

How Fast Is Our Campus Changing? A Field Survey of Rates

Investigation question: Which weathering, erosion and deposition processes are at work on our school grounds right now, how fast is each one going, and how long would it take for them to make a change everyone would notice?

Classroom field investigation

Groups of 4

1 session

Setup 8 · Activity 40 · Cleanup 4 min

MS-ESS2-2 · assesses

MS-ESS2-1 · supports

Scientific purpose

Students survey the school grounds for real evidence of surface change (a worn step, a root-widened crack, sediment piled at a downspout or curb, a crumbling concrete edge, rills on a bare slope), measure each change with rulers and tape measures, use dates from the school office (year built, year repaved, last cleaning) to turn each measurement into a rate, and then extrapolate: how long until the step wears through, the crack is a hand wide, the gutter fills. The campus becomes a landscape with the same processes as a canyon, running at rates the students measured themselves.

Why this helps students with this chapter

Students can recite that weathering and erosion shape Earth, but they place those processes in canyons and deserts, not where they stand. Measuring a worn step and dividing by the building's age gives a rate of a fraction of a millimeter per year, exactly the kind of rate that carves canyons, and the extrapolation to 'how long until the step wears through' makes the arithmetic of deep time personal. Finding sediment at a downspout and asking where it came from turns the weathering-erosion-deposition chain into something they can walk along.

Standards connections

MS-ESS2-2 (assesses, explaining surface change from the students' own measurements at small spatial scales and human time scales, then extrapolating): Students construct an explanation of how specific processes (frost and root weathering, water erosion, deposition) are changing specific campus features, supported by their own measurements and rates, and extend the reasoning to longer time scales. This is the 'small and slow' end of the PE with student-collected evidence, which the PE's practice explicitly allows.

MS-ESS2-1 (supports, weathering and sedimentation as observable steps in the cycling of Earth's materials): Sediment traced from a crumbling surface to a pile at a downspout is the first two steps of the rock cycle seen in one afternoon; Lesson 17 completes the loop.

Roles (rotate each session)

- **Navigator and safety lead:** Carries the campus map with the assigned stations, keeps the group inside the assigned areas and away from traffic, and manages the time at each station.

- **Measurer:** Takes each measurement three times with the ruler, tape or straightedge, calling out the values with units.
- **Recorder and photographer:** Writes every value in the table, photographs each feature with a ruler in the frame for scale, and sketches the station on the map.
- **Rate analyst:** Looks up the feature's age on the campus facts table, computes the average, the rate and the extrapolation back in the classroom, and checks every unit.

Materials

Item	Quantity	Per	Note
Ruler marked in millimeters	1	group	
Tape measure (3 m or longer)	1	group	
Straightedge (a 30 cm ruler or a strip of stiff cardboard) to lay across worn surfaces	1	group	
Clipboard, recording sheet and pencil	1 set	student	
Campus map with stations marked and the campus facts table (teacher prepares)	1	group	
Phone or camera for scale photographs	1	group	Optional; a sketch with measurements works.
Sidewalk chalk to mark measuring points so a later class can re-measure	1 stick	group	
Small zip bag and spoon for one sediment sample (station B)	1	group	
Disposable gloves for anyone handling sediment	1 pair	student	
Calculator	1	group	
Indoor alternative: lidded jar, sidewalk chalk sticks, aquarium gravel, kitchen scale	1 set	group	Only if the field survey cannot run; see lowCostAlternative.

Estimated cost: 3 to 10 per class (an estimate; Chalk, zip bags and gloves; rulers, tapes and clipboards are classroom stock. The indoor alternative adds about \$8 for a bag of aquarium gravel and a box of chalk.)

Safety

- Stay inside the marked areas and never enter parking lots, driveways, loading zones or streets; stations are chosen away from traffic.
- No climbing on walls, railings, slopes or roofs; measure only what you can reach standing on level ground.
- Wear gloves to handle sediment and wash hands afterward; do not touch broken glass, sharp metal, animal droppings or anything in a storm drain; report hazards to the teacher instead of removing them.

- Sun and heat: hats, water and shade breaks on hot days; on wet days surfaces are slippery, so walk and keep both hands free when moving between stations.
- Groups stay together and within sight of an adult; the navigator checks that all four members are present before leaving each station.
- Chalk marks only on pavement, never on walls, signs or plants; chalk washes off.

Teacher preparation and setup

1. Walk the campus a week ahead and choose four to six stations that show measurable change: a worn step or threshold, a crack in pavement with roots or weeds, a sediment deposit at a downspout, curb or storm-drain edge, a crumbling concrete or brick corner, a bare slope with rills, a rusting railing or sign post. Mark them on a simple map and number them A to F.
2. Get dates from the office or facilities staff: the year each building or walkway was built or last resurfaced, when the grounds were last swept or the gutters cleaned, and the date of the last heavy rain. Enter them on the campus facts table printed on the recording sheet.
3. Measure each station yourself once so you know the expected size of the numbers (a 10 to 25 mm dip in a 40-year-old step, a 5 to 30 mm crack, a few liters of sediment) and can spot wild errors.
4. Define the boundaries students may use and the areas that are off limits (parking lots, loading zones, roofs, drainage channels, any area near traffic) and brief the office that classes will be outside.
5. Assign each group three or four stations in a different order so groups do not pile up at one feature.
6. Prepare the indoor abrasion alternative in case of rain or heat: jars, chalk, gravel and a scale.

Investigation design

Independent variable	The feature and process being measured (each station is a different process and agent)
Dependent variable	The measured change (mm, or volume of sediment) and the rate computed from it (mm per year or liters per year)
Controlled	Three measurements per feature, averaged, by the same measurer with the same tool; Ages and dates taken from the same campus facts table for every group; Same rate and extrapolation formulas and the same noticeable-change targets
Trials	Three measurements per feature per group; groups that share a station compare averages in the debrief, and the chalk marks let a later class re-measure the same spots in a future year.
Comparison	Rates across stations (fastest to slowest process on campus) and student predictions versus measured rates.

Student procedure

1. In class, read the campus facts table and the station list. For each assigned station, predict in the first table what process and agent you expect to find and whether you think the rate will be fast or slow.
2. Station A (worn step or threshold): lay the straightedge across the step from edge to edge where the wear is deepest. Measure the gap between the straightedge and the lowest point of the dip with the

ruler, three times at slightly different spots. Record all three in millimeters. Mark the deepest spot with chalk for future classes.

3. Station B (sediment deposit): find the pile of sand, soil or grit at a downspout, curb or drain edge. Measure its length and width with the tape and its thickness at three points with the ruler. Collect one spoonful in the bag and note its color and grain size. Look uphill or up-gutter and write where the material most likely came from.
4. Station C (crack with plants): measure the crack's width at its widest point three times and its total length once. Note what is growing in it and whether the edges are crumbling.
5. Station D (crumbling corner, flaking paint or rust): measure how far the damaged zone extends from the original edge or surface, three times. Note whether the damage is chemical (rust, flaking, dissolving) or physical (chips, cracks).
6. At every station, photograph the feature with the ruler in the frame, sketch its location on the map, and write the agent you think is responsible (water, ice, wind, gravity, living things, chemical reaction, people and vehicles).
7. Back in class, average the three measurements for each station. Find the feature's age or the time since the last cleaning on the campus facts table. Compute the rate: average change $\div$ time, in millimeters per year (or, for the sediment pile, liters per year from length $\times$ width $\times$ thickness $\div$ 1,000 for cm^3 to liters).
8. Extrapolate for each station: choose a change everyone would notice (the step worn through at 150 mm; the crack 100 mm wide; the gutter or a 20-liter bucket full of sediment) and compute how long it takes at your rate: target $\div$ rate.
9. Answer the analysis questions individually, then write your explanation of how the campus is changing, which processes are involved, how fast each one is, and what would have to be true for your long-term predictions to come out right.

Expected observations

- A concrete or stone step 30 to 60 years old typically shows a wear dip of 5 to 25 mm at the center of the tread, giving rates on the order of 0.1 to 0.5 mm per year; a wooden threshold wears faster.
- Sediment at a downspout or curb after a rainy season is commonly 1 to 10 liters, made of sand and soil the color of nearby bare ground or planters, with an obvious uphill source; the rate is liters per year and dominated by a few storms.
- Pavement cracks with grass or tree roots run 5 to 30 mm wide; where a tree is nearby the crack and the lifted slab are the clearest evidence of living things weathering rock physically.
- Students' predictions usually say the step wears fastest because it is the most used; the measurement shows the opposite, which is a useful surprise for the debrief.

Likely difficulties

- The campus may lack one of the station types; substitute any measurable change (a rusting railing, a sagging retaining wall, lichens spreading on a wall measured against an old photo) and keep the method the same.
- Students measure the straightedge gap at an edge instead of the deepest point; model the measurement once at the first station.

- Ages are uncertain (the step may have been replaced); have students write the age they used and treat the rate as an estimate, which is honest and is what geologists do.
- Unit confusion in the sediment volume (cm^3 to liters, $1,000 \text{ cm}^3 = 1 \text{ L}$) and in the cliff extrapolation (meters to millimeters).
- Weather or supervision limits may force the indoor abrasion alternative; keep the same recording tables and treat 'number of shakes' as the time variable.

Structured debrief

1. Put every group's rates on the board by station. Ask why groups that measured the same step got different rates: where the straightedge was laid, how the dip was read, the age used. Then ask what geologists do about this (take many measurements, report a range, say what the rate depends on). The chalk marks mean next year's class can measure the same spots and add a second data point in time.
2. Rank the campus processes by rate. Typical results: sediment deposition at a downspout is the fastest (liters per year after a few storms), a root-widened crack next (millimeters per year), the worn step slowest (tenths of a millimeter per year). Point out that the worn step's rate is in the same range as the rates that carve canyons, and that the difference between a step and a canyon is time, not process.
3. Walk the extrapolation: a step wearing at 0.4 mm/yr takes about 375 years to wear through 150 mm, and would take about 750,000 years to remove a 300 m cliff. Then ask what the extrapolation assumes and why the real answer differs: use changes, surfaces get repaired, rain and frost vary. Connect to the Grand Canyon's debated age: the same uncertainty, on a bigger scale.
4. Close with the chain: at Station B the sediment came from somewhere (weathering of a surface upslope), traveled (erosion by runoff) and stopped (deposition where the water slowed). Ask students where it goes next if nobody sweeps it, and what the campus would look like in a thousand years if maintenance stopped.

Recording sheet: what students fill in

Lab 3 recording sheet: How fast is our campus changing?

Fill in the predictions before you go outside. At each station record three measurements with units, the agent, and a sketch on the map. Back in class complete the rate table, the extrapolation and the questions.

Field safety — Stay in the marked areas, away from parking lots and streets. No climbing. Gloves for sediment, then wash hands. Do not touch glass, sharp metal or anything in a drain; tell the teacher. Stay with your group.

Campus facts (teacher fills in before class)

Feature	Year built or last resurfaced	Age in years (this year minus that year)	Last swept or cleaned (date)	Last heavy rain (date)
Station A: steps or threshold at				
Station B: sediment at				
Station C: crack at				
Station D: crumbling or rusting				
Station E or F (if used)				

Predictions (before going outside)

Station	Process I expect (weathering, erosion, deposition)	Agent I expect	Fast or slow rate?
A			
B			
C			
D			

Field measurements

Station	What I measured (and units)	Measurement 1	Measurement 2	Measurement 3	Average	Agent observed and the evidence for it
A						
B (length, width)						
B (thickness)						
C (width)						
D						
E or F						

Rates and extrapolations (back in class)

Station	Average change (with units)	Time it took (years, from the campus facts)	Rate (change ÷ time, with units)	Noticeable change I chose	Time to reach it (target ÷ rate)
A				Step worn through: 150 mm	
B				A 20-liter bucket full	
C				Crack 100 mm wide	
D					

-  Sketch a map of your stations on the campus. At each station draw an arrow showing where material comes from (source) and where it goes (sink), and label the process on the arrow. Mark the station where the fastest rate was found with a star.

Answer: A sketch map with the stations placed in roughly correct positions, an arrow at each station from a plausible source (a planter, a wall, bare ground uphill) to the sink (the downspout pile, the drain, the crack's crumbs), each arrow labeled with the process (weathering at the source, erosion along the arrow, deposition at the sink), and a star at the station with the largest rate (usually B).

Why: The map shows whether students can see the campus as a system of sources, paths and sinks rather than isolated spots.

- Stations located on the map
- Source-to-sink arrows with process labels
- Fastest station starred and consistent with the rate table

1. Which station had the largest rate and which the smallest? Did your predictions match? Give the two rates with units.

Answer: Campus-specific. Typical: largest rate at Station B (sediment deposition, for example 4 L/yr) and smallest at Station A (step wear, for example 0.3 mm/yr). Predictions often say the step is fastest because it gets the most use.

Why: The point is that the most-used feature changes slowest and the one nobody watches (the downspout) changes fastest; any correct pair of rates with units earns credit.

- Both rates given with units
- Prediction compared honestly with the result

2. Did you find any evidence of a sudden event (for example, a sediment layer left by one storm, or a freshly broken chunk)? What told you it was sudden rather than gradual?

Answer: Campus-specific. Examples: a distinct sediment layer or a fan of sand at a downspout left by one storm (the date of the last heavy rain is on the facts table), a freshly chipped concrete corner with a pale unweathered surface, a branch-fall scar. Evidence of suddenness: sharp edges, no weathering or plant growth on the new surface, a single layer rather than many, matching a dated event.

Why: Students should use the freshness and the lack of layering or weathering as the sign of a sudden event, the same clues used for the rockfall in Lab 2.

Also acceptable: Accept 'no sudden evidence found' with a sentence about what evidence would have shown one.

Analysis questions: answer key

3. Show the rate calculation for Station A in millimeters per year. Example of the form: 18 mm of wear $\div$ 45 years. Then convert the rate to millimeters per century.

Answer: Example: 18 mm $\div$ 45 years = 0.4 mm/yr. Per century: 0.4 mm/yr $\times$ 100 yr = 40 mm per century.

Why: Check the student's own numbers; the age must come from the campus facts table and the units must be carried through.

Also acceptable: Any correct calculation from the student's own measurement and the table's age.

4. Using your Station A rate, calculate how many years it would take to wear the step through (150 mm). Then calculate how long it would take to wear away a cliff 300 m tall at the same rate (300 m = 300,000 mm).

Answer: Example at 0.4 mm/yr: 150 mm $\div$ 0.4 mm/yr = 375 years to wear through the step. Cliff: 300,000 mm $\div$ 0.4 mm/yr = 750,000 years.

Why: Checks the meters-to-millimeters conversion and the idea that a rate measured on a step, applied to a cliff, gives a geologic time scale. Point out in grading that the cliff is not worn by feet, so the second calculation is a thought experiment about rates, not a prediction.

Also acceptable: Accept any correct result from the student's own rate; 'hundreds of years' and 'hundreds of thousands of years' are the expected orders of magnitude.

5. Trace the sediment at Station B backward and forward: where did it come from (what was weathered, by what agent), what carried it (erosion by what), and where will it go next if nobody sweeps it? Use the three process words.

Answer: Source: a surface uphill or upstream of the deposit (bare soil in a planter, a crumbling wall, dust from the parking lot) was weathered by rain, frost, roots, foot traffic or chemical breakdown into loose grains. Carrier: runoff from rain (erosion by water) and sometimes wind moved the grains downhill or along the gutter. Sink: where the water slowed, at the downspout outlet, against the curb or at the drain grate, the grains settled (deposition). Next: the next big rain will pick some up again and carry them into the storm drain, then a creek, then eventually a river and the ocean, with deposition at every slowdown along the way.

Why: This is the three-process chain applied to a real sample. Full credit requires all three terms used correctly and a sensible next destination.

- Weathered source named with an agent
- Erosion by water (or wind) named as the carrier
- Deposition explained by the water slowing
- A next destination given

6. Your fastest and slowest rates on campus probably differ by a factor of 10 or more. Explain how the campus shows that one place can have changes on very different time scales at the same time, and give the space scale of each feature.

Answer: On one campus, in one afternoon, the sediment at the downspout changes by liters each rainy season (space: a pile tens of centimeters across; time: months), the crack widens by millimeters each year (space: centimeters; time: years to decades), and the step wears by tenths of a millimeter each year (space: millimeters; time: centuries to wear through). The same place holds processes whose time scales differ by factors of a hundred or more, which is why one landscape can look busy and frozen at the same time depending on which feature and which time scale you pick.

Why: Students should quote their own rates and attach a space scale to each feature. The key insight is coexistence of different time scales in one place.

- At least two rates from the student's data compared
- A space scale for each feature
- States that different time scales coexist in one place

7. Every extrapolation assumes the rate stays the same. List two things that could make the real rate at Station A or C speed up and two that could slow it down. Then say whether your 'years to wear through' answer is more likely too long or too short.

Answer: Speed up: more foot traffic (more students, a new route), harsher winters with more freeze-thaw, grit or sand on the step acting like sandpaper, a tree's roots growing larger in the crack, wetter years. Slow down: the surface being resealed or repaired, a route being closed, drier or milder years, the worn hollow collecting water that cushions the wear, the crack being filled. The answer is probably too long (that is, the real wear-through would come sooner) if use increases or the wearing surface gets softer below the hard top layer, and too short if the step is repaired, so the honest statement is that the number is an estimate whose assumptions should be written down.

Why: Students must recognize the constant-rate assumption and reason about both directions. Either direction is acceptable for the final judgment if justified.

- Two speed-up factors
- Two slow-down factors
- A justified judgment about the direction of the error

8. Uniformitarianism: a geologist finds a stone threshold in a 1,000-year-old building worn 60 mm deep. Could she use your Station A rate to check that age? Show the calculation, then explain what she would need to be careful about.

Answer: Example at 0.4 mm/yr: $60 \text{ mm} \div 0.4 \text{ mm/yr} = 150 \text{ years}$, far less than 1,000. So either the threshold was worn much more slowly than our step or the age is wrong. She would need to be careful because the rate depends on the material (stone versus concrete), on how many people walked through and in what shoes, on climate, and on whether the threshold was replaced; uniformitarianism lets her use the same process (feet wearing stone) but does not promise the same rate. She could check the age another way (records, other wear, dated layers) rather than relying on one rate.

Why: Checks that students apply the principle correctly: same process, possibly different rate. The calculation should be the student's own rate applied to 60 mm.

- Calculation shown with the student's rate
- States that the same process can be used but the rate may differ
- Names at least two things that would change the rate (material, traffic, climate, repair)

9. Write your explanation: how is our campus changing, by which processes and agents, at what rates, and how long until the changes are obvious? Cite at least three stations by letter and include at least two rates with units.

Answer: A full-credit explanation names the processes and agents at three or more stations (for example: physical weathering by roots and frost at the crack; weathering by feet and grit plus erosion of the dust at the step; erosion by runoff and deposition at the downspout; chemical weathering at the rusting railing), gives at least two measured rates with units, places each feature on space and time scales (millimeters and centuries for the step; tens of centimeters and months for the sediment), gives at least one extrapolation with the assumption stated (the rate stays the same), identifies what could change the rates (use, weather, repairs) and notes that different time scales coexist on the campus.

Why: Score against the criteria. Specific numbers come from the student's own tables, so check that they match.

- Three stations cited by letter with process and agent
- At least two rates with units from the student's data
- Space and time scales given
- Extrapolation with its assumption stated
- Factors that could change the rates

Individual evidence of learning

Each student submits their own prediction table, field measurement table, rate-and-extrapolation table, station map and written answers to q1 through q9. The rate table and q3 and q4 are the evidence for the rate target; q9 is scored against the criteria as evidence toward MS-ESS2-2.

Assessment criteria

Criterion	Proficient looks like
Field data	Three measurements with units for at least three stations, averaged correctly, with the agent named and supported by an observation at each.

Rates	Each rate computed as change ÷ time with units (mm/yr or L/yr) from the campus facts, and at least one extrapolation done correctly with the unit chain shown.
Process chain	Traces at least one campus sediment from its weathered source through erosion to its deposit, using the three terms correctly.
Explanation (MS-ESS2-2)	Names processes and agents for at least three stations, gives measured rates with units, places the features on space and time scales, states the assumptions behind the extrapolations, and identifies what could change the rates.

Accessibility adaptations

- Assign stations along accessible routes and at reachable heights; a student who cannot kneel can be the rate analyst or photographer while a partner measures at ground level.
- Provide a large-print recording sheet, a tape measure with high-contrast markings and a straightedge with a pre-marked center line.
- Allow the explanation (q9) to be recorded as a spoken 'site report' over the station map; allow the map to be built on a printed campus photo with stickers.
- Offer a bilingual word strip for the process and agent columns and a filled example row in the rate table showing the unit chain.

Low-cost alternative

If the field survey cannot run (weather, heat, supervision), do the indoor abrasion version: put one weighed piece of sidewalk chalk and about 100 g of aquarium gravel in a lidded jar with 100 mL of water, shake 100 times, dry the chalk briefly on a paper towel, and weigh it; repeat for three rounds of 100 shakes. Compute the mass lost per 100 shakes, then extrapolate how many shakes would remove the whole stick and how far a river carrying the chalk would have to tumble it. Everything needed costs under \$8 per class and the same tables apply with 'shakes' in place of years.

Model limitations

Campus rates are averages over the feature's whole life and assume the age from the office is right and nothing was repaired; a replaced step or a recent sweeping makes the rate wrong in a way the students cannot detect on one visit. Human use (feet, carts, vehicles) is an agent that does not act on natural cliffs, so the step rate is not a natural weathering rate even though the arithmetic is the same. The extrapolations assume constant rates, which the lesson itself says is not guaranteed. The activity has not been physically tested by the authors; the sizes and rates in expectedObservations are typical values and depend on the campus, its materials and its climate.

Teacher notes

Grade rates on the student's own measurements and the age they wrote down, not on a target number. If the campus facts are uncertain, accept a stated assumption ('we used 40 years because the office said the walkway dates from the 1980s'). The step-versus-cliff extrapolation in q4 is a reasoning exercise; make sure students say in q7 or q9 that feet are not a natural agent and that the rate transfer is a thought experiment.

Keep the chalk-marked spots and this year's data so next year's class can measure again; a two-year difference is the first direct measurement of a rate the school can make.