

Design Challenge: Salt Ponds or Marsh?

Planning a Bay Shoreline

Learning target: I can evaluate competing designs for restoring a bay shoreline against criteria and scientific, economic and social constraints, design an improved plan with calculations, and justify how it maintains biodiversity and ecosystem services.

Transfer and design

About 55 min

Pairs

MS-LS2-5 · assesses

MS-ETS1-2 · practice

MS-ETS1-1 · supports

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

You and a partner are advisers to a team restoring former salt ponds on the shore of San Francisco Bay. Read the background, which is real, and the problem, which is a simplified version invented for this worksheet. The numbers in both datasets are teaching estimates. Work through Parts A to D in order: understand the problem, evaluate three competing designs, build your own plan, then justify it. Plan together, but each of you writes your own answers to Part D.

You will need: This worksheet, Pencil, Calculator

Background: a real restoration

For more than a century, companies built shallow ponds along the edge of San Francisco Bay to make salt by letting seawater evaporate. Levees (walls of earth) around the ponds kept the tides out, and the tidal marshes that once grew there disappeared. In 2003, state and federal agencies bought 15,100 acres of these ponds in the South Bay to restore them. The project's goal is to turn at least half of that land back into tidal marsh, which is home to endangered animals such as the California Ridgway's rail and the salt marsh harvest mouse. But the ponds have become important too: tens of thousands of migrating shorebirds and ducks rest and feed in them. So the project opens some ponds to the tides, keeps others as managed ponds, measures what happens, and decides step by step whether to open more.

The problem (simplified for this worksheet) — The Bayview complex has 8 ponds covering 2,000 acres. Today about 30,000 waterbirds use it at the busiest time of year, and it has no tidal marsh. A separate project is already raising the levees behind the ponds, so every design keeps today's flood protection for nearby homes. The team's limits: building can cost no more than \$25 million; yearly upkeep can be no more than \$1.0 million; at least 15,000 waterbirds must still be able to use the complex; and at least half of it, 1,000 acres, must become tidal marsh. Neighbors also want to keep walking the trail on the outer levee. Beyond those limits, the team wants as many marsh animals, as much calming of storm waves near homes, and as fast a marsh as possible.

Three competing designs: predicted results after 20 years (teaching dataset)

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

Measure	A: Open all 8 ponds to the tides	B: Keep all 8 as managed ponds	C: Open about half, keep about half
Tidal marsh (acres)	2,000	0	about 1,000
Ridgway's rail pairs expected	60	0	about 30
Waterbirds at the busiest time (30,000 today)	under 3,000	30,000	about 15,000 to 20,000
Young fish raised in marsh channels	many	none	some
Storm waves calmed before reaching levees	most	little	some
Cost to build (\$ millions)	46	4	about 21 to 25
Yearly upkeep (\$ millions)	0.2	1.6	1.0
Biggest uncertainty	Will enough mud settle to build marsh before sea level rises?	Old pumps and levees wear out and cost more	Which ponds should be opened?

Simulated estimates for teaching, loosely based on the kinds of trade-offs the real South Bay project studies.

The eight Bayview ponds (teaching dataset)

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

Pond	Area (acres)	Mud supply for building marsh	Waterbirds at busiest time	Next to homes?	Cost to open to tides (\$ millions)
P1	300	high	2000	no	6
P2	250	high	6000	no	5
P3	200	low	1500	yes	7
P4	250	medium	5000	yes	6
P5	300	low	8000	no	6
P6	200	high	1000	yes	5
P7	250	medium	3500	no	5
P8	250	low	3000	yes	6

Simulated data for teaching. Rules for this model: an opened pond becomes tidal marsh, and most of its waterbirds leave (count them as lost). Marsh forms in about 10 years where mud supply is high, about 20 where it is medium, and 40 or more where it is low, and low-mud marsh may drown as sea level rises. A marsh next to homes calms waves before they reach the levee. Each pond kept costs \$0.2 million a year to run, and monitoring the new marsh costs \$0.2 million a year.

Part A: Understand the problem

1. Sort each requirement. Write **criterion** (something a design can do better or worse) or **constraint** (a limit every design must meet), and say whether it is mainly scientific, economic or social.

Criterion or constraint?	Scientific, economic or social?
1. Building costs no more than \$25 million.	
2. At least 15,000 waterbirds can still use the complex.	
3. More Ridgway's rail pairs is better.	
4. Yearly upkeep is no more than \$1.0 million.	
5. At least 1,000 acres become tidal marsh.	
6. Marsh should form before sea level rises much more.	
7. Neighbors keep their trail on the outer levee.	
8. More storm waves are calmed near homes.	

2. Name three ecosystem services a tidal marsh provides to people in this problem, and one benefit people get from the managed ponds.

Part B: Evaluate the three competing designs

3. Check each design against the four numbered limits from the problem. Write **pass** or **fail** with the number that decides it. In the last row, write whether the design is still in the running.

A: Open all	B: Keep all	C: Open about half
Build cost no more than \$25 million		
Upkeep no more than \$1.0 million a year		
At least 15,000 waterbirds		
At least 1,000 acres of tidal marsh		
Still in the running?		

4. Even the designs that fail have something valuable. Name the best feature of Design A and of Design B, and explain how Design C borrows from both.

Part C: Build your version of Design C

5. Choose which ponds to open. Fill in your plan's totals. Every limit must be met.

Your plan
Ponds opened (list them)
Total acres opened
Total cost to build (\$ millions)
Waterbirds kept (30,000 – birds in opened ponds)
Yearly upkeep (\$ millions)
Opened ponds with high or medium mud supply
Opened ponds next to homes

6. Show the calculations that prove your plan meets all four numbered limits. Explain why your plan must open at least 4 ponds to stay within the upkeep limit.

7. Pond P5 has the most waterbirds but a low mud supply. Pond P6 has few birds, a high mud supply and homes behind it. Explain your decision for each pond, naming the criteria you weighed.

Part D: Decide and justify

8. Write a recommendation to the restoration team. Explain why your plan is better than Designs A and B, using at least three numbers. Describe how it maintains biodiversity (name at least two groups of animals) **and** at least two ecosystem services. Say honestly which criterion your plan meets least well and what trade-off you are accepting.

9. The real project decides step by step. Describe what the team should measure in years 5 to 10 after your plan starts, and what results would tell them to open more ponds or to stop.

A three-step method for Part C

Step 1: Start with ponds that have a high mud supply, because marsh forms fastest there. Step 2: Add up acres as you go until you reach at least 1,000. Step 3: After each pond you add, subtract its birds from 30,000 and add its cost, and check that you still have at least 15,000 birds and no more than \$25 million. If a limit fails, swap one pond for another with fewer birds or a lower cost. Upkeep: $(8 - \text{ponds opened}) \times 0.2 + 0.2$ must be 1.0 or less.

Sea level changes the plan

Suppose new measurements show sea level is rising faster than expected, so in this model only marsh with a high mud supply forms in time; medium-mud marsh now takes 40 years. Redo your plan. Can you still meet every limit? If not, which limit would you ask the agencies to change, and why? Write a short paragraph arguing for your choice using numbers from the pond table.