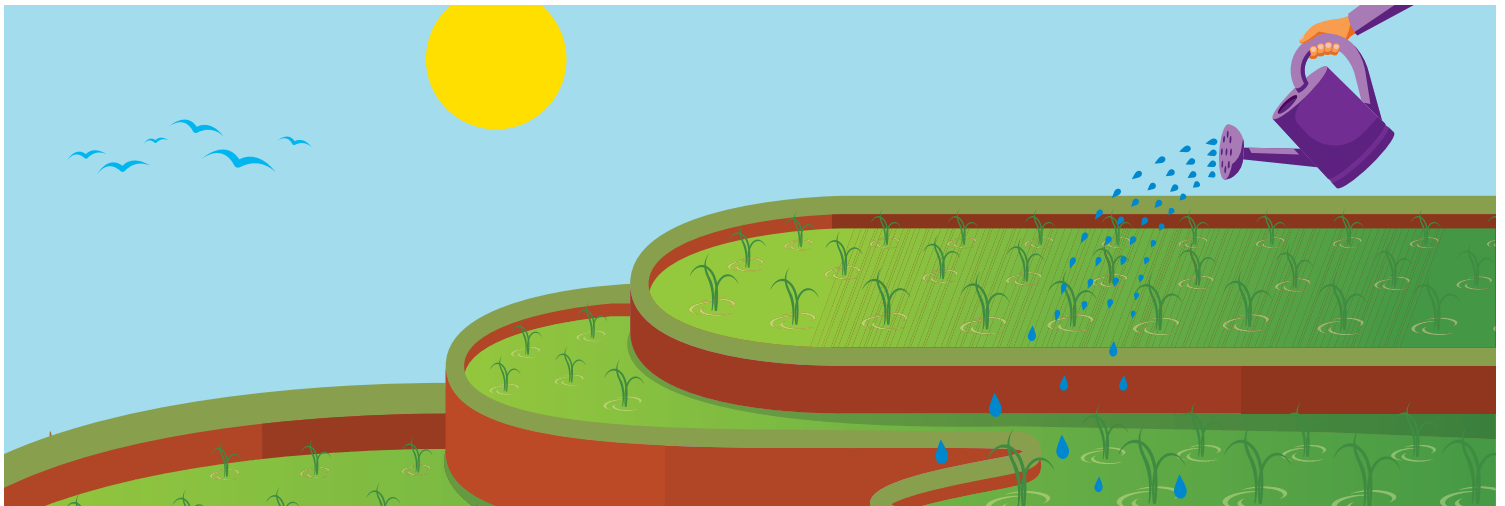# Irrigation Situation

Grade Levels: 3-5

Duration: 90 min

In this mechanical engineering lesson, learners will use the design process to create a hillside garden irrigation system that maximizes water efficiency.

Outline

Frame the Challenge	10 min total
Activate Prior Knowledge	5 min
Introduce the Scenario	5 min
Design Challenge Part 1	**50 min**
Define the Problem	10 min
Introduce the Design Challenge	10 min
Prototype (Build and Test)	15 min
Share Solutions	15 min
Design Challenge Part 2	**30 min**
Introduce Changes to the Design Challenge	5 min
Prototype (Build and Test)	10 min
Share Solutions	10 min
Debrief	5 min

Grade Levels: 3-5

Duration: 90 min

Concepts/Skills
Water conservation, irrigation, agriculture, liquid volume, terrace farming

Objectives
Students will:
- Engineer a hillside irrigation system that efficiently directs water to the plants.
- Determine criteria and constraints based on a "client" request.
- Evaluate the success of their design based on the criteria and constraints.
- Demonstrate why they chose to make specific iterations using sketches and written explanations.

Materials and Preparation

Materials

There are two types of materials for this challenge:
1. **Terrace Garden Test Rig** (1 set per group)
2. **Irrigation System supplies** (for the entire class to use)

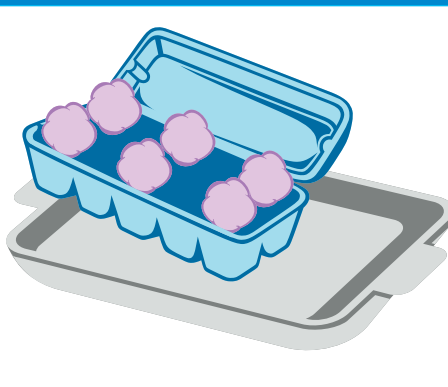| **Terrace Garden Test Rig Materials** *(1 set per group)* |
| --- |
| ☐ **Terrace Surface:** An egg carton, muffin tin, mochi ice cream tray or folded cardboard to create a "stepped" slanted surface

 ☐ **Base:** One tray/collection bin to catch runoff Ex: sheet pan, dish tub (deep enough to hold 8 oz of water)

 ☐ **"Plants":** 6 cotton balls, wadded paper towels or cut-up sponge to act as absorbent "plants"

 ☐ Water: 8 oz per test

 ☐ A graduated cylinder or measuring cup |
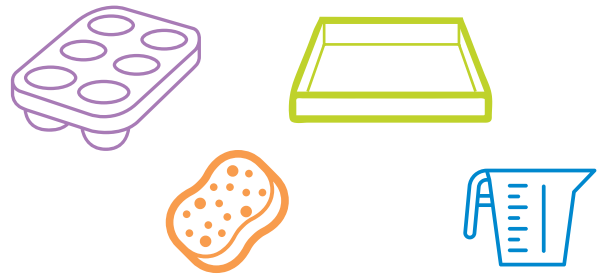
Terrace Garden Test Rig Set-Up

• Each team will need a model terraced hillside (set up at an angle) with a tray or bin underneath to collect any runoff water. Depending on the materials you have available, set-ups may vary between groups.

• Each garden should include 6 "plants" evenly spaced as in the examples below.

• During testing, students will slowly pour 8 oz of water through their irrigation system.

  – Test to make sure your base is deep enough to hold 8 oz of water.

  – **Tip:** Each test will require water, so make sure you have a reliable water source on hand or several 8 oz bottles of water per team.

  – Note: In Part 2 of the challenge, they will watch carefully and stop pouring when they have wet all of their plants. In this way they will see if they can reduce the amount of water used.
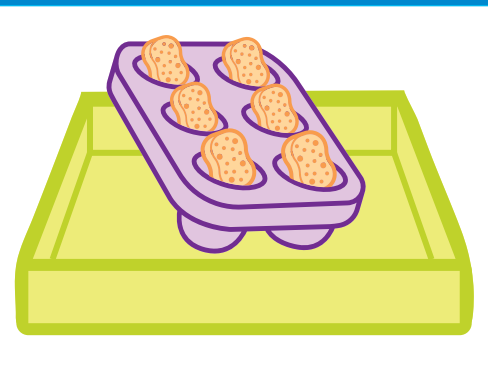
Possible Test Rigs
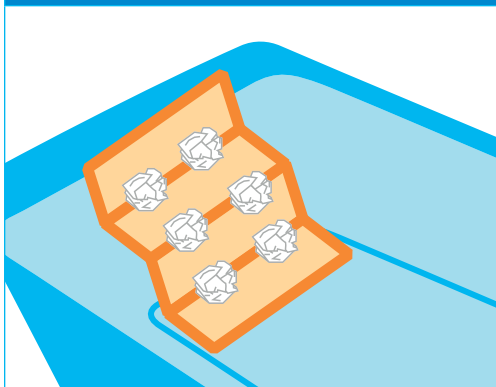
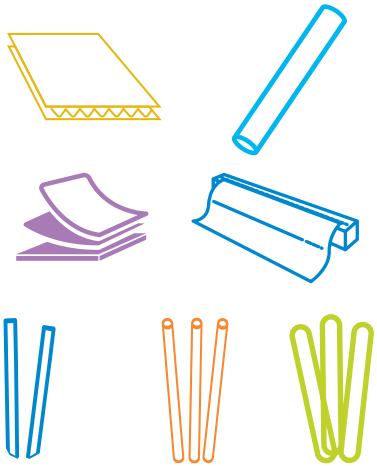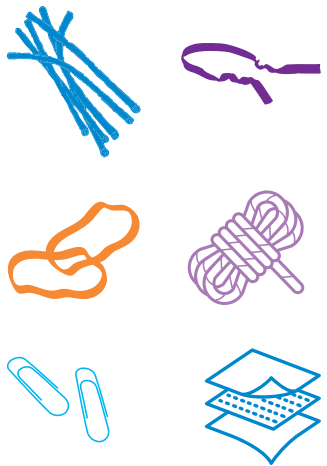| **Folded cardboard with paper towel "plants" in a tub.**	**Egg cartons with cotton balls in a sheet pan.**	**Ice cream mochi tray with sponges in a plastic lid.**

Irrigation System Supplies

Look for items from each category. Don't limit yourself to the items on this list. Use whatever you have on hand. Be creative!

(per class of ~32 students)	
Structural objects *(15-20 per team)*	**Connectors** *(15-20 per team)*
□ Cardboard □ Paper towel or cardboard rolls □ Styrofoam □ Paper/paper towels □ Foil □ Plastic wrap □ Straws □ Craft sticks □ Chopsticks	□ Twist ties □ Pipe cleaners (chenille stems) □ Rubber bands □ String □ Paper/binder clips □ Clothes pins □ Paper fasteners □ Fabric scraps

Additional Resources

Tools *(1 set per group)*	**Handouts**
□ Scissors □ Tape measure or ruler (helpful) □ 1 roll of masking tape	□ Irrigation Situation: Defining the Problem (*1 per student*) □ Irrigation Situation: Data Collection (*1 per student*) □ Irrigation Situation Challenge Cards (*1 per class*)

Lesson Preparation

1. Try to build a solution yourself, with other educators or kids you know. This will give you practice with the materials and tools to be able to anticipate student questions.

2. Collect, organize and set up materials.

   • If using the same test rig materials for each group, it may help to sort materials into "kits" in advance.

   • If test rig materials vary between groups, set up supplies buffet style and let teams design their test rig as part of their solution.

   • Depending on your preference set out the remaining irrigation supplies buffet style or in kits for each team.

   • Print or digitally share the handouts.

Adaptations for Distance Learning

Test Rigs
- Test rigs can vary significantly based on the materials students have available so encourage them to be creative with what they use.
  - Remind them that all the materials that they use will get wet during testing.
- Have students build their test rigs asynchronously and share photos of them before attending a synchronous video prototyping session. This will allow more time for solving the irrigation problem and learning from each other's designs.

Designing at Home
- Encourage students to test their irrigation system designs outsideor in a sink or bathtub if possible to reduce concern about mess and allow for more free and creative iteration.
- If students struggle with their testing and design, it is an opportunity to discuss other real-world issues with terrace gardening such as erosion, flooding and landslides.

For more tips on adapting Design Challenges to a virtual setting, see our Educator Tips for Remote STEM Learning.

Frame the Activity

Activate Prior Knowledge *(5 min)*

1. Begin the lesson by tapping into students' understanding of agriculture and it's differences across climates and cultures. In addition, find out how much students already know about irrigation and systems to move water.
2. Guiding questions may include:
   - *What are the essential pieces needed for farming?*
   - *How do you think those needs and farming itself have changed throughout history?*
   - *How do you think farming is different in different climates?*
   - *What ways have you seen people moving water from one place to another?*

Resources for Images of Terrace Farming

Possible resources include:
- Article with Images: Terrace Farming Facts for Kids
- Article with Images: 30 Spectacular Examples of Terraced Agriculture

Introduce the Scenario *(5 min)*

1. Let students know that, in this lesson, they will look at farming and irrigation in a specific setting, a hillside.
2. Share images of various terrace farms with students.
   - Terrace farming is common in cultures and locations around the world (Ex: Philippines, China, India, Indonesia, Pakistan, Peru, Italy, Portugal, Switzerland).
   - Show a range of types of terrace farms (Ex: rice and tea as well as arid lands).
3. Introduce the **design scenario/narrative** with students:

Congratulations! Your team of engineers has just been contacted by a housing developer to design an irrigation system for a community garden in a new housing development. The only open space for the garden is on a hillside and the area has been pre-engineered with stepped terraces.

Design Challenge Part 1

Defining the Problem *(10 min)*

1. Introduce the **Defining the Problem handout** to students or teams.

2. Review the design request from the "developer."

> *The people renting these apartments want a space to have a garden, but the only land we had left was on this hill. We had a team come in and form the terraces to put the plants in and now we **need** a way to make sure that all six of the planted areas get watered evenly. We **want** you to design a system that can do this without using too much water, no more than _____ ounces. We don't have enough **budget** to buy any new supplies for this test version so you can build the prototype using whatever you have on hand. We will need to see your completed design as soon as possible so we can stay on **schedule**. Don't take any longer than _____minutes to develop your prototype.*

3. Their role as "engineers" is to determine the criteria and constraints based on the request.

Criteria	The needs and wants of the "client." They tell how to make the design successful.
Constraints	The limits on the design. They tell what is and isn't allowed when creating the design.

- If students need support, help clarify the differences between criteria and constraints with some examples:
  - *When building a car, the criteria would be things like color or number of doors. The constraints would be how long it takes to manufacture it and the cost of the materials.*

4. After students have had a chance to fill in the handout, review their choices as a class and confirm the criteria and constraints that were requested by the developer.

- See the table in the next section for these details.

Introduce the Design Challenge *(10 min)*

1. Review the design problem, criteria and constraints.

Design Problem	Design a hillside irrigation system that collects and distributes water efficiently to all of the plants.	
Criteria	• System distributes water to all 6 plants. • Use 8 oz of water or less.	
Constraints	• Use the materials available to you. • Try to complete this challenge in 15 minutes.	

2. If you have not already done so, group students into teams of 2-4.
3. Explain the procedures students will follow for building, testing and sharing.
   - Remind students to test throughout build time to help them iterate as they go.
   - Hand out and explain the **Data Collection Sheet**.
4. Show a sample test rig. Have students assemble the test rig with their team. Then have students discuss and determine:
   - *How/where will your team pour the water when testing?*
   - *How will you measure the amount of water used during each test? Where will you record these results?*
   - *How often will you test your system?*
   - *What additional challenges do you notice?*

> **Test Rig Adaptations**
>
> If test rigs vary between teams and students will design their own test rig, then make sure they understand the possible set-ups and materials.

> **Brainstorm** *(optional)*
>
> Use one of these formal brainstorming techniques to spark creativity and help students begin to organize their ideas.
> - **Sticky Notes:** Give each individual a pad of sticky notes. Have them write and draw on sticky notes and read their ideas aloud as they post each to a team board.
> - **Materials Investigation:** Have each team member select a different material, share characteristics of their material (rigidity, absorbency, etc.) and ideas for how that material could be used in the team's solution. While one team member starts the sharing, others can provide additional ideas on the use of each material.

Prototype (Build and Test) *(15 min)*

1. During the prototyping time, walk around and support teams.
   - Help students to focus on the process, rather than on the success of their designs. If their design fails, ask them how many things they have tried, what they notice about what isn't working and what they might try next.
2. Ask open-ended questions to encourage students to reflect on their process:

   Prototype Questions:
   - *What are your design ideas for helping water to reach all of your plants?*
   - *Which materials might be most helpful in meeting this criterion? Why?*
   - *How can you modify the materials you have to get the water to all of your plants?*
3. Remind teams to test while they build, even if their design is not complete.
4. Encourage them to collaborate with each other and use the Data Collection Sheet.
5. Provide reminders on time and, if teams feel like they are done, ask them to consider how they might improve their design.
6. Let them know they will share their ideas in the next step.

Share Solutions *(15 min)*

1. At the end of the time limit, learners stop even if they haven't been able to build or complete something. Students can test/share about whatever progress they have made.

2. Sharing can be done by gathering where each team can show their test rig and irrigation system. Teams should test/demonstrate their device before they share.

3. Keep their sharing simple and focused on what they did and why.

4. **Sharing Questions** can include:
    *   *How does your design meet the criteria and constraints?*
    *   *How much water did your garden use?*
    *   *What additional challenges or limits (constraints) did you discover as you were building?*
    *   *What is one thing you would want to change or adjust in your design? How will that help your design to better meet the criteria or constraints?*

5. Have learners give each other positive feedback on their designs. Encourage them to tell the other team one thing they liked or noticed.

Content Connection

Before having students tackle Part 2 of the challenge, have them research and learn more about some indigenous farming techniques and how geography and climate influence these techniques.

Options include:
*   Video: Explore the Emerald Rice Terraces of the Philippines uploaded to National Geographic, 2018 (2:38 mins)
*   Video: "Hopi Dry Farming" Ahkima's Field Hopi Reservation uploaded to YouTube by rd47blog June 2012 (especially 2:15-3:15, 7:54-13:00)
*   Video: Encyclopedia Britannica Terrace cultivation on Portugal's Madeira Island
*   Study Ancestral Pueblo Farming National Park Service, 2017
*   Article: Ancient Farming - Concepts, Techniques, and Experimental Archaeology, ThoughtCo, By K. Kris Hirst, May 2019
*   Blog: These Ancient Agricultural Techniques are Making a Comeback, Teralytic, July 2018

After conducting this research, have them consider how they can apply what they have learned to their designs.

Design Challenge Part 2

Introduce Changes to the Design Challenge *(5 min)*

1. Introduce new aspects to the design scenario/narrative:

> *Farming on hillsides has been an engineering design challenge throughout history, but climate change has recently caused **droughts** in this area. How can you engineer your irrigation system to **use less water**?*

2. Introduce the new aspects of the design problem, criteria and constraints.
   - Ask students to help define the problem by helping to define a new criterion based on this new client need.
     - *What is our client's new need?*
     - *What new criteria do our solutions need to meet to address this need?*
     - *What do you think is the least amount of water we could use and still reach all the plants? What should our new target be?*
   - Drought can also increase the cost of using water, so you'll need to improve your solution quickly to save money for the community.

Design Problem	Design a hillside irrigation system that collects and distributes water more efficiently in order to conserve this precious resource.	
NEW Criteria	• System distributes water to all 6 plants. • Use less water than your previous design: reduce the amount of water needed by ___ oz.	
NEW Constraints	• Use the materials available to you. • Try to complete this challenge in 10 minutes.	

3. This new criteria will require students to test by slowly pouring the 8 oz of water into their irrigation system and stopping when it appears they have wet all their "plants." They will then measure the amount of water remaining and determine how much they reduced their water use.
   - As a class, determine the amount of water they want to target for this new criteria.
4. Engage students in a discussion about how they might change their designs.
   - *Based on what you've learned about historical farming techniques, are there techniques that might help to decrease the amount of water used?*
   - *What have you seen in historical irrigation systems that might inspire your next design improvements?*

Real-World Connections

Expand on the new scenario with an examination of how drought and other aspects of climate change affect sources of fresh water.

• Have students consider: How can we adjust our designs for gardening and landscapes in a way that considers the need for fresh-water conservation?

Resources include:

• California's climate continues to change with measurable evidence of frequent droughts. (Article & Video: California agriculture faces serious threats from climate change, study finds, Desert Sun, February 2018. 17.19 min)

• Worldwide drought hazards have seen an increase in recent years and the World Health Organization notes that 40% of people in the world are affected by water scarcity. They predict that by 2030, 700 million people may be displaced as a result of drought. (WHO Health Topic: Drought)

• Article: Explaining Drought to Kids, Washington Post, August 2012.

Adaptations for Advanced Engineers

• Frame the second part of the challenge as a futuristic design challenge. Students can design solutions for extreme landscapes (another planet, a ravaged homeland, a post-apocalyptic world). As they do this, have them also consider the agricultural struggles and pitfalls of past civilizations (Ex: Dust Bowl led to limited space/water, Mayan deforestation increased challenges with drought). Encourage them to apply this analysis to their own solutions.

Prototype (Build and Test) *(10 min)*

1. During the prototyping time, walk around and support teams as you did during the first round of building.

2. New open-ended, facilitative **Prototype Questions** may include:

   • *How have historical irrigation examples inspired this design?*

   • *What changes are you trying out?*

   • *How are your changes helping your solution to meet the new criterion to conserve water? What else will you try?*

3. Remind teams to test often while they build and record their results on the **Data Collection Sheet**.

4. Encourage learners to get inspiration from other groups, give credit to the originator(s) of the idea and adapt it.

5. Provide reminders on time and, if teams feel like they are "done," use the **Irrigation Situation Challenge Cards**.

Share Solutions *(10 min)*

1. At the end of the time limit, have learners stop and then demonstrate and share their designs again.

2. Keep their sharing simple and focused on what they did and why.

3. **Sharing Questions** can include:
   - *What changes did you make in this iteration? Why?*
   - *What ideas inspired you in this design? (could be from from historical farming techniques, your experience, other teams or the demands of new criteria or constraints)*
   - *How did the changes you made help your solution to meet the criteria and constraints?*
   - *What were the results of your data? What was the least amount of water your solution required?*
   - *What changes would you make if you had more time?*
4. Have learners give each other positive feedback on their designs.

💬 Debrief *(5 min)*

1. After students share their solutions, bring the conversation back to the engineering concepts and what they learned.
2. Lead a short discussion of **Debrief Questions**:
   - *Which criteria and constraints did you find easy to meet? Which criteria and constraints were more challenging to meet?*
   - *What other challenges do you think that hillside terraces face in the real world? What challenges might they face in the future?*

Content Connections

- **Future Thinking Technologies:** Have students use what they've learned to suggest future technologies to support farming in non-traditional landscapes. They can consider the real-world problem of increasing the amount of food we produce in the same amount of space, and other technologies that would help decrease the amount of water needed during increased drought.
- **Presentation:** Have students create a pitch or presentation to the developer showing how their solution meets the client's needs and wants. For this larger Unit plan, assessment and related resources see the **Irrigation Situation Unit Plan**.

Tech Tips

See our educator guides and videos for more design challenge facilitation techniques.
For this lesson check out:

- Materials Strategies for Engineering Design
- Prototyping - Test, Reflect, Iterate
- Sharing Solutions

Next Generation Science Standards

The 3 dimensions of NGSS allow for customization of standards to align with other content being taught. While this lesson aligns to the stated Performance Expectation, the descriptions of the 3 dimensions below it were specifically selected from the NGSS appendices to support the lesson objectives.

Grades	Standard	Description
3-5	ETS1-1	Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5	DCI	**Defining and Delimiting Engineering Problems:** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.
3-5	SEP	**Asking Questions and Defining Problems:** Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.
3-5	CCC	**Influence of Science, Engineering, and Technology on Society and the Natural World:** People's needs and wants change over time, as do their demands for new and improved technologies.

California History - Social Science Standards

Grades	Standard	Description
5	HSS-5.1.1	Describe how geography and climate influenced the way various nations lived and adjusted to the natural environment, including locations of villages, the distinct structures that they built, and how they obtained food, clothing, tools, and utensils.

Vocabulary

For more tips on vocabulary and common engineering terms, see our Tech Tip: The Language of Engineering.

- **Channel:** A passage through which something flows
- **Conservation:** Not being wasteful of resources
- **Drought:** Low rainfall for a long period of time
- **Irrigation:** The supply of water to land or crops, typically by channels
- **Resources:** Materials occurring in nature, like water, air, sunlight, minerals
- **Runoff:** Draining away of water
- **System:** A group of related things that work toward a common goal, like the digestive system
- **Terrace:** Flat areas made on a slope, like steps
- **Tolerant:** Able to endure specified conditions

Resources and References

1. Article with Images: Terrace Farming Facts for Kids
2. Article with Images: 30 Spectacular Examples of Terraced Agriculture
3. Video: Explore the Emerald Rice Terraces of the Philippines uploaded to National Geographic, 2018 (2:38 mins)
4. Video: "Hopi Dry Farming" Ahkima's Field Hopi Reservation uploaded to YouTube by rd47blog June 2012 (especially 2:15-3:15, 7:54-13:00)
5. Video: Encyclopedia Britannica Terrace cultivation on Portugal's Madeira Island
6. Study Ancestral Pueblo Farming National Park Service, 2017
7. Article: Ancient Farming - Concepts, Techniques, and Experimental Archaeology, ThoughtCo, By K. Kris Hirst, May 2019
8. Blog: These Ancient Agricultural Techniques are Making a Comeback, Teralytic, July 2018
9. WHO Health Topic: Drought
10. Article & Video: California agriculture faces serious threats from climate change, study finds, Desert Sun, February 2018. 17.19 min
11. Article: Explaining Drought to Kids, Washington Post, August 2012.

Handouts

Title	Page
Irrigation Situation: Defining the Problem	13
Irrigation Situation: Data Collection	14
Irrigation Situation: Challenge Cards	16

Name(s):   **Date:**

Irrigation Situation! Defining the Problem

Congratulations! Your team of engineers has just been contacted by a housing developer to design an irrigation system for a community garden in a new housing development. The only open space for the garden is on a hillside and the area has been pre-engineered with stepped terraces.

As an engineer, it's your job to determine the **criteria** (needs/wants) and the **constraints** (limits) of the problem you will work to solve. Read the request from the developer below and use the information to **define the problem**.

*The people renting these apartments want a space to have a garden, but the only land we had left was on this hill. We had a team come in and form the terraces to put the plants in and now we **need** a way to make sure that all six of the planted areas get watered evenly. We **want** you to design a system that can do this without using too much water, no more than _____ ounces. We don't have enough **budget** to buy any new supplies for this test version so you can build the prototype using whatever you have on hand. We will need to see your completed design as soon as possible so we can stay on **schedule**. Don't take any longer than _____ minutes to develop your prototype.*

Criteria are the needs and wants of the client we are designing for; they tell us how to make our design successful.

Constraints are the limits on our design; they tell us what is and isn't allowed when creating our design.

Problem: Design a hillside irrigation system that collects and distributes water efficiently to all of the plants.

Criteria	Constraints
Need:	Budget:
Want:	Schedule:

Name(s):   **Date:**

Irrigation Situation: Data Collection

Use the table below to record your test results:

	Test #	🌿 # of plants wet	🧪 Amount of water remaining
Design Challenge Part 1			
Design Challenge Part 2			

Use these tables to summarize your observations during testing about how well your design meets the criteria and constraints.

	Criteria *(list 2 criteria the client needs/wants)*	**How did your design meet these criteria?** *(consider: # of plants that got wet, how much water remained)*
Design Challenge Part 1	• •	
Design Challenge Part 2	• •	

Constraints	**Budget** *What materials did you use?*	**Schedule** *How long did you have to build?*
Design Challenge Part 1		
Design Challenge Part 2		

| **Design Challenge Part 1:** *Draw a diagram of your system.*	**Design Challenge Part 2:** *Draw a diagram of your system with iterations.* *(Show your iterations by drawing them in a different color)*
What is one change you will make in your next iteration?	**Compare your second design to your first design and explain how the changes impacted your results?**

Less is More

Try to make your irrigation system with fewer materials.
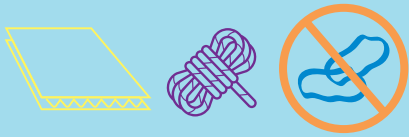
More Reliable

Make your system more reliable. Does it produce the same results 3 tests in a row?

More Plants

Add more plants to your garden but keep your water use low! Do all the plants get water?

Flooding

The area had a massive storm. How do you keep your garden from flooding?

No Puddles

Try to avoid mosquitos. How would you keep water from collecting where it's not supposed to?

Drought Resistant

What types of plants would you use in your garden? Research a specific type of plant and adjust the water based on that plant's needs.

Super Saver

Design a way to collect and recycle the extra water to use again.

Aesthetics

Add features and adjust your design to be more aesthetically appealing for the residents.

Team Choice

How can you challenge yourselves with new criteria?