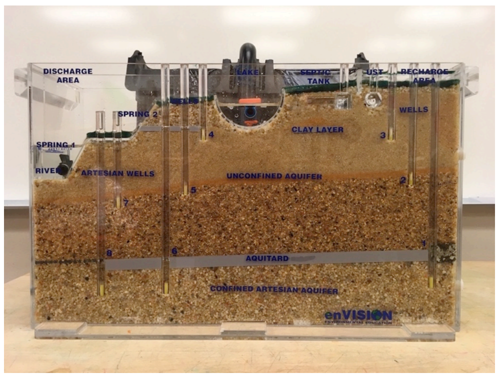
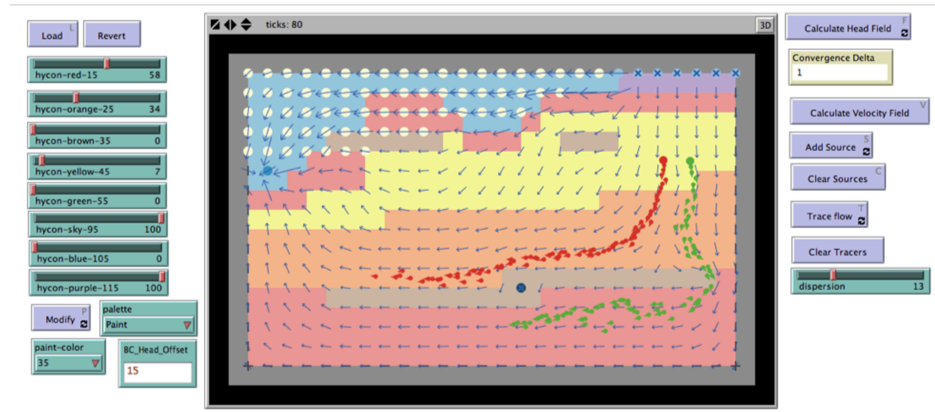
CompHydro

Water Science Through Physical, Conceptual, and Computational Modeling





Beth Covitt

Agatha Podrasky

University of Montana

NAAEE – Spokane, WA – October 11, 2018

UNIVERSITY OF MONTANA

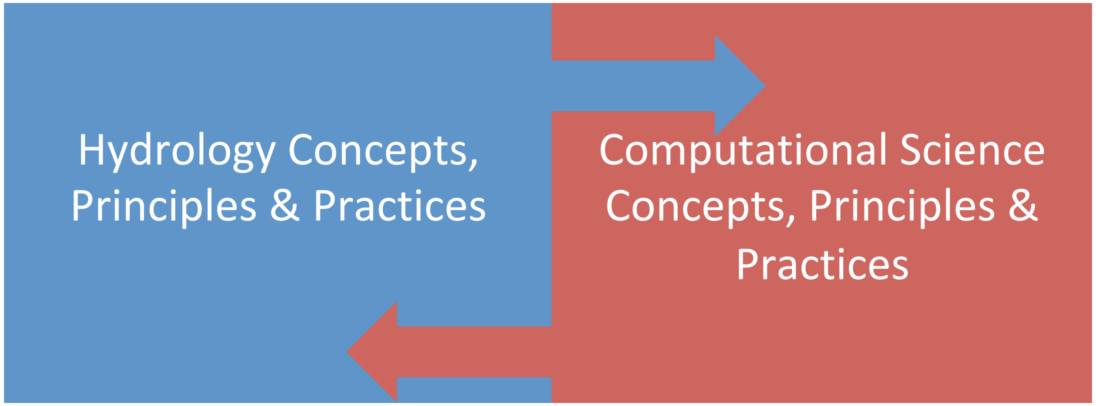
Colorado State University · Arizona · BEAR CENTER · National Computational Science Institute · Cary Institute of Ecosystem Studies

Agenda

- Project Introduction
- Groundwater Contamination Unit
- Try It Out
  - What determines how GW moves? (Head Tube Lab & Permeameter Lab)
  - Investigating with GW system models (Physical & NetLogo)
- Questions, Discussion

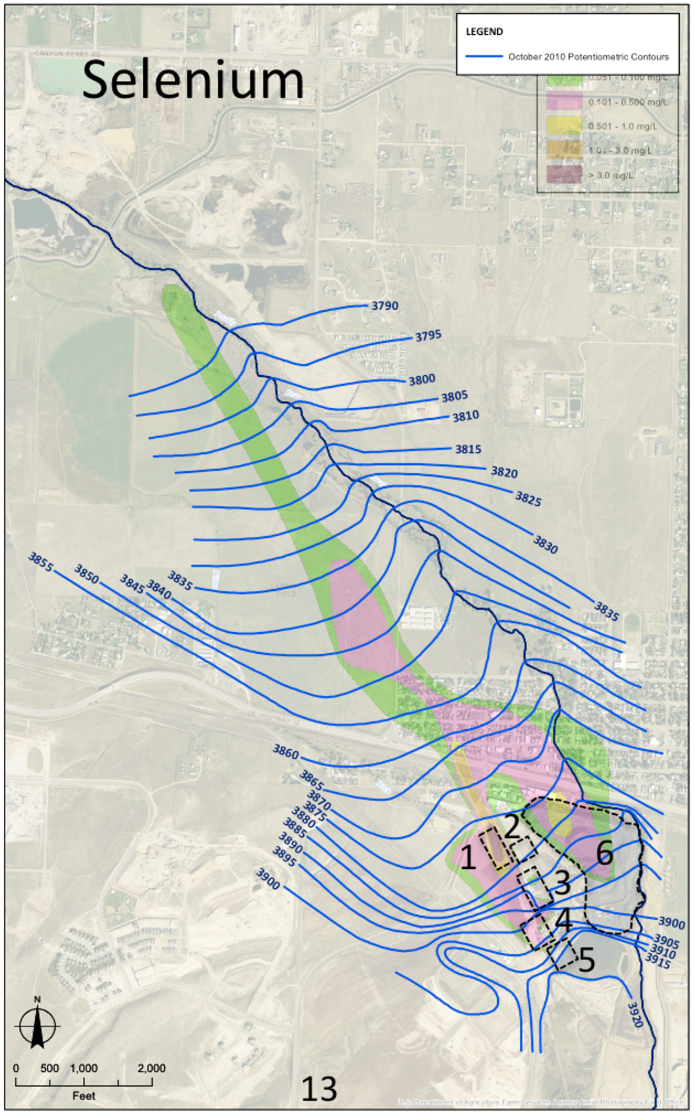
Project Goal

Integrate teaching & learning of environmental science w/computational modeling in authentic & innovative ways.



Hydrologic Problems Context

What knowledge and practice are needed to make sense of and make or evaluate decisions about hydrologic problems such as groundwater contamination?



Partners

Colorado State University

University of Montana

Cary Institute of Ecosystem Studies

Arizona

National Computational Science Institute

Bear Center

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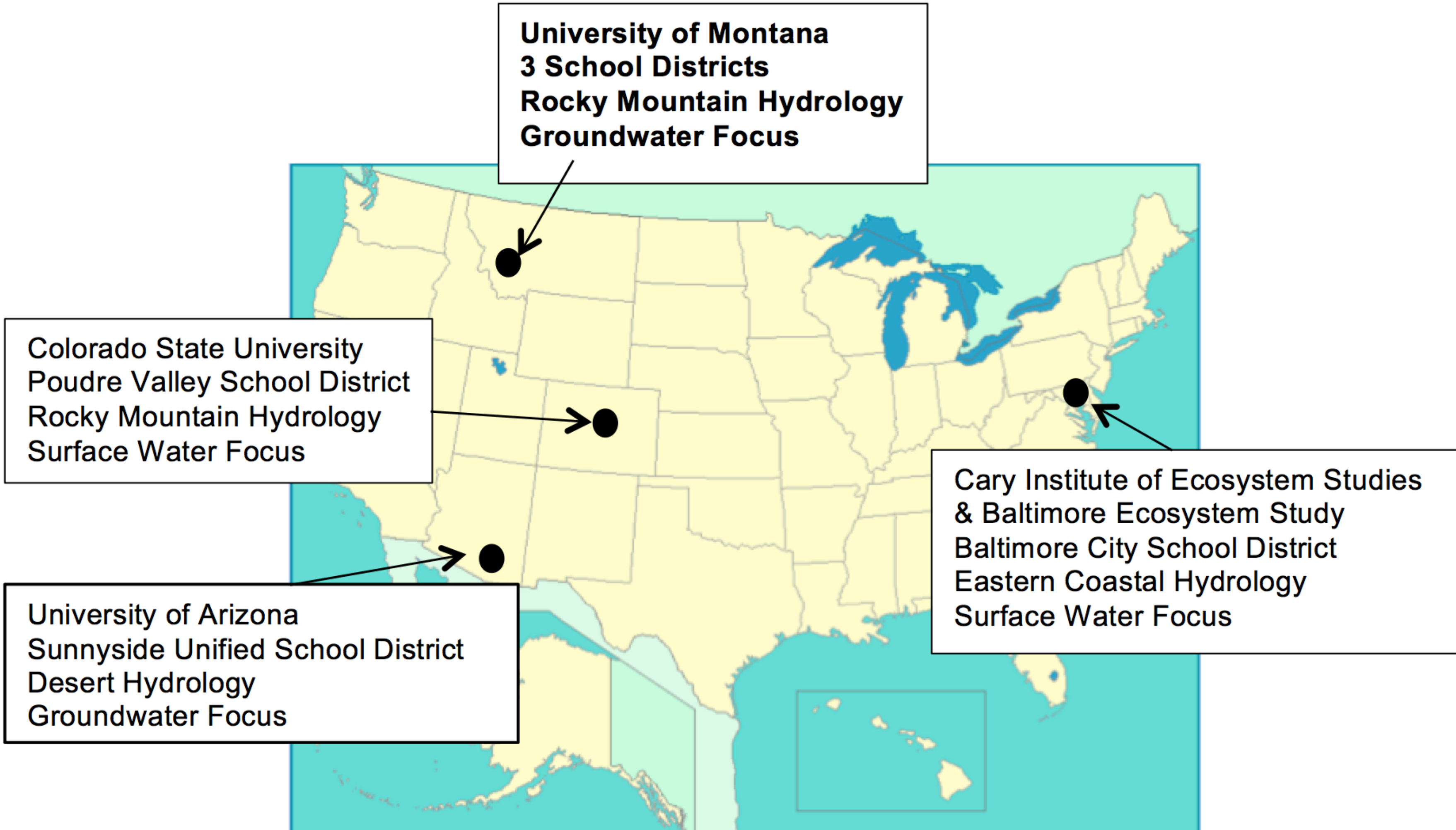

University of Montana
3 School Districts
Rocky Mountain Hydrology
Groundwater Focus
Colorado State University
Poudre Valley School District
Rocky Mountain Hydrology
Surface Water Focus
University of Arizona
Sunnyside Unified School District
Desert Hydrology
Groundwater Focus
Cary Institute of Ecosystem Studies
& Baltimore Ecosystem Study
Baltimore City School District
Eastern Coastal Hydrology
Surface Water Focus

Environmental Science Literacy

Capacity to understand & participate in evidence-based discussions and decision-making about socio-environmental issues.

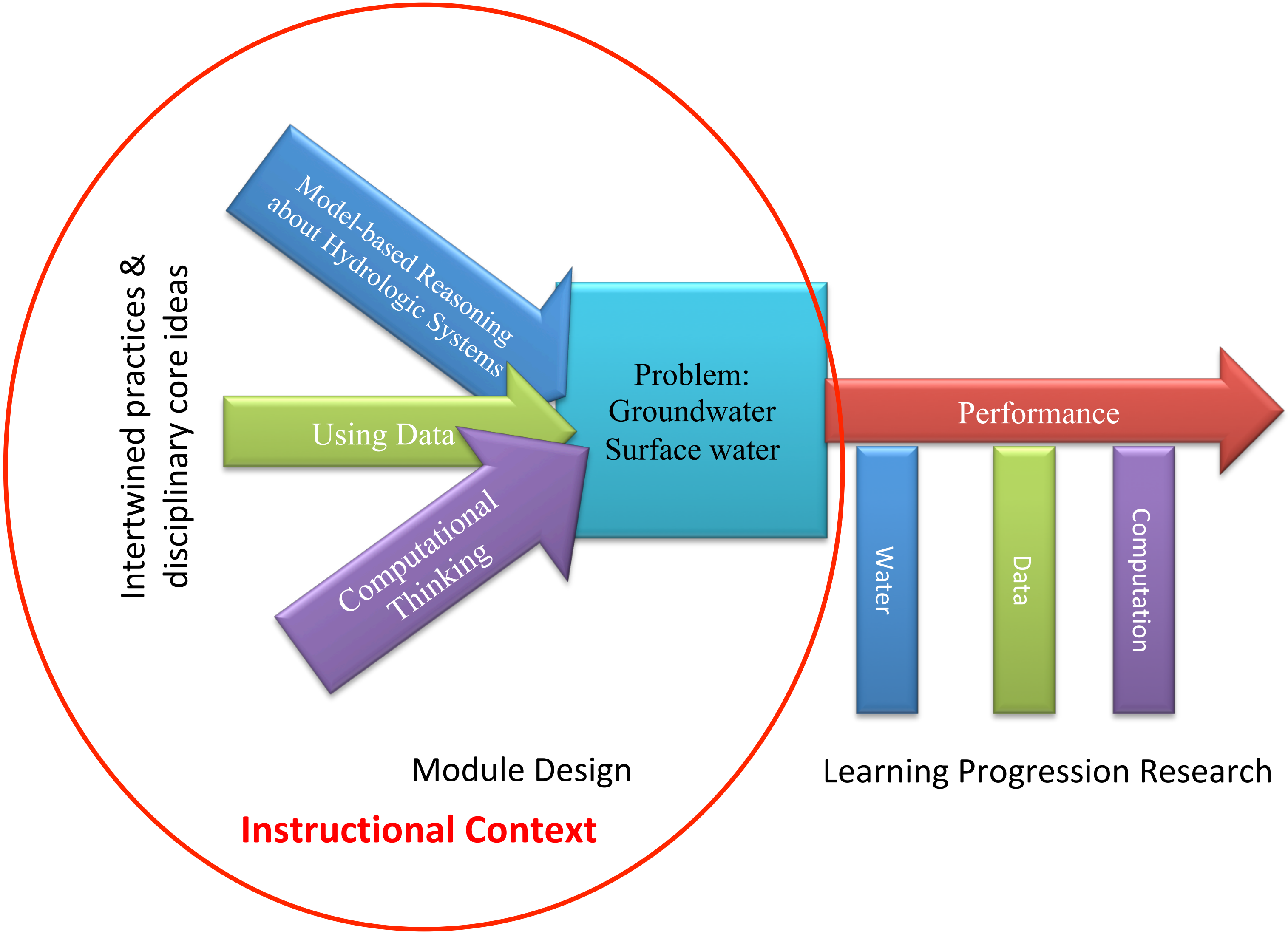
Environmental science literate individuals can…

- Understand & evaluate arguments of experts
- Choose actions consistent with their values

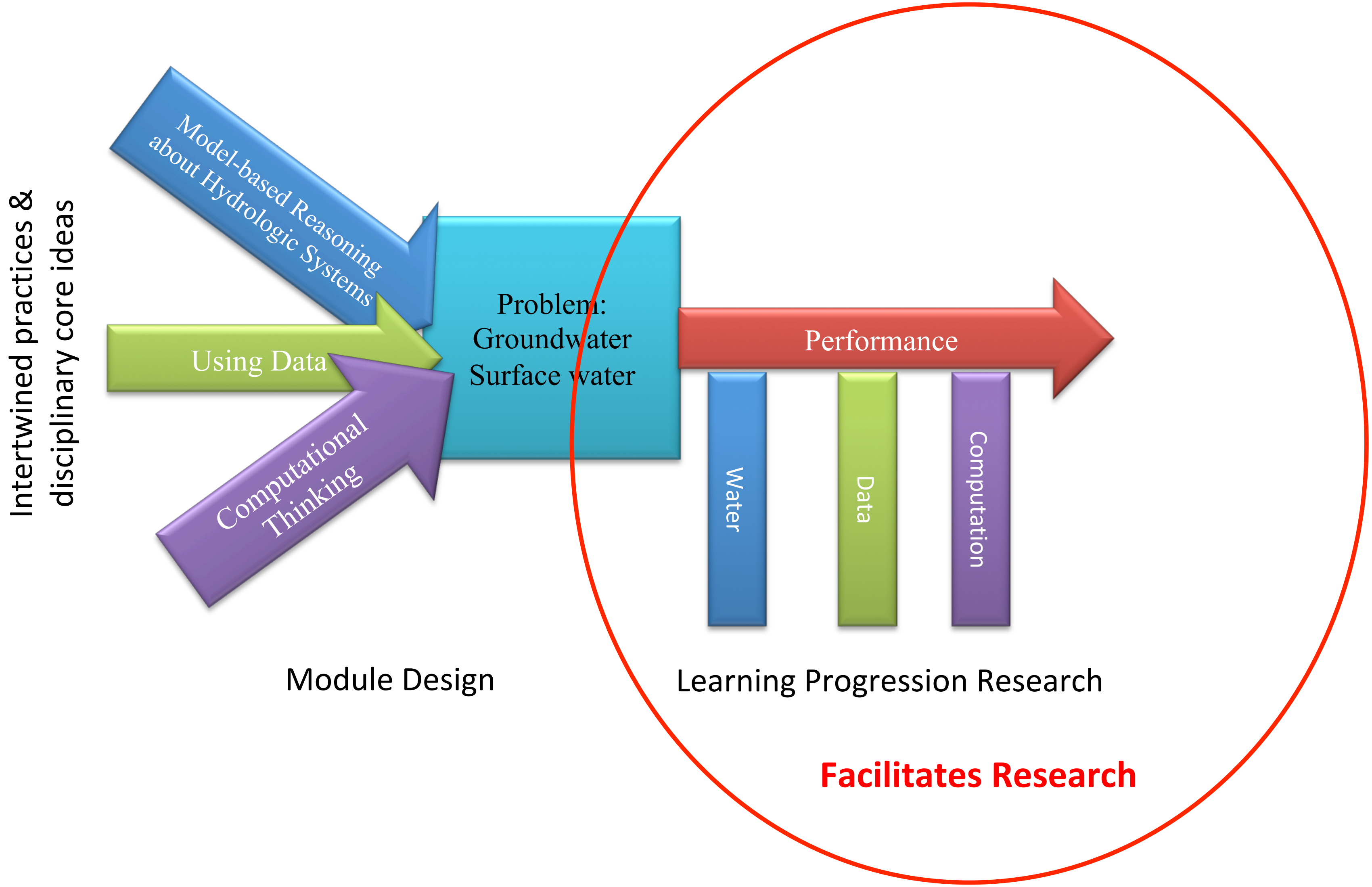
Project Objectives

1. Develop modules
2. Develop/conduct teacher PD
3. Develop learning progressions
4. Investigate how to support use in classrooms
5. Develop digital platform for above objectives

Integrated Instruction & Research



Integrated Instruction & Research



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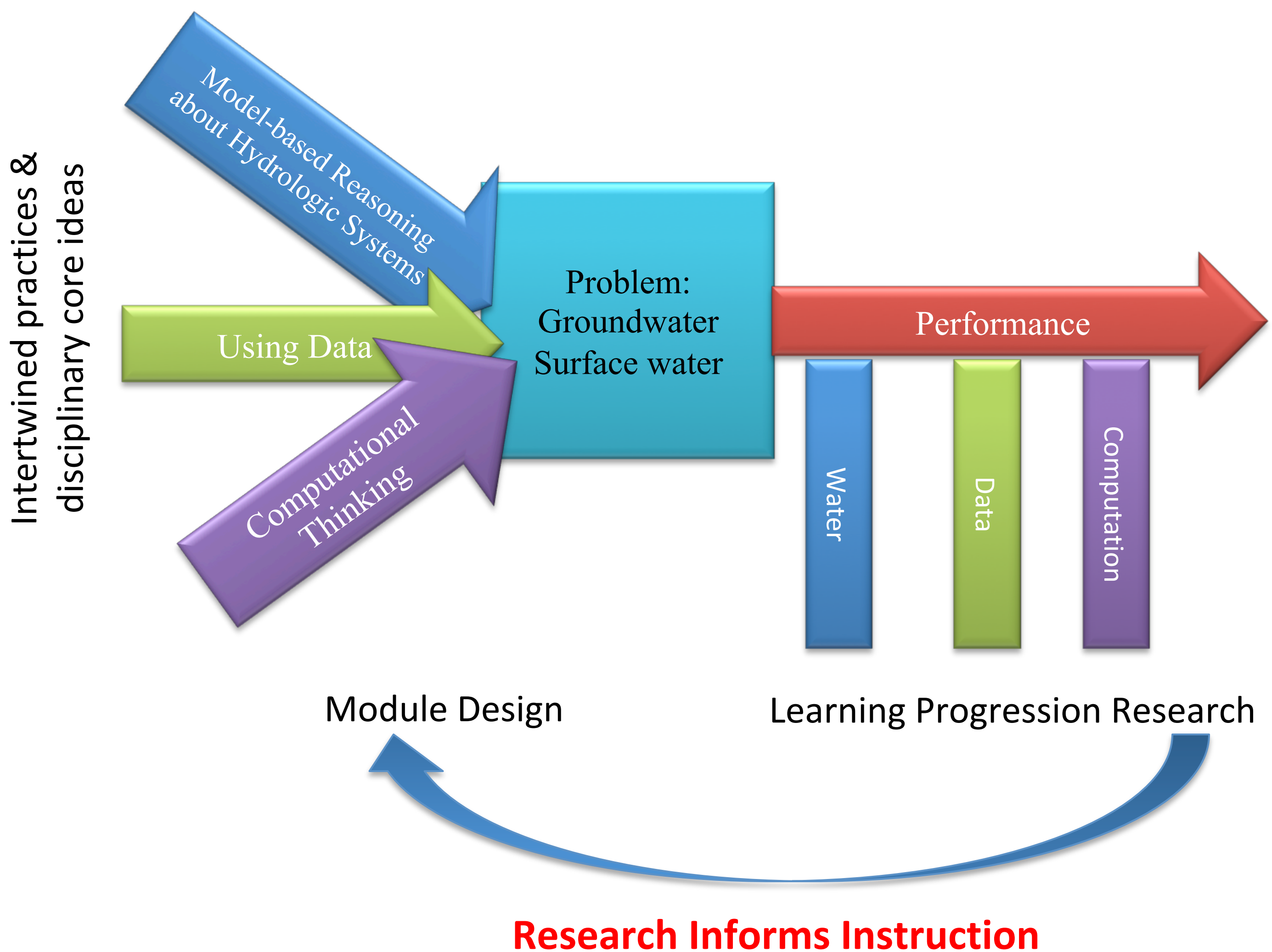
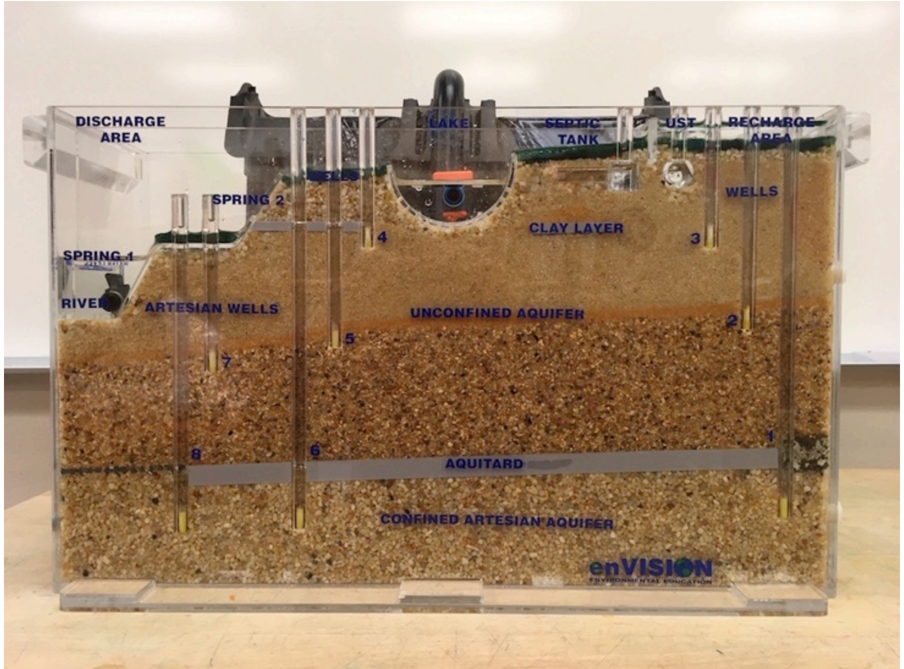


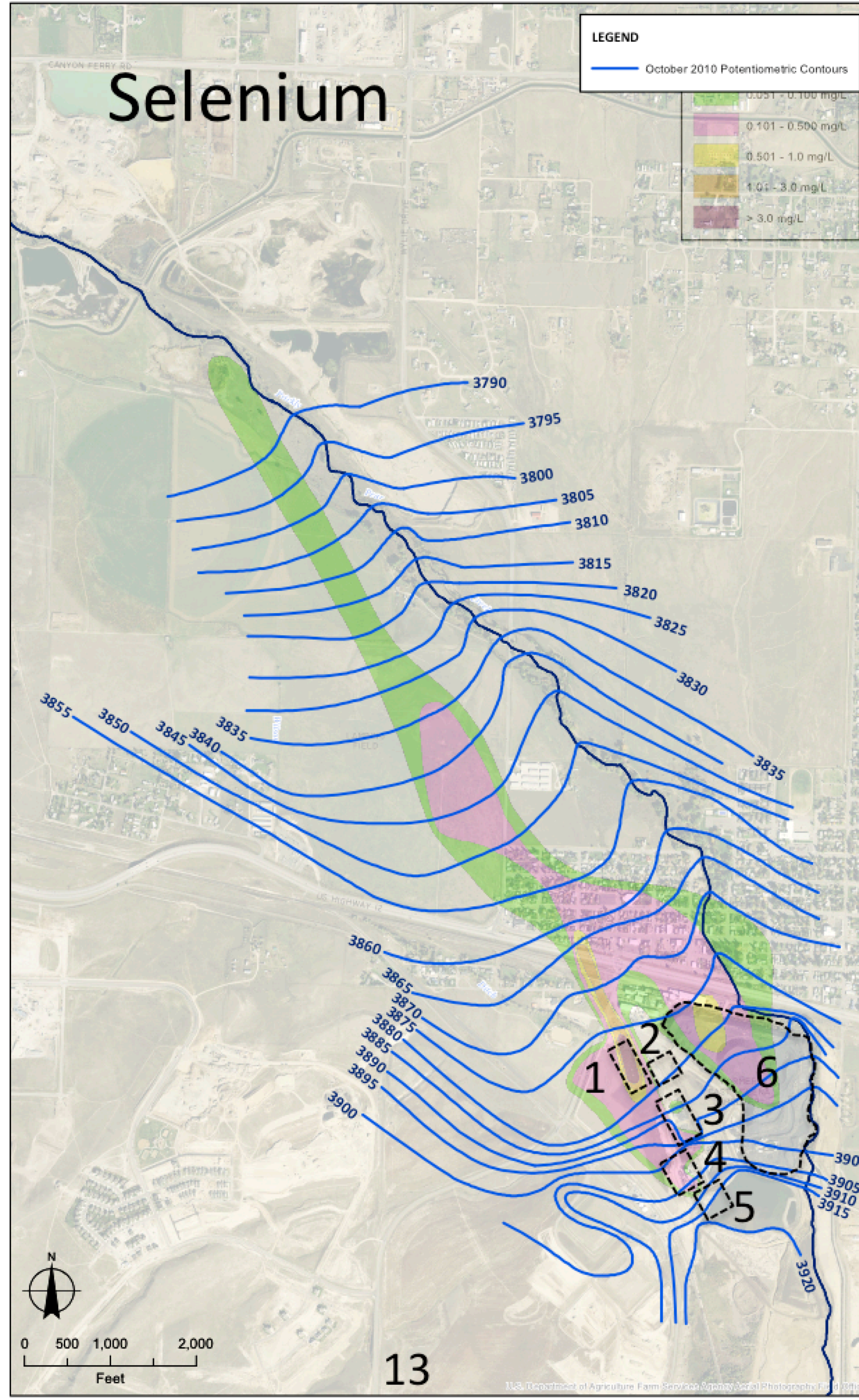
Hydrologic Concepts

- Groundwater (GW) system structure
  - Unsaturated & saturated zone, water table, aquifer
- GW system function
  - Potential energy & hydraulic conductivity govern flow of GW & contaminants



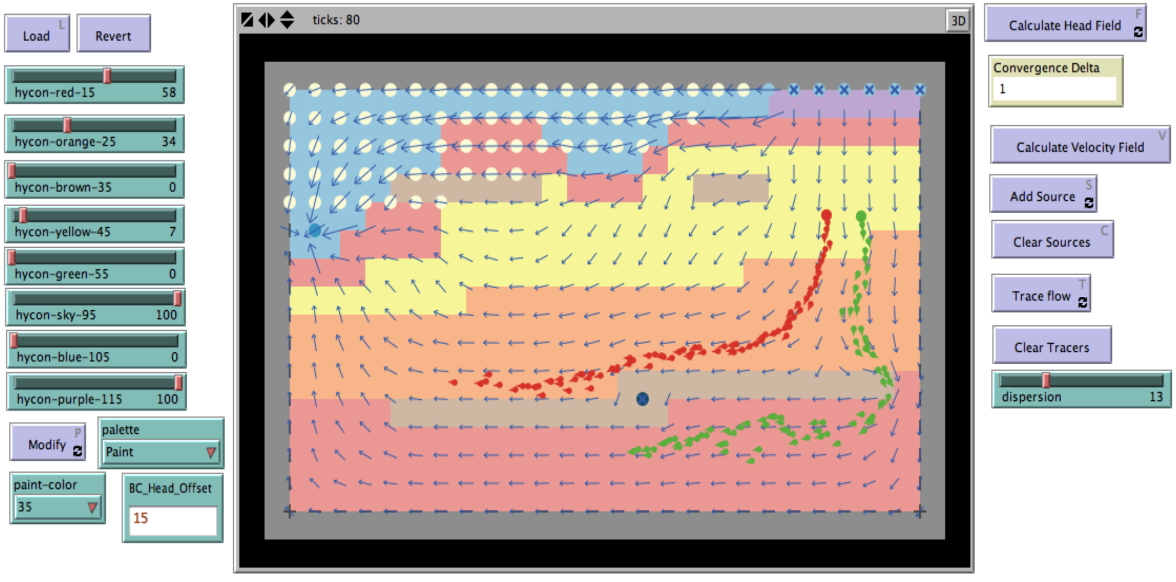
Interpreting & Using Data

- Connect levels of abstraction across multiple scales
- Make inferences about 3D systems from 2D representations & vice versa
- Manage uncertainty
- Bringing scientific principles to bear



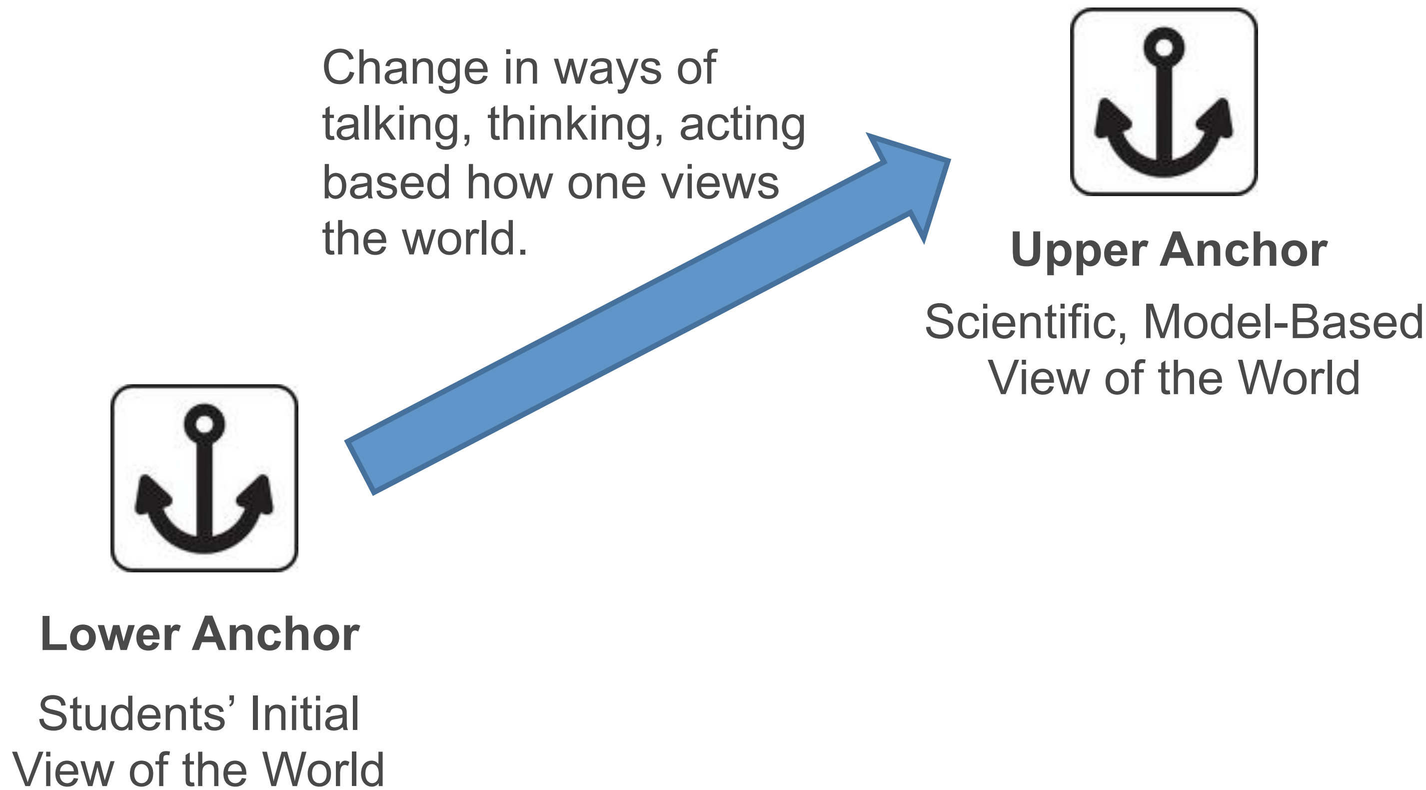
Computational Thinking

- Advantages & limitations of computer modeling
- Parameterization
- Discretization
- Boundary conditions
- Testing & falsifying models with observations

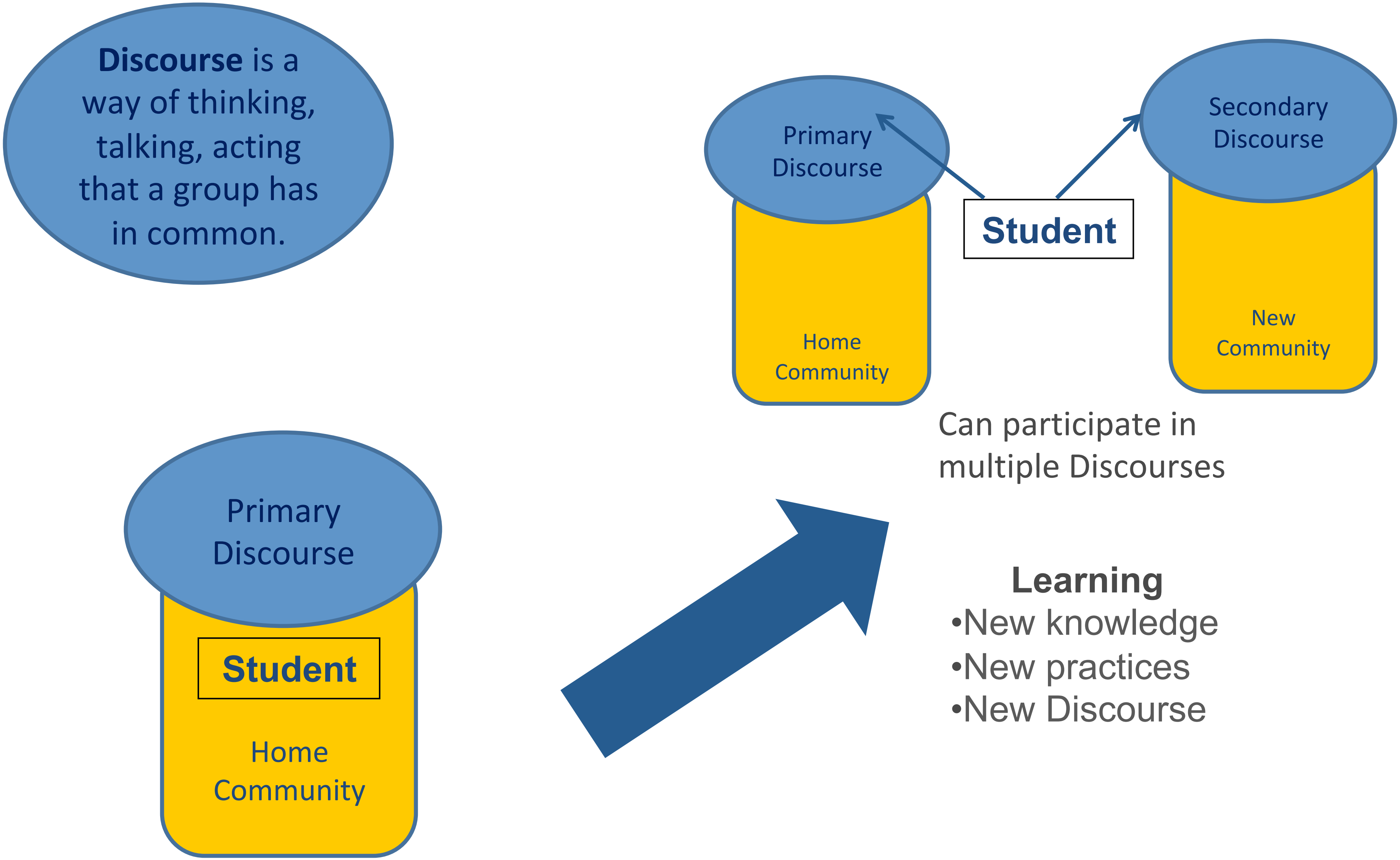


Learning Progressions

Descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time. (National Research Council, 2007)



What Progresses



Water Systems Learning Progression

Level 4 – Qualitative Model-Based Reasoning
System events follow mechanistic, model-based principles
Atomic-Molecular to Landscape Scales

Level 3 – School Science Accounts
Events in order, Names processes
Microscopic to landscape scales

Level 2 – Force Dynamic with Mechanisms
Actors, enablers, antagonists
Macroscopic only

Level 1 – Simple Force Dynamic Accounts
Water in isolated locations
Human-centric

Septic Tank Assessment Example

The contour lines on the map to the right show the groundwater elevation above sea level (in meters).

The triangle represents a septic tank and drain field, and the circles show the locations of different wells.

If someone installed the septic tank incorrectly and septic wastes percolated into the groundwater, in which well would contaminated groundwater most likely be detected first?

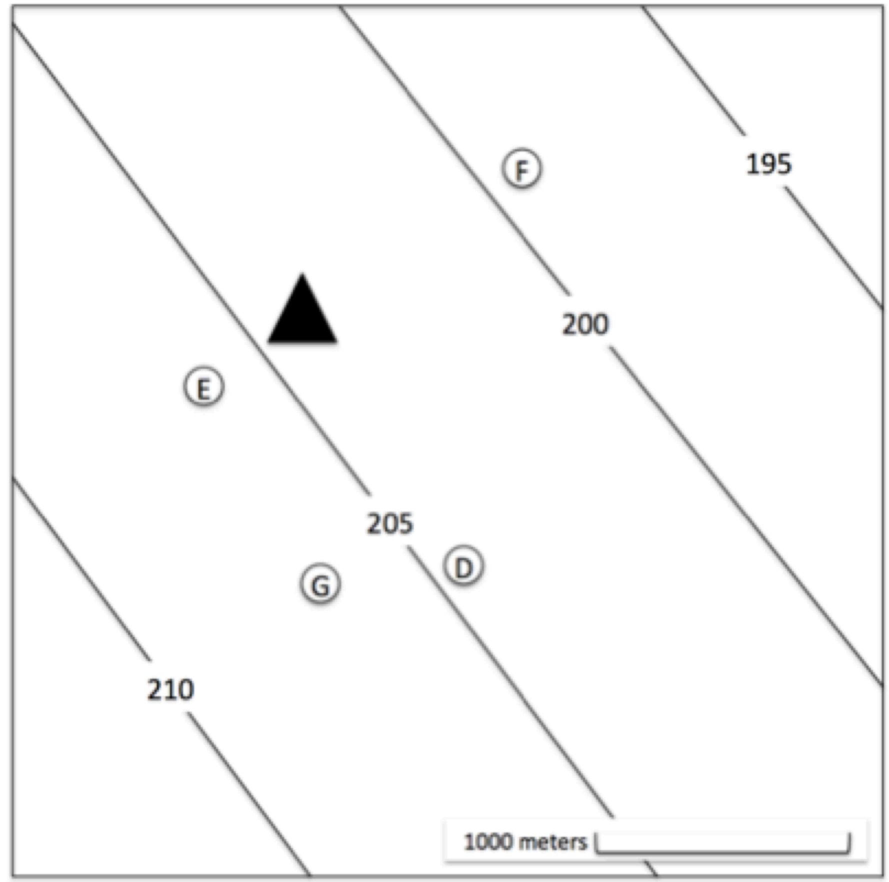
Select one:

___ D

___ E

___ F

___ G



Why would contaminated water be detected first in the well you chose?

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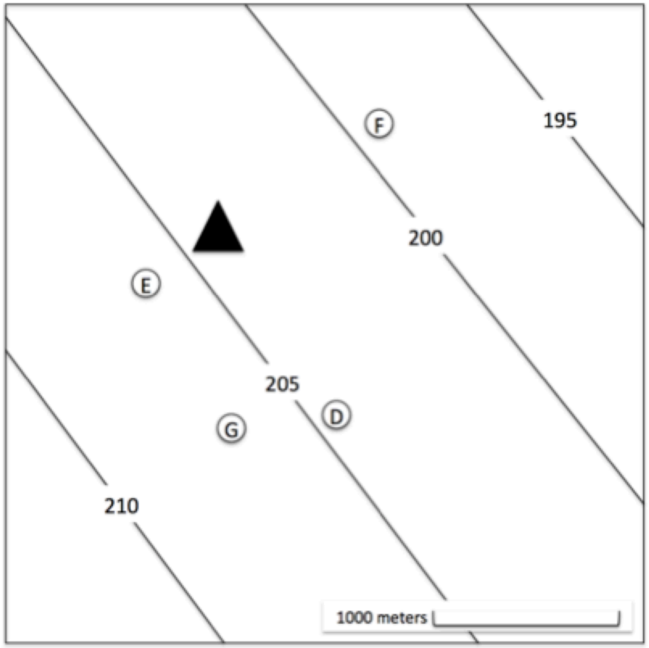


Why would contaminated water be detected first in the well you chose?

L4: Indicates GW moves from high to low potential energy and/or addresses hydraulic head
"F. Because groundwater moves from high elevation to low."

L3: Indicates down hill or down elevation but does not specify GW not surface water
"F. It is down hill from the septic tank."

L2: Strong proximity
"E. It's the closest to the septic tank."

L1: Literal map reading
"D. because it would go down."

Implications of Learning Progressions (LPs) for Research & Instruction

Research

- Develop integrated LPs for hydro reasoning, computational thinking, and data sense-making to inform…

Instruction

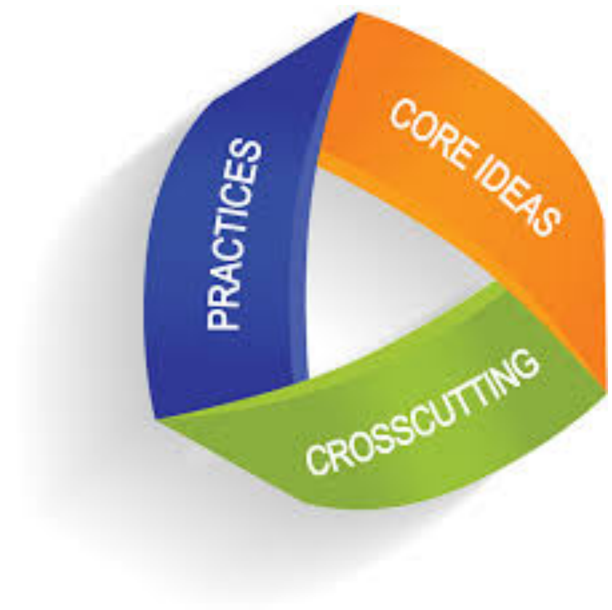
- (Unit) Provide students opportunities to engage in and develop sophisticated hydro reasoning, computational thinking, and data sense-making
- (PD) Provide teachers with tools and supports

NGSS Alignment

- **HS-ESS2-2:** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- **HS-ESS3-4:** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ESS3-6:** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activities.
- **HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- **HS-ETS1-3:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints including cost … as well as possible social, cultural and environmental impacts.
- **HS-ETS1-4:** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems.

NGSS Alignment

- **Science Practices**
  - Developing and using models
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations and designing solutions
- **Crosscutting Concepts**
  - Cause and effect
  - Scale, proportion, and quantity
  - Systems and systems models
  - Energy and matter
  - Structure and function



Building Connected Models

- Knowledge & practice through experiences w/ multiple models & representations
- Models & representations:
  - Physical models (table top GW flow model, 3D PVC pipe water table model)
  - 2D representations on paper (contour maps, cross-sections)
  - Conceptual scientific models (principled explanations of how systems work)
  - Computer models (NetLogo models)
  - Do not delve deeply into mathematical models

Montana GW Unit

Module 1: Establishing the Problem
Intro to E. Helena Smelter Site Case

Module 2: Intro to GW System & Flow
L1: What is a system? & intro to GW
L2: What determines how GW moves?
L3: Cross section of East Helena Site
L4: Intro to computer models of GW systems
L5: NetLogo GW Flow Model

Module 3: Landscape Scale Water Table & Flow Direction of Water & Contaminants
L1: Intro to investigation of East Helena with 3D modeling
L2: Virtual investigation of East Helena using Google Earth
L3: NetLogo contour map modeling of East Helena Plume
L4: Computer modeling of GW & contaminant dispersion in East Helena

Module 4: Addressing the Problem Teams review & evaluate cleanup options, develop remediation plans, present, & review what's being done in E. Helena

Montana GW Unit

Module 1: Establishing the Problem ← **(Need for hydrogeology training)**

Intro to E. Helena Smelter Site Case

Module 2: Intro to GW System & Flow

L1: What is a system? & intro to GW

L2: What determines how GW moves?

L3: Cross section of East Helena Site

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Montana GW Unit

Module 1: Establishing the Problem
Intro to E. Helena Smelter Site Case

Module 2: Intro to GW System & Flow ← **(2D system)**
L1: What is a system? & intro to GW
L2: What determines how GW moves?
L3: Cross section of East Helena Site
L4: Intro to computer models of GW systems
L5: NetLogo GW Flow Model

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(3D, Large Scale)

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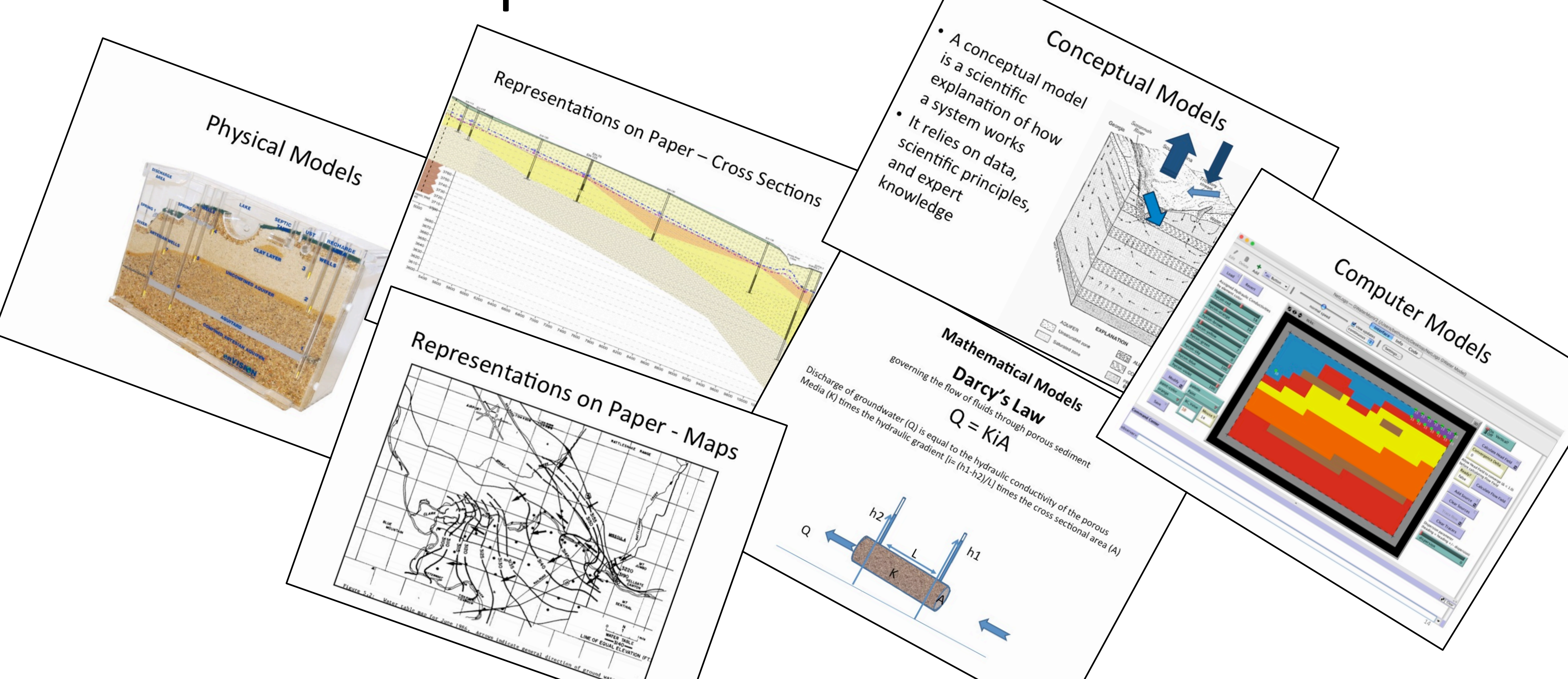
(Application)

Module 1: Establishing the Problem

- **Activity 1: There's a problem in East Helena**
  - History of E. Helena Smelter site & contamination
- **Activity 2: Who cares?**
  - Discuss stakeholders & their concerns
- **Activity 3: What do we need to know?**
  - Go back to 2009 & take on role of scientists to figure out what happened & what to do. Share ideas about what we need to know.

M2L1: What is a system?

- What is a system? (Formative Assessment)
- Define systems & preview types of system models & representations

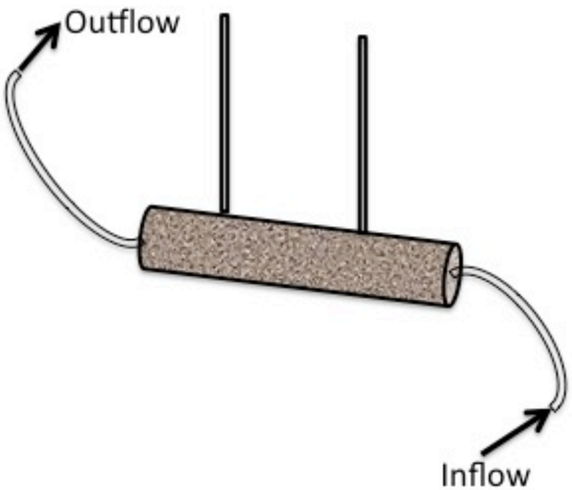


M2L2: What determines how GW moves?

Investigation Stations

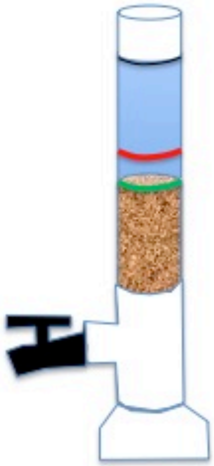
HEAD TUBE STATION

How can water underground flow uphill?



PERMEAMETER STATION

What affects how easily water can flow through different materials?



M2L2: What determines how GW moves?

Scientific Explanation of Hydraulic Head

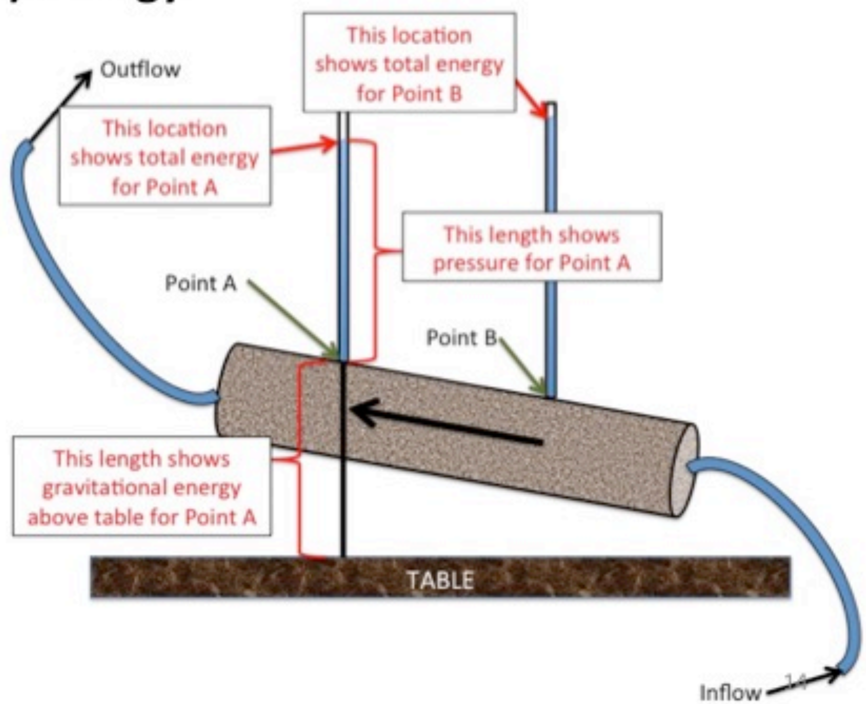
Height of the water in tubes shows…

Hydraulic head or **total potential energy**, which equals the amount of energy at a place in space that is a combination of…

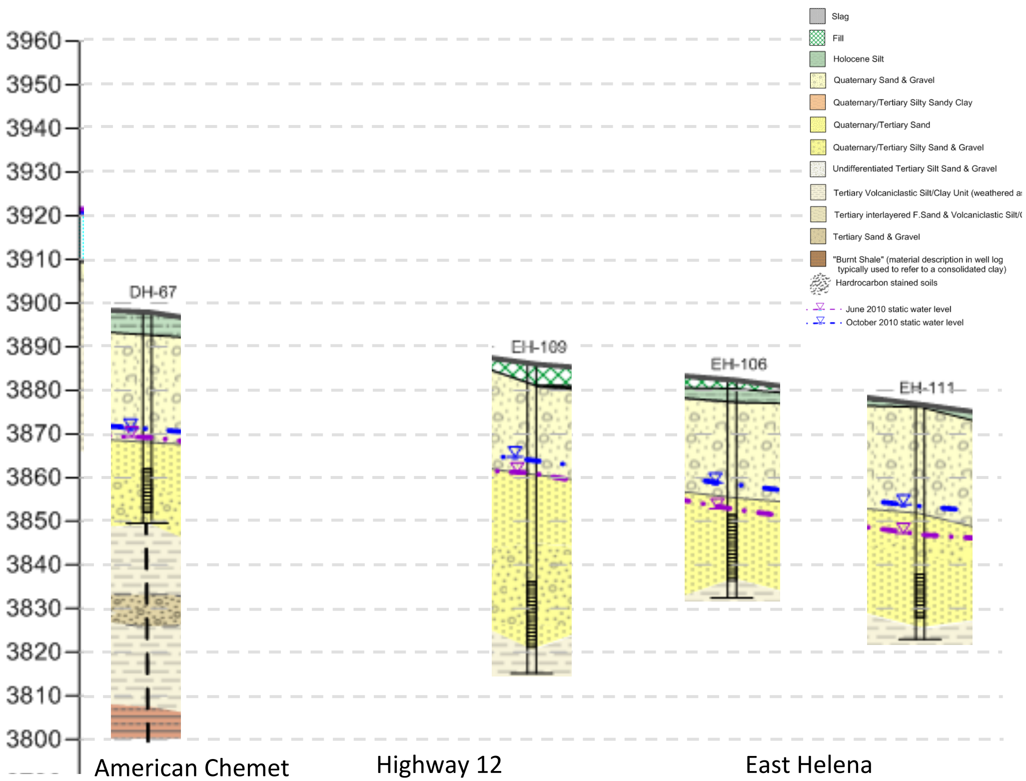
Gravitational (positional) Energy

And Pressure Energy

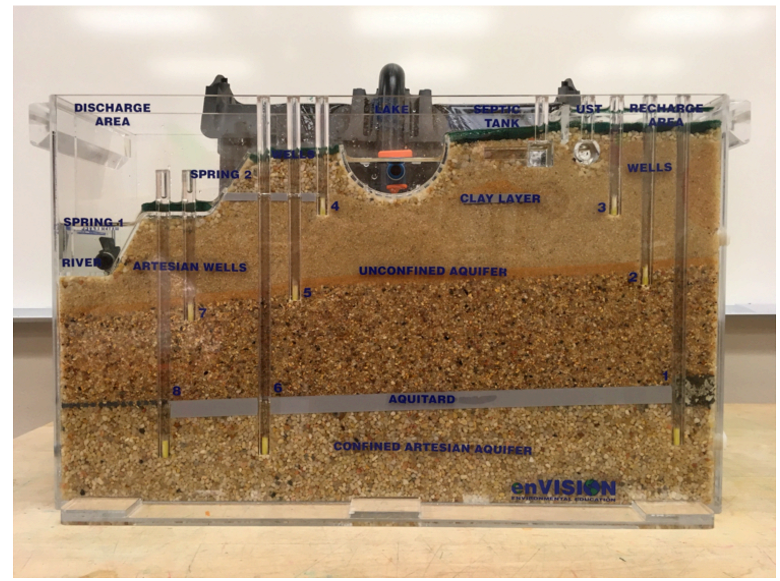
Groundwater always moves in direction from higher hydraulic head (total potential energy) to lower hydraulic head.



M2L3: Cross Section of East Helena & GW Flow Model Experiments

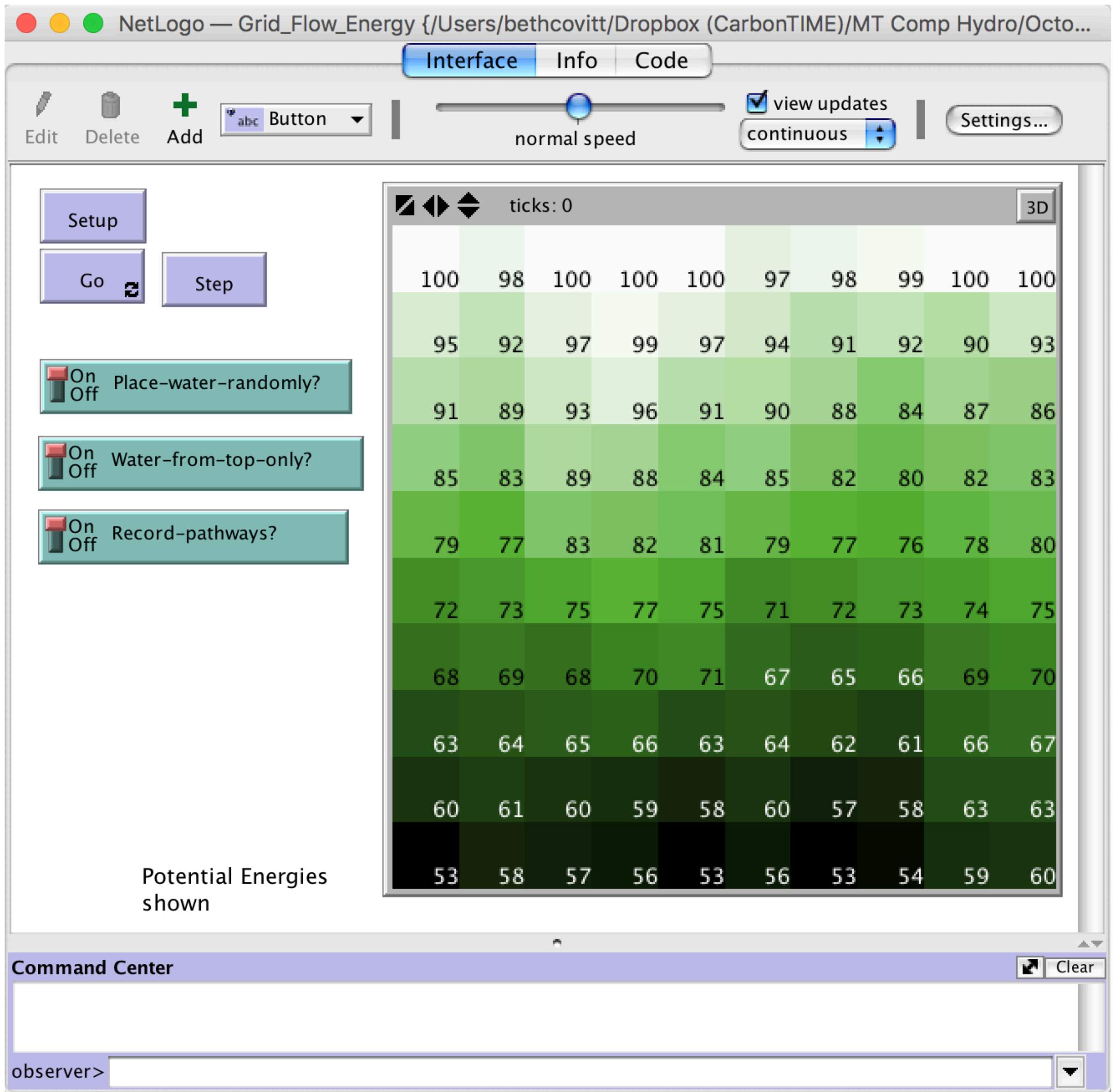


Data

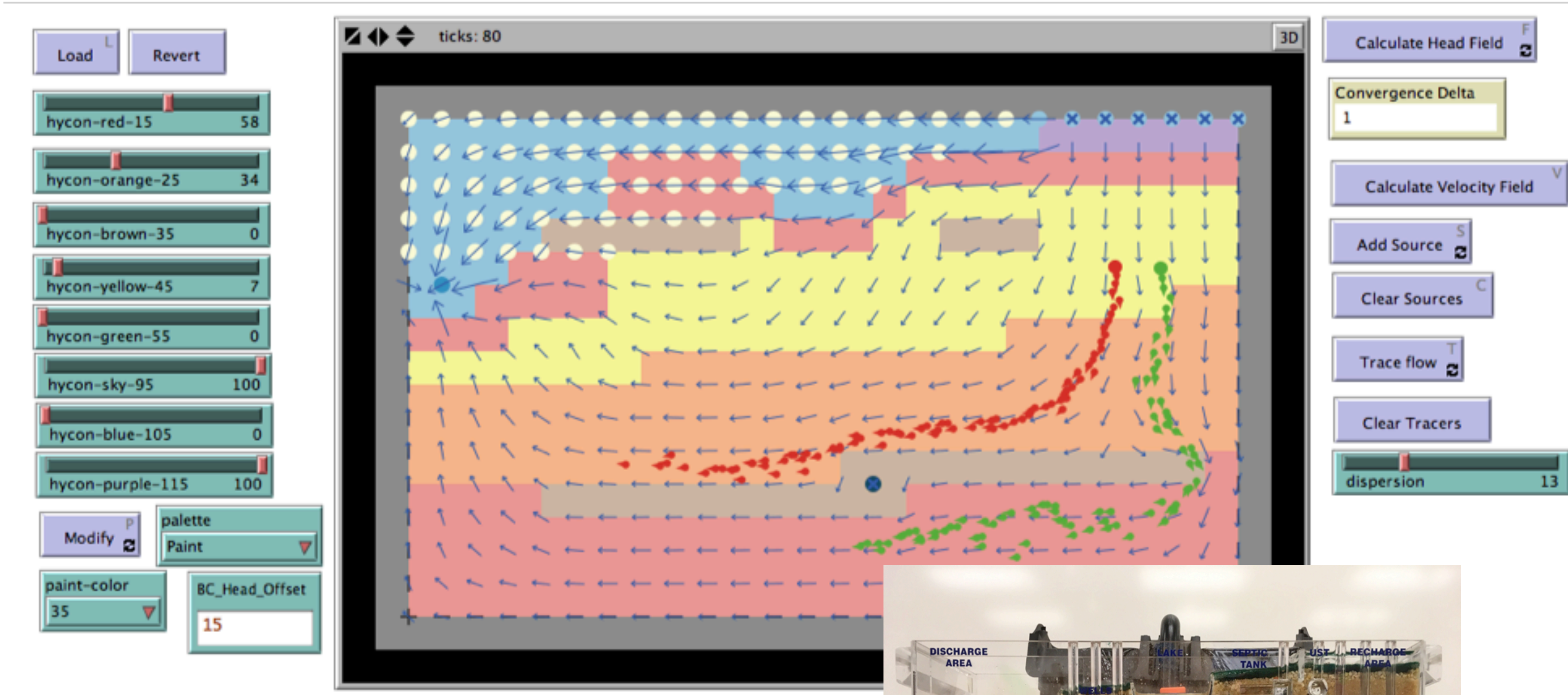


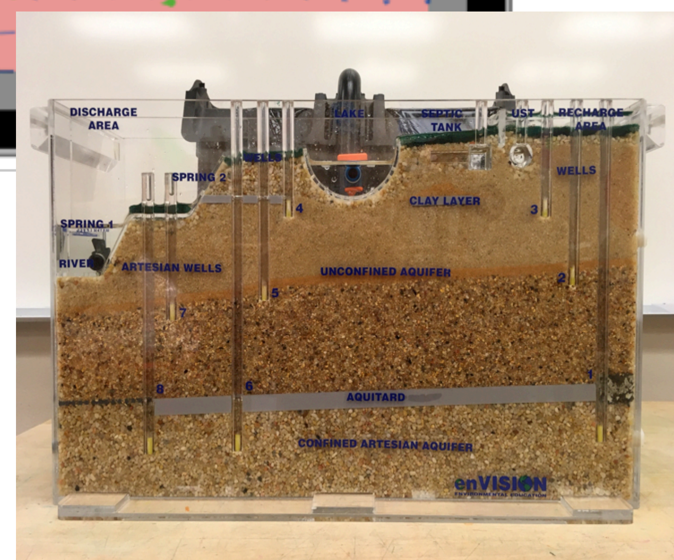
Qualitative Physical Model

M2L4: Intro to Computer Models



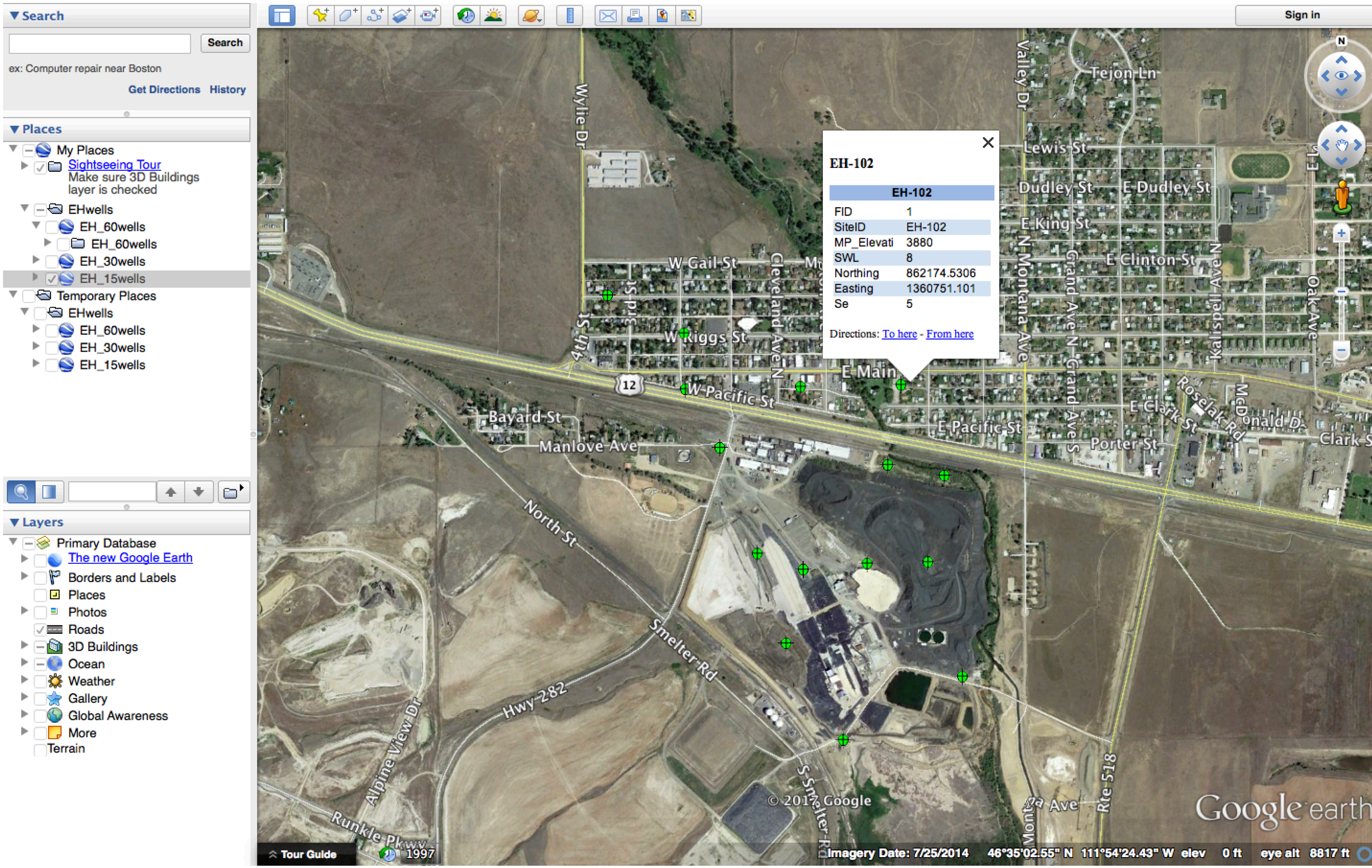
M2L5: NetLogo GW Flow Model



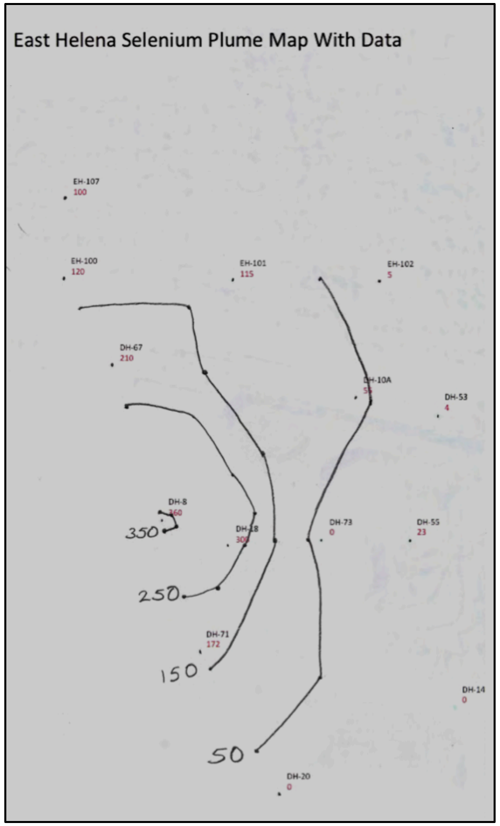


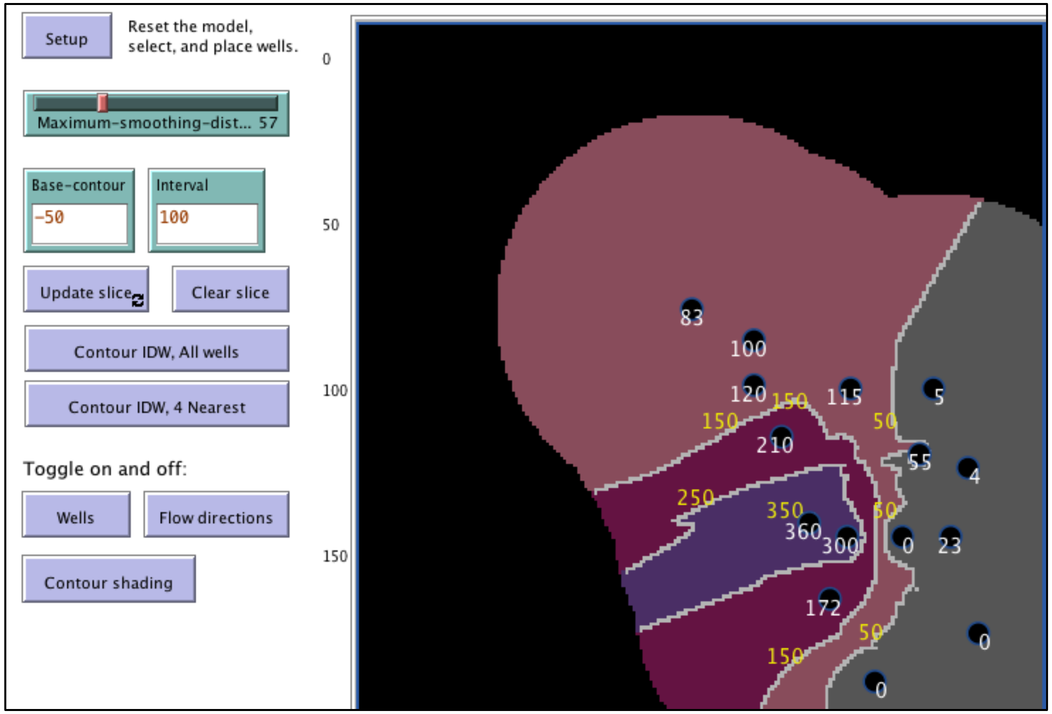
M3L1: Intro to E. Helena Investigation & 3D Model

M3L2: Virtual Investigation w/Google Earth



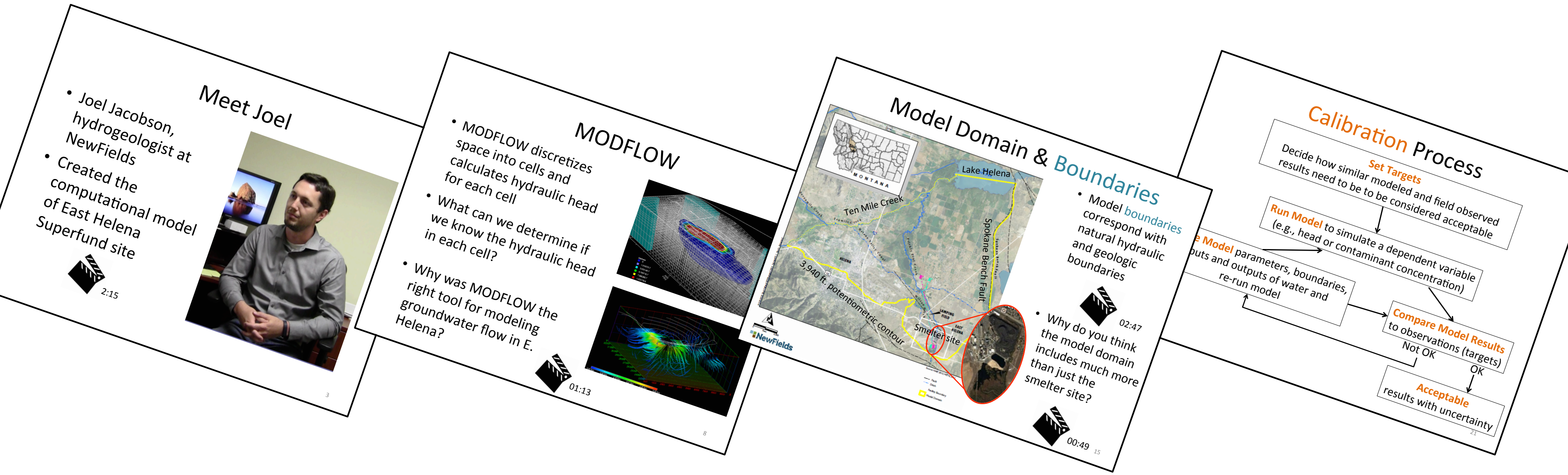
M3L2/L3: Contour mapping by Hand & Computer





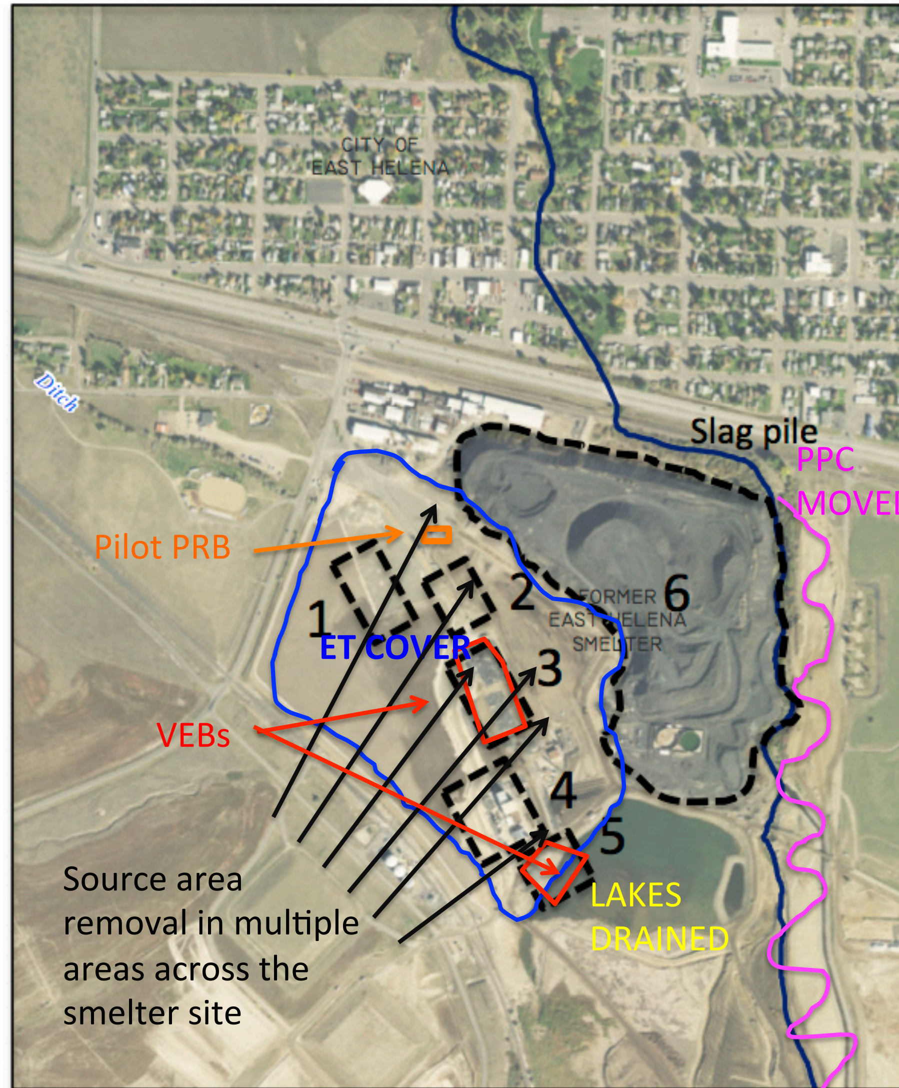
M3L4: Computer Modeling of E. Helena

- Explore how computational modeling was used to develop remediation plan at site
- Jigsaw using videos of scientist who developed the model



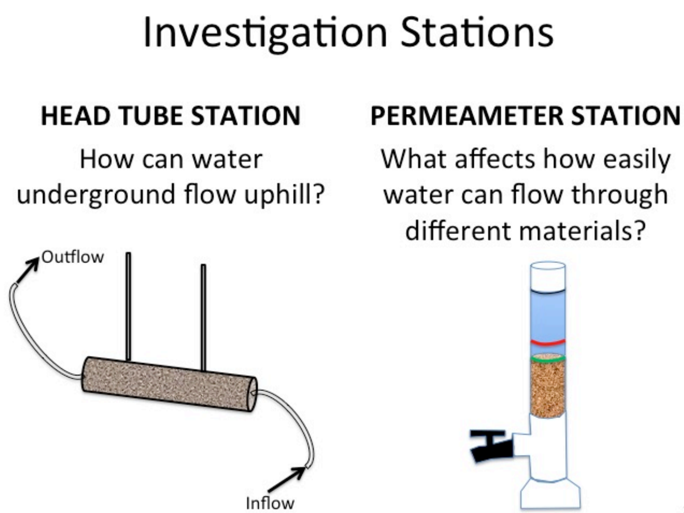
M4: Addressing the Problem

- Teams evaluate cleanup options
- Explore NetLogo remediation strategy models
- Develop remediation plans
- Present plans
- Review what's being done in E. Helena

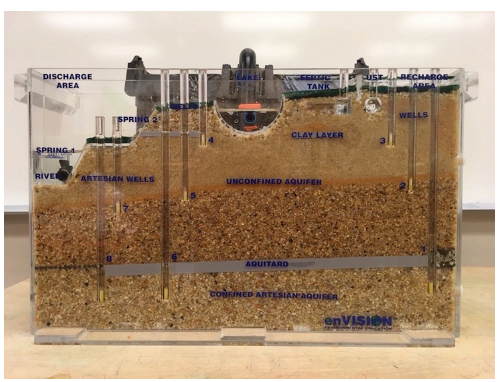


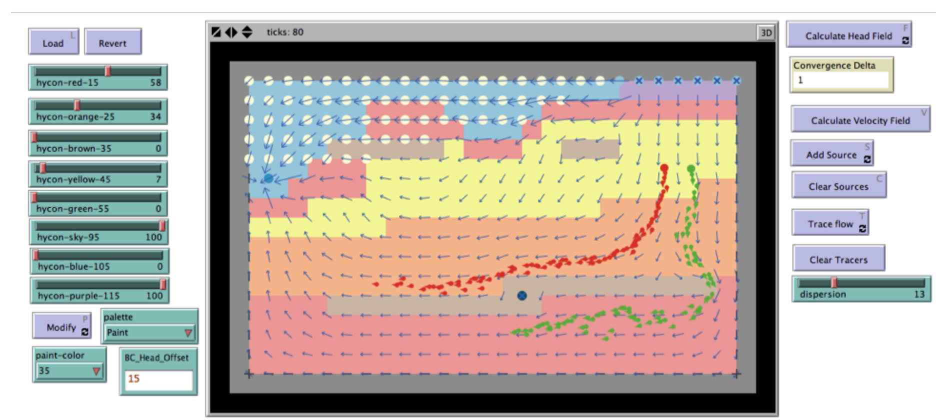
Try it out

- What determines how GW moves? (Head Tube Lab & Permeameter Lab)



- Investigating with GW system models (Physical & NetLogo)





Questions / Discussion / Thank you

Contact

- Beth Covitt, beth.covitt@umontana.edu
- Agatha Podrasky, agatha.podrasky@umontana.edu

Unit materials available upon request

To learn more about Comp Hydro, visit:
http://ibis.colostate.edu/comphydro/

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Generalized Environmental Science Learning Progression

Level of Achievement	Type of Account	Elements of Accounts		
		Structure & Systems	Scale	Principles
Level 4: Model-based accounts	Scientific, model-based explanations of how & why	Multiple, detailed & connected systems	Connected across atomic-molecular through large scales	Invoke scientific principles (e.g., driving forces, constraining factors)
Level 3: Phenomenological (school science) accounts	Descriptions of what happens	Connected systems; visible & some hidden components	Spans micro to macro scale, some challenges linking scales	Address ordered events, named processes, & make use of "school rules"
Levels 1 & 2: Force-dynamic accounts	Force-dynamic descriptions - actors fulfill purposes	Visible, familiar components of systems	Visible, macroscopic scale	Invoke actors' capacities & purposes as explanation

Developing LPs for Comp Hydro

Table 1: Preliminary Construct Maps and Progress Variables

	Lower Anchor (Informal Reasoning)	Upper Anchor (Model-Based Reasoning)
Water in Environmental Systems (Gunckel et al., 2012)		
Structure & Systems	Water in isolated, visible systems only	Traces water through connected systems
Scientific Principles	Invokes agents to move water	Identifies driving forces and constraints
Scale	Macroscopic only	Atomic-molecular through large scale
Representation	Disconnected from the physical world	Maps and cross-sections used as models
Dependency & Agency	Water serves human needs only	Humans part of environmental systems
Bringing Scientific Principles and Models to Bear in Making Sense of Data (Covitt, Dauer, & Anderson, In press)		
Answering Questions	Substitutes an easier question	Asks relevant scientific questions
Patterns in data	Uses stories not statistics	Weds computational thinking with knowledge of scientific models
Validating Models	Uses confirmation bias	Falsifies and test models
Explaining Events	Simple cause and effect	Recognizes mechanistic relationships
Recognizing Uncertainty	False certainty	Uncertainty is reduced and managed
Computational Modeling & Data Representation (based on preliminary explorations)		
Quantitative Reasoning	Qualitative descriptions of change; variability is human error	Identifies trends quantitatively; distinguishes variability & error
Design and Modeling	Unconstrained brainstorming	Identifies relevant constraints; parameterizes variables
Problem-solving	One & done	Iterative & recursive approaches
Simulation	Simulations disconnected from systems they model	Compares generated & empirical data
Data Visualization	Concrete and physical models only	Uses different levels of abstraction