

Floorlandia: Topography and Watersheds

Lesson Summary

Students observe how water moves across a physical tarp topographic 'model.' They then play a floor or tabletop game to simulate water movement across an imaginary landscape. This activity shows how a computational model can be used to quantify surface water runoff and help students understand what must be programmed into a computer to model and run a simulation of water flow.

Purpose/Objectives

- To understand how landforms impact water movement over the land surface.
- To demonstrate that water flows from high gravimetric potential to low gravimetric potential using multiple representations and models.
- To explain how computational models are developed to represent real-world phenomena.
- To explore computation principles including discretization, time-stepping, parameterization, rules or algorithms and boundary conditions.

Comp Hydro Learning Goals

C2

C3

C4

C5

D5

D7

H5

H6

Next Generation Science Standards

HS-ESS3-6

Materials Needed

- [Introduction to Floorlandia Powerpoint.](#)
- Printed [Grid of Floorlandia Elevations](#) (1 per every 2-4 students)
- Computers with internet access
- Student Pages
- [Expert Floorlandia with arrows and watershed boundaries](#)

For each research group of 3-6 students:

- Large tarp with or without grid
 - Spray bottle or bucket and cup
 - Water
 - Clipboards and writing utensils
 - Small boxes or trash cans
- Floorlandia floor model:
- Tiled floor or large lab table
 - Tape

- 8 sticky notes labeled 1-8, 8 sticky notes labeled A-H
 - At least 150 tokens (blue blocks or beads work well)
 - 64 note cards with elevations and row-column identifiers (eg. C-4)
 - Extra sticky notes with arrows drawn on them
- Floorlandia table-top model (each pair of students):
- Fine-tipped Blue and Black dry erase markers
 - Laminated [11x17 Floorlandia Grid](#) (1 per every 2-4 students)
 - Set of small tokens, beads or dry beans (at least 100 per group).

Agenda: If done in its entirety, this lesson will require 3 class periods (50 minutes each) demarcated by the bold lines in the table below

| Activity # | Activity Label | Timing | Activity Description |
|------------|---|--------|--|
| 1 | Big Tarp: Physical Model of Rain on a Landscape | 30 min | Students use a tarp with topography and spray bottles to visualize water flow pathways, watersheds and flooding. |
| 2 | Big Tarp: Thinking about Physical Models | 20 min | Teacher leads a discussion on modeling (physical, computational, simulation). |
| 3 | Flow on Floorlandia: Watersheds | 50 min | Setting up a Computational Model to explore water flow and watersheds. |
| 4 | Flow on Floorlandia: Hydrographs | 30 min | Using a Computational Model to create a hydrograph. |
| 5 | Net Logo Floorlandia | 20 min | Students simulate water flow in Floorlandia using a NetLogo computer model. |

Safety Concerns: Students will be using spray bottles. Ensure students only spray the model surface. Floors and other surfaces may become wet and slippery. Ensure all small tokens, beads or dry beans are collected at the end of the activity and swept from the floor.

Activity One: Big Tarp: Physical Model of Raining on a Landscape

Activity Summary

Students will be using a tarp to model a watershed and create a surface of high and low points. Students will identify forces and factors effecting water movement such as gravity, pathways and flooding in their watershed model.

Key Vocabulary

- Slope
- Watershed
- Boundaries
- Elevation
- Drainage Network
- Gravimetric Potential
- Contour
- Channel Flooding

Advanced Preparation

This activity is best completed on a clear day outside. Let your students know ahead of time to dress appropriately for the weather. Identify a location to lay out your tarps to dry after the activity is completed. Have all student pages for this activity printed prior to class.

Materials Needed

For each research group of 3-6 students:

- 💧 [Lesson 3 – Activity 1 - Student Pages](#) – 1 per pair of students
- 💧 Clipboard and pencil – 1 per pair of students

Decide if you will do the activity using a big tarp outside, or small ‘tarps’ in basins on tabletops inside.

| Outside Big Tarp | Indoor Version in Basins |
|--|---|
| <ul style="list-style-type: none"> 💧 Large blue tarp 💧 Spray bottles filled with water – 3-4 per class 💧 Boxes, small trash cans or similar things to place under the tarp to create topography 💧 A location in the schoolyard where students can safely stand around the tarp while spraying and observing water flow | <ul style="list-style-type: none"> 💧 A basin 💧 Aluminum foil or a plastic trash bag that fits inside the basin to serve as the “tarp” 💧 Materials to place under the tarp to create topography 💧 A spray bottle filled with water 💧 NOTE: students may need to empty their basin periodically, so access to a sink or large receiving bucket will be helpful |

Activity Sequence

1. Introduce the activity (optional: show slide from the [Introduction to Floorlandia Powerpoint](#)).
2. Give each pair of students the [Lesson 3 – Activity 1 - Student Pages](#) (on a clipboard with a pen or pencil).
3. Have students gather in one area of the schoolyard. Take the large tarp with grid and create a surface with high points and low points.
4. Students use the [Lesson 3 – Activity 1 - Student Pages](#) to record their initial ideas (Question #1) about what they think will happen to the water when sprayed on the tarp.
5. Use spray bottles to wet the surface and observe how the water moves down the slopes of the tarp.
6. Be sure to point out both small and large watersheds on the tarp. Guide students towards a more sophisticated understanding of watersheds by dispelling the belief that a watershed is a “shed” of water through which water travels.
7. Talking points might include:
 - A. Watersheds
 - a. A watershed is an area of land from which rain and melting



Continued: Big Tarp: Physical Model of Raining on a landscape

- d. Small watersheds are nested inside of larger watersheds.
- e. Try using analogies to help students visualize watersheds. For example: a dog or cat sheds its fur, or a snake sheds its skin - a watershed sheds water from the land surface within its boundaries to a single point in a stream or body of water. The lowest point in the watershed is the location to which water from the watershed will drain.
- f. Humans can influence drainage networks in watersheds. Such influences include:
 - 1) Building storm drains which move water from one area to another and not necessarily within the same watershed.
 - 2) Humans alter the shape of the land during construction by smoothing out some surfaces and making others steeper.

B. Gravity

- a. Water is driven downward through gravity.
- b. Gravimetric potential is higher for water at high elevation, and lower for water at lower elevation. Water flows from higher to lower gravimetric potential, or along a gradient of decreasing gravimetric potential.
- c. Slope indicates how steep the gravimetric potential gradient is and thus influences water movement.

C. Pathways

- a. Water flows perpendicular to contours, i.e., “straight down.”

D. Flooding

- a. Flooding occurs in low slope areas and channels/basins.
- b. Comp Hydro focuses on the phenomena of channel flooding and the role the watershed plays in where/when flooding takes place and the role people play in either exacerbating or reducing flooding.

- 8. Students use the checklist in Question 2 in the Student Pages to make sure they make the most of observing the physical model and then complete questions 3-8.

Activity Two: Big Tarp: Thinking about Physical Models

Activity Summary

Students evaluate the pros and cons of physical models. Students become familiar with quantitative computation.

Key Vocabulary

- Watershed
- Flooding
- Computational Model
- Simulation
- Discretization
- Parameterization
- Algorithms
- Boundaries

Advanced Preparation

Have all student pages for this activity printed prior to class.

Materials Needed

- [Lesson 3 – Activity 2 – Student Pages](#) – 1 per pair of students
- Clipboard or its equivalent and a pencil – 1 per pair of students
- [Introduction to Floorlandia Powerpoint](#)
- Flipchart or space on board for collecting students' ideas

Activity Sequence

1. Hand each pair of students a copy of the [Lesson 3 – Activity 2 – Student Pages](#) and something to write with.
2. Ask students to brainstorm with their partner
 - What other physical models do you know?
 - What are the pros (or advantages, uses) and cons (or limitations, problems) with using a physical model like Big Tarp to study the movement of water across a landscape. Have them record their ideas in the Worksheet Part 1, Questions #1-2.
3. Collect students' ideas about the pros and cons of physical models in two columns on the board, flipchart or directly into the blank PowerPoint slide. Consider showing them the slide provided with ideas from other Comp Hydro students, teachers and scientists.
4. Show the sequence of PowerPoint slides for the Introduction to Computational Modeling, making the following points about DISCRETIZATION:
 - [Slide #6] – remind students about the topography they looked at with Big Tarp and consider the question of what CONDITIONS could lead to flooding at the point in the landscape shown by the yellow star in the photo.
 - Explain that since flooding is a large AMOUNT of water at a point in a small PERIOD of time, we can use a QUANTITATIVE COMPUTATIONAL model to understand the CONDITIONS that lead to flooding in different landscapes and/or at different times.
 - Explain that the first step in making a COMPUTATIONAL MODEL is DISCRETIZATION. We break the SPACE up into different CELLS and the TIME into different TIME-STEPS.
 - [Slide #7] - Here is an example of a grid of equal-sized cells superimposed over the Big Tarp landscape. Point out the 'watershed' feeding the yellow star and the rough number of cells in it.
 - [Slide #8] - Here is the same landscape, but with smaller cells (half the size, 4x as many cells).
 - [Slide #9] – summarize the steps of DISCRETIZATION. Have students complete the next part of the Worksheet Part 2, Questions #3-5.
5. Show the PARAMETERIZATION & ALGORITHMS sequence of slides [Slides #10-12]
6. Have students complete Worksheet Part 3, Questions #6-7.
7. Show the final slide [Slide #13].
8. Have the students complete Worksheet Part 4, Question #8.

Activity Three: Flow on Floorlandia

Activity Summary

Students use Floorlandia to model elevations and surface water flow in the real world. Students examine the model for high points, low points and describe the general lay of the land. They also establish rules of water movement for their model and learn how to delineate a watershed.

Key Vocabulary

- Watershed
- Flooding
- Computational Model
- Simulation
- Discretization
- Parameterization

Advanced Preparation

Decide which version of Floorlandia you will use for your classes. If using the floor model, write out the note cards for your rows, columns and each cell ahead of time. Use the [Grid of Floorlandia Elevations](#) as a guide. Find a large, clear area to set up the floor model with enough room for your students to stand around the outside of the model. If using the table top version, laminate the 11x17 Floorlandia document so you can reuse the same set with each class. Have all student pages and instructions for this activity printed prior to class.

Materials Needed

- Optional Floor Version:
 - Set up Floorlandia on the Floor
 - See: [Instructions for setting up Floorlandia](#) resource
- Materials needed 1 for every pair of students
 - [Grid of Floorlandia Elevations](#) or laminated [11x17 Floorlandia Grid](#)
 - [Lesson 3 – Activity 3 – Student Pages](#)
 - [Lesson 3 – Activity 3 - Instructions](#)
 - 2 water bead marbles for every pair of students
 - 2 fine-tipped blue markers (1 for each student, dry erase if using laminated grid)
 - 1 fine-tipped black marker (dry erase if using laminated grid)
 - Transparency of [Expert Floorlandia with arrows and watershed boundaries](#) or a printout for every pair of students
- [Introduction to Floorlandia Powerpoint](#) (slides #14-31)

Activity Sequence

Optional Introductory Activity Sequence with Floor Version of Floorlandia:

- Ask the class to stand around the outside of the Floorlandia grid. Tell the students that this is a grid of elevations and is a 2D representation that can be used to simulate surface water flow in the real world. Explain that the landscape is broken into $8 \times 8 = 64$ small cells. Discuss why, revisiting ideas about discretization covered in Activity 2.
- Examine the topography of the model and find key features:
 - Highest point(s)
 - Lowest points(s)
 - General lay of the land

Next, simulate 'rain' on Floorlandia, with each student representing a raindrop. Assign each student a grid cell to stand in. Ideally, place students starting in the higher elevation cells, and if you have 20 or fewer students, assign them to alternating cells to give them a bit more room. Explain that you will model water movement in time steps; each student (drop of water) will move one cell for each time step. Discuss as a class the basic rules for how water will move in the model and then decide:

- In which direction does the water move from cell to cell?
- What happens to water droplets at the boundary of the model?
- Can droplets move at a diagonal?

Walk through the model following the rules established by the class, one 'step' per time-step. This should include a location where the droplets (students) will accumulate. I.e. where is the final low point? Is it off the grid or in one of the grid cells? Continue until all students have reached the edge of the model or left the grid. Discuss patterns of water movement in Floorlandia.

Continued: Flow on Floorlandia

Table-top Version of Floorlandia: (If doing this after the floor version, you can streamline steps 3 & 4. Alternatively, you can complete the entire sequence using just the floor model and sticky notes with arrows instead of dry erase markers.)

1. Have students sit in pairs for this activity.
2. Give each student a blue marker, and each pair of students a clipboard, the [Grid of Floorlandia Elevations](#) or laminated [11x17 Floorlandia Grid](#), the [Lesson 3 – Activity 3 – Student Pages](#), 2 water bead marbles and a pen or pencil. Tell the students that this grid of elevations is a 2D representation of a landscape that can be used to simulate surface water flow in the real world. Explain that the landscape is broken into $8 \times 8 = 64$ small cells. Discuss why, revisiting ideas about discretization covered in Activity 2.
3. **Part 1 - Lay of the land.** Have students examine the topography of the model, find key features and then complete Part 1 of the Student Pages.
 - a. Highest point(s)
 - b. Lowest points(s)
 - c. General Lay of the land
4. **Part 2 - Setting rules for water movement.** Have students discuss what the basic rules of the model should be and then record the rules in Part 2 of the Student Pages. They are prompted to consider:
 - a. In which direction does the water move from cell to cell?
 - b. Is diagonal movement allowed?
 - c. What about ties?
 - d. What happens to water droplets at the boundary of the model?
5. Students practice using the model based on their rules. They place a bead on any cell in the model they choose (preferably, a high elevation cell), then move the bead through the model following the established set of rules. Once they have completed one pathway, they should select one or two more starting cells and repeat the procedure. Have them discuss any changes they want to make to the rules and record these in Part 2 of the Student Pages and then complete the rest of Part 2 (reflecting on their rationale for the rules).
6. **Part 3 - Modeling flow paths of water droplets.** Ask students to use the blue marker to draw arrows from cell to cell along the pathway a water droplet would travel from each starting location, following the rules they established. Continue until each cell has a pathway of arrows leading to one of the low points on the model. Encourage them to divvy up the grid if that makes it easier to find flow directions for every cell. Emphasize that students are modeling how water moves over surfaces in the real world. Have students complete the Part 3 of the Student Pages (Question #3).
7. **Part 4 - Delineating watershed(s).** Instruct students to delineate the watershed boundary or boundaries on their grid. Use a black dry erase marker to draw a boundary between cells where water does NOT flow. This should result in a boundary around the large watershed that takes up much of the grid, and several smaller ones surrounding it.
8. When each group has covered their model in arrows and delineated their watershed boundary, reconvene as a class or do a gallery walk to compare each groups' grids. Give each group of students the transparency or print out with the "[Expert](#)" results from Comp Hydro hydrologists. Have a brief discussion about why groups might have different results from each other and from the scientists. Then have the students complete Part 4, Questions # 4-6 of the Student Pages.
9. Review the various steps involved in making the Floorlandia computational model using slides in the PowerPoint [slides 18-31].
10. **Part 5 - About the watershed.** Have the students work with their partner to complete Part 5 of the Student pages, Questions 7, 8 and 9, using the "[Expert](#)" version of flow paths and watershed boundaries from the Comp Hydro Hydrologists. Discuss their results as a class.

Activity Four: Flow on Floorlandia: A Simple Hydrograph

Activity Summary

Students will use Floodlandia to simulate rainfall and estimate the amount of water flow out of the central watershed.

Key Vocabulary

- Hydrograph
- Central Watershed

Advanced Preparation

Have all student pages and instructions for this activity printed prior to class.

Materials Needed

- [Introduction to Floorlandia Powerpoint](#) (slides #32-33)
- Materials needed for every pair of students
 - [Expert Floorlandia with arrows and watershed boundaries](#)
 - [Lesson 3 – Activity 4 - Student Pages](#)
 - [Lesson 3 – Activity 4 - Instructions](#)
 - 2 water bead marbles for every pair of students
 - 2 fine-tipped blue markers (1 for each student, dry erase if using laminated grid)
 - 1 fine-tipped black marker (dry erase if using laminated grid)

Activity Sequence

1. Explain that we are going to use the Floorlandia model to estimate how much water flows out of the central watershed over time after a simulated rainfall. The rainfall event will add one droplet to each cell and last just one time step (time 0). We will apply the rules that resulted in the blue arrows, and making the assumption that droplets will move one arrow's worth with each time step. Pass out the [Lesson 3 – Activity 4 - Student Pages](#)
2. Have students work in pairs and use the expert version of Floorlandia to calculate how many droplets will flow out of the watershed in one, two, three, etc., time steps. Help them realize that
 - a. The number of steps away from the outlet each droplet (cell) is will equal the number of time steps that droplet takes to leave the watershed according to the rules we've set.
 - b. They can figure this out by counting the number of arrows between each cell and the outlet.
 - c. They can then tally or add up how many droplets are each number of time steps from the outlet.
 - d. Since the watershed was dry at time zero (before the rain was added), make sure they include a time zero in their results.
 - e. Since the watershed empties completely according to our rules, make sure they include a final time step with zero droplets (the stream dries up!).

Have them record their results in the table in the Student Pages (Question 1) then complete the rest of the worksheet (making a graph and commenting on the graph).
3. Have a class discussion of these questions:
 - a. What ideas did you come up with for explaining the shape of the hydrograph?
 - b. Looking at your hydrograph, at what point in time is flooding at the outlet most likely? Why?

Activity Five: Floorlandia-NetLogo

Activity Summary

Students explore an online computational representation of the floor and table top Floorlandia model. Activities reinforce the pros and cons of using models.

Key Vocabulary

- Raster
- Boundaries
- Discretization
- Parameterization

Advanced Preparations

Ensure that the online simulation works on your school computers.

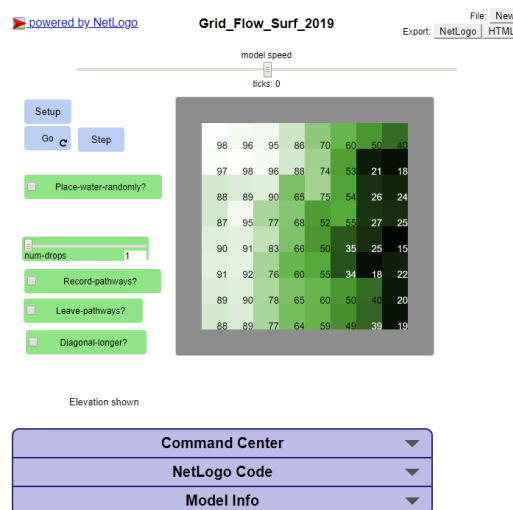
Materials Needed

- [Introduction to Floorlandia Powerpoint](#) (slides 34-38)
- Computers with access to the internet
- [Lesson 3 - Activity 5 – Student Pages](#)
- [Lesson 3 – Activity 5 – Instructions](#)
- [Floorlandia Netlogo Model](#)

Activity Sequence

Part I:

1. Begin with slide 34 of the Introduction to Floorlandia Powerpoint
2. Tell the students that they will now see and run a computer simulation of Floorlandia. Students should use the following instructions:
 - a. Open and download the NetLogo webpage by double clicking on the [Floorlandia Netlogo Model](#) file.
 - b. Click the Setup button. The Floorlandia grid will appear on the screen. This grid is a raster representation of the elevations used in the floor/desktop tile simulation.
 - c. Adjust switches (click) so that all are OFF and the num-drops slider is equal to 1.



- d. Click "Go". The software will give a message "Click to add a water droplet".
- e. Click OK, and then click anywhere on the grid. You should see a water droplet image form and then move through the grid.
- f. Add additional water droplets and observe their motion through the grid. Go through the remainder of the Powerpoint slides. Reinforce the computational ideas of boundaries, discretization and parameterization.

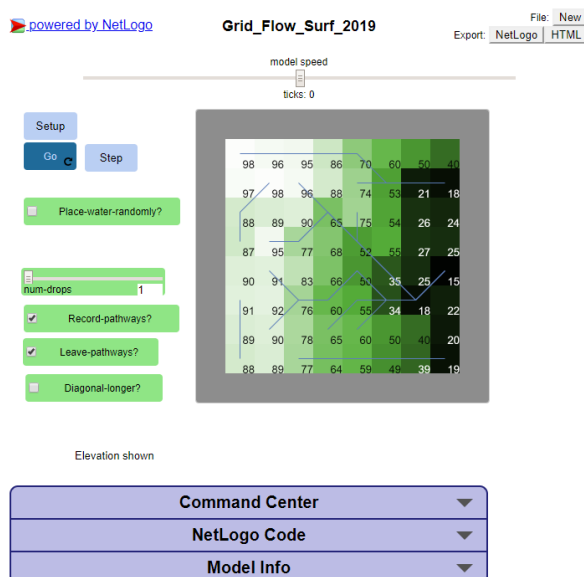
Continued: Floorlandia-NetLogo

Discussion Question:

💧 What rules determine the motion of water?

Part II:

1. Click the 'Record-Pathways' switch to turn it On.
2. Place a few more water droplets and observe the traced path. Does this help verify the rules you observed?
3. Click the 'Leave-Pathways' switch to turn it On.



4. Turn Off "Leave-Pathways" and then turn it On again to erase the current paths. ('Toggle' is the term to switch it off and then back on again)
5. Now Select "Place-water-randomly" to turn it "On" (note "Go" should continue to be highlighted, if not, click it to make it Go). Observe.

Discussion Questions:

- Can you see watershed boundaries?
- How well does this model represent the table top or floor version of Floorlandia?
- How well does this model simulate water flow across a real landscape?
- Discuss model improvements.

Teacher Resources

1. What is a watershed?
 - a. <https://oceanservice.noaa.gov/facts/watershed.html>
 - b. https://www.usgs.gov/special-topic/water-science-school/science/watersheds-and-drainage-basins?qt-science_center_objects=0#qt-science_center_objects
 - c. <https://www.pbs.org/video/curious-kids-curious-kids-what-watershed/>
 - d. <https://www.pbslearningmedia.org/resource/ket09.sci.ess.water.wshed/what-is-a-watershed/>
2. Information on Channel Flooding:
 - a. http://geology.isu.edu/wapi/EnvGeo/EG3_rivflood/eg3_rivers.htm
3. Information on Physical Models:
 - a. <https://study.com/academy/lesson/physical-models-scale-models-life-size-models.html>
4. Information on Topography Features:
 - a. <https://study.com/academy/lesson/what-is-a-topographic-map-definition-features.html>
 - b. <https://pubs.usgs.gov/circ/1955/0368/report.pdf>
 - c. Augmented topographic map to simulate water flow:
<https://www.atlasobscura.com/articles/make-topographical-maps-in-a-sandbox>



Students as rain simulate water movement through Floorlandia.