANTENNAE WITH TERMINAL BRISTLES

Chaoboridae
(p. 303)

BODY WITHOUT FLESHY PROCESSES, SOME HAIRS AT MOST

PROLEGS PAIRED (IF ONLY SLIGHTLY AT TIP)

Chironomidae
(p. 309)

PROLEGS COMPLETELY UNDIVIDED

Thaumaleidae
(p. 307)
SMALL TO LARGE LOBES RIMMING AT LEAST PART OF END OF ABDOMEN

ABDOMEN NOT ENDING IN DISC OF LOBES

TERMINAL LOBES VERY SMALL; HEAD NOT DISCERNIBLE

Sciomyzidae
(p. 323)

END OF ABDOMEN WITH CIRCLE OF 5-8 LOBES AND OFTEN SEVERAL ELONGATE FLESHY PROCESSES; PARTIALLY HARDENED HEAD RETRACTED

ABDOMEN ENDING IN PAIR OF BREATHING TUBES

BREATHING TUBES WELL DEVELOPED (SOMETIMES RETRACTED WITHIN ELONGATE SHEATH); PROLEGS ABSENT OR WELTIKE

Ephydridae
(p. 324)

Tipulidae
(p. 294)

DISTANT FAMILY: SCYMIA

ABDOMEN WITH VARIOUS TERMINAL PROCESSES AND/OR ELONGATED TERMINAL SEGMENT OFTEN SPLIT AT END

Muscidae—Anchomyiidae
(p. 327)

Tipulidae
(p. 294)

ABDOMEN NOT ENDING IN PAIR OF BREATHING TUBES

BREATHING TUBES SHORT TO MINUTE; TERMINAL PROLEGS SHORT, OFTEN WELTIKE

Empididae
(p. 319)

TERMINAL SEGMENT OF ABDOMEN SOMEWHAT BULBOUS WITHOUT WELL-DEVELOPED PROCESSES
Stream Insects and Crustaceans ID Card

Stream Insects and Crustaceans ID Card
Lines under picture indicate the relative size of organisms

Beetles: Order Coleoptera
1/2" - 1", disk-like oval body with 6 small legs and gill tufts on underside OR small black beetle crawling on streambed OR comma-like brown "crunchy" body with 6 legs on upper 1/3 and possibly gill tuft on back end, OR (miscellaneous body form - rare), somewhat tolerant of impairment

Midges:
Family Chironomidae
Up to 1/4", distinct head, worm-like segmented body, 2 leg-like projections on each side, often whitish to clear, occasionally bright red, tolerant of impairment

Black Fly: Family Simuliidae
Up to 1/4", end of body wider (like bowling pin), distinctive head, sucker on end, tolerant of impairment

Most True Flies:
Order Diptera
1/8" - 2", bodies plump and maggot-like, may have caterpillar-like "legs" along body, may have lobes or conical tails on end, tolerant of impairment

Gilled Snails:
Class Gastropoda
Up to 1/2", shell opening covered by a thin plate called an operculum, with helix pointed up shell opens to the right, intolerant of impairment

Lunged Snails:
Class Gastropoda
Up to 1/2", no operculum, with helix pointed up shell opens to the left, tolerant of impairment

Clams:
Class Bivalvia
Up to 1/4", shiny body enclosed between 2 clamped together shells (if clam is alive, shells cannot be pried apart without harming clam), somewhat tolerant of impairment

Glossary:
Abdomen
Thorax
Head

Tails: There are many different kinds of macroinvertebrate tails. The thin thread-like tails found on stoneflies and mayflies are called cerci. The oar-shaped tails found on a damselfly are not really tails - they are actually gills called caudal lamellae!

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http://www.iwla.org/SOS/index.html

Wonderful, Wacky, Water Critters
WONDERFUL WACKY WATER CRITTERS

HOW TO USE THIS BOOK

1. The "KEY TO MACROINVERTEBRATE LIFE IN THE RIVER" or "KEY TO LIFE IN THE POND" identification sheets will help you 'unlock' the name of your animal.

2. Look up the animal's name in the index in the back of this book and turn to the appropriate page.

3. Try to find out:
   a. What your animal eats.
   b. What tools it has to get food.
   c. How it is adapted to the water current or how it gets oxygen.
   d. How it protects itself.

4. Draw your animal's adaptations in the circles on your adaptation worksheet on the following page.
Critter Adaptation Chart

How does it get its food?
What is its food?

How does it get away from enemies?

Draw your "critter" here

Name of "Critter"

How does it get oxygen?

Other unique adaptations.
TWO COMMON LIFE CYCLES:

WHICH METHOD OF GROWING UP DOES YOUR ANIMAL HAVE?

WITHOUT A PUPAL STAGE?
THESE ANIMALS GROW GRADUALLY, CHANGING ONLY SLIGHTLY AS THEY GROW UP. THE LARVA LIVE IN WATER, THEN EMERGE AS FLYING ADULTS.

WITH A PUPAL STAGE?
THESE ANIMALS GO THROUGH FOUR STAGES AND LOOK DIFFERENT IN EACH. BEETLES, FLIES, MOSQUITOES AND MOTHS GROW IN THIS WAY.
WONDERFUL WACKY WATER CRITTERS

(Note: sizes of illustrations are not proportional.)

1. HYDRA: The amazing hydra is related to the jellyfish. Living only in clean, unpolluted waters, it likes to just “hang around,” but can either move slowly on its “foot” or somersault end over end like a gymnast. Long tentacles surround an opening that is used for both eating and going to the bathroom! The hydra dines on meals of one-celled animals, water fleas, and seed or clam shrimp. It paralyzes its food by injecting poison into the prey before eating. It gets oxygen right through its skin. Its “ears” are used as both fingers to feel surroundings, and as a nose, to smell!

2. PLANARIA: The planaria or flatworm looks a lot like a small flattened slug. You can tell the difference by its triangular head and two eyespots. It sucks up its favorite meal of seed shrimp or clam shrimp, water fleas and dead animals with a straw-like mouth. Don’t look for the mouth on its head — the mouth comes right out of the planaria’s belly. A planaria finds dead decaying animals not only a tasty meal but also a good place to crawl into and hide. It doesn’t need gills or lungs. It gets oxygen right through its skin! It is interesting that if you cut a planaria in two from head to tail, both halves will live and grow new, complete bodies.

3. NEMATODE: This tiny worm, also known as the threadworm or roundworm, is commonly found in bottom muck or on bottom plants throughout the world. You can tell it from other worms by its S-shaped swimming motion. Most roundworms prefer a quiet life eating tiny plants and animals, both dead and alive. Some nematodes live as parasites on clams, snails or fish. The threadworm gets oxygen right through its skin. This wiry hairlike animal finds quiet water a comforting home. Don’t confuse it with the long, tan horsehair worm.
4. **LEECH**: Can you imagine one of your friends clinging onto you, sucking your blood and increasing in weight by five times? That’s what some leeches do! A leech can cling onto sticks, stones, an animal or even you by means of a suction cup. After attaching to an animal, the leech scrapes open a little hole in the skin of its host and releases an anticoagulant, which is a chemical that keeps blood from clotting. This leech’s strange feeding habit puts it into a special category called a parasite. Some leeches eat a more “civilized” diet of dead plants and animal matter. The presence of a lot of leeches is a sign of mucky bottoms. The leech does not have gills or lungs. It gets oxygen through its skin. Many fishes find leeches great food – they’re an important part of a pond’s food web.

5. **TURBIFEX WORM**: This aquatic angleworm is right at home in mucky water. Sometimes called a sludge worm, it will even live in grossly polluted waters. It buries its head in the bottom mud, eating away while letting its tail wave in the current. Just like a land worm, an aquatic worm eats mostly dead plants. If a particularly juicy dead animal is nearby it will munch on that too, just as long as it doesn’t have to travel too far. Amazingly, this worm can live where there is hardly any oxygen. But it doesn’t seem to like it. It thrashes its tail wildly when this happens. This worm breathes right through its skin. It is also both male and female at the same time. Thus, when two worms mate both worms are fertilized.

6. **BRISTLE WORM**: These tiny, uncommon animals can be told from midge larvae and other worms by the pairs of bristles on each segment. Like most worms the bristle worm breathes through its skin and eats dead plants. It lives quite comfortably in bottom debris and plants.
7. CYCLOPS or COPEPOD: The copepod is a small crustacean that looks like a swimming apostrophe mark ('). It is sometimes called a cyclops because its single eyespot reminds people of the one-eyed monster in Greek mythology. The quiet waters of ponds, lakes and rivers are its home, since faster waters would wash it away. A copepod clings onto plants and feeds on algae, bacteria and organic debris that pass its way. When a female has egg sacs on the sides of its "tail," it looks something like a teeny, tiny Mickey Mouse balloon. Copepods are part of the many microscopic plants and animals that all together are called plankton. Plankton are important links in the food chain. They eat algae and are food for insects and small fishes. Other common plankton include water fleas, seed shrimp and clam shrimp.

8. SEED SHRIMP and CLAM SHRIMP: These tiny, almost microscopic members of the freshwater plankton are scavengers, living on dead plants and animals. If you watch one carefully with a hand lens or microscope you can see its shell opening and closing. You might even see its legs bringing its favorite meal of dead, decaying matter into the shell. Since many insects and fish find these small animals a wonderful meal, it's a good thing there are so many of them. You might find hundreds in one teaspoon of water.

9. WATER FLEA or DAPHNIA: Did you ever itch to catch a water flea? The name water flea is a nickname; it is also called cladocera or daphnia. These tiny critters are part of the freshwater plankton. A daphnia swims jerkily, using branched antennae, while eating algae, microscopic animals and organic debris. Watch its legs swirl food to its mouth. Its tiny size and transparent body help it hide from hungry insects and fish.
10. FAIRY SHRIMP: This graceful animal lives only in temporary ponds, never in ponds with fish. That's because it generally swims slowly and would make easy fish food. When disturbed it can dart quickly out of the way. It still has to watch out for hungry predaceous diving beetles, young salamanders and ducks. The fairy shrimp gets its dinner of microscopic animals and bits of organic debris to its mouth by waving its gill-legs. It also swims by moving its gills in waves – looking like it's playing a harp. Check to see if you have a male or a female. The male has large mouth claspers to hold the female. Sometimes the female will have two egg sacs attached behind her gills. The eggs have to go through both drying and freezing before they can hatch!

11. SCUD or AMPHIPOD: Can you tell why the scud is often called the sideswimmer? Its shape helps it cut through the river current without being washed downstream. Its shape also allows it to swim fast to get away from predators. Scuds are active mostly at night as they look for a tasty dinner of decaying plants and animals. The scud has an excellent sense of touch which helps it find food in the dark. This sideswimmer has gills for breathing. Can you find them? (Hint, look on its legs.) A young scud looks just like an adult, only smaller.

12. AQUATIC SOWBUG or ISOPOD: The isopod is a scavenger that uses its seven pairs of legs to scamper around the bottom of streams and ponds while feeding on dead plants. It breathes through gills located on its belly. The isopod's eyes are very sensitive to light; therefore, it is usually active only at night. The darkness also helps it hide from the watchful eyes of its enemies. An isopod can live in water with low oxygen, typical of water polluted with sewage or farm runoff. If you find many of these animals, what does that tell you about the quality of the water?
13. **CRAYFISH:** The crayfish (also known as
crawfish) is one of the most interesting of the
aquatic animals because of its large size and
impressive pincers. These claws are important
tools for catching food and for defense. Watch
how it moves sideways or shoots backwards as
if jet propelled. Its periscope eyes help it hunt
for food and see danger in all directions. Its
gills can't be seen — they are under the hard
body shell. The crayfish is an omnivore, hunting
mostly at night. It prefers a meal of plants and
dead animals but will catch its dinner if given a
chance. In the spring look for eggs or young
attached under the female's tail.

If your crayfish has a rusty spot on its shell, it is an
exotic. This rusty crayfish was accidentally intro-
duced into Wisconsin. Wherever it is introduced, it
causes problems. In some northern Wisconsin lakes
it has eaten most of the aquatic plants, hurting the
quality of the lakes. Fish that normally eat crayfish
don't like the feisty, aggressive “Rusty.” It takes
over the homes of native crayfish and has been
known to eat fish eggs. It is illegal to transport live
crayfish from one place to another or to use live
crayfish for fishing bait.

14. **FISHING SPIDER:** This water spider has eight
legs, no wings and a body which is divided into two
sections. The similar water strider (see #22) has
wings and six legs. The water spider captures food
by running it down with its hairy legs.
After catching it the spider bites it
and injects a poison that dissolves
the body. The spider then sucks
out its body juices — a type of
“animal slurpy.” When it takes a
rare trip below water, it carries a bubble of air
along like a scuba diver does. The spider's favorite
foods are insects, small fish and tadpoles. Don't
worry, they are too small to hurt you.
15. WATER MITE: The water mite is a round critter with eight legs and one eye. It is usually red in color, but it can be blue, green or spotted. Its small legs make it hard for it to swim. It does just fine in quiet water, but in fast water its round body makes it tumble through the current. The mite’s favorite pastime is to crawl into a juicy dead animal and eat away. It also likes a dinner of tiny microscopic animals. Because it is so small it can get all the oxygen it needs right through its skin.

16. SPRINGTAIL: Just like people at a mall, these tiny wingless insects mill around in huge numbers right on the water’s surface. When disturbed, the springtail will jump away quicker than your eye can follow. Under its back end it has a special trigger or spring that snaps with great force when it needs to escape an enemy. The springtail never goes into the water, preferring to live on the surface eating dead, decaying plant matter. Young springtails look just like adult springtails, only smaller.

17. STONEFLY: Stoneflies are one of the oldest insects and are a close relative to cockroaches. This large insect has transparent, brownish wings which fold over its back. The adult is a weak flyer and is often found hiding on stream bank vegetation. The young or larva lives mostly in clean, flowing water with lots of oxygen. The stonefly larva can be told from the mayfly larva by its two “tail” filaments. The stonefly larva’s gills are unusual. You will find them as tufts attached to each leg. As oxygen decreases in the water, stoneflies will do “push-ups” to increase the amount of water going over their gills. A meal of algae and dead plants is relished by some stonefly larva while others feed on animals, especially on mayfly and blackfly larva. Stoneflies are one of the trout’s favorite food.
18. FISHPHY, DOBSONFLY and ALDERFLY: The young of these insects are commonly called hellgrammites (hellgrammites sold as bait are usually dragonfly nymphs). Trout and other fish find them a delicacy. To avoid becoming trout food, the larvae hide under rocks and come out mostly at night. Fishflies and dobsonflies have little hooks at the end of their “tails” that help them hang onto rocks and sticks in fast-moving water. Fishfly and alderfly larvae are carnivores and sometimes cannibals, feeding on other smaller insects and each other! Don’t worry about those strange spines on their side; those are gills. But do watch out for their strong jaws. Large alderflies and dobsonflies can give a painful bite.

19. MAYFLY: The mayfly and damselfly larvae look almost like twins, but the damselfly is much larger! Damselflies swim by moving back and forth; mayflies move up and down. The mayfly has rows of feathery gills along its side between the legs and its three “tails.” The mayfly is one of the most common insects found in coldwater streams. Its young feed mostly on small plants. It is sometimes considered to be the “cow” of the stream since it grazes on algae on rocks. There are many different kinds of mayflies. How many did you find? The burrowing mayfly is unique. It has a large humped back, digging front legs and beautiful feathery gills. It gets its name from its habit of digging into the soft mud and silt at the edges of streams. The adult mayfly doesn’t eat anything during its short life of a few hours to a few days. As an adult, it mates, lays eggs and dies. Mayflies often swarm in huge numbers near water.
20. **DRAGONFLY:** It is interesting to watch a dragonfly larva catch its dinner of small insects and tadpoles. It uses a scoop-like lower lip called a labium (lay bee um) to reach out and grab its food. The larva breathes through gills located inside the tip of its abdomen. It can move as if jet-propelled with these gills. The adult is a swift, graceful insect that resembles a helicopter as it hunts for mosquitoes and other tasty, flying insects. Some adult dragonflies can eat over 100 mosquitoes a day. When it lands, it holds its wings out like an airplane. Old folk tales call them “Darning Needles,” but they can’t sew your mouth shut!

21. **DAMSELFLY:** The damselfly is closely related to the dragonfly. The damselfly larva is much slimmer than the dragonfly larva; in fact it looks a lot like a mayfly larva, but it is usually much larger. The larva has three platelike “tails” (which are really gills) at the tip of its abdomen. Be careful because these break off easily. The larva likes to feed on any aquatic animal it can overcome. It can be found in ponds, streams and rivers.

The adult damselfly cannot fly as fast as the dragonfly, but it is more graceful. When it rests on a handy leaf, stick or rock, it folds its wings over its back. The adult feeds on flying insects and loves to be out on sunny days.

22. **WATER STRIDER:** The water strider is sometimes called the “Jesus Bug” because it can walk on water. Hair on the tips of its legs keeps it from breaking through the water’s surface. This nervous critter escapes its enemies by scurrying across the surface. The water strider’s front legs are used for grasping its food. It is a scavenger and hunter, eating plants and insects that come up to get air. Most water striders will drown if caught under water. The **marsh treader** is a slimmer, light brown member of the strider family.
23. WATER BOATMAN: This insect's body is shaped like a boat, perfect for swimming. Its long, flattened hind legs make excellent paddles. The bug is actually dark colored, but an envelope of air used as its oxygen supply sometimes makes it appear silvery. This air also makes it hard for the insect to stay submerged. It has to grab onto plants or other objects to stay underwater. The water boatman feeds on oozy algae or dead plants and animals, which it scrapes toward its sucking beak with its front feet. The male attracts a female with a chirping sound made by rubbing his front feet against his beak and opposite leg. Aren't you glad we don't do that?

24. WATER SCORPIONS: How long can you stand without moving? A water scorpion can hang upside down perfectly still for hours. When an unsuspecting tadpole, fairy shrimp, or insect comes along, the water scorpion lunges forward and grabs it with razor-sharp front legs. Its long, thin mouth is inserted into the prey, and it gradually sucks out the insides and leaves an empty shell behind. The long "tail" isn't a stinger. It is a snorkel used for breathing. Watch how the tip is held right at the water surface, allowing the water scorpion to breathe and hunt at the same time.
25. GIANT WATER BUG: This huge insect sometimes grows to be two or more inches in length. The giant water bug is a superb predator, attacking and eating animals three times larger than itself, including tadpoles, fishes, frogs, very young ducks and other insects. It uses its strong front legs to grasp its prey while its beak is used to pierce, inject a poison and suck the victim's body juices. This true bug lives among plants at the bottom of the pond. It is a strong flyer and can often be found around lights at night. It does not have gills so it must make trips to the surface to get air. It breathes through the tip of its abdomen. The giant water bug is cooked in China and is considered to be a delicacy. Hold it from behind or the giant water bug might find you a delicacy too.

26. BACKSWIMMER: The name of this critter describes it perfectly. The backswimmer's keel-shaped back and powerful legs help it swim after its prey of small aquatic animals and escape its enemies. Its colorful body would help it play "hide and go seek," because it is camouflaged from both directions. The white back, when seen from underneath blends into the sky; the dark bottom, when seen from the air, blends in with the color of the water. The backswimmer must return to the surface for oxygen, which it gets through the tip of its abdomen. The backswimmer's bite can hurt, so be careful. The pygmy backswimmer is a smaller relative.
27. **WATER PENNY**: The water penny adult is a land-loving beetle. The young or larva stage has a streamlined body that allows it to live on rocks in very fast water, where it is protected from predators by the swift current. It looks like a suction cup, but it's alive! The slow-moving larva munches on algae that grow on the rocks. A silvery sheen on its belly is caused by air trapped in a coat of fine hairs. This is where its gills are too. The water penny can only live in streams or rivers that are clean and have lots of oxygen. The presence of water pennies indicates that the stream or river has year-round, pollution-free water.

28. **RIFFLE BEETLE**: Guess where this small black beetle likes to live? That's right, in riffles, the part of a stream where the water flows quickly over a rocky bottom. You'll never find the riffle beetle in calm lakes or dirty rivers. It's part of the clean stream team. Amazingly, it cannot swim. Instead, it crawls through the rocks eating algae. A riffle beetle larva is small, brown, and hard. The riffle beetle exchanges oxygen with the water across a thin layer of air attached to its hairy underside. What could you do to improve rivers for riffle beetles?

29. **PREDACEOUS DIVING BEETLE**: This beetle is one of the most common of all aquatic beetles. The diving beetle larva is sometimes called the "water tiger" or "dragon of the pond" because of its immense appetite. It will even eat its own kind. Both the adult and the larva wait in ambush for their favorite meal of insects, leeches, snails, tadpoles and fishes. (They're not very picky!) The diving beetle has strong, sharp jaws that are used for defense and to catch prey. Its hollow jaws are like hypodermic needles. The beetle can shoot digestive enzymes into its victim, predigesting the food before sucking it up. Since the beetle does not have gills, it has to come to the surface for air.
30. CRAWLING WATER BEETLE: This beetle lives among plants in shallow water. It especially likes a home made of algae, which is also its dinner. The round shape of the crawling water beetle makes it difficult for it to swim in swift water. It would be like trying to row a barrel; you would be sent spinning and bobbing downstream. (Keeping this in mind, where in the river would you look for this critter?) Can you see how it breathes? Look carefully at the tip of its abdomen and you will find a bubble of air. It carries its oxygen like a scuba diver. This animal is easily studied in an aquarium; just give it some algae to eat.

31. WHIRLIGIG BEETLE: This beetle zips in wild patterns all around the surface of quiet water. When disturbed it dives to the bottom. It also protects itself by giving off a strong smell like apple seeds. Look at its unusual eyes. It seems to have four eyes, two above the water and two below the water. It really has two eyes that are split in half. Why do you think this would be a good adaptation? This beetle is a scavenger, which means it eats dead plants and animals. Though it prefers swimming, it can fly to a new home if the old one dries up. This beetle is harmless, so don't be afraid the next time you are around it.

32. WATER SCAVENGER BEETLE: Unlike its "scavenger" name suggests, this beetle's larva is a predator which searches for and eats live food. The adult is an omnivore, eating both living and dead plant and animal matter. It has a special love for algae. The larva is a slow, clumsy swimmer, so it likes to lie still and wait for its prey to go by. The adult is a good swimmer. It is sometimes called the silver beetle. Hair on its body traps air, which shines silvery in the sun. It uses this layer of trapped air for breathing.
33. **BLACKFLY**: The blackfly larva moves like an inchworm, first spinning small loops of silk with its mouth, then attaching itself to the loops with tiny hooks on its back end. It is the original Velcro! It also uses the silk as a safety line to reel itself back if knocked off its rock. It eats whatever the river brings to it, mostly bits of dead plants. (Talk about a life of ease!) It gets its oxygen through gills located on its back end. The adult blackfly has a short body with a humped back. This critter can be a real pest in the summer. Its bite is not very painful ... until later. Some blackflies can only live in clean streams; other kinds are very tolerant of pollution. The female lays eggs on rocks in streams and rivers. The blackfly is food for many other animals.

34. **CRANEFLY**: The big, wormlike, cranefly larva has tentacles around its back end. It shoves the tentacles through the surface of the water for breathing. The cranefly larva is very important to life in the river. It chews on large leaves that fall from trees. Since it's a sloppy eater, tiny bits of leaves float away and become dinner for many other insects. Each type of cranefly is very specific about where it lives. Some species will only live in clean, flowing waters, others in wet meadows, and others in mud flats. The adult looks like a gigantic, long-legged mosquito. But it doesn't bite – it doesn't even have a mouth. It flies slowly and awkwardly. Keep an eye out for the delicate adults the next time you're around a light at night.
35. **MIDGE or BLOODWORM:** Young midges can be found in all sorts of water; some live in hot springs at temperatures of 124°F! The larva likes to snack on tiny bits of dead plants floating in the water and tiny microscopic animals. It eats by straining its food through brushes surrounding its mouth. Some midge larvae are bright red and are called bloodworms. The chemical that makes them red helps them get oxygen when levels are low. The chemical is hemoglobin, just like in our blood. The midge larva may seem pretty tiny to us but it is an important food source for fish, even the largest fish in Wisconsin – the sturgeon. So, indirectly, that little larva may be part of your dinner some day.

Most adult midges are harmless even though they look like a miniature mosquito. Some, the "no-seeums," are nasty biters. They dance over the water in great flocks or swarm around making a humming sound. Even the non-biting midges can be annoying at certain times of the year because of their huge numbers. Swarms of midges and mayflies near Lake Winnebago and the Mississippi River can completely cover houses, bridges and roads. They can create traffic problems by making roads slippery.

36. **PHANTOM MIDGE:** The phantom midge larva is so clear it's nearly invisible. What a great disguise for playing "hide and go seek!" It hunts tiny crustaceans by grabbing them with its antennae. The phantom midge breathes right through its body. The pupa of a phantom midge can swim with jerky movements. The adult looks similar to a mosquito but does not bite; it probably doesn't eat anything in its short adult life.
37. **MOSQUITO:** This interesting insect goes through four distinct stages: an egg stage which can spend the winter in dry soil and hatch when spring rains fill the puddles and small ponds; a larva stage which spends its life upside down breathing through a tube on its rear end; a pupa stage which swims but does not eat; and an adult stage that we are all too familiar with. Watch the larva move; when it is disturbed it races to the bottom of the pond. The mosquito larva eats microscopic plants, animals or organic debris with brushes surrounding its mouth. The pupal stage is called a “tumbler” and is almost all head. The adult female requires a blood meal to develop her eggs. No large animal is free from these pests. Some females make life miserable for animals such as deer, people or squirrels, while others torment frogs and turtles. The adult male lives on plant juices and flower nectar. Next time you swat at them remember, these critters are important food for fishes, frogs and birds.

38. **SOLDIER FLY:** It is ALIVE! The soldier fly larva may look dead but it eats, breathes, grows and moves (although rarely). Talk about the ultimate couch potato. You don’t have to move much when you eat tiny plants floating right past your mouth. The tuft of bristles on its back end is where it breathes. What do you think would happen if oil was spilled on the pond? Would it cover the soldier fly’s breathing disc?

39. **HORSEFLY and DEERFLY:** The seldom found larvae of these flies hunt for worms and snails to eat. They don’t look like ferocious predators, being almost headless, legless, wormlike animals, but that doesn’t seem to stop them. They’re usually found in swamps, small ponds and weedy places away from big carnivores like fish. These flies breathe through a small disc on their “tails” which they push up through the water’s surface into the air.
40. **WATER SNIPEFLY OR AHERIX:** This small fly larva looks like a cross between a maggot and a caterpillar. It doesn't look like it could hunt down and eat other small critters, but it does. It breathes through a small opening near its two "tails" called a spiracle. The adult snipefly feeds mostly on blood - maybe yours, but usually other animals! The presence of water snipefly larva is a sign of clean, fast water.

41. **RAT-TAILED MAGGOT or "MOUSIE":** You might find the type of home that this larva likes very yucky. It prefers very mucky, smelly, highly polluted waterways where it munches away at the organic matter in the sediment. In fact, it can even live in manure storage pits! The larva breathes through the end of its long breathing tube. It can extend this several inches through the sediment right up to the surface of the water. The adult is one of the common 'flower flies' that mimic bees and feed on nectar and pollen.

42. **CADDISFLY:** The caddisfly lives only a short time as an adult but may spend several years as a larva. Many larvae can do something few aquatic insects can - they build their own shelter. Different kinds of caddisflies build different types of homes. Some species build homes of leaves or twigs; others use tiny stones, while others are free-living. A few types of caddisflies build a pebble house attached to a larger rock. Some caddisflies like to live in temporary stagnant ponds while other types will only live in swift streams. All caddisflies eat plants but some catch tiny bits of plants by building a net to trap food as it drifts past. The caddisflies are very important food for fish, especially trout.
43. CATERPILLAR or PYRALID MOTH: A few species of moths have caterpillars or larvae that live in the water. These aquatic caterpillars look similar to land-loving caterpillars. They hide from enemies by either building a silk-lined case sandwiched between two pieces of leaves, or by weaving a thick web of silk over small pits in rocks. Aquatic caterpillars feed on a variety of plants and breathe through their skin and with gills. A young caterpillar changes into a pupa and then into a small, brownish gray moth.

44. SNAIL: Think how hard it would be to carry your house on your back! That’s what a snail does. Each kind of snail has a unique shape or color to its shell. How many kinds did you find? There are two major types of snails. The lunged and the gilled snails. The pouch snail, one of the lunged snails, lives in ponds and pools where oxygen is low. It can be found in slow, polluted rivers too. The orb snail, also one of the lunged snails, lives in clean, quiet waters. Gilled snails have a shell “door” (operculum) which they can close. This type of snail is typically found in clean rivers. They need more oxygen than the pouch snails. The snail’s shell provides protection from enemies. It also is a handy oxygen container. When a snail is seen crawling upside down on the surface of the pond it is gathering fresh air into its shell. When a snail is threatened it pulls its “foot” into its shell and is safe from most predators. A snail has both its eyes and mouth on its “foot!” Watch how it uses its eyes like periscopes as it moves along, scraping and feeding on algae. The snail is very sensitive to acid in the water which can dissolve its limey shell. Where do you think the acid might come from?

45. LIMPET: The limpet is a special type of snail. Its tiny shell is shaped like a flattened cone or tent. When a limpet is disturbed it clamps firmly to an object. It is almost impossible to remove without damage. It breathes with gills. The limpet is a harmless plant eater, so be kind the next time you see one.
46. FRESHWATER MUSSEL: How would you like to have a shell, no eyes and catch your food with your nose? No? Well, that’s what a mussel does. Freshwater mussels have a hard and strong shell that helps protect them from predators such as birds, raccoons, and turtles. Between its shell halves is a tongue-shaped “foot” used to pull it along the bottom of rivers and lakes. It breathes through gills. A mussel depends on the river to bring it microscopic plants and animals, which it filters out of the water. Poisons in the water are also filtered out and stored in the mussel’s body. Some mussels can be a tasty treat for people, although tough and chewy. Would you eat any mussels from areas where waste and chemicals from farms or towns wash into the water? Interestingly, the first buttons were cut from mussel shells. One of the first important fishing industries in Wisconsin was mussel fishing to make mother-of-pearl buttons. The mussel trade is still important in Wisconsin. Small pieces of freshwater mussel shells are sent overseas where they are inserted into oysters as the ‘seeds’ that will become cultured pearls.

In the Mississippi River, native mussel populations have declined greatly due to harvesting, loss of habitat, and the introduction of exotic zebra mussels. The zebra mussel is fingernail-size, and is black, white and tan striped. They usually live in clusters called “colonies.” If you think you have found a zebra mussel in inland waters other than the Mississippi River, contact your local Department of Natural Resources office.

47. PILL CLAM: This pale tiny clam never gets bigger than a fingernail. It’s even commonly called a fingernail clam. It likes to live on the bottom of many watery homes: ponds, brooks, rivers or lakes. Just like its bigger cousin, the pill clam filters bits of plants and organic debris out of water. All clams have two tubes on the top of the “foot.” One sucks in water containing food and oxygen. The other shoots out the clam’s waste.
48. **SHINERS AND CHUBS:** These small fish are common in streams and rivers. They are an important link in the food chain. A tasty meal for a shiner would consist of plankton, crustaceans and insects. It could become dinner for a giant water bug or a bass. All bodies of water— from swift, cool, trout streams, to warm, quiet lakes—are its playground. When it's time to mate, the male shiner builds a nest out of gravel. Many females will lay eggs in a single nest. The eggs are protected by the male but when they hatch, the young have to flee or the male will eat them. I'm glad he's not my father!

49. **JOHNNY DARTER:** Watch how this tiny member of the perch family moves and you can see how it got its name. The Johnny darter likes to sit quietly in one place and then zip with great speed after a dinner of small insects. Small black “W”-like markings on their sides make identifying Johnny darters easy. A male that is ready to mate will only build his nest under rocks in clear, unpolluted streams, so we must be careful to keep his home clean.

50. **BULLHEAD:** The bullhead is an interesting, smooth-skinned fish. It has a large mouth, and whiskers known as barbels. Watch how the barbels let the fish know what is nearby. The barbels, along with thousands of taste buds covering the entire body, help the fish locate food in muddy water and at night. Many people think that the barbels can sting, but that's false! The bullhead has another defense; a spine concealed in its top and side fins. The stinging sensation sometimes felt when jabbed by the spine of the “Mad Tom,” (a cousin of the bullhead) is caused by an irritating chemical produced in glands at the base of the spine. The bullhead can be found scavenging the bottom of quiet, warm
waters throughout North America looking for yummy dead stuff as well as insects, fish eggs and even young fish. Being a hardy animal, it can withstand polluted waters and very low oxygen levels. It gulps air at the surface if there’s no oxygen in the water. A bullhead without the head and spines makes a fine dinner if you remove the skin before cooking.

51. TADPOLE: Baby frogs or toads are called tadpoles. Many different kinds are found in Wisconsin. Some kinds turn into adults in two weeks, while others take two to three years. If you find a large tadpole in the pond it is probably a young green frog. Small black tadpoles found swimming in large groups could be called “toadpoles,” as they’ll turn into toads. Only the bullfrog tadpole is found in rivers; other tadpoles are not strong enough swimmers to survive the river currents. A tadpole eats only plants, especially algae, while a frog eats insects and small animals, even tadpoles.

52. SALAMANDER: A tadpole with gills? No, it’s not a mutant; it’s a salamander larva. In a few weeks, it will lose the gills, get flecks and spots and crawl out of the pond. Unlike frogs and tadpoles, salamanders have teeth. They’re hungry carnivores so teeth help them catch their prey of fairy shrimp, mosquitoes and other insects. The adult salamander can be found under damp logs, in leaves and even deep underground where it feeds on worms and other soil invertebrates. Salamanders are active at night. Watch for them in early spring when they mate with much tail thrashing and rolling in the water. A type of salamander called the “mud puppy” is fully aquatic – it spends its entire life in the water and is occasionally caught by people fishing.
GLOSSARY

ABDOMEN – The third or rear section of an insect where digestion, reproduction and air exchange occur.

CAMOUFLAGE – A plant or animal's ability to hide itself by appearing similar to its surrounding.

CARNIVORE – An animal that gets its energy by eating other animals.

CRUSTACEAN – Segmented animals having an exoskeleton (or shell-like covering), two pairs of antennae and breathe by means of gills. Most are microscopic, occurring in huge numbers in lakes, streams and especially the ocean. Others are large, such as lobsters, shrimp or crayfish.

EXOTIC – A plant or animal that is not native. Many exotics have been introduced by people into places where they are causing problems.

FOOD WEB – The overall sharing of energy between plants and animals that produce food, are eaten by others, or receive food by eating others.

HERBIVORE – An animal that gets its energy by eating plants.

LARVA – The immature form of an insect.

INVERTEBRATE – An animal that does not have a backbone.

MICROSCOPIC – Something very small in size – so small that people need tools, such as a microscope, to make it appear larger to see it.

OMNIVORE – An animal that gets its energy by eating both plant and animal matter.

ORGANIC DEBRIS – Dead plants and animal matter usually already partially broken up.

PARASITE – An animal that lives on or in other living organisms (plants or animals) and obtains its food from them.

PLANKTON – Microscopic, or nearly so, plants and animals that float or swim in water in vast numbers.

PREY – Animals that are eaten by other animals.

VERTEBRATE – An animal with a backbone.
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WDNR: WT-513-98
R-06-01-5M-200-S
RESOURCES
Calculate Your Ecological Footprint

Each organism uses resources from the ecosystem to exist. We express this essential requirement as an area of the planet that annually supplies these requirements each year and define this as the organism's ecological footprint. For humans, we can record the consumption data and convert it into an area that supplies these ecosystem resources that are annually appropriated by each person. This is an example of a "systems analysis" that is very helpful for us to understand the connections between our behavior and our dependency on the mother nature. Our ecological footprint helps us to appreciate what we get for free from the environment.

- http://www.esb.utexas.edu/drnm/ecoftpnt/calculate.htm
- http://www.lead.org/leadnet/footprint/intro.htm

Macroinvertebrate Links

Online Keys for Identification
- New York Department of Conservation: This key is a pictorial method of identifying aquatic macroinvertebrates. It is structured so the major groups of aquatic macroinvertebrates can be accurately identified primarily on the basis of photographs instead of traditional written keys that often require the knowledge of unfamiliar terminology. http://www.dec.state.ny.us/website/dow/stream/index.htm

Online Picture Sources
- Museum of Aquatic Entomology of the Florida A&M University: This page is to help coordinate the study of mayflies throughout the world. Your contributions can help us fulfill this task. http://www.famu.org/mayfly/index.html
- Mayfly Central: Mayfly Central is a place, a program, and an information resource. It is located in the Department of Entomology at Purdue University, where it is associated with the Laboratory of Aquatic Entomology. The program is a multidimensional research and education program dedicated to the pursuit and dissemination of knowledge about mayflies, or the insect order Ephemeroptera. [http://www.entn.purdue.edu/entomology/mayfly/mayfly.html](http://www.entn.purdue.edu/entomology/mayfly/mayfly.html)

- Welcome to the Aquatic Insect Collections of Brackenridge Field Laboratory, Department of Zoology, University of Texas at Austin. The lists on the following pages represent an attempt to catalog the aquatic insect species of Texas including those held in the collections at BFL and those from published records. [http://www.utexas.edu/research/bfl/collections/aqinsects/aqinpage.htm](http://www.utexas.edu/research/bfl/collections/aqinsects/aqinpage.htm)

- Macroinvertebrate Identification Charts: [http://www4.ncsu.edu/~aiclevel/ident.html](http://www4.ncsu.edu/~aiclevel/ident.html)

**Collecting Macroinvertebrates**

**Books**

- An Introduction to the Aquatic Insects of North America by Richard W. Merritt (Editor), Kenneth W. Cummins (Editor)


- Aquatic Insect Ecology: Biology and Habitat, Vol. 1 by J.V. V. Ward

- How to Know the Aquatic Insects by Dennis M. Lehmkuhl, Edward T. Cawley and John Bamrick

**Equipment Suppliers**

- Carolina Biological Supply (full line of living and preserved biological materials, supplies, etc) Telephone: 800-334-5551 Fax: 919-584-3399

- Connecticut Valley Biological Supply Co.-- (Collecting & storage equipment; supplies etc) Contact: P.O. Box 326, Southampton, MA 01073

- Edmunds Scientific, a major supplier of optics and science products to high-tech industries, but we are also dedicated to making these same exciting items available to schools and to families. On Line Catalogue at http://www.scientificsonline.com/

- Forestry Suppliers, Inc. -- (Full catalog of field supplies & equipment etc.) Phone: 601-354-3565

- Insect Lore--(Educational materials, books, kits, etc!!) Phone: 805-746-6047.

- Benz Microscope Optics Center -- (Excellent selection of low-cost microscopes for hobbyists, schools, and professionals) Phone: 313-994-3880


What’s in Your Water?
Abandoned Mine Drainage in Local Watersheds
AN EDUCATION MODULE

DEVELOPED BY:
Pamela Kattner, Environmental Education Intern
Valerie Taylor, Watershed Development Coordinator, OSM/VISTA
Eastern Pennsylvania Coalition for Abandoned Mine Reclamation
Shavertown, Pennsylvania, May 2006

www.OrangeWaterNetwork.org
www.ACCWT.org
What’s in Your Water?
Abandoned Mine Drainage in Local Watersheds

Type of Program: This is an Interactive discussion with games and hands-on experiments.

Goals: The goal of this lesson is to understand the effects of abandoned mine drainage (AMD) on water chemistry, aquatic life, and human consumption by discussing it in relation to non-point source pollution.

Objectives: The participants will be able to:
1. Define AMD, watershed, non-point and point source pollution
2. Discuss the pH scale
3. Connect the health of invertebrates to the health of the stream
4. Connect human activities to their effect on stream life
5. Understand how polluted water influences human activity
6. Discover ways to improve their watershed

Curriculum Standards: Pennsylvania Department of Education:
Environment & Ecology: 4.1.4E, 4.1.10E, 4.3.4A,B,C, 4.8.4C, 4.8.7C
Science & Technology: 3.2.4C, 3.4.7A, 3.5.4A
Reading, Writing, Speaking, Listening: 1.6.3A, 1.6.5A, 1.6.8A, 1.6.11A

Virginia Standards of Learning:
1.1, 1.5/ 2.1, 2.5/ 3.1, 3.6, 3.7, 3.9, 310, 3.11/ 4.1, 4.5, 4.8/ 5.5, 5.7/

Target Groups: School groups (adapted for kindergarten through 12th grade)

Evaluation: Review topics covered during program with a quizzing game.

BACKGROUND
Abandoned mine drainage (AMD), a type of non-point source water pollution, exists throughout the world and within our country, especially in Appalachia. Each discharge degrades all water downstream, elevating mine drainage to a watershed level concern. AMD comes from chemical reactions, uncommon in nature, which occur because mining exposes earthen layers to air and water. The orange result exterminates aquatic life. Correcting these discharges requires building a specialized treatment system specific to each site’s water chemistry. Many organizations and individuals cooperate to construct these systems. Broadening awareness enlists community support. Community support is the first step to treatment and remains our greatest chance to eliminate this pollution.
To learn about mine drainage we must examine its effect on watersheds: how water obtains pollutants from mines, the effect of one particular pollutant – iron oxide – on aquatic and human life, and options to remove these pollutants from our waterways.

**How Abandoned Mine Sites Contaminate Water**

Underground mines and surface mines expose rocks and minerals to air and water; consequences accompany this human-made alteration. Pyrite is the most common mineral in coal mines. Physical and chemical weathering of pyrite, the first reaction, takes place within the mine. Here, this mineral bonds with oxygen, producing sulfate and ferrous iron. The reaction generates one unit of ferrous iron for each unit of oxidized pyrite.

\[
\begin{align*}
\text{(1) } & \text{FeS}_2 + \frac{7}{2} \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}^{2+} + 2 \text{SO}_4^{2-} + 2 \text{H}^+ \\
\text{pyrite + oxygen + water} & \rightarrow \text{ferrous iron + sulfate + acidity}
\end{align*}
\]

When this water exits the mine, it contacts oxygen, causing the second reaction to occur. Ferrous iron oxidizes, forming ferric iron. Certain bacteria can metabolize iron, and increase the rate of the reaction, if in this situation the pH value nears 5. At lower pH values these bacteria do not exist, in which case the process of oxidizing iron slows. Also at this time, sulfur from the first step may evaporate as gaseous sulfate compounds (SO\(_4^{2-}\)), or a rotten egg scent. Losing aqueous sulfur sometimes elevates the water’s pH. This reaction is the “rate determining step” in the overall acid-generating sequence.

\[
\begin{align*}
\text{(2) } & \text{2 Fe}^{2+} + \frac{1}{2} \text{O}_2 + 2 \text{H}^+ \rightarrow 2 \text{Fe}^{3+} + \text{H}_2\text{O} \\
\text{ferrous iron + oxygen + acidity} & \rightarrow \text{ferric iron + water}
\end{align*}
\]

Hydrolysis of iron transpires as the third reaction, responsible for splitting water molecules. Formation of ferric hydroxide precipitate (when dissolved iron becomes solid, granular sediment clouding the water or settling on the stream channel bottom) depends upon pH. This orange sediment is also called iron oxide, rust, or yellowboy. If the pH is above 3.5, this sediment becomes visible more quickly. If it is below this value, little or no solids will form; instead, these heavy metals will remain dissolved in the water, often unseen.

\[
\begin{align*}
\text{(3) } & \text{Fe}^{3+} + 3 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 \downarrow + 3 \text{H}^+ \\
\text{ferric iron + water} & \rightarrow \text{ferric hydroxide + acidity}
\end{align*}
\]

The result of abandoned mine lands’ chemical reactions with air and water produce widespread non-point source pollution that is difficult to remediate (*AMD Education Modules, C1.3.25.3*).  

**Iron Oxide’s Effect on Aquatic and Human Life**

The layer of iron oxide on creek beds is not toxic to humans, though it is lethal for aquatic life. For humans, this silt-like iron solid is not dangerous to touch or smell, unless the discharge also contains poisonous heavy metals like aluminum. Aquatic macroinvertebrates (underwater insects, insect larvae, and crustaceans without backbones) respond to this iron coating in the same manner as any sediment. They die from buried habitats and clogged gills. Without the presence of these prey species, fish no longer live in affected waterways. Mine drainage in any tributary negatively impacts the biodiversity of all water downstream and the human activities that thrive on that water and its biodiversity.
Remediation for This Pollution
Remedying this orange waste entails cleaning the polluted water near the place it first emerges into the air. Cleaning this water may be accomplished with chemical treatment, wetland ecosystems, or a combination. Remediation techniques are relatively new and develop rapidly. However, two certainties do exist. Treatment must be specific to each site’s unique water chemistry, and establishing such a system requires a team of community organizations, government agencies, engineers, scientists, and businesses.

Smaller groups and individuals play essential roles both directly and indirectly in site treatment. Directly, they act as part of the remediation team described above, assist with treatment preparations such as water monitoring, and build vital community support. Outside of direct treatment, educating others about orange water is one of the most important tasks to complete.

Hands-on education projects facilitate connections between people and their local environment. Possible projects for non-point source pollution other than AMD include removing litter, planting trees on a stream bank to control soil sedimentation, or managing large amounts of animal waste. Addressing AMD by repairing other forms non-point source pollution reinforces a watershed view. Employing any of the multiple uses for iron oxide pigment including tie-dye shirts, paints, and chalk, builds awareness in its makers and fashions a market for the compound that will be supplied perpetually.

Remediation in every country, state, and town where this drainage exists is essential. Over 4,000 Pennsylvanian stream miles suffer from this devastation, the state’s greatest source of water pollution. While each discharge spurs a long reach of damage, one treatment system cleanses many miles of stream. Restoration continues while communities obtain funding, advance awareness, and organize widespread support.

PROCEDURE
Introduction
Ask the class a question, such as one of those below, and let each student provide their name and an answer.

- What is your favorite sound at a creek?
- Name a plant or animal that lives in a stream.
- What is your favorite thing to do in a creek?
- What color is the creek water where you play?

Watersheds
Local Watershed
- Introduce a map of the local watershed and define the term.
- Choose volunteers to come to the front of the room and point to specific locations on the map that you request such as:
  - their school
  - the creek nearest to their school
  - other landmarks they will recognize
- Ask the last volunteer to trace, with a finger, the creek nearest the school. Begin at the school or an upstream location and end in the river to which it travels.
- Ask class to define a watershed.
Larger Watershed
- Show or discuss a map of a regional watershed that includes the local stream and the largest body of water in which it ends, such as an ocean or bay.
  - In what state does this larger watershed begin?
  - In what body of water does it empty?
  - If you threw a paper cup in the creek near your school, could it float all the way to the Chesapeake Bay?

Pollution Sources
- Explain point-source pollution to the students.
  - (If you are walking down your creek and see a pipe with black goo dripping in to the stream, you know that is point-source pollution because you can point at the exact spot where pollution enters the stream.)
- Explain non-point source pollution.
  - When it rains, water falls on the ground and travels to the stream.
  - Can the water pick-up objects and take them to the stream? What objects do they carry?
    - (In floods: cars, people, houses, cows)
    - (In average rainstorms: dirt, oil in parking lots, grass clippings, sticks, loose dirt, animal waste)
  - Can you point to the exact place where this dirt begins? (No, it comes from too many places and that is why it is called non-point source pollution.)
- Suggested Activity: Stormwater Filter Game

Abandoned Mine Drainage
- Abandoned Mine Drainage (AMD) is another form of non-point source pollution.
  - Show picture of orange creek.
  - Who has seen a creek like this before?
  - Pass around bag of sludge.
- Discuss local mine drainage sites.
  - List a few local creeks that are affected by mine drainage.
  - Show pictures of these.
- Discuss its affects and sources.
  - Where does it come from? (abandoned coal mines)
  - What makes it orange?
    - HINT: What happens when your bike is left in the rain? (rust)
  - What is rust made of? From which metal does rust come from? (iron, oxygen)
  - Discuss local creeks with AMD
    - What does this do to animals that live in the creek? (impairs gills, destroys habitat)
    - Is this water toxic or poisonous? Would your finger fall off? (No, iron does not hurt humans through direct contact. This sediment is toxic to animals. If the water is acidic or contains metals other than iron it can become toxic to humans, and remains lethal to aquatic life.)
  - Where does the iron enter the water? What rocks are in a mine? (coal, dirt, pyrite)
  - Explain how water becomes orange.
    - (Pyrite is made of iron and sulfur.)
(Instead of chunks of fool’s gold swimming down the river, orange clay enters the water. Acidity of the water dissolves this metal. When the water becomes less acidic, the iron becomes a solid, bonds with oxygen, and coats the stream bottom.)

- **Suggested Activity:** Mine Drainage Role Play

**Acid/Base Discussion**
- Give the pH scale handouts to the students to share.
- Who has seen or used a pH scale before?
- Introduce the scale.
  - (The pH scale begins at 1 and goes to 14. Seven is the middle of the scale and is neutral. Any number less than 7 is an acid and any number higher than 7 is a base.)
- Ask students for examples of acids, bases, and neutrals.
  - What is the most acidic thing on your handout? The most basic?
- **Suggested Activity:** Limestone Experiment

**pH Testing**
- Introduce pH test.
  - Explain the three different samples of water that will be tested.
    - orange mine drainage
    - clear mine drainage
    - drinking water
  - Explain how the test works (compare it to litmus paper or testing pool water)
    - show equipment
    - drop indicator into water (color changes)
    - compare the color to the color wheel to determine pH
  - Make predictions.
    - Consider each water sample one at a time. Ask the class to guess if each sample will be basic, acidic, or neutral. Record their guesses on the chart.

<table>
<thead>
<tr>
<th></th>
<th>GUESS</th>
<th>ACTUAL</th>
<th>ACID, BASE, OR NEUTRAL?</th>
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<tbody>
<tr>
<td>Orange Mine Drainage</td>
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<tr>
<td>Clear Mine Drainage</td>
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</tr>
<tr>
<td>Drinking Water</td>
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</tr>
</tbody>
</table>

- Choose volunteers
  - (For younger children, have two volunteers test one water sample, present results, and then call two more volunteers to test the next sample. Let one test happen at a time.)
  - (For older youth, have three volunteers come to the front together. Let each student test one sample, all three tests occur at the same time.)
  - (For smaller groups, divide class into 3 groups, if age appropriate supervision is available, and let each group test a sample together and write their answer on the blackboard.)
Evaluate tests
- Let the class look at the completed chart. Ask if each pH is acidic, basic, or neutral and write the answer beside its pH value on the chart.
- Which water sample is the most acidic? Why?
- Is the pH of the tap water what we expected?
- If the pH of the most acidic water sample is raised, what dissolved metal would precipitate?

Evaluation
- What can you do to prevent or clean AMD?
  - (Students usually struggle to find an answer. It takes special treatment systems to clean orange water, but AMD is just one type of non-point source pollution.)
  - How can you clean or prevent other types of pollution?
    - (pick up litter or dump sites)
    - (only use what you need of lights and cars, so excess pollution is not made)
    - (wear a tie-dye shirt, so your friends will ask you about it. The most important thing you can do is to help other people learn about this so there will be more hands helping to clean and prevent.)
- For what can this sludge be used?
  - (Pigment for stains, paints, or dyes)
  - (Tie-dye shirts. Show example.)
- **Suggested Activity:** AMD Jeopardy
ACTIVITIES

Stormwater Filter Game
Materials: none.

This is a game that is similar to a less mobile version of tag and demonstrates how plants reduce or eliminate non-point source pollution. There are three scenarios: rainwater on a paved parking lot, rainwater on a grassy hill, and rainwater in a wetland.

1. **For each round, choose several students to be the plants and place them in a row facing the class.** “Plants” should stand so that their outstretched arms do not touch each other.
2. **Choose several more students to be rain.** Those students should line up shoulder-to-shoulder facing the line of “plants.”
3. **On your mark, the rain students run through the wall of plant students.**
4. **Those tagged by the “plants” become plants immediately and beginning tagging other “rain” still nearby.** The “rain” not tagged by “plants” have escaped.

**Part I – Parking Lot**
The “plants” are those little pieces of grass that grow in the pavement cracks. Space these plant volunteers farther apart than the other scenarios. They have roots and cannot move their feet from their spot in line. Their arms must stay at their sides. Rain may only be tagged by bending towards them with head or shoulders.

Usually all of the rain escapes this grass. In nature, a paved parking lot does not absorb any rain. All of the oil residue and litter is picked up by the stormwater, carried through stormwater drains, and directly deposited into streams, or waste water treatment facilities, receiving these drains.

**Part II – Grassy Hill**
This time the “plants” in this round continue to be grass, not moving their feet or arms. “Rain” may only be tagged by bending. However, there will be more plant volunteers and they will be placed a little closer to each other.

Less than half of the rain is usually tagged in this scenario. While a grassy hill slows stormwater a little and absorbs some direct pollution, many pollutants still reach receiving streams and facilities.

**Part III – Wetlands**
In a wetland the “plants” will be plentiful and placed closer together than the other two rounds. While these plants continue to have roots that do not let them stray from their line, they now have branches and may also use their arms to tag “rain.”

Only the most wily “rain” will escape the wetland. Wetlands are sponges for stormwater, collecting and holding a great volume for a longer amount of time than most other ecosystems. This allows the soil to absorb the stormwater where it is purified while percolating through the lithosphere. This is necessary to recharge springs and groundwater sources.
Limestone Experiment
Materials: bowl, limestone, hydrochloric acid (HCl), a dropper.

Have you ever mixed baking soda and vinegar? The fizzing that results evidences the acid and the base neutralizing. In this demonstration the presenter will place a few drops of HCl, a strong acid, onto the limestone. If the limestone is a base it will begin to fizz. If it is an acid, nothing will happen.

1. Do you think limestone is an acid or base? Take a vote.
2. Have students crowd around you to watch this demonstration.
3. Place a few drops of HCl onto the limestone. It fizzes.
4. Here are some evaluation questions to ask the students.
   a. Is the limestone an acid or a base? (A base.)
   b. Why was there fizz? (It was the result of neutralization.)
   c. Was there more of the base or the acid in this demonstration? (Base.)
   d. Which was neutralized, the acid or the base? (The acid.)

Mine Drainage Role Play
Materials: a piece of coal, a piece of pyrite, an orange blanket.

Guide students through acting Part I, then briefly discuss what they demonstrated. Follow the same pattern for Part II.

Part I – Water enters the mine and dissolves pyrite.
1. Choose four volunteers: coal, pyrite, oxygen, and water.
2. Hand a piece of coal to the student representing coal.
3. Give the piece of pyrite to the student representing pyrite.
4. The student playing oxygen jumps and twirl around others.
5. On your count, the student being water rushes onto the scene and steals pyrite away.

Part II – Water becomes orange when iron is exposed to oxygen and becomes rust.
1. Choose four volunteers: iron, two hydrogen, oxygen.
2. Iron stands on the scene.
3. The hydrogen and oxygen link arms to become water and march around iron.
4. Freeze the scene and rearrange the volunteers. One hydrogen stands alone and the other three (iron, oxygen, and one hydrogen) join arms creating rust (iron hydroxide).
5. Unfreeze the scene and have the new molecule fall to the ground. Throw an orange blanket over them.

AMD Jeopardy
Materials: index cards with a question on one side and a monetary value on the other.

1. Setup the game on a chalk board by writing the topic, which is AMD, and question values: 100, 200, 300, 400, and 500. The goal is for the class to answer each question correctly.
2. Students raise their hands to choose a question and then answer it.
3. If a student cannot answer a question he/she may phone a friend or poll the audience. Phoning a friend lets the student answering the question choose one person to answer the question in his/her place. Polling the audience lets the student ask the entire class for their suggestions and then choose the one he/she likes best.
4. The class wins the points, if the question is answered correctly.
5. Play this game until the class period ends, or until all questions are answered.
**VOCABULARY**

*Abandoned Mine Drainage (AMD):* Exposure of rocks and minerals to air and water and the pollution created by the chemical reactions that occur.

*Coal:* A sedimentary rock created with decaying plant material and geologic pressure.

*Erosion:* This occurs when sediment (soil, gravel, sand, etc) moves by water or air. This is a problem when large amounts are washed by water into streams.

*Non-Point Source Pollution:* Pollution whose source comes from many tiny, widespread places.

*pH:* A way to classify the acidic and basic qualities of liquid materials.

*Point Source Pollution:* Pollution with one, certain origin.

*Pyrite:* This inexpensive mineral made of iron and sulfur is also known as Fool’s Gold. It is commonly found with coal deposits.

*Stormwater:* Refers to the water that reaches the earth’s surface during a rain event.

*Treatment System:* These are designed and built to remove non-point source pollutants associated with mining from water.

*Watershed:* An area of land and the network of streams to which all of its water drains.

*Wetland:* This is an ecosystem of water-loving plants, animals, and soil that holds a large amount of water.

**RESOURCES**

Environmental Concern, Inc. and The Watercourse. 2003. WOW!: The Wonders of Wetlands. Published through a partnership of Environmental Concern, Inc., St. Michael’s, MD. and The Watercourse, Bozeman, MT.


What's in Your Water?

<table>
<thead>
<tr>
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<th>13</th>
<th>12</th>
<th>11</th>
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<td>Blue</td>
<td>Aqua</td>
<td>Green</td>
<td>Yellow</td>
<td>Orange</td>
<td>Battery Acid</td>
<td>Vinegar</td>
<td>Normal Rain</td>
<td>Acid Rain</td>
<td>Baking Soda</td>
<td>Hand Soap</td>
<td>Bleach</td>
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**The pH Scale**

Represented by the pictures below. You will see what color pH testing paper will turn when it is dipped in the substances. Color the boxes below with the color that is mentioned above it. When you are done, Happy Fish. Good Water & Bad Water & Not Many Fish.