Unit 3

How Can Work Be Done with Water Power?

Activity C

Can a reservoir be used like a recharge-able battery?

Introduction

Hydropower plants are dependent on the water cycle to provide rivers with precipitation and runoff. Some seasonal precipitation can be stored in a reservoir and used at a later time to produce hydropower. In this manner, the reservoir is acting like a rechargeable battery. The size of a reservoir can vary dramatically based on the natural contours of the land and the design and size of the hydropower plant.

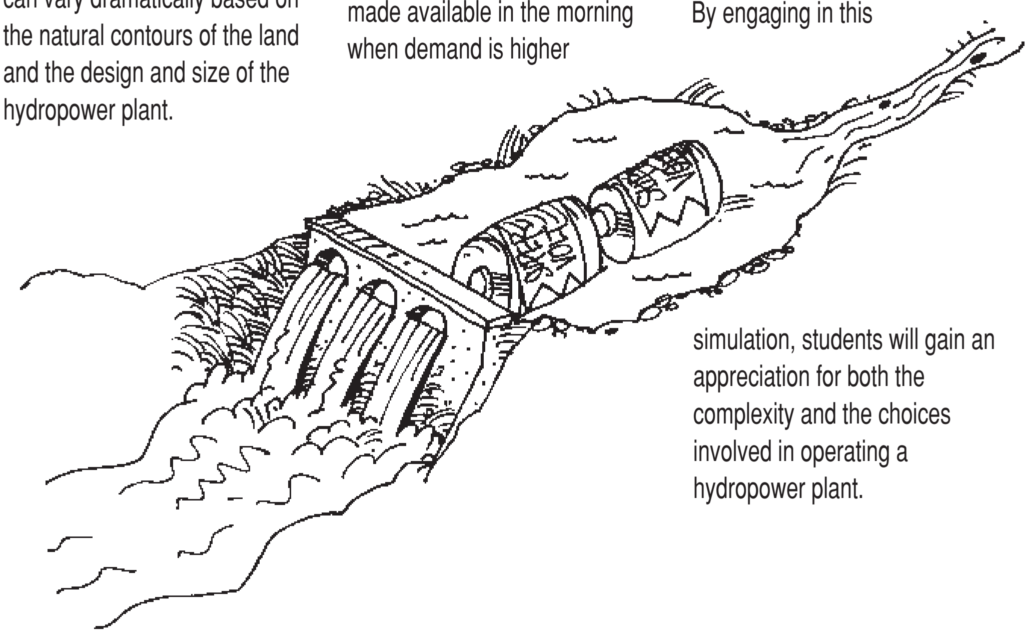
For the reservoir to remain in balance, its water levels must be kept between a minimum and maximum level. Typically, a reservoir's water level can vary by up to15%. If it is over the maximum water level, flooding can destroy habitats, agriculture, or development projects like housing. When under the minimum, habitats can also be destroyed and the water may not flow through the dam's intake port and into the turbine, decreasing electricity generation.

When excess precipitation or runoff is received, water can be released over the spillway to avoid flooding. During certain parts of the season, water may also be released over spillways to assist with fish migration or to meet other downstream water needs.

By using a reservoir, hydropower plants are better able to meet changes in consumer demand that occur on a daily and seasonal basis. For instance, more power can be made available in the morning when demand is higher because people are waking up, turning on electricity, and taking hot showers as they prepare for work or school. Similarly, consumers use more power in the summer and winter months for cooling and heating than in the fall and spring months.

Also keep in mind that once power has been produced it cannot be stored and must either be used by the community or sold to another utility. If a reservoir is at a maximum level, this results in a "use it or lose it" scenario for maximizing a plant's operating capacity. Similarly, if a reservoir is at a minimum and no additional precipitation or runoff exists, the utility must buy power from another utility to meet the communities' needs.

This hands-on simulation enables students to take on the roles of hydropower managers by manipulating and reacting to three essential variables: precipitation and runoff, power production needs, and spillage. By engaging in this simulation, students will gain an appreciation for both the complexity and the choices involved in operating a hydropower plant.



Scientific Learning Goals and Objectives for this Activity:

(Goals from Washington State Commission on Student Learning — Essential Learning Requirements for Science)

Goals

- Students will understand and apply scientific concepts and principles.
- Students will understand and apply technological concepts and principles as they relate to science.
- Students will communicate scientific understanding.
- Students will understand the interdependence among science, technology, and mathematics and their connections to the world beyond the science class.

Objectives

- Students will be able to simulate the usage of a reservoir as a rechargable battery to provide water for power production on demand.
- Students will experience the balancing process used to provide power on demand while also addressing other needs such as fish migration.
- Students will understand the complexity of managing a renewable resource by working as a team to successfully manage a hydropower plant.

Teacher Preparation

Preparation Time:
30 minutes

Materials
Prepare for the Entire Class:

- transparency of hydropower simulation set-up diagram
- water
- graduated cylinder (100 ml)

Prepare for Each Team:

Day One

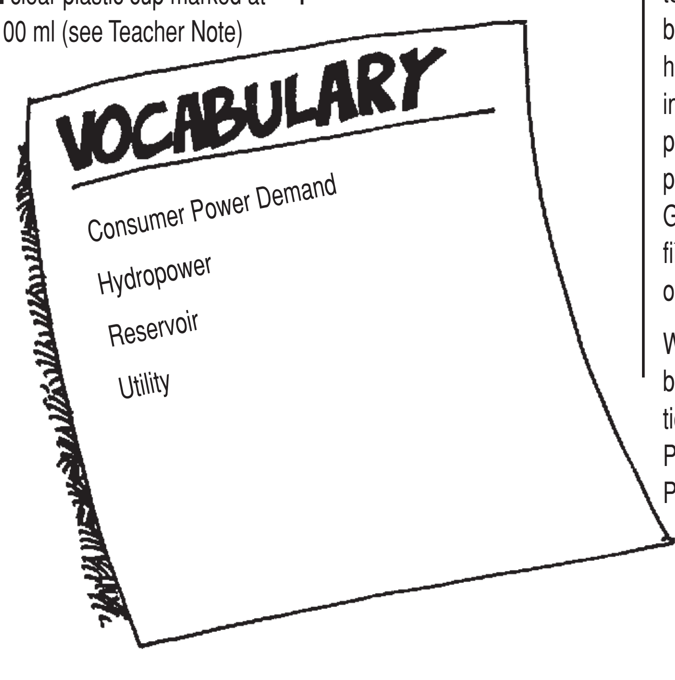
- 4 two liter bottles labeled: 1) Precipitation Supply 2) Reservoir 3) Power Needs 4) Spillage and Power Sales
- 1 pour spout (included in box)
- "T" joint (included in box)
- tubing: one 50 cm length, two 25 cm lengths, and one 10 cm length (reuse lengths cut for activity 2C)
- flow meter
- clear plastic cup marked at 100 ml (see Teacher Note)
- X-Acto or utility knife
- permanent marker
- plastic grocery bag
- funnel or other device to help pour water from one container to another (optional)

Day Two

- Day One model
- Hydropower Simulation Rules
- Seasonal Records and Operations Log
- die (or other tool that can randomly pick a number between one and six)
- stopwatch, digital watch, or clock with second hand
- 1 sheet money cutouts
- scissors

Prepare for Each Student:

- copy of journal page



Student Involvement

Activity Time:
Day One-50 minutes
DayTwo-50 minutes

Activity Processes:
Day One:

? Why do you think we have reservoirs behind dams?

1. Discuss responses.

Encourage students to recognize that reservoirs have a minimum level of water that must be sustained (discussed in introduction). Reservoirs also have a maximum level that relates to the height of the dam. By maintaining the water level in a reservoir between the minimum and maximum levels, the reservoir (like a battery) stores potential energy to meet future power demands. The rechargeable nature of a reservoir comes from the annual water cycle refilling it with precipitation and runoff.

2. Pass out materials to each team and explain that teams will be building and maintaining a hydropower plant. This includes buying and selling power. To successfully participate in the Hydro Generation Game, teams must first construct a working model of a hydropower system.

With permanent marker, label 4 bottles as follows: 1) Precipitation Supply 2) Reservoir 3) Power Needs 4) Spillage and Power Sales.

- Fill the Precipitation Supply bottle with water and set aside.
- Take the Reservoir Bottle and cut the bottom off with an X-Acto or utility knife (see Teacher Note). Put cap on, stand bottle on cap. Measure four inches from tabletop and draw a line around bottles, labeling line Reservoir Minimum. Fill bottle with water to Reservoir Minimum. Add 4 units of water (a standard unit will equal 100 ml and was marked on clear plastic cup handed to students by teacher). Label the resulting water line "Reservoir maximum." Empty water from Reservoir Bottle back into Precipitation bottle. Unscrew cap on Reservoir Bottle and insert pour spout. Attach 10 cm tubing to pour spout and attach T joint to other end of 10 cm tube.

? Are different amounts of power needed during different seasons?

3. Discuss student predictions. Encourage students to identify possible reasons for seasonal differences in power, such as heating and air conditioning during winter and summer.

Usage does vary by season in the Northwest. For the purposes of this activity, 10 units of power per year are

Student Involvement Continued

needed: 2.0 units in the fall, 3.5 units in the winter, 2.0 units in the spring, and 2.5 units in the summer.

Teams will now calibrate their Power Needs bottle accordingly.

■ Measure two inches from table top and draw a line around bottom of bottle, labeling line Starting Line.

■ Add 2 units of water (200 ml) to the bottle and mark this water level “Fall”.

■ Add 3.5 additional units of water (350 ml) and mark this water level “Winter”.

■ Add 2 additional units of water (200 ml) and mark this water level “Spring”.

■ Finally, add 2.5 additional units of water (250 ml) and label this “Summer”.

A total of 1000 ml is now in the Power Needs bottle. Pour water back into Precipitation Supply bottle. WARNING: Be sure to add air hole to bottle near the top.

Connect a 25 cm length of tubing to the flow meter. Connect the other side of this tubing to the T-joint. Connect a second 25 cm length of tubing to the other side of the flow meter. The tubing can be dangled into the Power Needs bottle (which is sitting on the floor) by a team member holding the Reservoir bottle approximately waist or thigh high .

? What happens when a reservoir receives more precipitation than it can store?

4. Discuss responses. Possibilities include:

■ spill excess water

■ produce more power

■ produce more power and resell it to other utilities

■ possible flooding if water is not released.

? Are there other reasons that a dam would spill water?

Discuss responses. Possibilities include:

■ spilling to help with fish migration

■ supporting downstream irrigation needs

■ providing recreational opportunities

■ maintaining an aesthetic appearance

■ supporting river transportation needs, or

■ helping meet other downstream fish and wildlife needs.

Teams will now calibrate their Spillage and Power Sales bottle.

■ Measure two inches from table top and draw a line around bottom of bottle, labeling line Starting Line.

■ Add 1 unit of water (100 ml), and mark the water line “1.”

■ Repeat the process and mark each water level “2,” “3,” etc. until 10 units of water (1000 ml total) have been added.

■ Between each water line, mark a line estimating the halfway point (.50 interval).

Pour water back into Precipitation bottle. WARNING: Be sure to add air hole to bottle near the top.

Take 50 cm section of tubing and connect one end to the remaining opening on the T-joint. When a team member holds the Reservoir bottle approximately waist or thigh high, the other end of the two foot section can dangle into the Spillage and Power Sales bottle (which will be sitting on floor).

? How is the amount of power production regulated?

5. Discuss responses.

Review the parts of a dam/reservoir system covered in activity 3B, emphasizing the rotation of turbines to generate power.

Teams will pinch tubing to regulate water supply from the reservoir.

? Can the model your team created be used to simulate the water supply, power demands, and variables affecting how much hydropower can be generated?

Discuss responses.

6. Using a student team model as a demonstration for class, teacher adds water from Precipitation bottle to Reservoir bottle. Using student assistants to pinch tubing, demonstrate how water can flow and be regulated to the Power Needs and Spillage bottles. Allow teams time to practice regulating water flow through their model.

A sample practice drill will be to place the water level in the Reservoir bottle halfway between minimum and maximum. Team members will need to assign roles, e.g.—person A does the pouring, person B regulates water to power needs bottle, etc. (see Teacher Note.) Allow teams time to play with their models to get used to regulating water flow and pouring.

7. Place labeled models in plastic bags and save for Day 2 activity.

Day Two:

1. Explain that each team represents a different hydropower utility in a community. Have each team name their utility.

Student Involvement Continued

Explain that the goal for each team is to maximize power production of their reservoir and dam system while also making water available for other needs such as fish migration and irrigation. The four variables each team will need to respond are:

- precipitation
- duration of precipitation
- spillage
- consumer demand (power needs)

Each season, teams will role the die three times to establish the scenario they will respond to. Given the scenario, each team must be able to do the following:

- Pour water into the Reservoir in the time allotted without going over the maximum or under the minimum lines.
- Spill at least that amount required to meet fish or other downstream water needs.
- Produce as much power as possible to meet consumer demand for each season.

2. Pass out Rules and Records sheet to each team (see Teacher Note). Review the objective of each team, which is to maximize operating capacity (power production) of their dam while also making water available for other needs such as fish migration. Review rules for playing selected game.

Encourage teams to recognize that they need to strategize in two important ways. First, they need to think not only about meeting power needs and spillage requirements for a given season, but what position they want to be in going into the next season. For instance, spilling all excess power by reducing the reservoir to its minimum may leave a team very vulnerable for meeting power needs in the following season. Second, to optimize their strategies students in teams will need to work together to manipulate the controls.

3. Pass out team models from Day 1. Teams should set up models and test to determine if all parts are functioning correctly. Teacher picks game 1, 2, or 3 to play. Game 1 is easiest and three is hardest.

4. Whether game 1, 2 or 3 is being played, begin simulation by announcing the season is fall. Teams do the following:

1) Roll die three times and record the amount of precipitation, duration of pour, and amount of spillage required.

2) In three minutes, strategize the following: how to make sure minimum spillage is provided, as much or all of power needs for the season are met (line shown on Power Needs bottle), rate of pour to stay within minimum and maximum lines, what level they would like to leave the reservoir at, and additional spillage they would like to release as a means for possibly reselling power.

3) After three minutes elapse, conduct the activity.

4) Enter results for the power generated and penalties in Seasonal Records Operations Log.

5. After each season, teams share strategies and discuss successes and failures.

6. Collect models. Students answer questions in their journal.

Notes

Day 1

Calibrate student clear plastic cups by adding 50 ml of water and marking water line 50 ml. Repeat the process and mark second line 100 ml. 1 will equal 100 ml of water or 1 unit of water. A standard unit will be 100 ml in this lesson. An annual total water for power needs will equal 1000 ml.

Step 2: An easy method of cutting a straight line is to first draw a line around the bottle with a permanent marker approximately 2" above the bottom of the bottle. Lay the bottle on its side, preferably in a shallow cardboard box (the kind canned pop comes in), and make an incision in the line large enough to place the knife blade into. Cut down towards the box while turning the bottle around on its side until a cut is made all the way around the bottle.

Step 5: Students can use clothespins rather than pinching tubing to regulate water flow.

Step 6: Team Member Roles

For 4 member teams:

1. Precipitation pourer
2. Power Needs bottle regulator
3. Spillage/Power Sales bottle regulator
4. Timer for precipitation duration and monitor of reservoir maximum and minimum

For 5 member teams:

Same as 4 member team but separate roles to include a Timer and a Controller, or someone to hold and monitor precipitation bottle.

For 6 member teams:

Same as 5 member. Add a Recorder role.

Day 2

Step 4: Game #1 is the simplest form of the simulation. Game #2 adds an actual precipitation factor, and Game #3 utilizes economic considerations in buying and selling power with other utilities. Students should play at least one year of any game. Copy extra record tables to play more than one year.

If a die roll results in spillage of a 25 ml increment, students will estimate 25 and 75 measurements

For Game #3

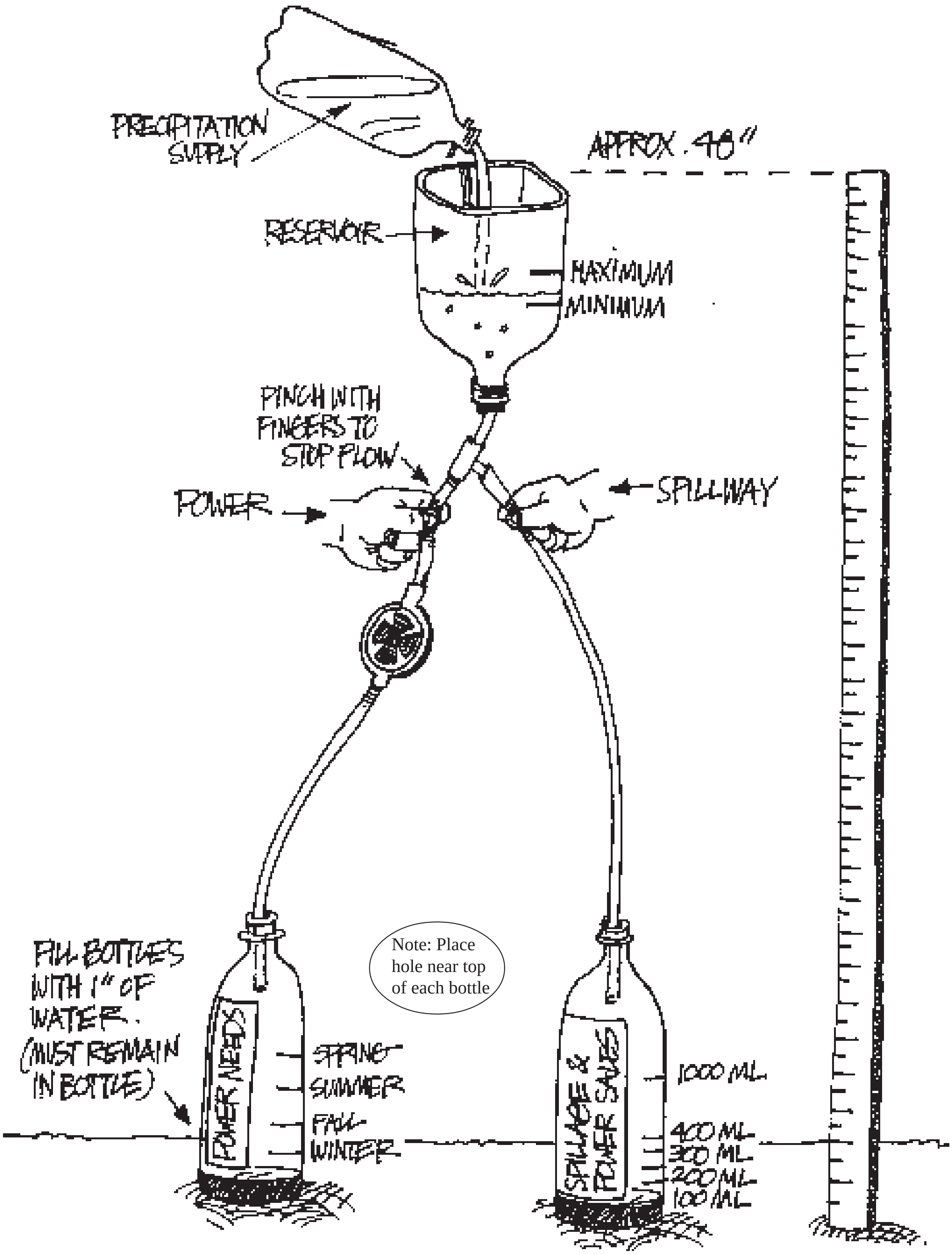
Pass out money sheets and scissors. Teams can cut out money and use it to purchase power from other utilities. Each half unit of water power purchased (50ml) will cost $10.00 (therefore a full unit will cost $20.00). If no power is available from another team (utility) the teacher can sell power at $10.00 per 50 ml unit.

If a utility (team) does not meet spillage requirements, goes outside the Reservoir's maximum and minimum lines, or does not complete their pour in the time allowed, they must pay a penalty of $40.00 to the teacher.

Teams announce whether they want to buy or sell power. As appropriate, they exchange dollars and water. Water is exchanged by one team taking from their Spillage/Power Sales bottle and supplying another team's Power Needs bottle. By doing this, each new round of the game sees each teams Power Needs bottle filled to the correct seasonal line. For instance, before starting the winter round, each team's power needs bottle is filled to the fall water line.

Each team records results for buying and selling in the Operations Log. They also calculate and record cash position.

Hydropower Simulation Set-up



Hydro Generation Game #1
Simulation Rules

1. Fill Reservoir halfway between Reservoir minimum and maximum lines.
2. Roll die three times and record in Season Records.

   Roll #1: amount of precipitation (100 ml x number shown on die)

   Roll #2: duration of precipitation pour (5 seconds x number shown on die)

   Roll #3: amount of spillage required (25 ml x number shown on die)
3. Begin simulation:

   Pourer adds precipitation to Reservoir bottle.

   Timer monitors duration of precipitation pour.

   Power Needs Controller attempts to reach "Fall" level in Power Needs bottle.

   Spillage Controller attempts to meet required spillage and collect additional water for Power Sales in Spillage and Power Sales bottle.

   Controller monitors and maintains Reservoir minimum and maximum levels.
4. Team assesses results of season simulation and uses Seasonal Records to tally points.

   1 point is given if Power Needs are met.

   1 point is given if Spillage requirements are met.

   1 point is deducted if water exceeds reservoir maximum or goes below minimum.
5. Prepare for next season simulation by adjusting amount of water in Power Needs bottle to correct seasonal line. For example, to start Winter, fill Power Needs bottle to Fall line.
6. Repeat steps 2 - 5 for the remaining 3 seasons, tallying and recording points seasonally. Add up the total year points.

Game #1
Seasonal Records

TRIAL 1

	Precipitation/ Runoff (100 ml - 1 unit) Die roll x 1 unit	Duration of Precipitation (pour in seconds) Die roll x 5	Required Spillage (25 ml = .25 unit) Die roll x .25 unit	Points
Fall	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Winter	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Spring	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Summer	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
			Total	

TRIAL 2

	Precipitation/ Runoff (100 ml - 1 unit) Die roll x 1 unit	Duration of Precipitation (pour in seconds) Die roll x 5	Required Spillage (25 ml = .25 unit) Die roll x .25 unit	Points
Fall	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Winter	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Spring	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
Summer	____ x 1 = ____	____ x 5 = ____	____ x .25 = ____	
			Total	

Hydro Generation Game #2
Simulation Rules

1. Fill Reservoir halfway between Reservoir minimum and maximum lines.
2. Roll die three times for each season and record in Seasonal Records.
   Roll #1: amount of precipitation
      Fall: 100 ml x number shown on die
      Winter: 100 ml x number shown on die
      Spring: 200 ml x number shown on die
      Summer: 0 ml x number shown on die

   Roll #2: duration of precipitation pour (5 seconds x number shown on die)

   Roll #3: amount of spillage required
      Fall: 25 ml x # on die
      Winter: 25 ml x # on die
      Spring: 50 ml x # on die
      Summer: 25 ml x # on die
3. Begin simulation:
   Pourer adds precipitation to Reservoir bottle.
   Timer monitors duration of precipitation pour.
   Power Needs Controller attempts to reach "Fall" level in Power Needs bottle.
   Spillage Controller attempts to meet the required spillage and collect additional water for Power Sales in the Spillage and Power Sales bottle.
   Controller monitors and maintains Reservoir minimum and maximum levels.
4. Team assesses results of season simulation and tallies points in Seasonal Records.
   1 point is given if Power Needs are met.
   1 point is given if Spillage requirements are met.
   1 point is given for each full unit (100 ml of water) in Spillage and Power Sales bottle that exceeds required spillage amounts.
   1 point is deducted if team exceeds reservoir maximum or goes below minimum.
5. Prepare for the next season's simulation by adjusting the amount of water in the Power Needs bottle to correct seasonal line. For example, to start winter, fill the Power Needs bottle to Fall line.
6. Repeat steps 2 - 5 for the remaining 3 seasons, tallying and recording points seasonally. Add up the total points for year.

Game #2
Seasonal Records

TRIAL 1

	Precipitation/ Runoff (100 ml = 1 unit) Die roll x 1 unit	Duration of Precipitation (pour in seconds) Die roll x 5	Required Spillage (25 ml = 1 unit) Die roll x 1 unit	Points
Fall	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____	
Winter	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____	
Spring	_____ x 2 = _____	____ x 5 = ____	_____ x .50 = _____	
Summer	_____ x 0 = _____	____ x 5 = ____	_____ x .25 = _____	
			Total	

TRIAL 2

	Precipitation/ Runoff (100 ml = 1 unit) Die roll x 1 unit	Duration of Precipitation (pour in seconds) Die roll x 5	Required Spillage (25 ml = 1 unit) Die roll x 1 unit	Points
Fall	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____	
Winter	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____	
Spring	_____ x 2 = _____	____ x 5 = ____	_____ x .50 = _____	
Summer	_____ x 0 = _____	____ x 5 = ____	_____ x .25 = _____	
			Total	

Note: Because of seasonal variances in the hydrologic cycle and when spillage will most help downstream fish migration, a seasonal variable has been added when calculating spring and summer water release needs.

Hydro Generation Game #3
Simulation Rules

1. Hand out money sheet and scissors.
2. Fill Reservoir halfway between Reservoir minimum and maximum lines.
3. Roll die three times for each season and record in Seasonal Records.

   Roll #1: amount of precipitation

      Fall: 100 ml x number shown on die

      Winter: 100 ml x number shown on die

      Spring: 200 ml x number shown on die

      Summer: 0 ml x number shown on die

   Roll #2: duration of precipitation pour (5 seconds x number shown on die)

   Roll #3: amount of spillage required

      Fall: 25 ml x # on die

      Winter: 25 ml x # on die

      Spring: 50 ml x # on die

      Summer: 25 ml x # on die

4. Begin simulation:

   Pourer adds precipitation to Reservoir bottle.

   Timer monitors duration of precipitation pour.

   Power Needs Controller attempts to reach "Fall" level in Power Needs bottle.

   Spillage Controller attempts to meet required spillage and collect additional water for Power Sales in Spillage and Power Sales bottle.

5. Teams buy and sell power as follows:

* 50 ml units of water in the Spillage and Power Sales bottle that exceeds required spillage may be sold and transferred to other teams at a price of $10 per 50 ml.
* Teams that did not meet their seasonal power needs may purchase power in 50 ml increments from teams with available power sales.
* Teams may buy power from the teacher at $10 per 50 ml if power is unavailable from other teams.
* Teams that do not meet seasonal spillage requirements are fined $40 per season.
* Teams that go outside the Reservoir minimum or maximum lines are fined $40 per season.
* Teams that do not complete the precipitation pour in the alloted time are fined $40 per season.

6. Record all seasonal money transactions, including cash position, in Power Operations Log.

Game #3
Seasonal Records

	Precipitation/ Runoff (in water units) Die roll x 1 unit	Duration of Precipitation (pour in seconds) Die roll x 5	Required Spillage (25 ml = .25 unit) Die roll x .25 unit
Fall	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____
Winter	_____ x 1 = _____	____ x 5 = ____	_____ x .25 = _____
Spring	_____ x 2 = _____	____ x 5 = ____	_____ x .50 = _____
Summer	_____ x 0 = _____	____ x 5 = ____	_____ x .25 = _____

Note: Because of seasonal variances in the hydrologic cycle and when spillage will most help downstream fish migration, a seasonal variable has been added when calculating spring and summer water release needs.

Power Operations Log

	Power Needs (in units of water)	Power Generated (in units of water)	Penalties (in dollars)	Power Purchased (in dollars)	Power Sold (in dollars)	Cash Position
Fall	2.0					
Winter	3.5					
Spring	2.0					
Summer	2.5					
Total	10					

Cash Position Calculation: Your utility has $100.00 to start with. By adding or subtracting power purchased, sold, and penalties from this $100.00, you can calculate your cash position.

Money Sheet

$20 $20

Hydro Currency

$10 $10

Hydro Currency

$20 $20

Hydro Currency

$10 $10

Hydro Currency

$20 $20

Hydro Currency

$10 $10

Hydro Currency

$20 $20

Hydro Currency

$10 $10

Hydro Currency

$20 $20

Hydro Currency

$10 $10

Hydro Currency

Journal 3C
Can a reservoir be used as a rechargeable battery?

Name ____

Team Name ____

Date ____

In your simulation activities, what variables most affected your team's hydropower operations? Why?

____

____

____

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____

____

If you did the simulation again, what would you try differently?

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