This manual was originally composed as part of the Transportation and Civil Engineering (TRAC) Program created by the American Association of State Highway and Transportation Officials (AASHTO). For more information on the original manual, see the complete final report, NCHRP 20-52.

The manual was updated and revised in 2017 by the Center for Technology & Training (CTT) at Michigan Technological University for the Michigan Department of Transportation (MDOT).
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Executive Summary

This module contains three activities to provide a comprehensive overview of environmental considerations in highway design. Concepts are introduced independently in the activities and then pulled together in experimental demonstrations, hands-on projects, and computer-based simulations. Each activity contains the following sections:

1. Instructor’s Reference. This section is intended for both instructor and volunteer use, and contains an activity summary and preparation information for the activity.
2. Instructor’s Answer Key & Discussion Ideas. This section serves as an instructor companion to the Research Manual and Research Notes and contains all answers to the questions given to students. It also contains suggested points of discussion that relate to the activity.
3. Research Manual. This section is intended for student use, and contains all background, setup, and procedure information and instructions for completing the activity.
4. Research Notes. This section is intended for student use while working on the activity, and lists the same questions found in the Instructor’s Answer Key & Discussion Ideas section.

This manual also contains a complete activity overview table, instructor introduction to the module, and a copy of the National Education Standards. Below are summaries and potential volunteer topics for each activity.

Activity 1: Settling Out

Activity 1 addresses particle size in relation to settling rate in still water. Engineers must consider particle size when designing methods that limit suspended soil particles entering nearby natural waterways.

Volunteer Topics

Students compare the settling rates of gravel, sand, and clay. An Environmental Engineer or Environmental Specialist could discuss problems arising as a result of large quantities of sediment being washed away in heavy rains. In addition, they could explain the various methods used in the field to alleviate these effects. A Civil Engineer could provide slides, photographs, or other audio-visual materials that illustrate how particle size is considered in road design and construction. Either of the volunteers could cover the field operations conducted concerning the prevention of large quantities of contaminants from highway runoff entering nearby waterways (refer to Table 1, p. 17).

Invite a guest speaker to discuss the department of transportation’s current and proposed methods to limit pollutants from entering water resources. Local transportation departments can be contacted for information.

Activity 2: Filtering the Silt

In Activity 2, students implement a filtering efficiency test model used by engineers to determine what filter fabric is most effective in catching suspended particles in runoff. The amount of particles removed from suspension varies in relation to the type of fabric selected and the type of soil where it is best used. Clay- and silt-laden soils will be more difficult to filter using fabrics than sandy soils. Students will test
filter fabric for its effectiveness in trapping suspended soil particles and collect particulate settling data for later analysis of fabric filtering ability.

Soil erosion is one of many environmental factors that highway engineers work to limit in planning and maintaining highways. As urban areas continue to expand, highway engineers must find ways of limiting the impact on the environment. Growing populations decrease the natural habitat available for indigenous species. For example, in the Washington DC metropolitan area, population expansion has allotted more land to the development of residential and commercial properties. This loss of natural habitat has compressed the available land for the white-tailed deer, causing overpopulation in the area. This, in turn, has resulted in numerous vehicular accidents fatal to both humans and deer. Other metropolitan areas are experiencing similar effects. Additional factors accompany the increase in population—traffic congestion, air pollution, and noise pollution—that engineers and highway planners must address when planning new highways.

Volunteer Topics

A transportation engineer can provide information on regulations governing what must be done in the field before, during, and after construction to limit erosion. This should also include procedures used to place silt fences. Slides, overheads, or other audio-visual materials could be used to illustrate uses of erosion control in the field. Additional materials for silt fence testing would add to the lesson.

Activity 3: The Connector Highway Project

Activity 3 considers four major issues (air pollution, noise pollution, water quality, and habitat loss) often included in the judgment of environmental quality of a populated area. In this activity, students must decide whether or not to approve a new highway necessary to alleviate traffic congestion in a growing metropolitan area. Taking on the role of environmental specialists, students will determine what environmental factors are most problematic for their regions, and find possible solutions for these problems that would support the development of the highway, while limiting impacts on the environment. Through their research and discussions, students will recognize that population growth invariably affects the environment; however, implementation of alternative methods can limit the extent of environmental impact.

In the transportation industry, engineers and contractors must find ways of addressing population growth while limiting negative impacts on the environment. For example, to minimize erosion in highway construction zones, engineers must determine the best strategies and materials to limit eroded particles from entering waterways. Additionally, contractors erect noise barriers in residential areas to limit the amount of disturbance from highways. Auto manufacturers are challenged to create more fuel-efficient automobiles to decrease emissions for better air quality, while metropolitan areas place greater investments in public transportation. Small towns and large cities are equally affected by problems arising from population growth. City planners, highway engineers, environmental specialists, and highway contractors must work together to find effective solutions to address these issues.

Volunteer Topics

This unit provides students with a brief overview of environmental topics considered in highway planning and development. A highway engineer could present and discuss real world examples of proposed highways and the approval process that highway planners must follow before beginning highway construction. Examples could include field procedures that are necessary to meet federal requirements, environmental studies, an overview of federal and state highway development
regulations, and the amount of input community members have in making decisions to approve highway plans. Additionally, connecting students’ research with real-world examples would help develop a better understanding of highway planning and development practices. Any road or highway plans currently under consideration (or past situations), from small rural roads to major highways, are applicable. Providing real world examples of projects in the immediate area would be of higher interest to students than major projects in other locations.
Instructor’s Introduction

Engineering is not simply about solving problems. It is about solving problems in the most efficient and elegant manner possible, while not creating new problems along the way. In order to come up with the most efficient solution, some amount of prior knowledge is usually needed. Frequently, this knowledge is mathematical or experiential.

For centuries, scientists, mathematicians, and engineers have studied the physical world and recorded their observations. They have derived mathematical formulas that describe the way materials and systems behave. They have also conducted experiments and drawn conclusions from their results. This body of knowledge that has accumulated over time is what engineers study and apply to solve problems every day. This process is what differentiates engineering from tinkering.

Tinkering is what we do when we try to solve problems by relying on trial-and-error. Tinkering can be fun, but it is usually not the most efficient way of solving a problem. Although solutions to engineering problems can sometimes be found by tinkering, these solutions tend to be neither efficient nor optimal.

Engineering can be fun, too. There is a great deal of satisfaction to be gained from approaching a problem theoretically. Typically, an engineer will try to find a set of equations that describe the problem mathematically. These equations will give the engineer clues about how to solve the problem at hand. Using these clues, engineers can arrive at the optimal solution much more quickly than they could have if they had relied on tinkering alone.

As part of the TRAC & RIDES Program it is key to understand where funding comes from and how decisions are made in the world transportation planning/engineering. Transportation plays a huge role in our everyday lives, and Metropolitan Planning Organizations/Transportation Planning Organizations (or MPOs/TPOs) are a critical component of a city’s transportation system. MPOs help plan the future of transportation in a region, and chances are, there is a MPO in your city making decisions that affect all of us and how we get around. MPOs are made up of local elected officials, elected by the people of a city or region, who decide how to spend taxpayer money on transportation projects. MPOs plan all types of transportation, from roads and highways to public transit and bike lanes. Public involvement is very important to decision makers, and your voice matters! Learn more about your local MPO, and find out how you can get involved in planning the transportation system of the future. As you implement any of the TRAC & RIDES modules we suggest you investigate the MPO/TPO in your area and encourage your students to do the same. It will open up a whole new area where students can explore career opportunities in transportation planning and engineering.

Two websites to begin your student’s research:

- Association of Metropolitan Planning Organizations [www.ampo.org](http://www.ampo.org)
- National Association of Regional Councils [www.narc.org](http://www.narc.org)

All of the activities in this module focus on a central theme in transportation: the environment. Engineers are responsible for designing and constructing new roads and bridges, but they must always do so with respect for the environment. In turn, ensuring both the construction and the long-term presence of new roads and bridges cause minimal or no environmental effects. Activity 1 looks at the time necessary for sediment to settle out of water. Activity 2 involves experimentation to test the effectiveness of different filter fabrics used to help prevent runoff from getting into lakes and streams.
Activity 3 is a research activity where students broaden their knowledge on air pollution, noise pollution, water pollution, and loss of habitat through research.
National Education Standards

National Science Education Standards: Physical Science

Grades 5-8

Science as Inquiry

- Identify questions that can be answered through scientific investigations.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Use technology and mathematics to improve investigations and communications.
- Think critically and logically to make the relationships between evidence and explanations.
- Formulate and revise scientific explanations and models using logic and evidence.

Science Content

- Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.
- Water is a solvent. As it passes through the water cycle, it dissolves minerals and gases and carries them to the oceans.

Science & Technology

- Identify Appropriate Problems for Technological Design: Students should develop their abilities by identifying a specified need, considering its various aspects, and talking to different potential users or beneficiaries. They should appreciate that, for some needs, the cultural backgrounds and beliefs of different groups can affect the criteria for a suitable product.
- Understanding Science and Technology: Technological designs have constraints. Some constraints are unavoidable (for example, properties of materials or effects of weather and friction). Other constraints limit choices in the design (for example, environmental protection, human safety, and aesthetics).

Science in Personal & Social Perspectives

- Populations, Resources, and Environments: When an area becomes overpopulated, the environment will become degraded due to the increased use of resources.
- Risks and Benefits: Students should understand the risks associated with chemical hazards (pollutants in air, water, soil, and food).

Grades 9-12

Science as Inquiry

- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
Science & Technology

- **Identify a Problem**: Students should be able to identify new problems or needs and to change and improve current technological designs.
- **Propose Designs and Choose between Alternative Solutions**: Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes.
- **Communicate the Problem, Process, and Solution**: Students should present their results to students, teachers, and others in a variety of ways, such as orally, in writing, and in other forms.

Science in Personal & Social Perspectives

- **Population Growth**: Populations can increase with effects on resource use and environmental pollution.
- **Environmental Quality**: Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.
- **Natural and Human-Induced Hazards**: There are slow and progressive changes that result in problems for individuals and societies. For example, change in stream channel position, erosion of bridge foundations, sedimentation in lakes and harbors, coastal erosions, and continuing erosion and wasting of soil and landscapes can all negatively affect society. Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards.
- **Science in Technological Local, National, and Global Challenges**: Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use—which decreases space available to other species—and pollution, which changes the chemical composition of air, soil, and water.

National Educational Technology Standards for All Students

**Technology Foundation Standards for Students**

Basic operations and concepts

- Students are proficient in the use of technology.

Technology productivity tools

- Students use technology tools to enhance learning, increase productivity, and promote creativity.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.

Technology communications tools

- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.
Technology research tools
- Students use technology to locate, evaluate, and collect information from a variety of sources.
- Students use technology tools to process data and report results.
- Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.

Technology problem-solving and decision-making tools
- Students use technology resources for solving problems and making informed decisions.
- Students employ technology in the development of strategies for solving problems in the real world.

Standards For Technological Literacy For The International Technology Education Association

Design
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities of a Technological World
- Standard 12: Students will develop abilities to use and maintain technological products and systems.

The Designed World
- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.
- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.
- Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

For the full documentation of TRAC and the National Education Standards, see the TRAC/Michigan Education Standards page on the MDOT website: http://www.michigan.gov/mdot/0,4616,7-151-9623_38029_38059_41397-184233--,00.html.
Activity 1: Settling Out

<table>
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<th>Activity Summary</th>
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<td>Instructor Prep Time</td>
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<tr>
<td>Class Time</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Grade/Class</td>
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<td>Suggested Activity Grouping</td>
</tr>
<tr>
<td>Technology</td>
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<td>National Science Education Standards</td>
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</table>

Introduction

A common misconception is that all particles sink to the bottom when dispersed in water, or “settle out”, but this is not always the case. For rocks and pebbles, this misconception holds true; although, smaller particles (such as clay and heavy metals present on roadways) are held floating or “suspended” in water for a longer duration of time. The occurrence of suspended particles in water is what can cause the water to appear dirty or murky. In the process of erosion, water moving across earth’s surface removes small soil particles and carries them away. These small soil particles, such as clay, act like glue to hold the soil together. The loss of these particles from hillsides and slopes causes larger particles to be exposed to the surface and allows them to erode. These eroded particles are often carried to streams and rivers by the rain water, where the larger particles are deposited as sediment. The smaller particles, however, remain suspended in the streams and rivers for long distances before eventually settling as sediment. This activity focuses on settling rates of particles with varying size in still water. The activity is designed as an inquiry lesson, but can also be conducted as a class demonstration.

Note about suggested activity grouping and material dispersion:

For small groups and class bottle: If you divide the class into 7 groups (4 students per group), the class will need 28 2-liter bottles, 420 ml of aquarium gravel, 420 ml of sand, 840 ml of clay, 280 ml of sodium carbonate, 7 funnels, and enough water to fill 28 2-liter bottles. Additionally, for the classroom bottle, you will need 1 2-liter bottle, 60 ml aquarium gravel, 60 ml sand, 60 ml clay, 40 ml sodium carbonate, 1 funnel, and enough water to fill the 2-liter bottle.

For classroom demonstration: You will need a total of 5 2-liter bottles, 120 ml of aquarium gravel, 120 ml of sand, 180 ml of clay, 80 ml of sodium carbonate, 1 funnel, and enough water to fill five 2-liter bottles.
Objective

In this activity, students will be able to:

- Associate rate of sedimentation with the size of particles in suspension.
- Identify the addition of a water softener as one method to increase the settling rate of clay.

Background

This activity introduces students to the concept of settling rate. They will learn that suspended particles of different sizes settle at different rates. For example, gravel sinks to the bottom of a bucket of water much faster than small clay particles.

Settling rate is the key design feature of settling ponds and other structures designed to hold polluted water long enough to allow suspended particles to settle. Once the suspended particles have settled, the now clear water can be released into the environment. Settling ponds can be cleared of sediment much easier than natural bodies of water, so engineers must understand settling rates in order to properly design these systems.

Activity Expansion Ideas

Wait It Out

Keep both clay bottles (Bottles 3 & 4) set aside past the 48 hours that this activity instructs you to do. Observe the bottles periodically over a 2 week period or until all the clay particles have settled. This will further reinforce to students that clay takes a long period of time to settle, and that the water softener allows the clay to settle much more quickly. Discuss the distance suspended particles might travel in moving water. Students should understand that clay materials often settle out at river deltas (the end of rivers), where fresh water meets the salt water. The salt water serves as an electrolyte that allows the clay particles to more easily settle out.

Optimal Sodium Carbonate Levels

Electrolytes, such as sodium carbonate, can be used to settle particles out of the water. Adding sodium carbonate to the water will decrease the time it takes to settle the clay out of the water. However, there is an optimal quantity of electrolytes to add; more is not always better. Have students run an experiment that would determine the optimal quantity of sodium carbonate needed to settle clay the fastest. Each student group should choose a quantity of sodium carbonate, add it to a bottle with clay and water, mix it, and let it sit still for a week. Students will be able to see which bottle settles the fastest. Have students identify possible variables and controls in their experiment before they try it, using Activity 1 as a starting point. Challenge students to think about the potential effectiveness of using flocking agents to limit pollutants entering the water supply in settling ponds. Consider environmental impact as well as cost.
# Activity 1: Settling Out

## Data Sheet

The students are asked to estimate setting rates. The estimated settling rate column is omitted from the table below. The actual settling rates and expected observations are listed below.

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Actual Setting Rate</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquarium gravel (Bottle 1)</td>
<td>2 s</td>
<td>Gravel settles to the bottom immediately after shaking. Water column is clear.</td>
</tr>
<tr>
<td>Sand (Bottle 2)</td>
<td>2 – 5 min</td>
<td>Initially after shaking bottle, the water appears cloudy. However, shortly a large portion of the sand settles to the bottom. Most of the sand has settled after one minute, with a few particles remaining suspended in the water. Water column is nearly clear after two minutes. Sand is layered across the bottom of the bottle.</td>
</tr>
<tr>
<td>Clay (Bottle 3)</td>
<td>3 days to 3 weeks</td>
<td>A very small amount of clay settles to the bottom immediately after shaking; the rest is suspended in water, causing the water to appear cloudy or opaque. After 2 minutes, the water still remains this way. After 48 hours, only a little more of the clay will settle.</td>
</tr>
<tr>
<td>Clay and sodium carbonate (Bottle 4)</td>
<td>2 days to 2 weeks</td>
<td>Follows similarly to Bottle 3, however, more visible settling will occur after 48 hours.</td>
</tr>
</tbody>
</table>
| Mixed Aggregate (Classroom Bottle 5 with aquarium gravel, sand, and clay) |                     | Aquarium gravel and a large portion of the sand will settle on the bottom after the first two minutes, the water will still be milky white.  
After sodium carbonate is added the water became very cloudy. After an hour or two, the sand and gravel remain settled on bottom, with a thin layer of clay on top. Water is still cloudy.  
After a day, a noticeable layer of clay is at the bottom of the water column. Water is less opaque. Can see through the water.  
After two days, the water column is nearly clear. A thick, white slurry layer will be found atop the sand and gravel layer at the bottom. |
Questions

1) Prior to pouring water into the containers, in what order do you think the particles will settle? Be specific in terms of particle size and mass.

Particles of larger sizes will settle before particles of smaller sizes, and the clay with the flocking agent will settle before the clay without. Overall, particles will settle in the following order: gravel, sand, clay with sodium carbonate, clay. This translates to an order of Bottle 1, Bottle 2, Bottle 4, Bottle 3. However, this question is just a prediction; students may respond with a different order, which is acceptable here.

2) Immediately after filling the containers with water, explain the appearance of the water in each container. Is it transparent (allows all visible light to pass through; clear), translucent (allows some light to pass through; murky), or opaque (allows very little or no light to pass through; cloudy)? Is anything on the bottom? Remember to be specific in your observations.

The clay bottles (Bottles 3 and 4) should be opaque (cloudy), because the particles will not settle out for some time. The sand bottle (Bottle 2) will initially be opaque (cloudy), but will become translucent (murky) then transparent (clear) as the sand settles relatively quickly. The gravel bottle (Bottle 1) will become transparent almost instantly, as these particles settle quickly.

3) In what order did the particles settle in bottles 1-4? How about the classroom bottle (Bottle 5)?

Again, the order should be gravel, sand, clay with sodium carbonate, clay. This translates to an order of Bottle 1, Bottle 2, Bottle 4, Bottle 3. In the classroom bottle, the same order should be observed.

4) What factors determine the settling rate in water?

Students could have offered several different factors for determining the settling rate, commonly the size and mass of the particles. Other factors that may be listed include velocity of moving water, depth of water, water temperature.

5) Describe what you observed in the clay bottle (Bottle 3) after it was set aside for 48 hours. How does it compare to the clay bottle with water softener (Bottle 4)?

After 48 hours, a small amount of clay in Bottle 3 may have settled in a thin film at the bottom of the bottle. However, the water will still be milky and opaque, meaning that there is still clay that has not settled. In Bottle 4, there will be a larger film of clay at the bottom of the bottle. The water will likely be milky and opaque, but not to the extent of Bottle 3. This is because the sodium carbonate coagulates clay particles, and allows them to settle faster.

6) What effect, if any, did the water softener have on the settling rate of clay particles?

As noted in the response to the last question, Bottle 4 will have more settlement at the bottom than Bottle 3 after 48 hours. The water softener allows the clay to coagulate, which allows it to settle more quickly.
7) Studies have shown that the first runoff from rainfall carries the highest volume of pollutants and fine soils from road surfaces (listed in Table 1-1) into surrounding streams and rivers. Once in the water system, these particles can have adverse effects on the ecosystem. From this experiment, what might you recommend to help slow the introduction of these chemicals to the environment?

It was observed in this experiment that settling times vary between particle sizes and masses, and that some particles take a very long time to settle. The background section also indicated to students that still water settles particles more quickly than flowing water, and introduced the concept of settling ponds. From these observations, the students should infer that settling ponds are a great way to separate unwanted particles from waterways, and that the stillness of the ponds allows particles to settle more quickly. You should also mention that other natural filters exist, such as roadside vegetation and percolating soils that catch pollutants prior to them entering the water system.

8) What implications does this experiment have on rivers that serve as water resources for the public water supply?

This experiment has shown that small particles take a long time to settle, even in still water. When polluted water runoff makes its way into waterways that the public uses, the public may be exposed to the harmful pollutants. Protecting our waters from pollutants is crucial for public health. For this reason, highway engineers and planners construct silt fences to filter out suspended particles. Other methods include constructing riprap ditches to limit the amount of sediment carried away from the ditch. Most importantly, slopes and other disturbed areas are seeded immediately after grading is complete to limit the amount of sediment carried away from slopes and slow the movement of water down the slope.

Discussion

Students will observe that aquarium gravel settles out more quickly than sand or clay. While the sand will still settle out relatively quickly, the clay will remain suspended in the water column for a considerable amount of time. Discuss with students the importance size and mass have on settling rates, guiding them to the conclusion that smaller particles remain suspended in water for a longer time period. Link this conclusion to information in the background section, stating that colloidal-like dispersion is the cause for the clay not settling quickly. Similarly, the sodium carbonate is an electrolyte that causes the clay particles to flocculate and settle quickly.

Discuss students answers to questions 7 and 8 as well. Help students understand that we would like to control runoff to protect our waterways, particularly runoff from highways. Point out settling ponds as a great way to control pollutants from reaching waterways. In addition, point out that roadside vegetation can help to hold soils in place and prevent erosion, as well as capture pollutants before they reach waterways. You can also mention the percolating soils that capture pollutants as the water sinks into the ground at these locations.
Activity 1: Settling Out

Introduction

A common misconception is that all particles sink to the bottom when dispersed in water, or “settle out”, but this is not always the case. For rocks and pebbles, this holds true; although, smaller particles (such as clay and heavy metals present on roadways) are held floating or “suspended” in water for a longer duration of time. The occurrence of suspended particles in water is what can cause the water to appear dirty or murky. In the process of erosion, water moving across earth’s surface removes small soil particles and carries them away. These small soil particles, such as clay, act like glue to hold the soil together. The loss of these particles from hillsides and slopes causes larger particles to be exposed to the surface and allows them to erode. These eroded particles are often carried to streams and rivers by the rain water, where the larger particles are deposited as sediment. The smaller particles, however, remain suspended in the streams and rivers for long distances before eventually settling as sediment. This activity focuses on settling rates of particles with varying size in still water.

Objective

In this activity, you will be able to:

- Associate rate of sedimentation with the size of particles in suspension.
- Identify the addition of a water softener as one method to increase the settling rate of clay.

Background

Erosion is a natural process that shapes and changes the contours of the land. As rain hits the earth’s surface, tiny soil particles are displaced and become suspended in the rain water. These suspended particles are carried to streams and rivers by the flowing rainwater, where they eventually settle out, forming sand bars and shallow areas in the stream. The smallest particles, such as clay, are carried great distances and form river deltas, such as the Mississippi River delta.

Have you ever noticed rainbow colors on a wet road? These rainbow colors are evidence of oils and other liquids that have leaked from passing vehicles. Did you know that a majority of substances found in road runoff comes from vehicle and pavement wear? When it rains, runoff water washing over the road surface carries away this waste, along with eroded roadside sands and clays. Many of these particles washed from the road will remain suspended in water as it flows into nearby waterways, while some of the particles will become caught in roadside vegetation, trapped in the soil, or settle out in roadside settling ponds. This highway runoff includes materials that can be harmful to the environment in large quantities, such as nitrogen, phosphorus, lead, zinc, iron, copper, cadmium, nickel, and manganese, to name a few.

Water is often referred to as the universal solvent as a result of a large number of materials being soluble in water. The bond structure of the water molecule is what makes it an excellent solvent; although a water molecule has no overall charge, its asymmetric H₂O structure creates electrically polar properties at the oxygen and hydrogen ends of the bond. Water molecules are triangular in shape, with the oxygen atom forming the top of the triangle and the two hydrogen atoms forming the base. The oxygen atom tends to draw electrons toward it, causing the oxygen to form a slightly negative electrical charge, while the hydrogen atoms in turn form a slightly positive electrical charge. Negative ionic
(charged) particles are attracted to the positively charged hydrogen atoms at the polar ends of the water molecule, forming weak hydrogen bonds. These negatively charged particles often form weak hydrogen bonds with multiple water molecules, which trap the particle in the water and keeps it suspended. Particles will stay suspended until they are given sufficient time to settle.

Different-sized particles settle at different rates. Scientists and engineers use the term water column to describe the water quality from the bottom of a body of water to the surface of the body of water. When left undisturbed, smaller particles tend to stay present in the top layers of the water column, while larger particles have already settled out of the top layer and would be more likely to be found near the bottom of the water column. In a lake, for example, the water column would describe the sediment at the bottom of the lakebed, the larger suspended solids just above the bottom, and the smaller suspended solids in the water all the way up to the surface.

When flowing water reaches a calm location, such as a lake or a wide, slow river, the larger suspended particles, such as sand, will settle out first, forming a layer of sediment along the streambed. The tiniest suspended particles, such as clay, however, do not settle out as easily. These small particles remain suspended for long periods of time in colloidal-like dispersion, even in slowly moving or still water. These colloid-like mixtures make the water appear cloudy, or “turbid.”

Why does the clay not settle out of water quickly? Several factors work to maintain colloidal dispersion, most commonly electrostatic repulsion. The suspended clay particles are surrounded by water molecules and connected by the positively charged hydrogen bonds, as described earlier. The hydrogen atoms in the water molecule are thus drawn towards the center of the particle, leaving the negatively charged oxygen atom facing away from the center. The outward facing oxygen atoms form a negatively charged sphere around the clay particle, which repels other negatively charged clay particle spheres. This constant repulsion keeps the clay particles in motion and, therefore, suspended and unable to settle. See Figure 1-1 for a visual representation of this. This can be demonstrated by placing a colloid in an electric field as the colloidal molecules will all gather around the source of the positive charge, illustrating their like negative charge.

Colloidal behavior can be disrupted by heat or the addition of an electrolyte. These processes each cause the colloidal molecules to bond, or “coagulate,” forming an aggregate that is large enough to settle more easily. Heat increases the molecular velocities of the colloidal molecules, causing them to collide against one another with enough energy to break through the negative ionic oxygen layer. This occurrence, in turn, allows aggregate bonds to form. The addition of an electrolyte achieves a similar effect. Electrolytes, such as common table salt (NaCl), neutralize the outer ionic layer of a colloidal molecule by forming bonds with the negatively charged outer sphere. For example, the sodium in salt is positively charged, and will stick to the negative oxygen sphere. The sodium in the salt, as well as the chloride, can then form other bonds with oppositely charged atoms in different colloidal molecules. This is why clay often settles at river deltas. When fresh water carrying suspended clay in the river mixes with saltwater from the ocean, the salt in the saltwater neutralizes the clay in the freshwater and forms a coagulated aggregate that settles out. Electrolytes that cause coagulation are known as flocking agents.
In the transportation industry, settling ponds, like the one shown in Figure 1-2, are dug to trap particles in runoff water, preventing them from reaching waterways. Chemicals and eroded soils from highways flow into these settling ponds and are able to settle due to the stillness of the water. Occasionally, flocking agents are added to the settling ponds to neutralize suspended particles, such as clays and heavy metals. Some of the particles most often found in highway runoff are listed in Table 1-1. Table 1-2 identifies typical locations for runoff containing the materials listed in Table 1-1.

Figure 1-2: A settling pond is dug prior to construction to limit the sediment carried away in surface water from the site.

Table 1-1: Highway runoff components and sources

<table>
<thead>
<tr>
<th>Component</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulates</td>
<td>Pavement wear, vehicles, atmospheric deposition, maintenance activities</td>
</tr>
<tr>
<td>Nitrogen, Phosphorus</td>
<td>Atmospheric deposition and fertilizer application</td>
</tr>
<tr>
<td>Lead</td>
<td>Tire wear</td>
</tr>
<tr>
<td>Zinc</td>
<td>Tire wear, motor oil, and grease</td>
</tr>
<tr>
<td>Iron</td>
<td>Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts</td>
</tr>
<tr>
<td>Copper</td>
<td>Metal plating, bearing and brushing wear, moving engine parts, brake lining wear, fungicides and insecticides</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Tire wear and insecticide application</td>
</tr>
<tr>
<td>Chromium</td>
<td>Metal plating, moving engine parts, and brake lining wear</td>
</tr>
<tr>
<td>Nickel</td>
<td>Diesel fuel and gasoline, lubrication oil, metal plating, bushing wear, brake lining wear, and asphalt paving</td>
</tr>
<tr>
<td>Manganese</td>
<td>Moving engine parts</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Anti-caking compounds used to keep deicing salts granular</td>
</tr>
<tr>
<td>Sodium, Calcium, Chloride</td>
<td>Deicing salts</td>
</tr>
<tr>
<td>Sulphates</td>
<td>Roadway beds, fuel, and deicing salts</td>
</tr>
<tr>
<td>Petroleum</td>
<td>Spills, leaks, antifreeze and hydraulic fluids, and asphalt surface leachate</td>
</tr>
</tbody>
</table>
Table 1-2: Potential stormwater locations that may carry high amounts of particles listed in Table 1-1.

<table>
<thead>
<tr>
<th>Potential Stormwater Locations with High Levels of Particulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport deicing facilities</td>
</tr>
<tr>
<td>Auto recycler facilities</td>
</tr>
<tr>
<td>Commercial nurseries</td>
</tr>
<tr>
<td>Commercial parking lots</td>
</tr>
<tr>
<td>Fueling stations</td>
</tr>
<tr>
<td>Fleet storage areas (bus, truck)</td>
</tr>
<tr>
<td>Industrial rooftops (depending on the surface)</td>
</tr>
<tr>
<td>Marinas</td>
</tr>
<tr>
<td>Outdoor container storage of liquids</td>
</tr>
<tr>
<td>Outdoor loading/unloading facilities</td>
</tr>
<tr>
<td>Public Works Storage areas</td>
</tr>
<tr>
<td>Vehicle service and maintenance areas</td>
</tr>
<tr>
<td>Vehicle and equipment washing/steam cleaning facilities</td>
</tr>
</tbody>
</table>

Materials

Per group of students + Per class

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Liter bottle with lid (clear)</td>
<td>4</td>
<td>2-Liter bottle with lid (clear)</td>
<td>1</td>
</tr>
<tr>
<td>60 ml (1/4 cup) aquarium gravel</td>
<td>1</td>
<td>60 ml (1/4 cup) aquarium gravel</td>
<td>1</td>
</tr>
<tr>
<td>60 ml (1/4 cup) sand</td>
<td>1</td>
<td>60 ml (1/4 cup) sand</td>
<td>1</td>
</tr>
<tr>
<td>60 ml (1/4 cup) clay</td>
<td>2</td>
<td>60 ml (1/4 cup) clay</td>
<td>2</td>
</tr>
<tr>
<td>40 ml (8 teaspoons) sodium carbonate</td>
<td>1</td>
<td>40 ml (8 teaspoons) sodium carbonate</td>
<td>1</td>
</tr>
<tr>
<td>Funnel</td>
<td>1</td>
<td>Funnel</td>
<td>1</td>
</tr>
<tr>
<td>Stopwatch</td>
<td>1</td>
<td>Stopwatch</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>As needed</td>
<td>Water</td>
<td>As needed</td>
</tr>
</tbody>
</table>

OR per class demonstration

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Liter bottle with lid (clear)</td>
<td>5</td>
</tr>
<tr>
<td>60 ml (1/4 cup) aquarium gravel</td>
<td>2</td>
</tr>
<tr>
<td>60 ml (1/4 cup) sand</td>
<td>2</td>
</tr>
<tr>
<td>60 ml (1/4 cup) clay</td>
<td>4</td>
</tr>
<tr>
<td>40 ml (8 teaspoons) sodium carbonate</td>
<td>2</td>
</tr>
<tr>
<td>Funnel</td>
<td>1</td>
</tr>
<tr>
<td>Stopwatch</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>As needed</td>
</tr>
</tbody>
</table>
Setup

There are two setups for this activity. The setup chosen will depend on whether your instructor has you work in small groups or chooses to do a classroom demonstration. If working in small groups, you will need four bottles per group, plus one bottle to be shared by the whole class. If working as a class, you will need a total of five bottles. Other items needed for this activity are listed in the Materials section above. See Figure 1-3 for a visual representation of the experiment setup.

Figure 1-3: Activity Setup

Procedure

1. Label bottles 1-4 for your group. Classroom bottle 5 should also be labeled.

2. Measure out 60 ml (¼ cup) of each soil (gravel, sand, and clay), plus 40 ml (8 teaspoons) sodium carbonate.

3. Place 60 ml (¼ cup) of gravel in Bottle 1, 60 ml (¼ cup) of sand into Bottle 2, 60 ml (¼ cup) of clay into Bottle 3, and 60 ml (¼ cup) of clay plus 40 ml (8 teaspoons) sodium carbonate in Bottle 4. Use the funnel to add the particles to the bottles.

4. Predict the order and time it will take for the contents of each bottle to settle out in water. Record your predictions in the Research Notes section (Question 1 and data table).

5. Fill each bottle just below the neck with water, and secure the lids tightly. With a timer ready, shake bottles vigorously until the bottle’s contents are evenly dispersed throughout the water. No sediment should be stuck to the bottom of the bottle. Set the containers back on the table and begin timing. Immediately observe the appearance of the water and record your observations in the Research Notes section (Question 2 and data table).

6. Observe each bottle for two minutes and record results in the data table in the Research Notes.

7. After observing the bottles for two minutes, the classroom bottle (Bottle 5) should be prepared. Measure and place 60 ml (¼ cup) of all of the soils (gravel, sand, and clay) in the bottle.

8. One student should shake the bottle vigorously and then place it on a tabletop where all students can observe. Again, the timer should be started when the bottle is placed on the table.
9. Observe the sediment in the bottle for two minutes and record your observations in the data table in the *Research Notes* section.

10. After two minutes, add 40 ml (8 teaspoons) of sodium carbonate to the classroom bottle (Bottle 5). Shake the bottle vigorously to mix all the materials and set aside on a table.

11. Allow both clay bottles (Bottle 3 and 4), and classroom bottle, to stand for 48 hours. Observe and record changes in the mixtures at the end of this period. Then, answer the remaining questions in the *Research Notes*. 
Activity 1: Settling Out

Data Table

Answer Questions 1 and 2 of the Research Notes when directed to in the Procedure section. After completing the observation table and the observing the effects of the sodium carbonate, answer the remaining questions.

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Estimated Settling Rate (min)</th>
<th>Actual Settling Rate (min)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquarium gravel (Bottle 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand (Bottle 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay (Bottle 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay and sodium carbonate (Bottle 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Aggregate (Classroom Bottle 5 with aquarium gravel, sand, and clay)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Questions

1) Prior to pouring water into the containers, in what order do you think the particles will settle? Be specific in terms of particle size and mass.

2) Immediately after filling the containers with water, explain the appearance of the water in each container. Is it transparent (allows all visible light to pass through; clear), translucent (allows some light to pass through; murky), or opaque (allows very little or no light to pass through; cloudy)? Is anything on the bottom? Remember to be specific in your observations.

3) In what order did the particles settle in bottles 1-4? How about the classroom bottle (Bottle 5)?

4) What factors determine the settling rate in water?
5) Describe what you observed in the clay bottle (Bottle 3) after it was set aside for 48 hours. How does it compare to the clay bottle with water softener (Bottle 4)?

6) What effect, if any, did the water softener have on the settling rate of clay particles?

7) Studies have shown that the first runoff from rainfall carries the highest volume of pollutants and fine soils from road surfaces (listed in Table 1-1) into surrounding streams and rivers. Once in the water system, these particles can have adverse effects on the ecosystem. From this experiment, what might you recommend to help slow the introduction of these chemicals to the environment?

8) What implications does this experiment have on rivers that serve as water resources for the public water supply?
Activity 2: Filtering the Silt

<table>
<thead>
<tr>
<th>Activity Summary</th>
</tr>
</thead>
</table>
| **Instructor Prep Time** | 10 minutes getting dirt  
20 minutes setup |
| **Class Time** | 50 minutes (1-2 class periods, based on the amount of trials the class will complete) |
| **Grade/Class** | 6 - 12 Environmental Science / Earth Science |
| **Suggested Activity Grouping** | Class demonstration or four groups to perform one activity each  
(Trial A, Trial B, Trial C, Trial D) |
| **Technology** | Low Tech |
| **National Science Education Standards** | Appropriate tools  
Think critically  
Structure of the Earth  
Water is a solvent  
Natural and human induced hazards  
Environmental quality |

Introduction

In preparation for a new highway, contractors use large construction vehicles to remove vegetation and soil from the site, leaving the ground open to erosion. Rainfall washing over the site carries away large amounts of loose soil which can find its way into nearby waterways, endangering aquatic habitats and affecting other food webs. For this reason, transportation engineers must plan effective management practices to minimize the effects of erosion. One way to limit the amount of sediment entering nearby streams is to use silt fencing that filters small particles, such as silt and clay, from the water running off construction sites. In order to select the optimal filtering material for a silt fence, engineers must consider a variety of factors: the effectiveness of the filtering fabric, the soil type at the site, the effect of sunlight on the fabric, and the placement of the fence. These factors change based upon the fence’s location and specific environmental conditions. In this activity students will test various fabrics to determine the best fabric to use for silt fencing in their area. This activity is analogous to the tests that civil engineers conduct to determine the filtering ability of different materials.

In Trials 1 and 2 of the experiment students will determine if the slope of the flume affects the ability of the filter fabric to remove suspended solids from the water. This simulates different runoff slopes on a construction site. In Trials 3 and 4, students will test two different types of filter fabric and conclude if one is better than another for their soil type. If there is not enough time to complete all four trials in one class period, trials can be split up over two periods.

**Note:** It is best to use DRY soil from your area by allowing the soil to be exposed to sunlight prior to the activity. Several samples from different layers of soil will provide students with an interesting study. Potting soil will not work well for this activity because of the high level of organic material.
For ease of cleanup, it is recommended to conduct this activity outside in order to minimize potential spillage and overflow. If you plan to do the activity inside the classroom, it is advised that you place a large container under your catch bucket and have towels available for cleanup.

Objective

In this activity, students will:

- Determine what material filters best for their type of soil.
- Learn how the slope of a hill effects runoff and the effectiveness of filter fabric on slopes.

Background

Construction crews use a variety of products and techniques to reduce the effects of erosion at a job site. As explored in the last activity, a settling pond can filter out sediment displaced by erosion over time; however, settling ponds are not always an option at construction sites. Silt fences are a relatively cheap, effective method for protecting the environment surrounding a job site by filtering out the displaced soil from runoff water before it is carried to waterways. Silt fencing is very popular due to its effectiveness at almost any job location. Many different materials can be used to construct silt fences, and this activity will look at the working properties of some of these options.

Activity Expansion Ideas

Experiment Expansions

Civil engineers have developed and implemented an analogous test to determine the optimal filtering material to be applied to ditches and other erosion prone areas. A number of other activities can be designed using the flume. The following is a short list of possibilities:

1. Test different types of soil with the same fabric to determine if a fabric is better used in particular environments.
2. Add additional pollutants, such as food coloring, to identify the effectiveness of the fabric in filtering particles smaller than suspended soil particles.
3. Design a test to determine what effect slope has on the ability for the fabric to filter particles from the water.
4. Repeat the same filter test several times to determine which fabric filters best after multiple rains.

Note: Testing the ability of different fabrics to filter the same type of soil will show how some materials perform better than others under the given circumstances. Whereas testing the ability of one material to filter different types of soil will show that a fabric can remove certain soils from runoff better than other types of soils.

Erosion Effects on the Food Web

In addition to this activity expansion, students could also be taught the importance of the food web, or food chain, through an interactive activity. As mentioned in the background of the research manual, habitats and food webs are affected by erosion and other pollutants. The effect on the environment should be taken into consideration before construction can begin. For this activity expansion, the
instructor could print off pictures of animals in the food web and assign each student an animal. In a large open area, the students need to be organized in a food web (using string to make connections) and given a brief overview of how the food web works and how it keeps the ecosystem stable. Then, one animal (or student) should be removed from the food web. At this point the instructor should narrate how the ecosystem would fall apart. Every time an animal is removed from an area, the respective student should be removed from the food web. Although, it should be noted that this process would happen over an extended period of time, not instantly.

For example, if the food web involved hawks eating snakes and shrews, snakes eating frogs and shrews, frogs eating crickets, shrews eating grasshoppers and crickets, etc. Then if the shrews were removed from the equation, the hawks would only have snakes to eat and the snakes would only have frogs to eat on the predator side of the equation. Whereas, the crickets would have one less animal feeding on them and the grasshoppers would have nothing feeding on them, on the prey side of the equation. Essentially, the presence of crickets would increase, the presence of grasshoppers would increase exponentially, the presence of frogs would decrease (until snakes disappear) or disappear, the snake population would disappear because the hawks have less food options, and the hawk population would either go extinct due to no available food or they would be forced to adapt.
Activity 2: Filtering the Silt

General Activity Discussion
The results of this activity will vary on several factors, most notably the properties of the soil used to perform the tests. Soil can have many different properties depending on its mineral composition, the amount of organics present, and the size and distribution of particles. The supplied filters may produce different results for different types of soil.

<table>
<thead>
<tr>
<th>Unfiltered Water Sample (mm)</th>
<th>8% Slope (Filtered) Sample (mm)</th>
<th>Unfiltered Water Sample (mm)</th>
<th>8% Slope (Filtered) Sample (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 1 minute</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
</tr>
<tr>
<td>After 2 minutes</td>
<td>6 mm</td>
<td>3 mm</td>
<td>6 mm</td>
</tr>
<tr>
<td>After 5 minutes</td>
<td>9 mm</td>
<td>6 mm</td>
<td>7 mm</td>
</tr>
<tr>
<td>After 10 minutes</td>
<td>10 mm</td>
<td>7 mm</td>
<td>8 mm</td>
</tr>
<tr>
<td>After 20 minutes</td>
<td>10 mm</td>
<td>7 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 30 minutes</td>
<td>10 mm</td>
<td>7 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 60 minutes</td>
<td>10 mm</td>
<td>7 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>After 24 hours</td>
<td>10 mm</td>
<td>7 mm</td>
<td>10 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unfiltered Water Sample (mm)</th>
<th>12% Slope (Filtered) Sample (mm)</th>
<th>Unfiltered Water Sample (mm)</th>
<th>12% Slope (Filtered) Sample (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 1 minute</td>
<td>Minimal</td>
<td>3 mm</td>
<td>7 mm</td>
</tr>
<tr>
<td>After 2 minutes</td>
<td>8 mm</td>
<td>4 mm</td>
<td>8 mm</td>
</tr>
<tr>
<td>After 5 minutes</td>
<td>8 mm</td>
<td>5 mm</td>
<td>8 mm</td>
</tr>
<tr>
<td>After 10 minutes</td>
<td>9 mm</td>
<td>6 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 20 minutes</td>
<td>9 mm</td>
<td>6 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 30 minutes</td>
<td>9 mm</td>
<td>6 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 60 minutes</td>
<td>10 mm</td>
<td>7 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>After 24 hours</td>
<td>10 mm</td>
<td>7 mm</td>
<td>10 mm</td>
</tr>
</tbody>
</table>

Activity Graph: Sediment Depths
Students should draw a line graph that includes all four sediment depths: unfiltered sample (two trails), 8% grade effluent (filtered) sample, and 12% grade effluent (filtered) sample. The graph should represent the settling of the sediment in the first 60 minutes. Recommend that students use different colored pens or pencils to identify each sediment type and have them create a legend to identify lines for each sediment depth.

**Sediment Depth Data for 8% Slope (Trials 1 & 3)**

**Sediment Depth Data for 12% Slope (Trials 2 & 4)**

**Questions**
1) Which material was the most effective at catching small soil particles suspended in the water?

Answers will vary; however, answers should reflect results represented in students’ graphs.

2) How does the unfiltered water sample compare to the filtered runoff sample after each has been allowed to settle for 20 minutes? Provide quantitative data to support your observations.

The unfiltered water should have had a greater amount of sediment on the bottom of the sample container and perhaps small particles floating on the top. Unfiltered water may remain cloudy after 20 minutes if soil has a high clay content. The filtered water should have a lesser amount of sediment, as some was filtered out.

3) Use the graph to predict the sediment depth from the 8% grade runoff after the solution has settled for 15 minutes.

Answers will vary, but student answers should reflect results represented in their graphs. A good way to go about this is to take the average of the depth at 10 minutes and 20 minutes.

4) What effect, if any, did the increased slope (12% slope) have on the filtering rate?

The increased slope of 12% caused an increased flow rate through the filter material. (The flow rate through the filter material will also be affected by the amount of sediment in the water). Increased flow rates translate to more sediment attempting to pass through the filter at once, which causes sediment to build up in front of the filter. This can clog up the filter, and decrease the ability of the fence to pass water, potentially causing issues. Although, the result of the material itself to perform shouldn’t be affected, except that it would filter at a slower rate.

5) If a construction site is located in sandy soil, how effective would the silt fencing be in limiting the amount of soil particles entering nearby streams? Explain your answer.

The sandy soil would be stopped by the silt fence for the most part, because sand particles are relatively large and would not pass through the fabric’s fibers. The sand would build up behind the silt fence, so it would have to be watched that an excessive amount of soil does not get backed up, which would limit water flow or cause water to pour overtop the silt fence.

6) How effective would silt fences be in areas with clay soil? Explain your answer.

The filter should catch some of the clay suspended in the runoff; however, not all particles will be trapped in the filter, as the clay particles are small. Overall, silt fences would decrease the amount of sediment entering nearby streams, but not prevent it entirely. The clay particles do not settle easily, and would be carried far downstream before settling.

7) Silt fences are placed in areas most susceptible to erosion during highway construction. The fences are designed to permit water to flow through the material but catch small soil particles suspended in the water. The more effective the material, the smaller the amount of soil that will be carried to nearby streams. If you were asked to recommend one of these materials for use in silt fencing to limit erosion from a recently disturbed slope, which would you recommend? Support your answer with data you collected from the activity.
The answer here will vary region to region, based on the soil tested; however, students should be able to defend their selection with results from the experiment. Since the students are asked to select the best fabric for reducing erosion from a slope, they should assume that a high volume of water runoff may be present with a high potential for suspended particles. As such, based on their graph, they should select a material that filtered the most soil in the shortest amount of time. Generally, this means a more porous fabric would be most effective. A fabric that filters more particles but requires a greater amount of time to do so (less porous) could cause the runoff to backup and overtop or flow around the silt fence.

8) What are the drawbacks of the material you recommended in question 7?

The filter for question 7 is the one that can handle the highest flow, not necessarily the most effective filtering material. The filter for question 7 will filter out the larger particles, but will still allow smaller particles to pass through, in order to prevent water from flowing overtop the silt fence in heavy rainfall. If there is a shallower slope, a less porous filtering material can be used, and more soil particles could be filtered out.

Discussion

The water will flow quickly through the filter fabric and/or burlap on the first test. Many students will expect few particles to be filtered from the dirty water. After comparing the unfiltered and filtered samples, discuss the effectiveness of the two fabrics in trapping particles. How many layers of soil were visible in the unfiltered jar compared to the filtered jar? Discuss with students that the filter fabric and/or burlap cannot trap all particles. Testing has proven burlap to be an effective filtering material; however, burlap exposed to ultraviolet rays over a 2-month period quickly rots. What other materials could engineers use?

Filter fabric does have its limitations. When filtering the water time and time again, students may expect the water to be clear after running it through the filter material. However, this is not the case. Due to clay and other fine particles in the soil, the water will remain murky because the particles are fine and pass directly through. Clay material can be quite difficult to remove using filter fabric.

Discuss the effects that loss of clay has on a slope (or hillside). Where does the clay go after being washed down the slope? How might this affect the environment? Sediment carried into the stream will settle and fill in the streambed. Sediment affects the benthic organisms—insect larvae, crustaceans (crayfish or shrimp), and mollusks (clams and mussels)—that live there. The loss of these organisms affects other forms of life that rely on them for food. In essence, sediment buildup in streambeds will negatively affect the organisms that reside there. Plants counteract the effect of erosion by slowing the flow of water over the ground surface and anchor the soil in place with their roots. Highway engineers avoid creating steep slopes (8% grade is optimum, 12% is the maximum grade permitted) along main highways to limit erosion. Techniques including silt fencing and building terracing on hillsides are implemented to catch soil carried by the water before it enters nearby streams. As soon as construction has reached completion, the contractor seeds graded slopes to establish root systems that will hold the soil in place.
Activity 2: Filtering the Silt

Introduction

In preparation for a new highway, contractors use heavy equipment to remove vegetation and soil from the site, leaving the ground open to erosion. Rainfall washing over the site carries away large amounts of loose soil which can find its way into nearby waterways, endangering aquatic habitats and affecting other food webs. For this reason, transportation engineers must plan effective management practices to minimize the effects of erosion. One way to limit the amount of sediment entering nearby streams is to use silt fencing that filters small particles, such as silt and clay, from the water running off construction sites. In order to select the optimal filtering material for a silt fence, engineers must consider a variety of factors: the effectiveness of the filtering fabric, the soil type at the site, the effect of sunlight on the fabric, and the placement of the fence. These factors change based upon the fence’s location and specific environmental conditions. In this activity students will test various fabrics to determine the best fabric to use for silt fencing in their area. This activity is analogous to the tests that civil engineers conduct to determine the filtering ability of different materials.

Objective

In this activity, you will:

- Determine what material filters best for their type of soil.
- Learn how the slope of a hill affects runoff and the effectiveness of filter fabric on slopes.

Background

Soil erosion is a natural process that shapes and changes the contours of the land. As raindrops hit the ground, they dislodge small particles of soil. Rainwater carries soil away, leaving small indentations called rivulets. These rivulets continue to develop as more particles are carried away, forming small paths in the soil. Since fine soil particles, such as clay, act like glue to hold larger particles in place, larger particles are then exposed and carried away after the fine particles are lost. As the process continues, large gullies are formed. The small particles carried from an area are often deposited in nearby waterways, in turn, adding to the streambed and making the water depth shallower. Consequently, endangering the habitat of organisms living there.

Road construction may speed up the erosion process. When constructing a highway, the ground must be dug up in certain areas, thus loosening a large amount of soil. Rainwater can carry away this loose soil more easily than compact soil, which speeds up the negative effects on a streambed. To compensate, silt fences are used to capture the loose soil before it can reach these streambeds.

In order to better understand the concept of soil make up, it may help to visualize soil in terms of particles of different sizes. Think of a container filled with softballs. This container would represent a soil consisting of only one particle size and would be referred to by a soils (geotechnical) engineer as a poorly-graded soil. A soil would be considered well-graded if there were a better distribution of particles sizes. Think of what would happen if you added golf balls and marbles to the bucket of softballs. The smaller balls would fill in the voids between the softballs and create a more stable “soil” matrix.
Materials
Per Class

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flume</td>
<td>1</td>
</tr>
<tr>
<td>Soil (not provided)</td>
<td>1 bucket</td>
</tr>
<tr>
<td>Plastic buckets</td>
<td>3</td>
</tr>
<tr>
<td>Sieve set (lid, #6, #20, catch container)</td>
<td>1 set</td>
</tr>
<tr>
<td>1/4 measuring cup (60 ml)</td>
<td>1</td>
</tr>
<tr>
<td>Filter fabric and/or burlap</td>
<td>2 types or weaves</td>
</tr>
<tr>
<td>Small sample container with lid</td>
<td>8</td>
</tr>
<tr>
<td>Stopwatch</td>
<td>1</td>
</tr>
<tr>
<td>Ruler</td>
<td>1</td>
</tr>
<tr>
<td>Colored Pencils or Pens</td>
<td>As Needed</td>
</tr>
<tr>
<td>Paper</td>
<td>As Needed</td>
</tr>
<tr>
<td>Water</td>
<td>As needed</td>
</tr>
</tbody>
</table>

Setup

Figure 2-1: Activity Setup

Soil

1. Observe the texture and appearance of the soil your instructor has gathered and record your observations in your Research Notes.

   **Note:** Make sure the soil is dry before sieving. (If necessary, spread the soil out on a pan ahead of time to allow it to dry.)

2. Gather the lid, sieves #6 and #20, and the catch container. Stack the sieves and catch container in the following order: #6, #20, catch container. Add soil to the #6 sieve. Place the lid snugly on top of sieve #6 and shake the soil back and forth while holding the sieves upright, sifting the soil through the sieves.
3. Once most of the soil has been sifted through, carefully and gently separate the sieve set. Do not use great force.

4. Observe the texture and appearance of the soil remaining in each of the sieves. Soil sifted through the sieve is called minus material. Material remaining on the sieve is called plus material. For example, since the first sieve is #6, soil that sifted through this sieve to the next is called minus 6 material. Material remaining on the #6 sieve is called plus 6 material. Similarly, soil sifted through the #20 sieve is called minus 20 material and soil remaining on sieve #20 is called plus 20 material.

5. Record the texture and appearance of the minus 6 material, the plus 6 material, the minus 20 material, and the plus 20 material in your Research Notes.

6. Measure 175 grams (approximately ½ cup) of minus 20 material and set aside.

Flume

1. Choose one piece of filter material and stretch it across the open end of the flume.

   Note: Burlap or construction filter fabric may be used for this experiment. The remaining piece(s) of filter material can be used in Trials 3 & 4.

2. Place the flume frame on top of the filter material. Fasten, tighten, and clamp the flume frame to the open end of the flume, making sure the filter material fits snugly so water will not pass around the material. See Figure 2-2.

   Figure 2-2: Fastening the flume frame

3. After fastening the fabric to the flume, position the flume at the edge of a table, placing the catch bucket underneath, as depicted in Figure 2-1. Be sure the catch bucket surrounds the entire open end of the flume, or water from the flume will spill onto the floor.

   Note: The flume is already at an 8% slope, which is the preferred grade of most ditch lines.
Procedure

Flume Trial 1 (8% slope)

1. Place the catch bucket under the fabric end of the flume to catch the runoff (effluent) from the flume during the experiment.

2. Put 2 liters of water in a second bucket. Add 175 grams (approximately ½ cup) of minus 20 soil into the water and stir until it is thoroughly dispersed.

3. Dip a sample container into the second bucket and fill it with the solution. Make sure the solution in the sample container is evenly dispersed so the sample collected represents the entire contents of the bucket. Cap the container and label it. Set this sample aside.
   
   **Note:** It is recommended that you mark this sample “unfiltered.” Label the sample with masking tape or write “unfiltered” on a scrap of paper and set the sample on top of the paper.

4. Prepare to time the drainage for the next part of the experiment. (You will start the stopwatch when the solution is poured into the flume.) Stir the water-soil solution in the bucket again until the soil is thoroughly mixed. Pour the water-soil solution into the flume as close as possible to the top of the incline, occasionally swirling or stirring the solution to keep the soil dispersed. See Figure 2-3.

5. Water will begin to pass through the fabric and drip into the catch bucket. When no more water is passing through the fabric, stop the stopwatch and record the drainage time.

6. Stir the caught runoff (effluent) solution in the catch bucket until it is thoroughly mixed. Dip a second sample container into this evenly dispersed solution. Cap the container, label it “filtered,” and set aside. (Same as step 3.)
   
   **Note:** It is recommended that you mark this sample “filtered.” Label the sample with masking tape or write “filtered” on a scrap of paper and set the sample on top of the paper.

7. Shake the unfiltered and filtered samples until both samples are thoroughly mixed. Put the labeled samples in a location where they will not be disturbed and note the time.
8. As class time allows, measure the height (in millimeters) from the base of the container to the top of the sediment at 1, 2, 5, 10, 20, 30 min., and 24 hours after shaking. Record the measurements in your Research Notes.


10. Discuss your findings with the class.

Clean Up

1. Carefully remove the fabric from the flume and rinse it thoroughly. This fabric can and should be reused for future labs. Rinse the flume until clean.

2. Dump remaining water from catch bucket outside.
   
   **Note:** To avoid clogging drains, do not discard the soil-water solution down a drain.

3. Dump the sieve containers into the soil bucket, cleaning them of any remaining soil.

Flume Trial 2 (12% Slope)

1. Repeat the steps from the Soil portion of the Setup section. Reserve 175 grams (approximately \(\frac{1}{2}\) cup) of minus 20 soil for Flume Trial 2.

2. Repeat the procedure from Flume Trial 1, this time at a 12% slope. Use the same fabric as in Trial 1, making sure it is rinsed clean. Place the extra block under the flume to create the 12% slope.

3. After completing Trial 2, record your data and observations in the Research Notes.

4. Discuss your findings with the class.

Flume Trials 3 & 4: Fabric Testing

1. Repeat the procedure for Trials 1 and 2 using a different type of fabric (i.e. a burlap with a different weave or a geotextile fabric).

2. Compare the differences in filter time and runoff solution between all four trials to determine the best type of filter fabric for the soil you used.

3. Discuss your findings with the class.
Activity 2: Filtering the Silt

Flume Trials 1 & 3 (8% slope)

<table>
<thead>
<tr>
<th>Soil Filtering Observations for 8% Slope (Trials 1 &amp; 3)</th>
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<tbody>
<tr>
<td>Trial 1 Observations</td>
</tr>
<tr>
<td>Soil (before sifting)</td>
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<tr>
<td>Plus 6 soil (after sifting)</td>
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<tr>
<td>Minus 6 soil (after sifting)</td>
</tr>
<tr>
<td>Plus 20 soil (after sifting)</td>
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<td>Minus 20 soil (after sifting)</td>
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Sediment Depth Data for 8% Slope (Trials 1 & 3)

<table>
<thead>
<tr>
<th>Fabric Type:</th>
<th>Fabric Type:</th>
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<tbody>
<tr>
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<tr>
<td>Unfiltered Water Sample (mm)</td>
<td>8% Slope (Filtered) Sample (mm)</td>
</tr>
<tr>
<td>After 1 minute</td>
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<td>After 2 minutes</td>
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<td>After 5 minutes</td>
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<td>After 60 minutes</td>
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<td>After 24 hours</td>
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# Flume Trials 2 & 4 (12% slope)

<table>
<thead>
<tr>
<th></th>
<th>Soil Filtering Observations for 12% Slope (Trials 2 &amp; 4)</th>
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<tbody>
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<td>Trial 2 Observations</td>
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<tr>
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<td>Minus 6 soil (after sifting)</td>
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<thead>
<tr>
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<th>Sediment Depth Data for 12% Slope (Trials 2 &amp; 4)</th>
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<td></td>
<td>Flume Trial 2</td>
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<tr>
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<tr>
<td>Height of Sediment Layers (mm)</td>
<td>Unfiltered Water Sample (mm)</td>
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<td>After 1 minute</td>
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<td>After 60 minutes</td>
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<td>After 24 hours</td>
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</table>
Activity Graph: Sediment Depths for 8% Slope

Draw a line graph for all four sedimentation depths: the unfiltered sample (two trials), the burlap effluent (filtered) sample, and the filter fabric effluent (filtered) sample. Use different colored pens or pencils to identify each trial and fill in the legend.

Legend

- Unfiltered (1)
- Filtered (Burlap)
- Unfiltered (2)
- Filtered (Fabric)
Activity Graph: Sediment Depths for 12% Slope

Draw a line graph for all four sedimentation depths: the unfiltered sample (two trials), the burlap effluent (filtered) sample, and the filter fabric effluent (filtered) sample. Use different colored pens or pencils to identify each trial and fill in the legend.

Legend

- Unfiltered (1)
- Filtered (Burlap)
- Unfiltered (2)
- Filtered (Fabric)
Questions

1) Which material was the most effective at catching small soil particles suspended in the water?

2) How does the unfiltered water sample compare to the runoff sample after each has been allowed to settle for 20 minutes?

3) Use the graph to predict the sedimentation depth from the 8% grade runoff after the solution has settled for 15 minutes.

4) What effect, if any, did the increased slope (12% slope) have on the filtering rate?

5) If a construction site is located in sandy soil, how effective would the silt fencing be in limiting the amount of soil particles entering nearby streams? Explain your answer.

6) How effective would silt fences be in areas with clay soil? Explain your answer.
7) Silt fences are placed in areas most susceptible to erosion during highway construction. The fences are designed to permit water flow through the material but catch small soil particles suspended in the water. The more effective the material, the less soil will be carried to nearby streams. If you were asked to recommend one of these materials for use in silt fencing to limit erosion from a recently disturbed slope, which would you recommend? Support your answer with data you collected from the activity.

8) What are the drawbacks of the material you recommended in Question 7?

Discussion Notes
Activity 3: The Connector Highway Project

Introduction

Environmental considerations are important in every transportation project. This activity guides students through the research of four environmental issues that are commonly considered by engineers: air pollution, noise pollution, water pollution, and loss of habitat. Project components include research, a written report, small group discussion, a group PowerPoint presentation, and a class debate. Some of the project components will be completed in small groups, while others will be done individually.

Note: If there are not enough computers for each student to conduct individual research, students can pair up and work with a student who is researching the same issue.

Students will work in various groups throughout the activity:

1. Region Councils: comprised of four students, each assigned a different environmental specialty. Each Region Council represents one of six regions in the metropolitan area.
2. Specialist Task Forces: comprised of students from each region who share the same environmental specialty.
3. Metropolitan Planning Board: comprised of all six Region Councils.
This activity can be completed in three or four days or extended over a couple of weeks if students work at home. The three-day schedule is as follows:

Day 1: Organize students into groups of four (depending on class size) to create six Region Councils. Assign each Region Council to one of the six regions. Determine each student’s role as an environmental specialist for their Region Council. Conduct research for a specific environmental specialty, and write a detailed summary of potential environmental issues and proposed solutions.

Day 2: Reorganize into Specialist Task Forces for discussion. Design and prepare a PowerPoint presentation for the Metropolitan Planning Board hearing.

Day 3: Specialist Task Forces present at the Metropolitan Planning Board hearing. Small group discussion within Region Councils should take place. Region Councils debate. Each citizen votes for or against the highway project. Governor (instructor) approves or denies state funding for the project based on the vote.

**Objective**

Students will be able to:

- Identify causes and effects of air pollution, decreases in water quality, increases in noise pollution, and loss of habitat due to road construction and traffic.
- Prioritize issues related to a given environmental problem and determine the best solution that provides the least impact on the environment.
- Gain perspective on the impact that daily actions can have on the environment and how to limit the effect of the impact.

**Background**

Environmental issues have become an important part of urban planning and development, affecting project planning in urban, suburban, and rural areas alike. Environmental concerns associated with highway planning and development include air pollution, water quality, noise pollution, and the loss of natural habitats for area wildlife. City and highway planners and developers must take these issues into consideration throughout the planning and construction process by finding methods to limit the impact of development on the environment. Development requires construction of roads, parking facilities, and building space, all of which exacerbate environmental problems; such as, erosion, air pollution, and water pollution. Many of these issues are unavoidable, although, with careful planning and research, the impact can be limited. This project provides students the opportunity to investigate these issues and attempt to find possible methods to limit their impact on the environment.

**Activity Expansion Ideas**

**Federal Environmental Historic Policies**

Federal regulations have been established to preserve the environment, protect endangered species, and protect historically significant locations. Highway planners and engineers must obtain permission to build a highway on undeveloped land and historic areas. Permission procedures may include, but are not limited to: land and animal surveys, ecological testing, and other measures to ensure standards of environmental quality. Have students research one of the four federal environmental policies listed to
determine the purpose for the bill, when it was established, and what must be done to obtain permission to plan and build a road.

- National Environmental Policy Act (NEPA)
- Endangered Species Act (ESA)
- National Register of Historic Places (NHRP)
- Clean Water Act

Get Involved

In order to get exposure to real world situations, students could attend a public meeting (city council or township/county board) where transportation issues will be discussed. At these meetings, experts discuss different aspects of the project – such as design, construction, utilities, electrical, and environmental considerations. The experience encountered at the meeting along with additional background research on the project, specifically on the environmental impacts, could be used by the students to give presentations or conduct a mock town hall meeting.
Activity 3: The Connector Highway Project

Questions

The following questions are to be answered during the student’s research. After collecting the necessary information, they should write a summary outlining the major environmental concerns they have identified in their target area. They should explain each issue, including its causes, consequences (to environment and citizens), and possible solutions.

Note: The answers provided below are examples, there could be much variation in responses to this activity.

Air Pollution

1) What is air pollution?

Air pollution is the presence of harmful or undesired particles and gases in the atmosphere, released as a result of some process.

2) How does traffic increase air pollution?

Transportation is the second leading source of emissions according to the Environmental Protection Agency (EPA); cars produce harmful greenhouse gas emissions that build up in the atmosphere. Lots of traffic equates to a large amount of emissions released in one area.

3) What particles and gases are emitted from car exhaust?

Car exhaust contains a high percentage of carbon dioxide, a harmful greenhouse gas, which gets released into the atmosphere. This carbon dioxide is the result of the fossil fuel combustion within the engine. There are other emitted gases released in car exhaust as well, such as nitrogen, carbon monoxide, and water vapor.

4) Do any of these have an effect on the environment? On people? What are those effects?

The carbon dioxide emissions of car exhaust has negative effects on the environment. The buildup of greenhouse gases such as carbon dioxide have been linked to an increase in acid rain and expediting climate change. Carbon dioxide, as well as carbon monoxide, cause negative effects on people; the gases can cause lung disorders and diseases, and can prevent oxygen from effectively transferring to the blood, which can lead to asthma.

5) What are possible solutions to help alleviate these problems?

There are a multitude of solutions to alleviate air pollution problems resulting from car emissions, most of which are focused on reducing the amount of emissions produced. Solutions include carpooling, using public transit, and not allowing cars to idle. Solutions focused on preventing the release of emissions are generally in the form of environmental regulations from the EPA or state and local governments.
6) **Explain how each solution would assist in lessening air pollution.**

Carpooling and public transit decrease overall traffic and, therefore, decrease the amount of carbon dioxide released into the atmosphere. As for not allowing cars to idle, more gas is consumed by idling for more than 30 seconds than turning one’s vehicle off and back on. When less gas is consumed, less carbon dioxide is emitted.

The EPA and other governing agencies set standards for vehicle manufacturers on the amount of emissions that can be released by their vehicles. Vehicle manufacturers must comply with these regulations in order to sell their cars within certain regions and/or face heavy fines. As time has progressed, these restrictions have become increasingly strict, forcing vehicle manufacturers to develop new technologies to meet them. For example, car bodies are far more aerodynamic today than they used to be, resulting in greater fuel efficiency, which causes them to release fewer emissions.

**Noise Pollution**

1) **What is noise pollution?**

Noise pollution is the presence of disruptive or undesired noise that may be considered disturbing or excessive.

2) **What are some major causes of noise pollution?**

Some major causes of noise pollution are highways, airports, factories, power plants, concert venues, etc.

3) **How does traffic increase noise pollution?**

Traffic increases noise pollution due to the actions that drivers make while driving; such as, accelerating, braking, and honking their horns. The more traffic on a roadway, the more noise pollution is emitted.

4) **In what way would noise pollution affect the area you are researching? (Residential, public schools, public services, natural areas)**

Answers will vary depending on the student’s respective research area. Near a public school, noise pollution can make it difficult for students to focus on their classes and school work. In residential areas, noise pollution can prevent residents from getting sufficient sleep and is generally bothersome. In natural areas, it can affect the behavioral patterns of animals in areas surrounding the noise pollution source.

5) **What concerns would your target area have regarding noise pollution?**

Concerns with noise pollution would generally be associated with preventing or reducing the noise pollution in order to mitigate the respective problems listed Question 4, depending on the target area selected.
6) What are possible solutions to these problems?

Answers will vary depending on the student’s respective research area. However, the best solution to noise pollution is to prevent it in the first place; keeping major sources of noise pollution separated from sensitive areas has the greatest noticeable impact. Well-developed urban planning can route major transportation routes away from and separate industrial areas from residential areas, public schools, etc.

However, prevention of noise pollution is not feasible once the problem exists, so other solutions have been developed. For example, the public school could install noise walls around the exterior of the property, dampening or preventing the noise heard by students. These can also be constructed around the noise polluters themselves; for example, around a major highway in the section that borders a residential area.

7) Explain how each solution would assist in lessening noise pollution.

Answers will vary depending on the student’s respective research area. Generally, well-developed urban planning can lessen the likelihood of noise pollution from becoming an issue and sound barriers can dampen the intensity of the noise pollution reaching affected areas, or prevent it.

Water Pollution

1) What is water pollution?

Water pollution is the presence of harmful or undesired particles or chemicals in water bodies; both at the surface level and underground.

2) How can the highway affect water quality?

Highway construction often causes sediment to be displaced as a result of moving soil to create the roadway. Sediment is often delivered to bodies of water, such as rivers and streams, by rain water, causing undesired changes in the downstream ecosystems and water quality. This problem is of prominent concern when construction sites border bodies of water, particularly when a bridge is being installed.

Once a highway is installed, it can contribute to water pollution. The asphalt pavement of a highway does not allow water to pass through it, causing water from rain and other sources to runoff into bordering ecosystems. This runoff often contains harmful chemicals and pollutants present on highways that find their way into groundwater and surface water, affecting the local environment and water quality.

Excess runoff can cause problems too. Large, multi-lane highways require a large amount of asphalt pavement to be laid down, which results in a large amount of runoff produced. Where this water could once infiltrate directly into the soil, it is now pushed to other areas, causing problems with the landscape if those areas are ill-equipped to handle the excess runoff.
3) **What highway runoff is most problematic to streams?**

Runoff containing pollutants from the roadway is the most problematic runoff to streams. Oil (either from traffic or the asphalt pavement itself), rock salts (used as deicers in colder climates), fertilizers / pesticides (used to encourage vegetation growth), and automobile remnants (tire tread, leaking fluids, etc.) found on or near highways all contain harmful chemicals and particulates that are carried away by runoff water. These chemicals and particulates, such as lead, iron, and sulfates, find their way into local water bodies and groundwater, producing a wide range of adverse effects on the local ecosystem and our drinking water. Many examples of adverse effects could be listed here.

4) **Are there other natural problems, such as erosion, that can add to water pollution?**

Erosion, such as the result of construction activates, can dislodge sediment into local water bodies as discussed under Question 2. This sediment causes excess turbidity in water, which affects drinking water quality (causes problems with disinfection) and the ability of aquatic plants to perform photosynthesis (less light reaching the plants). If the problem is significant enough, the turbidity could kill off aquatic plants, and affect the entire food chain of the local ecosystem. For this answer, students may want to reference the internet.

5) **What concerns would your target area have about water quality?**

Answers will vary depending on respective research area. In general, concerns will be about the effects of water pollution on plants and animals within an ecosystem, and/or the effects on human drinking water sources. Most target areas would be concerned with preserving our ecosystems and protecting our drinking water. For example, natural areas would be concerned about the local plants and animals being affected by water pollution. Residential areas would be concerned about the quality of the water they are drinking, where it is sourced from, and what can be done to protect that source.

6) **What are some possible solutions to limit water contamination from the new highway?**

Sediment displaced during highway construction can be contained by the use of silt fences and regulated by the implementation of permits. Solutions for controlling runoff chemicals have come in the form of legislative restrictions and the implementation of runoff control mechanisms, such as storm sewers.

7) **Explain how each solution would assist in lessening water pollution.**

Silt fences are mesh barriers that are strategically placed prior to construction, preventing a large amount of sediment from passing a certain point. After construction, they are carefully removed.

Runoff control mechanisms, such as storm sewers, gather runoff water from highway and direct it towards a single output location. This way, the runoff does not flow from the roadway directly into the surrounding environment.

Legislative regulations and permits restrict the use of certain chemicals, require that contractors implement erosion and pollution control plans, and restrict the building of highways through certain areas. These solutions collectively prevent pollution and preserve water quality.
Loss of Habitat

1) **What is loss of habitat?**

   Loss of habitat is the process in which a local ecosystem loses its ability to support a particular species, resulting in a lack of biodiversity and the potential collapse of the ecosystem.

2) **What are major causes of loss of habitat?**

   Students will present varying answers, although major causes include deforestation and pollution. Forests are destroyed to use land to grow more crops as farmland is degraded. Urbanization and the development of transportation routes also contribute to this problem. Pollution also affects local ecosystems, which can prevent certain species that once resided in them from surviving.

3) **What consequences does the town need to consider in relation to loss of natural habitat?**

   The town will need to consider the loss of the plant and animal population, and the decrease in biodiversity in the area, as well as the increased presence of animal life in the residential and town areas.

4) **What animals would be most affected by a loss of habitat in your area? How would they be affected?**

   Answers will vary between students. For example, in the Upper Peninsula of Michigan, the loss of habitat would greatly influence the movement of white-tailed deer and migrating birds and animals.

5) **What are the effects of decreasing an animal's habitat in populated areas?**

   A decrease in habitat may cause animals to encroach on a community. These animals may cause problems within a community and act as a nuisance to residents.

6) **Other than loss of habitat, how else can the highway affect the animal populations?**

   Highways create foreign obstacles for the animals in an area. Animals will have to cross the roadway in order to follow migration paths. The animal population may experience a decline as animals are struck and killed by vehicles on these roadways.

7) **Are there any ways to alleviate animals crossing the highways?**

   Allow students to be innovative with their ideas for this question. Most areas experiencing this problem don’t attempt to keep animals from crossing the roads but instead try to prevent drivers from hitting the animals. This is done through trimming long grass, cutting the trees back further from the road, and placing animal crossing signs at concentrated migration paths.

8) **What are possible solutions to loss of habitat?**

   Some solutions to habitat loss include raising awareness about the loss of habitat, educating the community on the effects of lost habitat, and replacing the destroyed habitats in other locations, although this is difficult.
9) **Explain how each solution would assist in lessening a loss of habitat or the impact on animal welfare.**

Referring to the previous examples, raising awareness and educating the community will alleviate ignorance and allow people to consider prevention techniques. Replacing destroyed habitats will encourage new life to form and increase biodiversity.

**Discussion**

Following the group presentations, discuss with students their strategies for selecting the solutions they presented in class. Students should be able to explain how their group decided on the solutions they proposed, what criteria they used to make these decisions, and the compromises they had to make. In practice, the federal government requires an environmental impact study to be completed prior to beginning any construction. Be sure students understand other factors that might affect their decision, such as the addition of new shopping areas that could provide additional jobs in the area and boost the region’s economy, or the loss of treasured natural areas. Ask students to identify other tangential factors that would impact the environment as a result of the new highway development.

As students shuffle through internet sources to find information to use for their group presentations, the importance of how to be safe on the internet, how to locate credible sources, and how to cite sources could be discussed. Placing a high priority on internet safety is important. As students will be doing a lot of internet research during their time in school, it is also important to obtain and utilize credible sources for research projects. Generally, being able to locate an author, a publishing date, a source list, and a domain (such as .com, .org, .net, and .gov) are all ways to note that the site is credible. Being able to locate these aspects is an easy way to distinguish credibility because these determine if the information is relevant (on an information basis and on a timeline basis) and that the information is backed by the author and domain. Another tell-tale sign of the credibility of a source is the spelling and grammar because credible sources look to make their material easy to understand and learn from. Conducting internet research will follow the students throughout their lives.
## Group Work Rubric

<table>
<thead>
<tr>
<th>The Connector Highway Project: Group Work</th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1: Research Time Utilization</strong></td>
<td>The group was always on task and did not need reminders to get back to work.</td>
<td>The group was usually on task but needed occasional reminders to get back to work; all work is appropriate.</td>
<td>The group was usually on task but needed occasional reminders to get back to work; all work is appropriate.</td>
<td>The group needed continual reminders to get back to work. Work is not always appropriate.</td>
</tr>
<tr>
<td><strong>Part 2: Project Participation</strong></td>
<td>Team worked well together and no injection was necessary. Group discussed each solution and decided on the most effective approach together. Team created the Power Point Presentation together.</td>
<td>Team effort was visible, although not all members supported the group effort equally throughout the project. Some discussion occurred. The Power Point Presentation was not created equally among the group members.</td>
<td>Team effort was visible, although not all members supported the group effort equally throughout the project. Some discussion occurred. The Power Point Presentation was not created equally among the group members.</td>
<td>Team effort was not visible. Little discussion occurred in group as students decided on the best solutions to each issue. Individuals worked separately to create Power Point presentation with some conflict in group.</td>
</tr>
<tr>
<td><strong>Part 3: Project Content and Topic Understanding</strong></td>
<td>There was a clear organization of topics and the group had notable understanding of their environmental role.</td>
<td>Knowledge of their role was visible and shows some organization.</td>
<td>Some knowledge was visible with some organization of the material.</td>
<td>Little to no understanding of the material is visible. There is a lack of organization in the material.</td>
</tr>
<tr>
<td><strong>Total Points</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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## Individual Work Rubric: Part 1

<table>
<thead>
<tr>
<th>The Connector Highway Project: Individual Work</th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1: Research and Report</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Research</strong></td>
<td>Information includes definition of environmental issue, its cause, and several well outlined solutions that could be used in the target area.</td>
<td>Information includes definition of environmental issue, its cause, and a solution. Although solution is not supported substantially and doesn’t completely correlate to the target area.</td>
<td>Information includes definition of environmental issue, its cause, and a solution. Although solution is not well supported or specific to target area.</td>
<td>Information includes definition of environmental issues and their causes but lacks information leading to a probable solution.</td>
</tr>
<tr>
<td><strong>Grammar and Mechanics</strong></td>
<td>Paper is very well organized without spelling or grammar errors.</td>
<td>Paper is well organized with few or no spelling and/or grammar errors.</td>
<td>Paper organization is visible with a noticeable amount of spelling and/or grammar errors.</td>
<td>Paper lacks organization and is hard to follow with spelling and grammar errors throughout.</td>
</tr>
<tr>
<td><strong>Total Points</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Individual Work Rubric: Part 2

<table>
<thead>
<tr>
<th>The Connector Highway Project: Individual Work</th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 2: Decision Making and Presentation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Information Presented</strong></td>
<td>Information was very well organized. Each issue was well explained, including issue identification, causes, and practical solutions. Went above and beyond assigned information. Included graphics, charts and/or graphs and other info to support presentation.</td>
<td>Information was well organized. Presentation included all necessary info including issues and definitions, identified the causes, and offered good solutions. Could have used more detail. Some graphics, charts, or graphs included.</td>
<td>Information organization was visible. Presentation included most of the necessary information. Could have used more detail and more fully covered each topic to clarify the intent.</td>
<td>Poorly organized and difficult to follow. Information given does not clearly identify environmental issues affecting the targeted area.</td>
</tr>
<tr>
<td><strong>Power Point Presentation</strong></td>
<td>Creative and well organized. Easy to read including key points discussed in the presentation. Graphics and web links enriched the presentation.</td>
<td>Clear and easy to read. Had all key points discussed in presentation.</td>
<td>Comprehendible, although needs work. Some key points were discussed in presentation.</td>
<td>Difficult to read. Not well laid out. Missing information in presentation.</td>
</tr>
<tr>
<td><strong>Presentation Mechanics</strong></td>
<td>Speaker easy to understand with good voice modulation. Presented information confidently, answering questions at the end of the session.</td>
<td>Speaker clear and easy to understand. Knowledgeable and articulated well.</td>
<td>Speaker could be understood but could use improvement. Understanding of information was visible, but was not well presented. Speaker struggled to answer questions, although was able to provide an answer.</td>
<td>Speaker was difficult to hear, didn't know information, and/or read information to audience. When asked questions, speaker could not answer questions concerning his/her topic.</td>
</tr>
<tr>
<td><strong>Total Points</strong></td>
<td></td>
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</table>
Activity 3: The Connector Highway Project

Introduction

Environmental considerations are important in every transportation project. This activity will guide you through the research of four environmental issues that are commonly considered by engineers: air pollution, noise pollution, water pollution, and loss of habitat. Project components include research, a written report, small group discussion, a group PowerPoint presentation, and a class debate. Some of the project components will be completed in groups, while others will be done individually.

You will work in three different groups throughout the activity:

1. Region Councils: comprised of groups of four, each group will represent one of six regions in the metropolitan area and each member will be assigned a role as an environmental specialist.
2. Specialist Task Forces: comprised of alike disciplines from each region, the members will be organized by their environmental specialty.
3. Metropolitan Planning Board: comprised of all six Region Councils.

Objective

You will be able to:

- Identify causes of air pollution, decreased water quality, increases in noise pollution, and loss of habitat due to road construction and traffic.
- Prioritize issues related to a given environmental problem and determine the best solution that provides the least impact on the environment.
- Gain perspective on the impact that daily actions can have on the environment and how to limit the effect of the impact.

Background

Environmental issues have become an important part of urban planning and development, affecting project planning in urban, suburban, and rural areas alike. Environmental concerns associated with highway planning and development include air pollution, water quality, noise pollution, and the loss of natural habitats for area wildlife. City and highway planners and developers must take these issues into consideration throughout the planning and construction process by finding methods to limit the impact of development on the environment. Developing areas experience construction of roads, parking facilities, and building space, all of which exacerbate environmental problems; such as, erosion, air pollution, and water pollution. Many of these issues are unavoidable, although, with careful planning and research, the impact can be limited. This project provides you with the opportunity to investigate these issues and attempt to find possible methods to limit their impact on the environment.

An environmental specialist is responsible for identifying potential problems that could originate from a transportation project and determining the causes and solutions to minimize impact on the environment.
Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer with internet connection</td>
<td>1 per student or pair</td>
</tr>
<tr>
<td>PowerPoint or Google Slides</td>
<td>1 per group</td>
</tr>
<tr>
<td>Presentation System</td>
<td>1 per classroom</td>
</tr>
</tbody>
</table>

**Optional Materials**

<table>
<thead>
<tr>
<th>Pictures/Posters depicting:</th>
<th>City smog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pollution</td>
<td></td>
</tr>
<tr>
<td>Articles in books or periodicals:</td>
<td>Water pollution</td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
</tr>
<tr>
<td>Noise pollution</td>
<td></td>
</tr>
<tr>
<td>Air pollution</td>
<td></td>
</tr>
</tbody>
</table>

Project Overview

Springfield is a large metropolitan area that has experienced exponential growth over the past several years. As the population grows, more people have moved to the regions surrounding the metro area; which is increasing traffic congestion at peak hours, specifically in the morning and evening. The Springfield Metropolitan Department of Transportation has brought the Region Councils from the surrounding area together to plan the construction of a major highway: the Springfield Connector. The six-lane highway will link the communities west of Springfield to the communities east of Springfield, while minimizing the traffic congestion and long commutes presently causing daily backups. Many citizens and business owners are excited about the project and look forward to decreasing current traffic problems while increasing business revenue for their regions. There are others in the communities who are not as excited about the project. Many opponents associate the highway with more pollution and other environmental problems stressing the area. The governor has agreed to fund the project only if the majority of citizens endorse the project.

Public outcry against the proposed highway is slowing the progress of the project. As employees of the local Department of Transportation, your Region Council has been asked to analyze potential environmental problems that may arise or be worsened by the new highway in your region. The Metropolitan Planning Board has hopes that your solutions will alleviate public opposition, resolving issues that are preventing the approval and progress of the highway. Your Specialist Task Force, comprised of yourself and all other workers who share your environmental specialty, will focus on one of four target areas—residential neighborhoods, public schools, public health services, and parks and natural areas—to identify significant environmental issues and their possible solutions. The Specialist Task Forces will report their findings at the Metropolitan Planning Board hearing. You will need to be prepared to fully explain and defend your ideas.

Regions

In order to provide context to each region’s environmental concerns, the regions are described below. Each of the six regions has a residential area, public school system, public health services, and parks and natural areas, although the following descriptions indicate the primary make up of each region.

**Region 1** – Comprised of a plethora of shopping and eating destinations, this region is denoted as a consumer area (or shopping district), located at the heart of the metro area.
Region 2 – Including subdivisions and small parks, this region covers a residential setting in the northern portion of the region.

Region 3 – Being that a university campus consumes a majority of this region, it is almost a small town in and of its own, located just north of the center of the metro area.

Region 4 – Along the outskirts on the Southern end, this region consists of agricultural land (e.g. dairy, cattle, grain, corn, wheat, potato farms, etc.).

Region 5 – Located on the eastern outskirts, this region holds the Federal Park land, where there are lakes, campgrounds, and wildlife areas.

Region 6 – Set off to the west, this region encompasses the industrial and business district.

Roles

Assume the roles of environmental specialists working with the local Department of Transportation to identify crucial issues of concern in relation to the proposed project. Each Region Council will be comprised of four specialists each covering a different focus within a region. These will include a residential specialist, a public schools specialist, a public health services specialist, and a natural resources specialist.

As a residential specialist, you are concerned with maintaining the clean and quiet communities that currently exist around Springfield. A number of residents have voiced their concerns about the proposed highway destroying their pristine neighborhoods. Your job is to identify potential environmental issues—such as losing the current clean and quiet atmosphere that brought them to this area—and their solutions that would put the area residents at ease. Other factors may be present that have yet to be identified. You may find that some issues will not affect residential areas. Use your best judgment.

As a public schools specialist, you are concerned with the accessibility and safety of the students, faculty, and other community members involved with the elementary school in relation to the Connector Highway. Parents, the school board, school personnel, and community members have voiced concern about the Connector Highway passing so close to the school systems. Your job is to determine potential issues—such as child safety, air quality, excessive noise, and destruction of the water quality in the school pond—and solutions that would address these concerns. Other factors may be present, but have not yet been identified. You may find that some issues will not affect the school. Use your best judgment.

As a public health services specialist, you are concerned with the safety and accessibility of the hospital and environmental issues that could have negative effects on hospital programs, patients, and employees. Citizens and hospital administrators have voiced concern about the Connector Highway passing so close to the hospital. Your job is to identify potential environmental issues—such as Emergency Entrance accessibility, excessive noise from the highway, and decrease in air quality—and the solutions that would address the concerns of the hospital. Other factors may be present that have yet to be identified. You may find that some issues will not affect the hospital. Use your best judgment.

As a natural resources specialist, you are concerned with the well-being of wildlife and species in the area. Concerned citizens are wary of the proposed Connector Highway Project, fearing the highway will lead to the loss of natural wildlife and the peace and quiet they currently enjoy in their parks. Your job is to identify potential environmental issues—such as run-off into Lake Buckeye, prized for its natural trout
and bass fishing— and the solutions that would put highway opponents at ease. Other factors may be present that have yet to be identified. You may find that some issues will not affect natural areas. Use your best judgment.

Task: Part 1
As one of the environmental specialists for your Region Council, you will complete research on potential environmental problems. These problems should be addressed with regard to your role and your region of representation. Most often associated with traffic and highway, these problems should be analyzed within four major areas of environmental research: air pollution, noise pollution, water pollution, and loss of habitat. Each environmental specialist will gather information to help identify potential environmental problems, determine the causes and effects, and consider possible solutions.

Each member of your Region Council will write and submit a detailed summary explaining each of the issues and possible solutions that apply to your region, based upon your specific environmental specialist role. For example, the residential specialist would see a roadway water runoff situation and address it as a possible problem for contamination of the drinking water. A natural resources specialist would identify the same problem, though he or she would address it as a potential concern for the wildlife in the area.

Task: Part 2
After gathering initial information on how the highway will affect your region’s makeup, reorganize into four Specialist Task Forces with the students that share your environmental specialty (residential, public schools, public health services, and natural resources, respectively). Share the research from your individual report. Prioritize the issues, analyze the proposed resolutions, and decide upon the best solutions to account for each environmental issue.

Work with your Specialist Task Force to prepare a PowerPoint presentation that summarizes your findings and recommendations. You will present at the Metropolitan Planning Board (class) hearing.

Task: Part 3
After all Specialist Task Forces present, regroup with your Region Council to discuss possible arguments supporting your council’s decision to approve or reject the Connector Highway Project. Next, the citizens (your class) will debate the issues and vote on whether or not to approve the new highway. If the majority of citizens agree to the highway project, the governor (instructor) will agree to fund it. A majority vote against the highway project will result in no state funding.

Procedure
Part I
1. Divide into groups of four (Region Councils) to represent each of the six regions.
   a. If there are fewer than 24 students in the class, divide into groups of three and four, forming six or fewer Region Councils.
2. Read the provided Project Overview, Roles, and Task sections, discussing the controversy and brainstorming environmental issues that may affect target areas (residential area, public schools, hospitals, and parks and natural areas). Discuss your ideas before assigning environmental specialist roles.
3. Members of each Region Council should then decide what role they wish to play during the Connector Highway Project.
   a. In cases where there are three students in a group, limit the target areas to residential, public schools, and natural resources areas.
4. Begin your research at credible websites on the Internet. Answer the questions in the Research Notes section to help guide your research. Identify which environmental issues will affect your region with respect to your role, along with the causes, consequences, and possible solutions.
   a. Be sure you understand the assignment and the topics you are to research before beginning the research segment of the activity.
   b. Remember that additional information is available in books, scholarly journals, newspapers, magazines, etc.
   c. Create a bibliography (citation page) to display your sources in the format that is specified by your instructor.
5. After gathering information, write a detailed summary including the environmental issues affecting the region with respect to your role, causes of the problems, consequences, and possible solutions for each.
6. Submit this report to the governor (instructor).

Part II
1. After you complete your issue summary, reorganize into Specialist Task Forces.
   a. Each Specialist Task Force will be made up of similar specialists, e.g. students representing public schools make up one group, natural resources another, etc.
2. Each Specialist Task Force will discuss the different issues identified in Part 1 that they believe will affect their region.
3. Next, work together to prioritize the issues and determine the most probable solutions for each issue. Be sure to support your decision (cost, optimal solution to limit the environmental problem, etc.).
4. Produce a PowerPoint presentation outlining the identified issues, the causes, the consequences, and the solutions the group recommends.
5. Present this PowerPoint at the Metropolitan Planning Board hearing. Be prepared to defend the presented information and your standing on the topic.
6. After all specialist groups have presented, reconvene with your Region Council to discuss your arguments for supporting or rejecting the Connector Highway Project.
7. Next, stage a class debate about each of the issues. (If necessary, the instructor can assign each Region Council to take a particular side on the issues.)
   a. For example, one Region Council may be opposed to the highway because it could negatively impact a natural park there, while another region is for the highway because they believe the economic windfall will far outweigh any negative consequences.
8. Conclude the debate with a discussion of the issues and the key points to arguments made by the opposing groups.
9. Take several minutes to discuss whether or not to endorse the highway project. At the end of class, ask individual citizens (all students) to vote on the issue. After the vote, the governor (instructor) should announce his/her decision whether or not to support funding for the highway.
Activity 3: The Connector Highway Project

Activity Flowchart

Discuss project with entire class

Divide class into groups of four to form the Region Councils

Number & size of groups will vary

Groups must determine the important issues to consider for their region, then select student roles and conduct research

Reorganize class to form four Specialist Task Force groups.

Residential Specialist

Public Schools Specialist

Public Health Services Specialist

Natural Resources Specialist

Each Specialist Task Force presents a PowerPoint at the town hearing.

Region Councils debate the issues at hearing

Class approves project & governor agrees to fund construction project.

Students vote on highway project

Class rejects project & governor refuses to fund construction project.
Activity 3: The Connector Highway Project

Questions

The following questions are to be answered in your research. After collecting the necessary information, write a summary outlining the major environmental concerns you have identified in your area. Explain each issue including its causes, consequences (to environment and citizens), and its possible solutions.

Air Pollution

1) What is air pollution?

2) How does traffic increase air pollution?

3) What particles and gases are emitted from car exhaust?

4) Do any of these have an effect on the environment? On people? What are those effects?

5) What are possible solutions to help alleviate these problems?

6) Explain how each solution would assist in lessening air pollution.
Noise Pollution

1) What is noise pollution?

2) What are some major causes of noise pollution?

3) How does traffic increase noise pollution?

4) In what way would noise pollution affect the area you are researching? (Residential area, public schools, public works, parks/natural areas)

5) What concerns would your target area have about noise pollution?

6) What are possible solutions to these problems?

7) Explain how each solution would assist in lessening noise pollution.
Water Pollution

1) What is water pollution?

2) How can the highway affect water quality?

3) What highway runoff is most problematic to streams?

4) Are there other natural problems to consider, such as erosion that can add to water pollution?

5) What concerns would your target area have about water quality?

6) What are some possible solutions to limit water contamination from the new highway?

7) Explain how each solution would assist in lessening water pollution.
Loss of Habitat

1) What is loss of habitat?

2) What are major causes of loss of habitat?

3) What consequences does the town need to consider in relation to loss of natural habitat?

4) What animals would be most affected by a loss of habitat in your area? How would they be affected?

5) What are the effects of decreasing an animal's habitat in populated areas?

6) Other than loss of habitat, how else can the highway affect the animal populations?

7) Are there any ways to alleviate animals crossing the highways?

8) What are possible solutions to loss of habitat?

9) Explain how each solution would assist in lessening a loss of habitat or the impact on animal welfare.
Discussion Notes
Appendix A: Document Links

NCHRP 20-52

The NCHRP 20-52 final report details the completion of the original TRAC PAC 2 program, including the original manual.

TRAC/Michigan Education Standards
Link: [http://www.michigan.gov/mdot/0,4616,7-151-9623_38029_38059_41397-184233--,00.html](http://www.michigan.gov/mdot/0,4616,7-151-9623_38029_38059_41397-184233--,00.html)

The Michigan Education Standards are outlined in terms of how TRAC meets the benchmark goals. This page includes the standards for 6th, 7th, and 8th grades as well as high school standards. The standards for the TRAC modules and bridge building competition are listed.
Appendix B: Glossary of Terms

Air pollution: the presence of harmful or undesired particles and gases in the atmosphere, released as a result of some process.

Asymmetric: Not identical on both sides of a central, dividing line; unsymmetrical; lacking symmetry.

Colloid: A mixture where small particles of a substance in one material state remain evenly distributed throughout another substance in the same or different material state. (For example: solid particles evenly distributed in a liquid, liquid particles evenly distributed in a gas, gas particles evenly distributed in another gas, etc.)

Contours: A graphical outline of a shape represented by a series of lines (For example: an outline of the curvature of a road, the outline of hills on a section of land)

Electrolyte: A substance that separates into ions when in a solution, acquires the capacity to conduct electricity. (Examples of ions: potassium, chloride, calcium, magnesium, and phosphate)

Electrons: Subatomic particles of an atom that have a negative electrical charge, acting as the primary carrier of electricity in solids.

Electrostatic Repulsion: When two particles of a substance with the same electrical charge come together, they will drive away each other. (For example: a positively charged particle will repel another positively charged particle)

Erosion: The gradual destruction and displacement of soil, rock, etc. by wind, water, or other natural agents.

Flocking Agents: Chemicals that promote the evenly distributed particles in colloids or other suspended particles in solutions to join together.

Grade: The angle of a slope as measured from the horizontal. Used for describing hills, roads, or railways.

Loss of Habitat: the process in which a local ecosystem loses its ability to support the species present, resulting in a lack of biodiversity and the collapse of the ecosystem.

Noise Pollution: the presence of disruptive or undesired noise that may be considered disturbing or excessive.

Repulsion: A force under the influence of which objects tend to move away from each other.

River Deltas: A landform resulting from the build-up of deposited sediment where a river enters slower-moving or a standing body of water.

Runoff: The overland flow of water (and substances carried by it) on an area of land, pavement, etc. Often caused by large rainfall events.

Sediment: Eroded minerals and other natural material transported and deposited by the action of wind, water, ice, gravity, or other force.
Appendix B: Glossary of Terms

**Silt Fencing:** Temporary sediment control device used on construction sites to protect water quality. Prevents loosened sediment from being washed into nearby streams, rivers, lakes, etc. by runoff water and/or construction activity.

**Slope:** A surface of which one end or side is higher than another; an inclined surface (rise/run).

**Soluble:** Capable of being dissolved.

**Solute:** The dissolved substance within a solution.

**Solution:** A mixture of two or more substances in which at least one substance is dissolved within another.

**Solvent:** Liquid in which a solute is dissolved to form a solution (i.e. able to dissolve other substances).

**Streambed:** Channel bottom overtop of which a stream or river flows or has previously flowed.

**Water Column:** Conceptual separation of varying layers from the surface of a body of water to the bottom sediments. Water columns are mainly utilized for environmental studies.

**Water Pollution:** the presence of harmful or undesired particles or chemicals in water bodies; both at the surface level and underground.