WOW Pump It Up!

Student Handout

Background

Considered one of the most impressive engineering feats of the 20th century, the Central Arizona Project (CAP) was implemented in the late 1960s and early 1970s in order to end water insecurity throughout the state of Arizona. It took over 20 years to plan and construct the canal system – one of the largest of its kind in the United States. Today, the CAP is responsible for providing more than 1.5 million-acre feet of Colorado River water per year to cities, communities and agricultural producers.

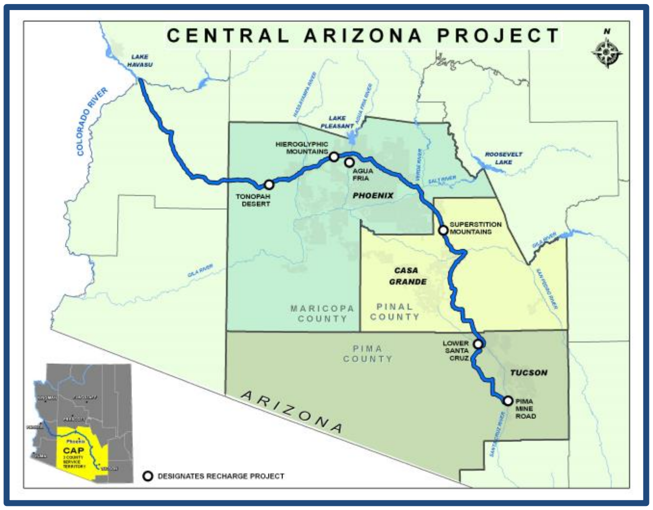

Figure 1 - Central Arizona Project Map

The CAP canal carries water from the Colorado River at Lake Havasu uphill 336 miles across southern Arizona to users including the cities of Phoenix and Tucson. Over that distance, the water has to move uphill about 2,900 vertical feet! To meet demand, CAP moves more than 1.3 billion gallons of water a day! To lift the water, CAP operators manage 115 giant pumps along the system. Some of them can pump 2,740 gallons of water every second - enough to fill up to 125 bathtubs per second!

In most years, the CAP system delivers more than 500 billion gallons (more than 1,534,441 acre feet) of water from the Colorado River. Pumping this volume of water uphill takes 2.8 million megawatt hours of electricity. That's a lot of energy, especially if you consider that there are a million watts to a single megawatt. In fact, CAP is the biggest user of electricity in Arizona.

Adapted from *It Takes Power to Bring Water to Us!* Nonfiction Reading Passage, CAP webpage: http://www.cap-az.com/education/nonfiction-reading-passages and http://www.cap-az.com/about-us/background

Vocabulary

- **Criteria:** a measurable requirement or condition that must be met to solve the problem.
- **Constraint:** a limitation or restriction that must be considered in the design.
- **System:** a group of related parts that work together.
- **Reservoir:** a natural or artificial pond or lake used for the storage of water.
- **Electric Power:** the rate at which electrical energy is transferred by an electric circuit.
- **Watt:** a unit for measuring electric power. 1 kilowatt (kW) = 1000 watts, 1 megawatt (MW) = 1,000,000 watts.

Engineering Challenge

Imagine that you are part of a team of engineers designing the Central Arizona Project (CAP). Your challenge is to design and test a system to deliver water uphill and a distance away using a model. The distance between the water source and canal end is 4 feet (each inch represents 7 miles) with an elevation gain of 1 foot (each inch represents 241.7 feet in elevation). The best design will deliver the most water from the initial to the final reservoir in one minute of pumping time. You may only use the materials provided, but do not have to use all of them.

Figure 2 - CAP Canal

Criteria

- Design must be 4 feet in length (Scale: 1” = 7 miles)
- Final Reservoir must be 12” high (Scale 1” = 241.7 feet in elevation)
- 4 reservoirs
- 2 canals

Constraints

- Canals must flow by gravity between 2 different reservoirs.
- Limit of 3 pumps
- No additional materials allowed.
- Not all materials have to be used.

Materials per Group

- **3** – pumping devices of different sizes
- **2** – 1-foot sections of Styrofoam “canals”
- **10** – plastic containers to build 4 reservoirs (lids are optional)
- **20** – Styrofoam cups for canal supports
- **1** – yardstick or ruler
- **1** – stopwatch (Day 2)
- **1 –** 1-liter graduated cylinder (Day 2)

Things to Keep in Mind

1. Take your time -- it’s not a race to see who can build their pumping system the quickest!
2. Remember to go through the **Engineering Design Process**.
    a. **Ask** – Define problem, criteria, and constraints. What determines the best design?
    b. **Explore** – How does your equipment work? What testing are you going to do on the components of your system?
    c. **Imagine** – Think of the best way to arrange your reservoir pieces and canals. Try different ways of grouping them.
    d. **Plan** – Sketch out your system design and label it. Outline your testing plan.
    e. **Create** – Build your system. Explain any differences between your original design plan.
    f. **Test** – Collect data. Record observations
    g. **Improve** – Analyze data. What did you like about design? What worked in your design? What didn’t work? How would you improve it? If you have time, re-design and re-test.

WOW - Pump It UP! - Engineering Design Process Notebook

Name:	Date:

Please use this as a lab notebook to document your engineering design.

ASK: What is the problem you are solving? What are your criteria? What are the constraints? What determines the best design?

EXPLORE: Get to know your materials. Use the dimensions on the "to scale" reference photos to help you plan your design. Below write your procedures (e.g. measuring the parts available to you) and the sizes measured.	
Test Procedures	**Test Results**

IMAGINE: **First, brainstorm multiple ways to arrange and configure your parts to design your water supply system and make rough sketches here. Your team will need to discuss and agree on the best idea to move forward to the PLANNING stage.**

Design 1:

Design 2:

Design 3:

PLAN: **Use graph paper (preferably) or the space below to plan your chosen system. Be sure to include an aerial perspective (top) as well as a cross sectional view (side).**

Cross-sectional View

Aerial Perspective

DAY 2 - CREATE: **Return to your sketches above. Are the parts labeled and do they demonstrate water movement with arrows and explanations? If you need to change anything, sketch your final build or explain how it is different from your plans below.**

DAY 2 - TEST: **Use the space below to record test results of your design. Record detailed observations!**

DAY 2- IMPROVE: What did you like about this design? What worked or didn't work with it? How would you revise your plan in order to improve your results? (Include testing results in your discussion.)

Conclusion

The Central Arizona Project consists of a series of 14 pumping plants, 1 hydroelectric pump/generating plant at the New Waddell Dam, 39 radial gate structures to control the flow of water, and 50 turnouts that deliver water to customer systems. CAP is the largest single end-user of power in the state of Arizona.

1. Explain the difficulties you encountered with moving water uphill and how you solved them.

2.Reflect on the usefulness of the engineering design process in solving this problem. Be specific.

3. Relate your experience in designing this system to the problem(s) that engineers might have encountered in designing the CAP system.

4. If you were tasked with designing pumping stations today for the CAP canal what features would you include in your design?