Pebble Count Substrate Study

ADAPTED FROM: Harrelson, C.C., Rawlins, C.L., Potyondy, J.P., 1994. "Bed and Bank Material Characterization" in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique.*

GRADE LEVEL: Intermediate

DURATION: 40 minutes

OBJECTIVES: Students will learn how to classify sediment grains based on size.

VOCABULARY: chemical weathering, mechanical weathering, sediment, capacity, competence, suspended load, bed load, dissolved load, mature sediments, immature sediments, saltation, alluvium, point bars, natural levees, backswamps, wetlands.

RELATED MODULE RESOURCES:

- Sediment grain size charts

MATERIALS (INCLUDED IN MODULE):

- Calipers
- Clear plastic rulers
- Meter stick
- Pebble count tally sheet

ADDITIONAL MATERIALS (NOT INCLUDED IN MODULE):

- Hip Waders or creek shoes
- Clipboards (optional)
- Buckets or bags

ACADEMIC STANDARDS:

STEELS- 3.3 Earth and Space Science

6-8 Grade

3.3.6-8.E Construct an explanation based on evidence of how geoscience processes have changed Earth's surface at varying time and spatial scales.

9-12 Grade

3.3.9-12.H Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems.

OVERVIEW SUMMARY: Students will measure the waterway's average substrate size by using the Wolman Pebble Count method.

BACKGROUND:

Characterizing the substrate composition of a streambed is a way to learn how streams behave.   The classification of stream bed material is important for learning about the stream's character, channel form, erosion rates, sediment supply, habitat health, and other parameters.

A waterway's substrate is a very important component of a stream to study. **Substrate** refers to the mineral and organic substances on the bottom of the waterway channel. It is simply the rocks, sands, silt, muck, vegetation, twigs, and cement that may be found in our stream bottoms. A waterway's substrate influences aquatic life, water chemistry, and stream appearance and it can reveal a lot about what is happening in the stream.

Sediments make up the substrate. **Sediments** are composed of mineral material ranging from tiny clay particles to small bits of rock to big boulders and organic material such as dead leaves and twigs.

Sediments enter the water either from surrounding land surfaces and soil or from larger rocks. The weathering of rocks can create sediments. There are two types of weathering, **chemical weathering** and **mechanical weathering**. Chemical weathering occurs when water and rocks combine and the chemical makeup of a rock is altered. Mechanical weathering is the physical breakdown of rocks and can occur when water freezes in the cracks of rocks and breaks them apart. Mechanical weathering also occurs when water erodes the surfaces of rocks.

Sediments range in size from boulder (> 256 mm in diameter) to very small silt and clay particles. Sediments are usually classified by their size, but the sediment size classifications vary from source to source. Examples can be found at the end of this activity.

Sediments are transported and deposited, creating changes to the landscape. Water is the most common transporter of sediments. When water flows over the landscape, it picks up sediments. Within a stream, sediments are on the move. The amount and type of sediment that a stream transports is determined by the stream's velocity and size, the composition and texture of the sediment, the stream's interaction with the surrounding land and land uses, and the characteristics of the bedrock through which the stream flows.

BACKGROUND CONTINUED:

The maximum load of sediment that a stream can transport is its **capacity**. Capacity is expressed as the volume of sediment passing a given point on the stream bank in a given amount of time. Capacity is proportionate to discharge: the more water flowing in the channel per second, the greater the volume of sediment that is transported in that time. The diameter of the largest particle that a stream can transport is the measure of a stream's **competence**. Streams transport sediment in different ways, depending on particle size.

The total volume of sediment carried by a stream is its **sediment load**. The sediment load consists of three components - dissolved load, suspended load, and bed load. Dissolved minerals from a stream's substrate and ions from groundwater entering a stream through the channel walls make up a stream's **dissolved load**. Typically streams carry only about 120 ppm (parts per million- 120 ions per million water molecules). In streams that flow over particularly soluble minerals like halite or gypsum may contain over 1,000 ppm of dissolved ions. The **suspended load** of a stream contains tiny, solid grains (silt or clay size) that swirl along with the water without settling to the floor of the channel. The suspended load accounts for the bulk of sediment carried by a river. Large particles that bounce and roll along the stream bottom are known collectively as the **bed load**. Bed-load movement involves a process known as **saltation.** Saltation occurs when grains get knocked into the water column, follow a curved trajectory downstream and sink to the bed of the stream again. Here they may bump other grains into the water column and the process repeats.

Sediment load is material mixing and moving with the flowing water, making the water muddy. The fine material will eventually settle in the water because of its density and weight, but it can be lifted again from the bottom into the water column during disturbances (high flow rates, dredging, boating, swimming, and water withdrawals for industry or municipalities). When the motion of the water slows or stops, suspended solids settle out of the water in a process called **sedimentation**. The smallest, lightest soil particles stay suspended in the water the longest, and the largest, heaviest settle first. A slow moving or still area in a waterway allows sedimentation to occur. Pools will have more fine sediment settling than in riffle areas. The mid-channel of a creek (larger substrate size) is usually faster flowing and has larger substrate size as compared to closer to the shore. In fast water, the small particles do not have a chance to settle out or do not remain at the bottom. High velocity waters erode and transport large boulders, but

BACKGROUND CONTINUED:

they also transport small particles, flat clay particles and mica flakes. Higher velocities are sometime required to move clay and silt particles because electrical forces on their surfaces cause them to cling to the streambed. Once in the streamflow the fine clay particles remain suspended and are transported long distances.

Substrate changes from headwaters to the mouth of the stream. At the headwaters of a stream the sediment grains are very **immature**. The grains are poorly sorted; they vary in size from large boulders to silt size grains and the grains have sharp, jagged edges. **Mature sediments** have a well-rounded shape, very fine particle size (1/16 - 1/8 mm), and the sediments are well-sorted (uniform size of sediments). A stream sorts the particles it carries by depositing them in order of size, the heaviest are deposited first and the lighter sediments are carried downstream to the mouth of the stream. The further particles travel the more mature and better sorted they become. (*Refer to the grain size sorting charts included in the module for grain sizes, sorting and shape comparisons.*)

Deposited stream sediments are described collectively as **alluvium**. During normal flow, a stream with large amounts of coarse bed-load sediment often deposits some of its load in its channel as mid-channel bars. As sand and gravel accumulates the stream flows around the channel bars and the stream becomes braided. The bars become more resistant to erosion as vegetation begins to grow on them. In-channel deposits may also be in the form of **point bars**, where sediments from the outside banks of meandering streams are deposited on the inner banks. Point bars are where meandering streams drop their heaviest particles.

When a stream's channel is unable to contain the water flowing through it, the water overflows onto the surrounding floodplain. Flood plains catch large volumes of sediment from floodwaters because the velocity of the water is decreased and the sediments settle out. **Natural levees** are ridges of coarser sediment deposited on both banks of a stream during successive flooding. Natural levees grow higher from sediment accumulation from each flood and tend to be the highest points on a flood plain. **Backswamps** are the portion of the flood plain near the river where deposits of fine silts and clays settle from standing waters following a flood. If a floodplain has surface depressions water may remain at the surface as **wetlands**.

BACKGROUND CONTINUED:

Excessive erosion, transport, and deposition of sediment in surface waters is a major problem in the United States. The 1996 National Water Quality Inventory (Section 305(b) Report to Congress) indicates that sediments are ranked as a leading cause of water quality impairment of assessed rivers and lakes. Human disturbance of land (deforested, plowed, and constructed on) can increase erosion levels, increasing the sediment load faster than ecosystems can adjust. Heavy rainstorms and sudden snow melts can increase soil and sediment **erosion**, the process of wearing away the earth's surface into the stream. Moving water moves soil, and the stronger the water flows, the more soil it moves.

Excessive deposition of sediments can pose hazards to fish and benthic macro-invertebrate communities by disrupting habitats, degrading spawning habitats, and reducing the flow of oxygen through gravel beds. High concentrations of suspended sediment can adversely affect aquatic species that filter and ingest water. Poor land-use practices increases the amount of sediments that find their way into streams. Areas undergoing intense development create large quantities of sediments. These sediments are then eroded away through surface runoff, severely impacting water quality, fish and wildlife, and ecological habitats as they are carried to streams and lakes. Increased sedimentation can also cause streams and rivers to flood. Sedimentation in the stream bed narrows the stream channel also decreasing the amount of water the stream can transport. When heavy rains fall, the stream is unable to contain the water and the stream floods the surrounding area.

One technique used to analyze streambeds and banks is the Wolman Pebble Count. The Wolman Pebble Count (from 1954) calls for one person equipped with a metric ruler or stick to wade across the waterway. As the person progresses across the waterway, they classify the substrate sediments/rocks according to their size. Pebble counts are made by using grids, transects, or a random step-toe procedure (described in this activity).

References

Chernicoff, Stanley, 1995.<u>Geology</u>. New York, NY: Worth Publishers.
Hauer, F.R., and G. Lamberti, 1996. <u>Methods in Stream Ecology</u>. San Diego, CA: Academic Press.
Marshak, Stephen, 2001. <u>Earth: Portrait of a Planet</u>. New York, NY: W.W. Norton & Company, Inc.
Morisawa, Marie, 1968. <u>Streams: Their Dynamics and Morphology</u>. New York, NY: McGraw-Hill Book Company.

PROCEDURE:

Teacher Preparation:

1. Be sure the stream is safe for students to enter. Do not enter the stream if it is flowing faster than normal; currents can be misleading, powerful, and cause you to lose balance. Water should not be entered in the winter (late November- mid March), even if you are wearing hip waders, because of the threat of hypothermia. Be careful not to slip or fall on rocks in the creek.

2. Divide the class into groups of two or three, depending on the size of the class. Each group of students will need calipers and/or clear plastic ruler, and a data sheet. In each group, one student will record the data while the other student/s/ will be collecting and measuring the substrate.

Student Experiment or Activity:

1. Students will be working in groups or pairs. Select one person in the group to stay on shore and record the data streamside. The other student/s/ will enter the stream, collect the substrate / rocks and sediment.

2. Students should establish a transect line across the width of the creek. Transect lines should be relatively perpendicular to the bank. The teacher should instruct the students where along the waterways students should be conducting their measurements (riffle, pool, run, etc).

3. One student should remain on the bank, while the student/s/ collecting and measuring the substrate should enter the stream carrying a ruler or meter stick. Once in the stream, the student should walk carefully to the opposite bank, turn around and face his or her partner.

4. To begin the data collection, take one step, be careful not to slip or fall. Watch where you step! Reach down and pick up the first particle (generic term for rock, pebble, boulder, sediment, etc.) your index finger touches at the big toe of your shoes or hipwaders. It does not matter what size the particle is whether a tiny sand grain or a large rock. If it is too big to pick up, see next step.

5. Pick up the particles, and place them in a bucket or bag and carry them to shore for measurement. DO NOT throw rocks to shore for measurement.

6. Repeat this step-and-measure procedure in a straight line across the width of the stream. For accurate results be sure to analyze at least 100 particles. Note: The more rocks you include in your survey, the better the average and accuracy.

PROCEDURE CONTINUED:

7. To measure the particle you must measure the intermediate axis (*see figure below*), not the longest or the shortest side for each particle. If it is embedded or too big to pick up, measure the smaller of the two exposed axes while in the stream (don't skip over any particles regardless of size!).

8. On shore, after the data collector completes a measurement, they should call out the data to the data recorder. The data recorder will either place a tally mark next to the corresponding size class of the particle measured on the data sheet provided OR instead of a tally mark, an actual size can be recorded.

9. Unless told otherwise by your teacher, return all rocks/sediment back to the stream.

DISCUSSION:

How did the substrate change as the data collector traveled across the stream? *Typically, the sediment will change from less coarse on the banks to more coarse in the middle.*

Under what classification did the majority of the particles fall under? *This will vary according to your stream.*

How did your results differ from a group that was further upstream or downstream from your site? *Sediments/particles tend to be larger and less mature upstream and smaller and more mature downstream.*

How would the substrate of a stream affect the behavior (stream velocity, weathering, erosion, deposition) of a stream? *See background information.*

Describe any in-stream depositional features. What was the classification of particles measured there? *Some small streams have small mid-channel bars of sediment that has collected in the center of the stream. Usually the particles in mid-channel bars are larger in size (between gravel and cobble).*

What is the range of particle sizes in a pool area of the stream? Riffle zone? *In a pool area the particles will be sand size or smaller. In a riffle zone the particles will be larger in size compared to a pool, and will vary among streams.*

Where do you think the sediments in the stream originated? *Erosion of rocks and soil is the parent material of sediments. Possible sources include nearby farmland, erosion of stream banks, development site, or large rocks and boulders in the stream.*

What would you estimate to be the competence of the stream you examined today? *See background for explanation of competence, it will vary from stream to stream.*

EVALUATION:

- Correctly completed data sheets.
- Describe the trends found in the particles measured across the stream.
- Construct a stream profile according to data collected.
- Discussion questions above.

EXTENSIONS & MODIFICATIONS:

- You may choose to have students present their data in chart form to the class.
- Students could combine their data and construct a longitudinal stream profile.
- While in the stream measuring the rocks, students could choose several of them to identify.

NOTES (Please leave suggestions you have for Teachers using this activity in the future):

Data Sheet: Pebble Count

Name: ____ **Date:**______________

Pebble Count Tally Sheet

Size Range (millimeters)	Size Class	Number Measured (either check mark or write actual size)
< 2	Sand	
2 – 4	Very Fine Gravel	
4 – 8	Fine Gravel	
8 – 16	Medium Gravel	
16 – 32	Coarse Gravel	
32 – 64	Very Coarse Gravel	
64 – 90	Small Cobble	
90 – 128	Medium Cobble	
128 – 180	Large Cobble	
180 – 256	Very Large Cobble	
256 – 512	Small Boulder	
512 – 1024	Medium Bolder	
1024 – 2048	Large Boulder	
2048 – 4096	Very Large Boulder	