

Bringing Back Arroyo Verde: Design a Creek Restoration

Learning target: I can define the criteria and constraints of a creek restoration problem precisely, evaluate competing designs against them, and justify a design by predicting how its physical changes will affect populations.

Transfer and design

About 55 min

Pairs

MS-ETS1-1 · practice

MS-ETS1-2 · practice

MS-LS2-4 · practice

engineering design

data analysis

writing

Standards connections

MS-ETS1-1 (practice, stating criteria and constraints with enough precision, and tying each constraint to a real limit): Students sort the council's goals into criteria and constraints, find a vague goal and rewrite it as something measurable, and connect each constraint to a real limit such as flood safety, budget and the bird-nesting season. The problem is already partly defined for them, so the role is practice.

MS-ETS1-2 (practice): Students evaluate five designs and a combination with a decision matrix, eliminating any design that breaks a constraint before comparing how well the rest meet the criteria. This is the systematic evaluation the PE describes, applied to a given set of options.

MS-LS2-4 (practice): Students predict how the physical changes in their design (shade, still pools, removing an invasive plant) will shift populations, and plan the before-and-after and with-and-without measurements that would supply empirical evidence for those predictions.

Purpose: extend · **Time:** about 55 minutes · **Format:** pairs

Answers with reasoning

The problem

Arroyo Verde is a small creek that runs 1.2 kilometers through a city park in California, passing behind the houses on Maple Street in its upper half. In the 1960s it was straightened into a ditch to carry floodwater away quickly. Today **giant reed**, an invasive grass native to northern Africa and Asia that can grow taller than a two-story house, lines both banks. Giant reed uses a lot of water, crowds out native willows and cottonwoods, burns easily, and casts little shade on the water, so the creek runs warm in summer: about 22.5 °C in the pools in August. Surveys find no breeding frogs and few native birds. The council has money for a three-year project and wants a design that brings native populations back without putting the neighborhood at risk.

The council's list (not yet sorted) — 1. Pacific chorus frogs breed in the creek by the third spring. 2. The total cost is no more than \$250,000 over three years. 3. The creek should look nicer. 4. August water temperature in the pools is below 20 °C by year 5. 5. In a big storm, floodwater behind the Maple Street houses must not rise above today's level. 6. No heavy equipment works in the creek from February through August, when birds nest. 7. Giant reed covers less than 10 percent of the banks by year 3. 8. The park trail stays open except for short closures.

Part A: Define the problem

1. Sort the council's eight statements. A **criterion** describes what success looks like and can be met well or less well. A **constraint** is a limit that every acceptable design must stay within. Some statements are **too vague** to use as either.

Answer: 1. Criterion: a measurable sign of success (frogs breeding). 2. Constraint: a firm budget limit. 3. Too vague: 'nicer' cannot be measured, and people will disagree about it. 4. Criterion: a measurable target for success. 5. Constraint: a limit set by flood safety that no design may break. 6. Constraint: a limit on when work can happen, to protect nesting birds. 7. Criterion: a measurable target for removing the invasive plant. 8. Constraint: a limit set by how people use the park.

Why: Criteria can be met to different degrees and are scored; constraints are pass-or-fail limits. Statement 3 is the deliberate trap for precision, which is the heart of MS-ETS1-1.

Also acceptable: Accept statement 8 as a criterion if the student explains that 'short closures' allows some flexibility; the key point is that it is about people's use rather than habitat.

- Statements 1, 4 and 7 marked criteria
- Statements 2, 5, 6 and 8 marked constraints
- Statement 3 marked too vague
- Each 'why' refers to measurable success or a firm limit

2. Rewrite the vague statement as a precise, measurable criterion. Then explain what the council would actually count or measure to check it.

Answer: Example: 'By year 3, native plants (willows, cottonwoods and other natives) cover at least 60 percent of the banks.' The council would measure it by walking set lines along both banks each summer and recording the percent of each line covered by native plants.

Why: A precise criterion names a quantity, a target value and a deadline.

Also acceptable: Accept other measurable versions, such as the number of native bird species seen on a spring survey, or the percent of park visitors in a survey who rate the creek as attractive.

- Rewrite names something measurable, a target and a time
- Describes how it would be measured

Part B: The options

A city engineer has estimated what five options would do. A **beaver dam analog** is a row of wooden posts pounded into the creek bed with willow branches woven between them. Like a beaver dam, it slows the water and backs up a pool, and it can be built with hand tools. Options can be combined if the total cost still fits the budget.

Engineer's estimates for five options (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Option	What is done	Cost over 3 years	Flood level at Maple Street in a big storm	Still pools for breeding frogs by year 3?	August pool temperature by year 5	Giant reed on banks by year 3
A	Remove giant reed every fall for 3 years and plant native willows and cottonwoods along the whole creek	\$120,000	no change	no	19.5 °C	under 10%
B1	Build 6 beaver dam analogs along the whole creek	\$90,000	15 cm higher	yes	20.5 °C	about 70%
B2	Build 3 beaver dam analogs in the lower half only, downstream of Maple Street	\$45,000	no change	yes, in the lower half	20.5 °C (lower half)	about 70%
C	Dig a new curving channel with a wide floodplain and plant natives	\$900,000	20 cm lower	yes	18.5 °C	under 10%
D	Line the banks with rock (giant reed removed during construction)	\$80,000	no change	no	22.5 °C	under 10%

Simulated estimates for teaching. Costs and effects are invented to be realistic for a small urban creek. Today: pool temperature about 22.5 °C in August, giant reed on about 70 percent of the banks, no still pools.

Part C: Evaluate

3. The engineer did not estimate the combination A + B2. Predict its cost, its effect on the Maple Street flood level, and its August pool temperature in the lower half, and explain your temperature prediction.

Answer: Cost: $\$120,000 + \$45,000 = \$165,000$, within the budget. Flood level: no change, because A has no effect and B2's structures sit downstream of Maple Street. Temperature in the lower half: below 20 °C, probably about 19 to 19.5 °C or a little lower. Option A alone reaches 19.5 °C through shade from the new trees, and B2's pools add depth, which warms more slowly than a shallow trickle, so the combination should be at least as cool as A alone.

Why: Students must reason from mechanisms (shade, water depth) because no estimate is given; the answer should not be warmer than A alone.

Also acceptable: A prediction of 20 °C with the argument that pools in the open warm in the sun until the trees grow is acceptable if the student notes the trees will shade them by year 5.

- Correct cost sum
- Correct flood conclusion with a reason
- A temperature prediction below 20 °C (or a justified 20 to 21 °C) explained by shade and depth

4. Complete the decision matrix. First check the two constraints in the table; write 'eliminated' in the last column for any option that breaks one. Score the others: **Frogs** 2 = still pools by year 3, 0 = none. **Temperature** 2 = below 20 °C, 1 = 20 to 21 °C, 0 = above 21 °C. **Giant reed** 2 = under 10 percent, 0 = not removed. For A + B2, use your prediction from q3.

Answer: A: within budget yes (\$120,000), flood yes (no change); frogs 0, temperature 2 (19.5 °C), giant reed 2; total 4. B1: within budget yes, flood NO (15 cm higher); eliminated. B2: yes, yes; frogs 2, temperature 1 (20.5 °C), giant reed 0; total 3. C: within budget NO (\$900,000); eliminated. D: yes, yes; frogs 0, temperature 0 (22.5 °C), giant reed 2; total 2. A + B2: yes (\$165,000), yes (no change); frogs 2, temperature 2 (predicted below 20 °C), giant reed 2; total 6.

Why: Constraint checks come first. Scores follow the stated scale exactly; the combination scores highest because A supplies shade and reed removal while B2 supplies still pools.

Also acceptable: If a student predicts 20 to 21 °C for the combination and scores temperature 1 (total 5), accept it with reasoning; the combination still ranks first.

- B1 and C eliminated with the correct constraint
- Scores for A, B2 and D match the scale
- Combination scored with a reasoned temperature prediction

5. Which options are eliminated, and which constraint does each break? Why is it a mistake to choose an eliminated option even if it would create the best habitat?

Answer: B1 is eliminated because it raises the flood level behind the Maple Street houses by 15 cm, breaking constraint 5. C is eliminated because it costs \$900,000, far over the \$250,000 limit in constraint 2. Constraints are limits every acceptable design must meet; a design that floods homes or cannot be paid for will not be built, so its habitat benefits never happen.

Why: This is the distinction between 'how well' (criteria) and 'whether at all' (constraints).

Also acceptable: Accept the point that C might become possible with outside grant money, as long as the student says it is eliminated under the current constraint.

- Names B1 and C
- Names the broken constraint for each
- Explains why constraints override habitat quality

Part D: Decide and justify

6. Write your recommendation to the council: one option or a combination that meets every constraint. Justify it with your decision matrix and with science: explain how each physical change in your design (shade, still water, removing giant reed) changes resources for living things. Say honestly which criterion your design meets least well.

Answer: Model: We recommend combining Option A (remove giant reed for three years and plant native willows and cottonwoods) with Option B2 (three beaver dam analogs in the lower half). It meets every constraint: it costs \$165,000, below the \$250,000 limit; it does not raise the flood level at Maple Street because the analogs are downstream of the houses; the work can be scheduled outside the nesting season; and the trail needs only short closures. It scored 6 of 6 in our matrix, higher than A alone (4), B2 alone (3) or D (2). Science: removing giant reed frees water, light and space for native willows and cottonwoods; as the trees grow they shade the creek, so the pools stay below 20 °C, and cooler water holds more dissolved oxygen for aquatic insects. The analogs slow the water and back up still pools, the habitat Pacific chorus frog tadpoles need, so frogs should breed by year 3. Native trees also give nesting sites and insects to native birds. The criterion we meet least well is temperature in the early years, because the trees will not shade the creek fully until about year 5, and frogs will breed only in the lower half.

Why: Full credit requires a design that meets all constraints, use of the matrix, a mechanism for each physical change, and an honest weakness.

Also acceptable: A recommendation of Option A alone can earn high marks if the student argues for lower risk and admits it does not meet the frog criterion. Recommending B1 or C cannot earn full credit.

- Recommends a design that meets all constraints
- Cites matrix scores or comparisons
- Explains at least two physical changes and the resource each changes for a population
- Names the criterion met least well

7. Your design changes physical components of the creek. Predict **two** populations that should increase and **one** that might decrease, and explain each prediction through a resource that changes.

Answer: Increase: Pacific chorus frogs, because the analogs create still pools where tadpoles can develop; native willows and cottonwoods, because removing giant reed frees water, light and space; native songbirds that nest in willows, because new trees provide nest sites and insects; still-water insects such as dragonfly larvae, because the pools are new habitat. Might decrease: insects that need fast, shallow riffles in the lower half, such as some mayfly and stonefly larvae, because the pools slow the water there; any animals now sheltering in the giant reed lose that cover until natives grow.

Why: A design is an ecosystem change, and like any change it has winners and losers; naming a loser shows students are not treating the design as purely 'good'.

Also acceptable: Accept mosquitoes as a possible increase in still pools if the student notes that dragonfly larvae and other predators eat mosquito larvae.

- Two increasing populations, each with a resource-based reason
- One plausible decreasing population with a reason

8. Plan the evidence. Name two measurements, where you would take them (include a comparison place that is not restored), and when (before and after the work). What result in year 3 would show your design is working?

Answer: Example: (1) Count chorus frog egg masses or tadpoles in the lower half each spring; (2) measure August pool temperature with a logger in several pools. Take both measurements for one to two years before the work and every year after, in Arroyo Verde and in a similar unrestored creek or stretch nearby. Success in year 3: tadpoles present in the restored pools but still absent in the comparison creek, and restored pools cooler than they were before and cooler than the comparison, heading toward the 20 °C target by year 5.

Why: This uses the chapter's evidence logic: before-and-after plus with-and-without, measured the same way each time.

Also acceptable: Accept percent cover of giant reed and native plants as one of the two measurements.

- Two measurements tied to the criteria
- A comparison place
- Before-and-after timing
- A specific year-3 result that would count as success

9. Constraint 6 bans heavy equipment in the creek from February through August. Give a schedule for your design's work that respects it, and explain what the constraint protects.

Answer: Remove giant reed and plant willow and cottonwood cuttings from September through January, when the plants are dormant and birds are not nesting; build the beaver dam analogs with hand tools in late summer or fall when the water is low, and after August if any machine is used. The constraint protects birds that nest along the creek from February through August, because noise and machines near nests can make adults abandon them.

Why: Seasonal work windows are a real kind of environmental constraint; the answer should place every task inside September to January or use only hand tools.

Also acceptable: Accept a schedule that spreads reed removal over three falls, which matches Option A.

- All machine work scheduled September to January
- Explains that the constraint protects nesting birds

10. Name one risk or trade-off of your design and one way to reduce it.

Answer: Examples: giant reed regrows from underground stems, so removal must be repeated each fall and checked for several years; a big storm could wash out an analog, so inspect and repair them after storms; the new trees need watering for the first dry summers or many will die; real beavers might move in and build dams nearer Maple Street, so monitor water levels and plan a way to limit pond height.

Why: Every design has trade-offs; naming one with a practical fix shows engineering thinking.

Also acceptable: Accept cost overruns with a contingency plan, if the student says what would be cut first.

- Names a realistic risk of the chosen design
- Gives a practical way to reduce it

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
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Defining the problem (q1, q2)	Sorts all eight statements correctly with reasons, and rewrites the vague goal as a measurable criterion with a target, a deadline and a method.	One statement mis-sorted, or the rewrite lacks a target or a method.	Several statements mis-sorted, or the rewrite is still vague.	Criteria and constraints confused throughout.
Evaluating options (q3 to q5)	Eliminates B1 and C for the right constraints, scores the rest exactly by the scale, and predicts the combination's cost, flood effect and temperature with a mechanism.	Correct eliminations with one scoring slip, or a combination prediction without a reason.	Scores options without checking constraints first.	Matrix incomplete or guessed.
Justifying with science (q6, q7)	Recommendation meets every constraint and explains how each physical change alters a resource for a named population, including one population that may lose.	Sound recommendation and mechanisms, but no population that loses, or one mechanism missing.	Recommendation justified by cost or scores alone, with little science.	Recommends an eliminated option, or no justification.
Planning evidence and managing trade-offs (q8 to q10)	Monitoring plan has two measurements, a comparison place, before-and-after timing and a clear success result; schedule respects the nesting constraint; a realistic risk with a fix.	Plan missing one of comparison or timing; schedule and risk sound.	Plan names measurements only; schedule or risk vague.	No usable plan.

Teacher notes

Arroyo Verde, its costs and its estimates are invented, but the problem is typical of California urban creeks. Giant reed (*Arundo donax*), native to northern Africa and western and central Asia, is rated a High-impact invasive plant by the California Invasive Plant Council: it crowds out willows and other natives, uses large amounts of water, adds fire fuel, and shades streams poorly, which warms the water. Beaver dam analogs (posts with woven willow) are a real low-cost restoration method in western streams; they slow water, build pools and often attract beavers, which is why the extension raises the flood question. Willow and cottonwood cuttings are normally planted in the dormant season, and work windows that avoid the bird-nesting season are a common permit condition. The intended best answer is the A + B2 combination, but students who argue for A alone with honest trade-offs should score well. This sheet formalizes the slide 25 discussion and supplies the criteria-and-constraints list named in the chapter's evidence of learning.

Scaffold offered to students: Constraints first, criteria second

Engineers check constraints before anything else, because a design that breaks one is not allowed no matter how good it is. Go down the 'Cost' column and cross out anything over \$250,000. Go down the 'Flood level' column and cross out anything that raises the water. Only then score what is left. For q6, try this frame: 'We recommend ___ because it stays within ___ and ___. It meets the criteria for ___ because ___ (shade, still pools, reed removal) changes ___ for ___. It meets ___ least well because ___.'

Extension: When the beavers move in

Beaver dam analogs often attract real beavers, which may then build their own dams, sometimes in places engineers did not plan. Suppose a beaver family arrives at Arroyo Verde in year 4 and starts a dam just downstream of Maple Street. Write a short plan for the council. Which criteria might the beavers help? Which constraint might they threaten? Research one method communities use to live with beavers, such as a pipe-and-fence flow device that keeps a pond from rising past a set level, and explain how it would keep the design within its constraints.