Learning Progressions for How Students Make Sense of Water in Environmental Systems

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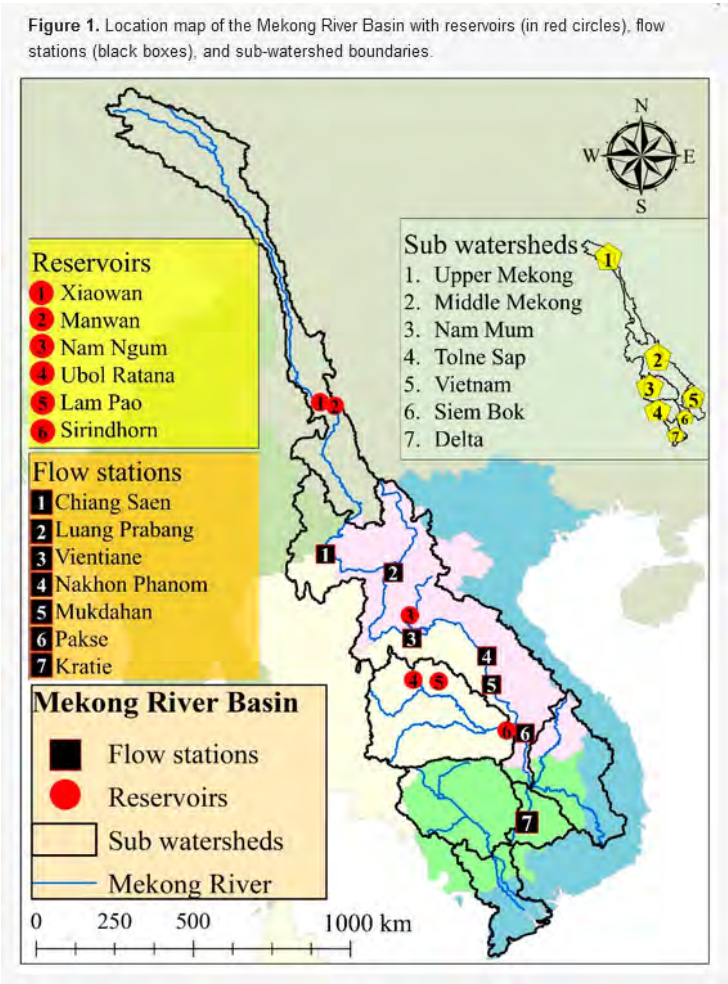
In order to understand the science behind why this happens….

A narrow section of water flowed through the dried-out riverbed of the Mekong near Sangkhom, Thailand, in January. Adam Dean for The New York Times

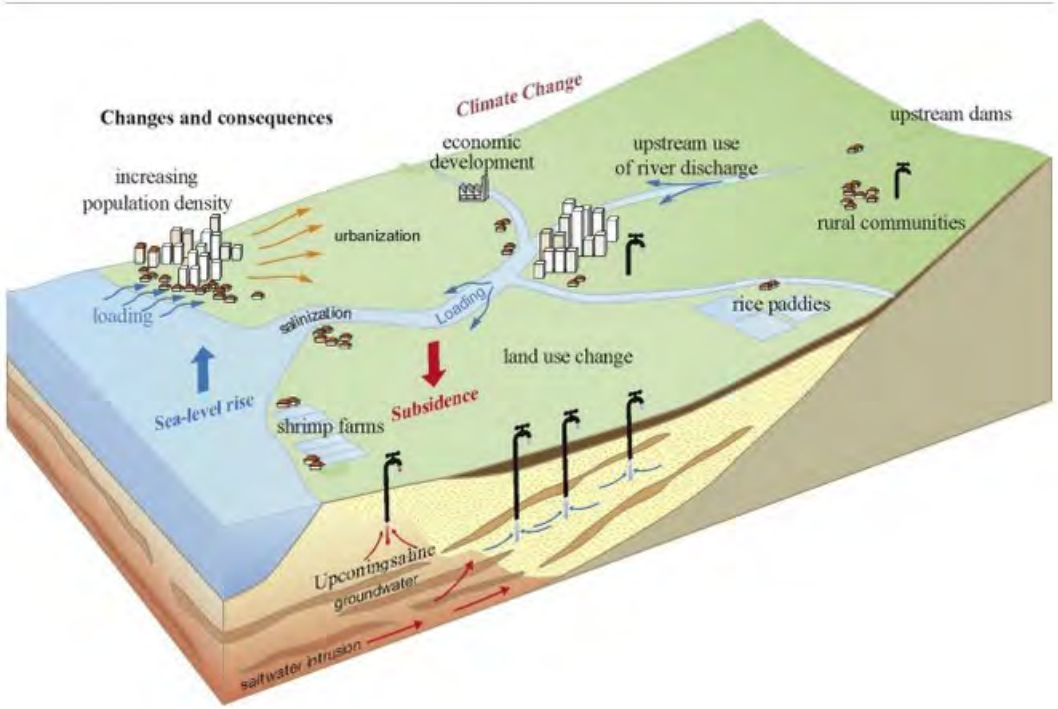
Beech, H. (2020, April 13). China limited the Mekong's flow. Other countries suffered a drought. *New York Times*. https://www.nytimes.com/2020/04/13/world/asia/china-mekong-drought.html

You need to understand how water flows through watersheds and aquifers, and how human-engineered structures affect the flow of water through these systems.

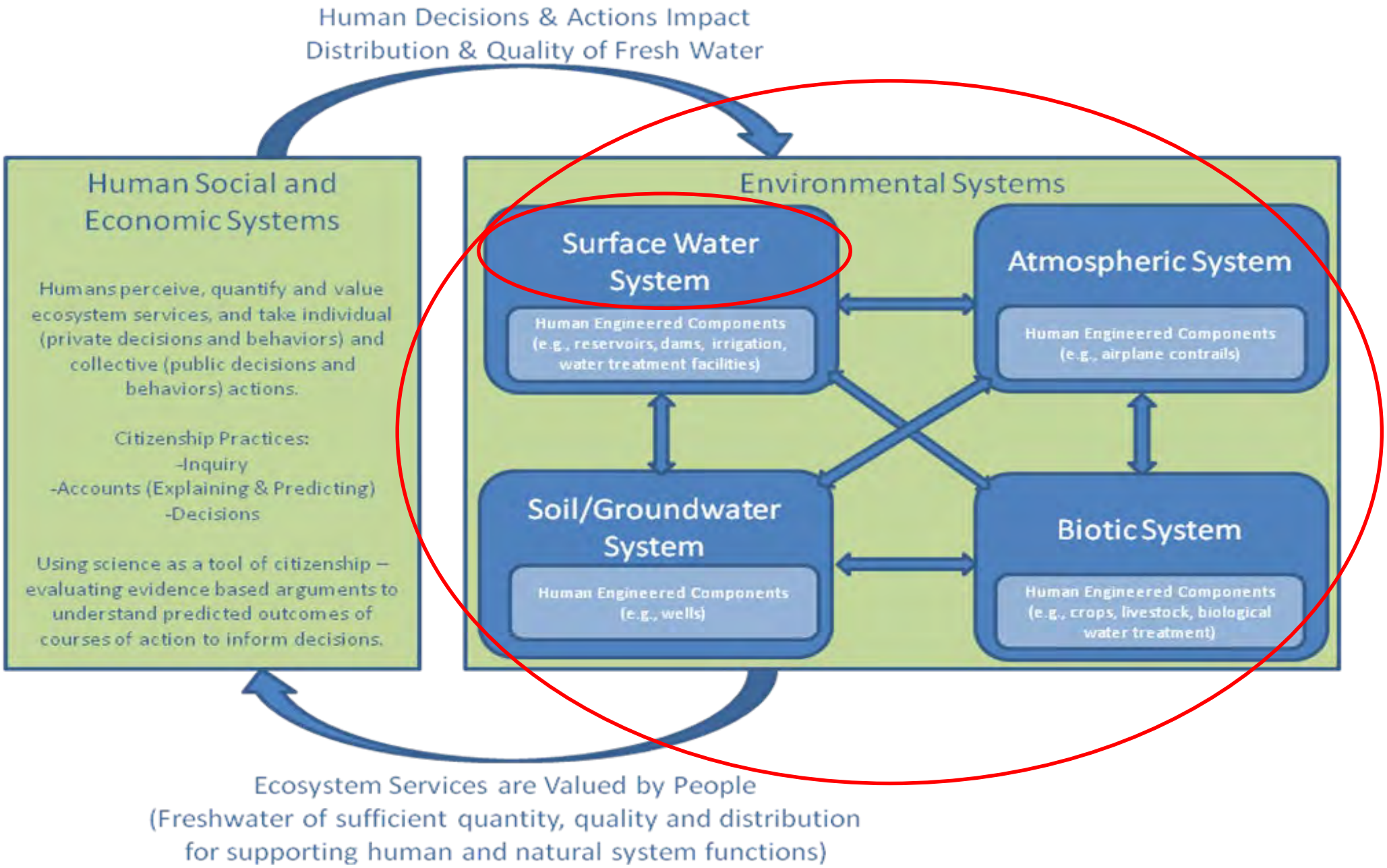


Sridhar, V., Kang, H., & Ali, S. A. (2019). Human-Induced Alterations to Land Use and Climate and Their Responses for Hydrology and Water Management in the Mekong River Basin. *Water*, *11*(6), 1307. MDPI AG. Retrieved from http://dx.doi.org/10.3390/w11061307

Fig. 1. Overview of threats to coastal aquifers in the Mekong Delta, Vietnam (MKD): Changes (e.g. urbanization, sea-level rise) and consequences (e.g. subsidence, salinization) in the Mekong Delta, Vietnam (after Delsman, 2015).



Pham, H.V., van Geer, F. C., Tran, V. B., Dubelaar, W., Oude Essink, G. H. P., 2019. Paleo-hydrogeological reconstruction of the fresh-saline groundwater distribution in the Vietnamese Mekong delta since the late Pleistocene. Journal fo Hydrology: Regional Studies, 23 (2019), 1-22. https://doi.org/10.1016/j.ejrh.2019.100594

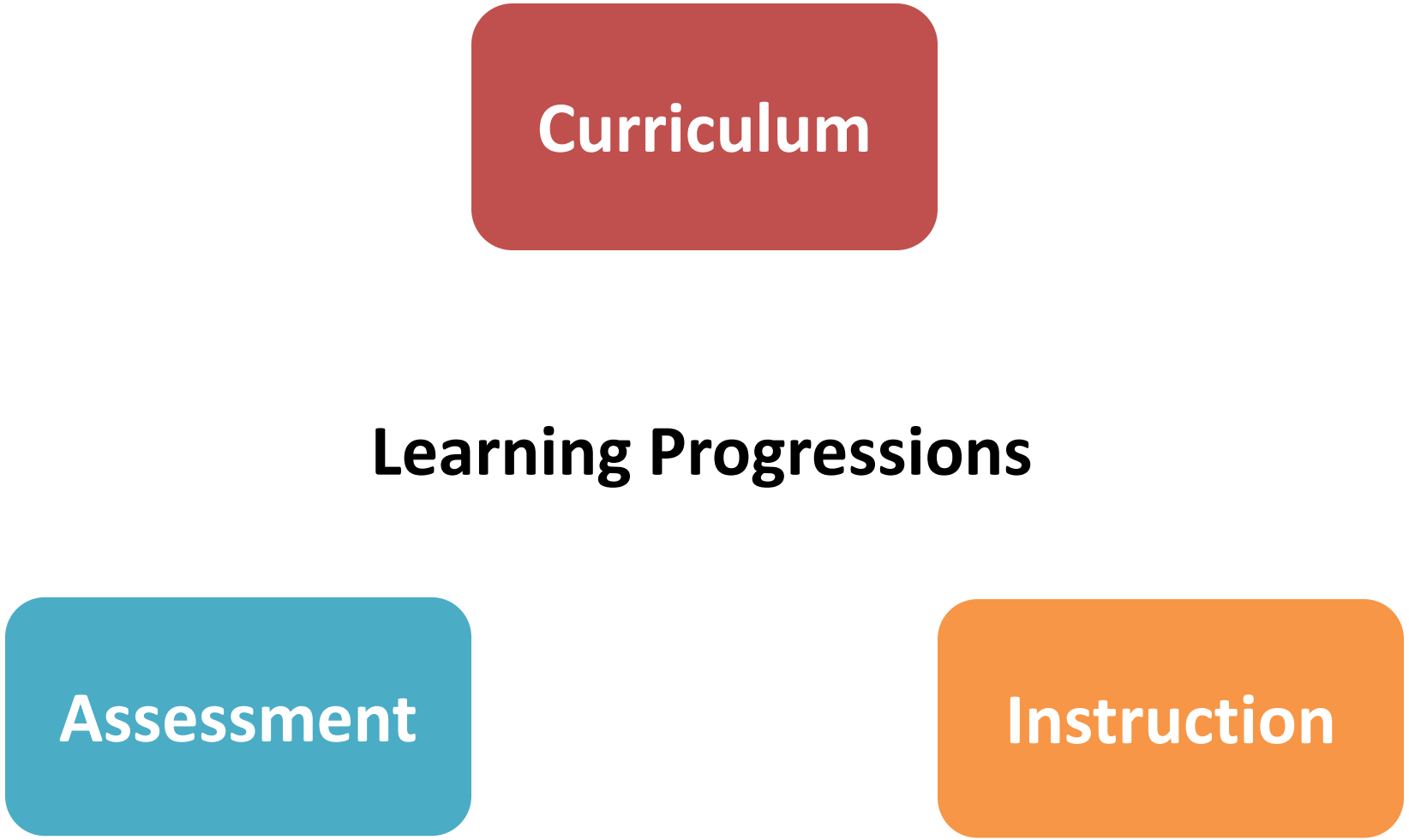

Human Decisions & Actions Impact
Distribution & Quality of Fresh Water
Human Social and Economic Systems
Humans perceive, quantify and value ecosystem services, and take individual (private decisions and behaviors) and collective (public decisions and behaviors) actions.
Citizenship Practices:
-Inquiry
-Accounts (Explaining & Predicting)
-Decisions
Using science as a tool of citizenship – evaluating evidence based arguments to understand predicted outcomes of courses of action to inform decisions.
Environmental Systems
Surface Water System
Human Engineered Components (e.g., reservoirs, dams, irrigation, water treatment facilities)
Atmospheric System
Human Engineered Components (e.g., airplane contrails)
Soil/Groundwater System
Human Engineered Components (e.g., wells)
Biotic System
Human Engineered Components (e.g., crops, livestock, biological water treatment)
Ecosystem Services are Valued by People
(Freshwater of sufficient quantity, quality and distribution for supporting human and natural system functions)

As teachers, we need to know……

- What sense do students make of how water moves through environmental systems?
- How teachers can build on student ideas in curriculum, instruction, and assessment?

Learning Progressions

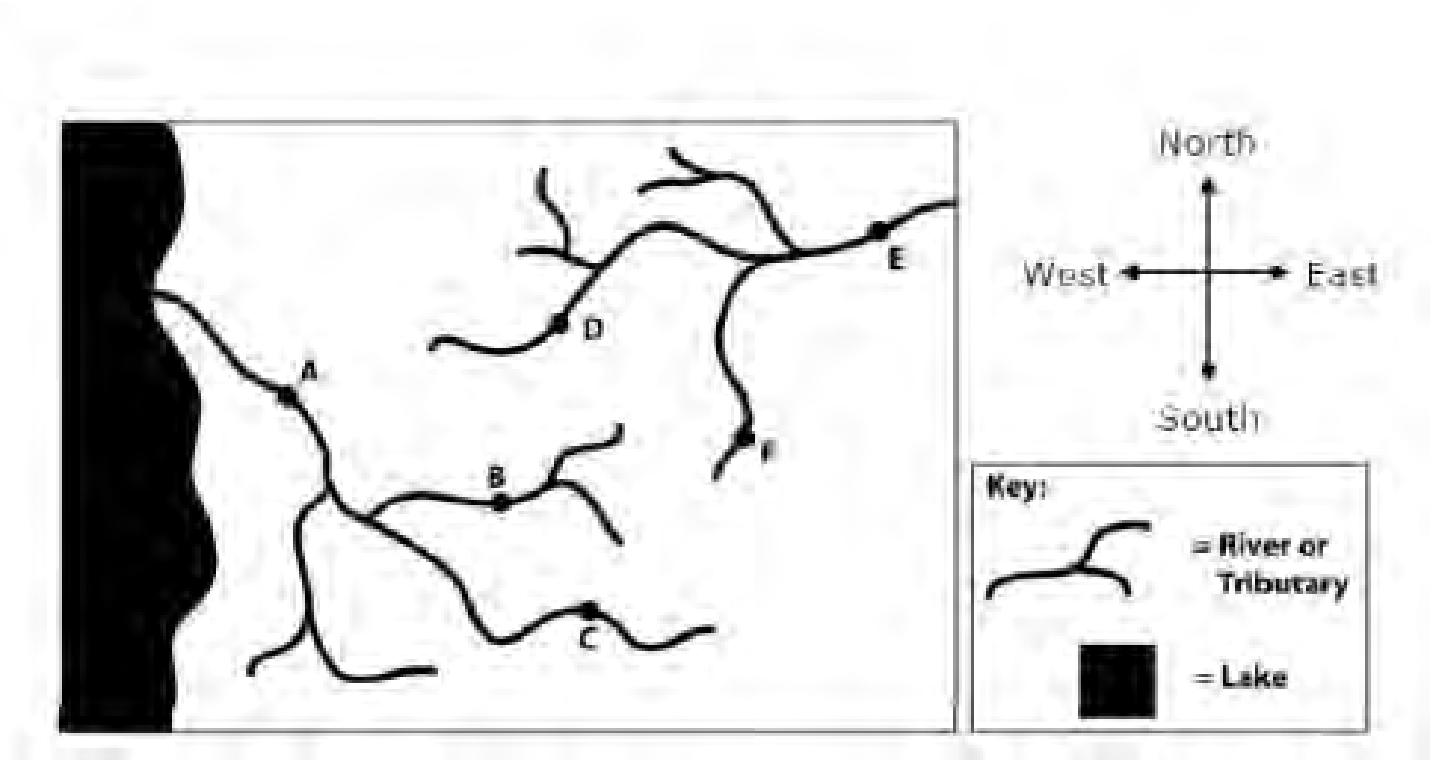
- Descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time. (NRC, 2007)
- Foundational to the *Framework for K-12 Science Education* and the Next Generation Science Standards


Curriculum
Learning Progressions
Assessment
Instruction

River Maps Assessment Item

a. Can pollution in the river water at point B get to point C?

b. Explain why or why not.

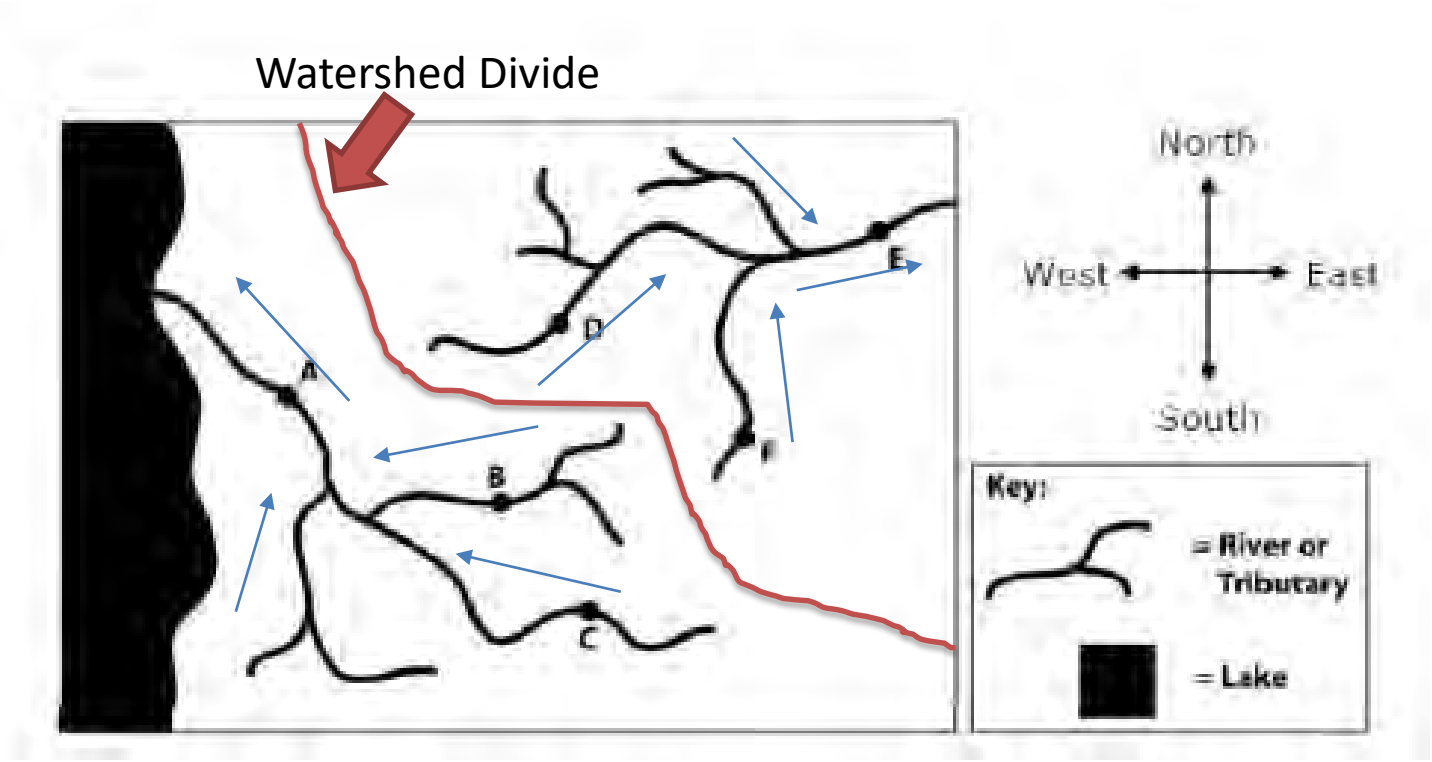


River Maps Assessment Item

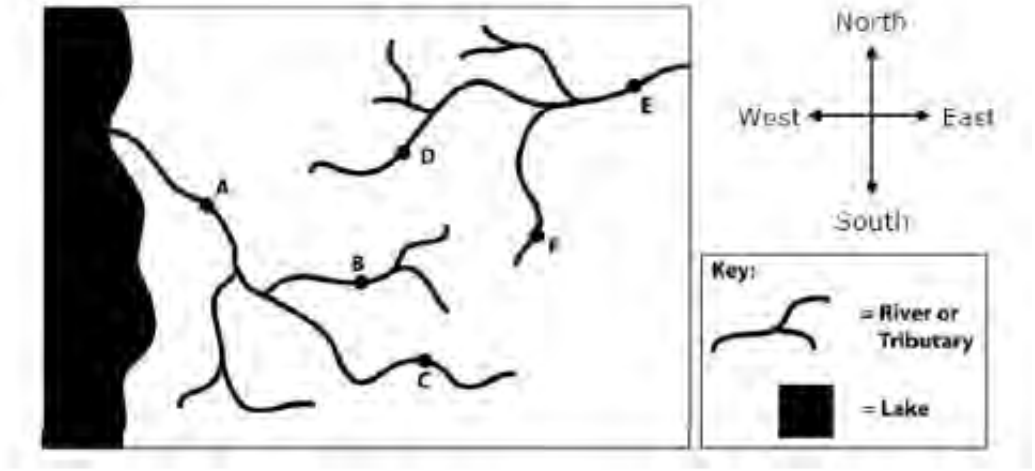
a. Can pollution in the river water at point B get to point C? No

b. Explain why or why not.

The highest elevation is the watershed divide between river system A-B-C and river system D-E-F. The water at point B and the water at point C are both flowing downhill towards the lake. The water from the river from point B would have to flow upstream against gravity in order to reach point C.

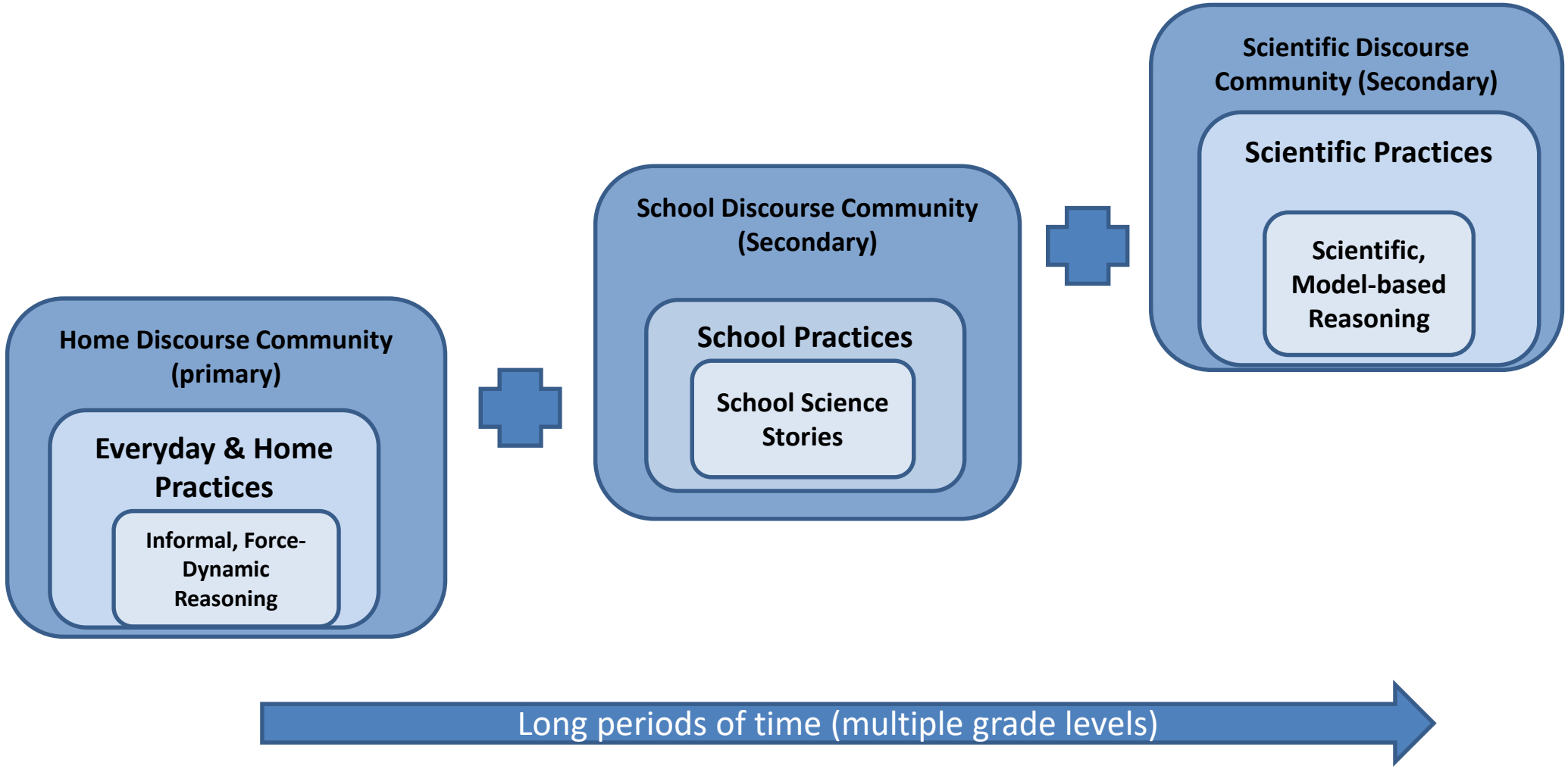


River Maps Assessment Item: Student Responses

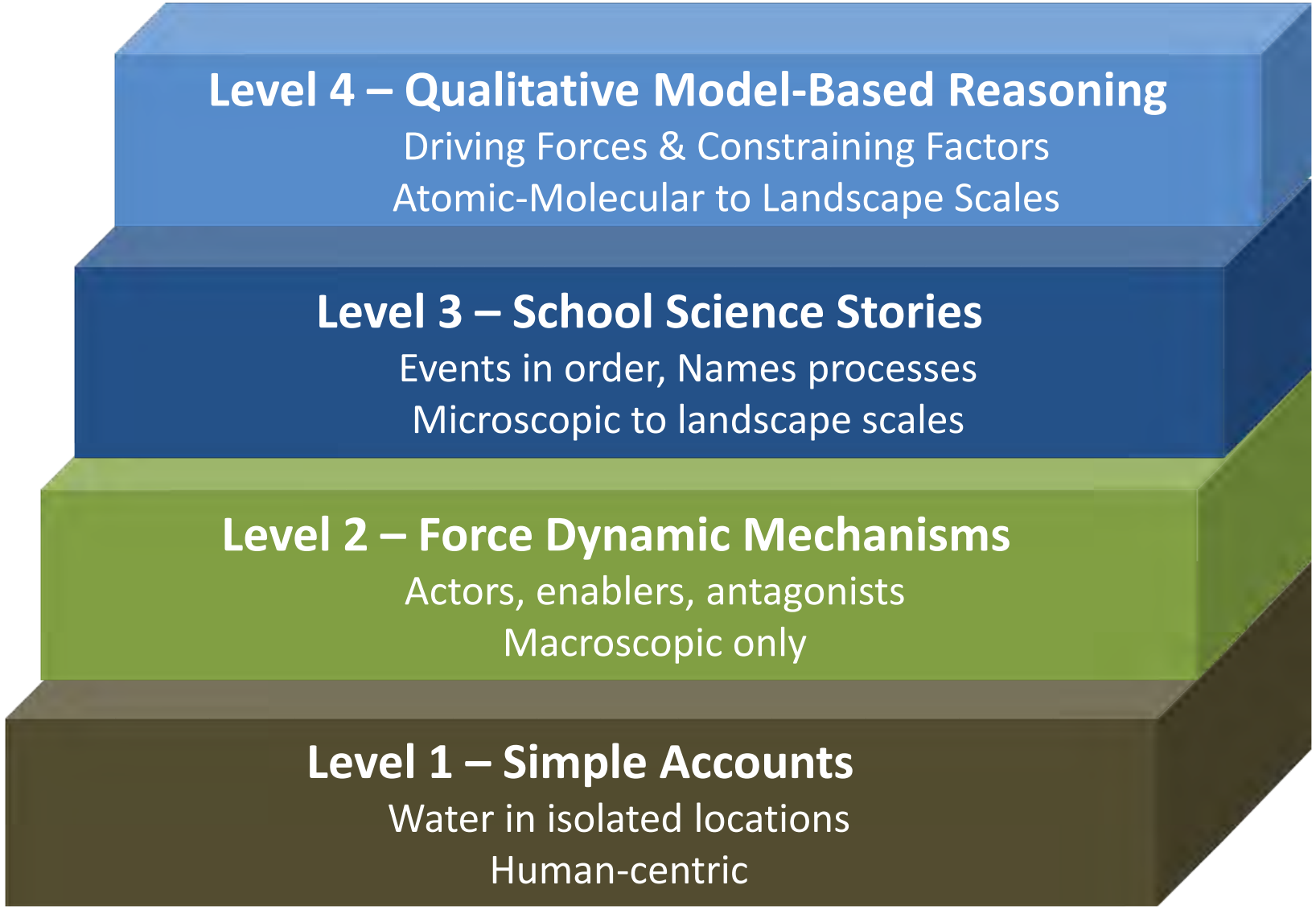


	Student Response	Your Ranking
A	No, because water runs from the tributaries to major water sources, not the other way around.	
B	Yes because they connect so they will have the same pollution.	
C	Yes. Water flows down or south.	
D	No. Because it would be against gravity. All tributaries flow into the lake where the elevation is lower.	
E	Yes because the water current of river c could catch the pollution	
F	No, due to the watershed.	

What Progresses?



Water Systems Learning Progression



Level 1: Simple Force Dynamic Accounts of Water

Key Features

- Water exists in visible and isolated containers
- Water is visible
- Few connections between natural and human-engineered systems.
- Human-centric mechanisms and reasoning

Examples

Where does the water in a puddle go?

It dries up.

How does water get into a river?

It could get into a river by being rained into.

It flows

If a well is built near a river, could the well affect the amount of water in the river?

No, because well water doesn't come from rivers.

How does water get into a well?

From sinks and bathtubs

How does a sewage treatment plant change the water?

It makes it better to drink

Level 2: Force Dynamic Mechanism

Force Dynamic Discourse – A theory of the world rooted in and shaped by the grammatical structure of language.

- Actors and abilities
- Events or actions
- Purposes and Results
- Needs or enablers
- Settings or scenes

Examples

Where does the water in a puddle go?

Sucked into the clouds.
Soaked into the ground.
Evaporated by the water cycle.

How does water get into a river?

Water gets into a river by another river, the ocean, or rain.

If a well is built near a river, could the well affect the amount of water in the river?

Yes, by the well draining the river's water.

How does water get into a well?

Water that overflows from river gets in there.

How does a sewage treatment plant change the water?

Kills off bad substances.

Level 3: School Science Stories

Key Features

- Names processes
- Puts events in order
- Recognizes invisible and microscopic

Examples

Where does the water in a puddle go?

It evaporated into the air, where it condensed [sic] in the clouds, and precipitated in another area.

How does water get into a river?

Water gets into a river by rain, or by the water melting off a mountain, and traveling by stream until it gets to a river.

If a well is built near a river, could the well affect the amount of water in the river?

The water can go through the ground and get in the well.

How does water get into a well?

The well is below the water table so water from the aquifer can seep in.

How does a sewage treatment plant change the water?

Boiling it: removes bacteria.

Level 4: Qualitative Model-Based Reasoning

Key Features

- Identifies driving forces (e.g., gravity, heat energy)
- Identifies constraining factors (e.g., topography, permeability)
- Recognizes connections between natural and human-engineered systems
- Recognizes and reasons about water at atomic-molecular through landscape scales
- Identifies and reasons about multiple pathways.

Examples

Where does the water in a puddle go?

Down through the soil layers, or if the soil was high in clay the water may have evaporated.

How does water get into a river?

1: runoff from the cornfield irrigation. 2: rain from above. 3: the water in aquifer 1 and well 1 could travel to the river.

If a well is built near a river, could the well affect the amount of water in the river?

Yes. As water level in aquifer is used, water level drops if it is not replenished quickly enough. If enough water is pumped the water in the river could drop as water seeps through permeable soil into the aquifer, below ground level.

How does water get into a well?

Rainwater accumulates underground on top of the impermeable layer, the well is in the aquifer, so the water is in the well.

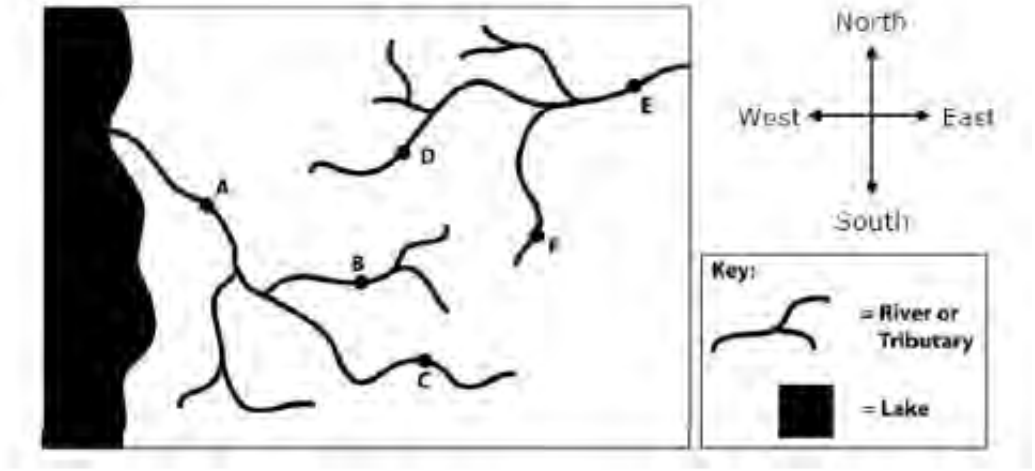
How does a sewage treatment plant change the water?

Depends on what is polluting it. If anything boil to kill microorganisms. Distill to remove fertilizers, salts, medicines. Chemically treat to kill microorganisms.

Learning Progression Rubric

Level 4 Qualitative Model-based Accounts	• Uses topography, gravity, and permeability as principles to reason about water flow. • Uses maps and diagrams to interpret structure of water systems.
Level 3 School Science Stories	• Uses school rules to trace water without indicating attention to underlying conceptual principles such as forces (e.g., gravity, potential energy) or constraining factors (e.g., permeability, topography). • Relies on naming processes or features without indicating how they explain the phenomenon.
Level 2 Force Dynamic Accounts with Mechanisms	• Views water as having natural tendencies such as “flowing,” “traveling,” “spreading,” “drifting”. • Invokes forces such as wind or current. • Says water flows down the page or down the map or south (as down)
Level 1: Simple Force Dynamic Accounts	• Describes water becoming polluted because it is connected to other polluted water.

River Maps Assessment Item: Student Responses



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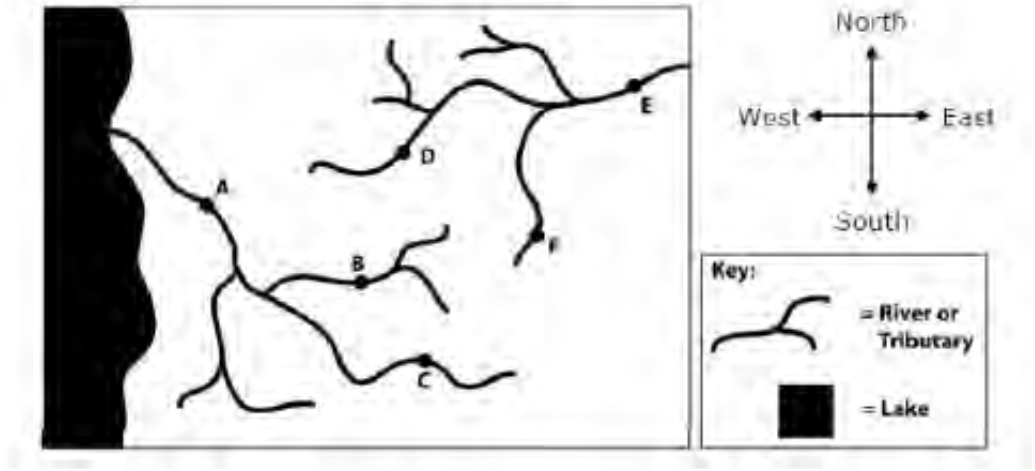
River Maps Assessment Item: Student Responses



	Student Response	Level
A	No, because water runs from the tributaries to major water sources, not the other way around.	3
B	Yes because they connect so they will have the same pollution.	1
C	Yes. Water flows down or south.	2
D	No. Because it would be against gravity. All tributaries flow into the lake where the elevation is lower.	4
E	Yes because the water current of river c could catch the pollution	2
F	No, due to the watershed.	3

Distribution Across Levels by Grade Bands

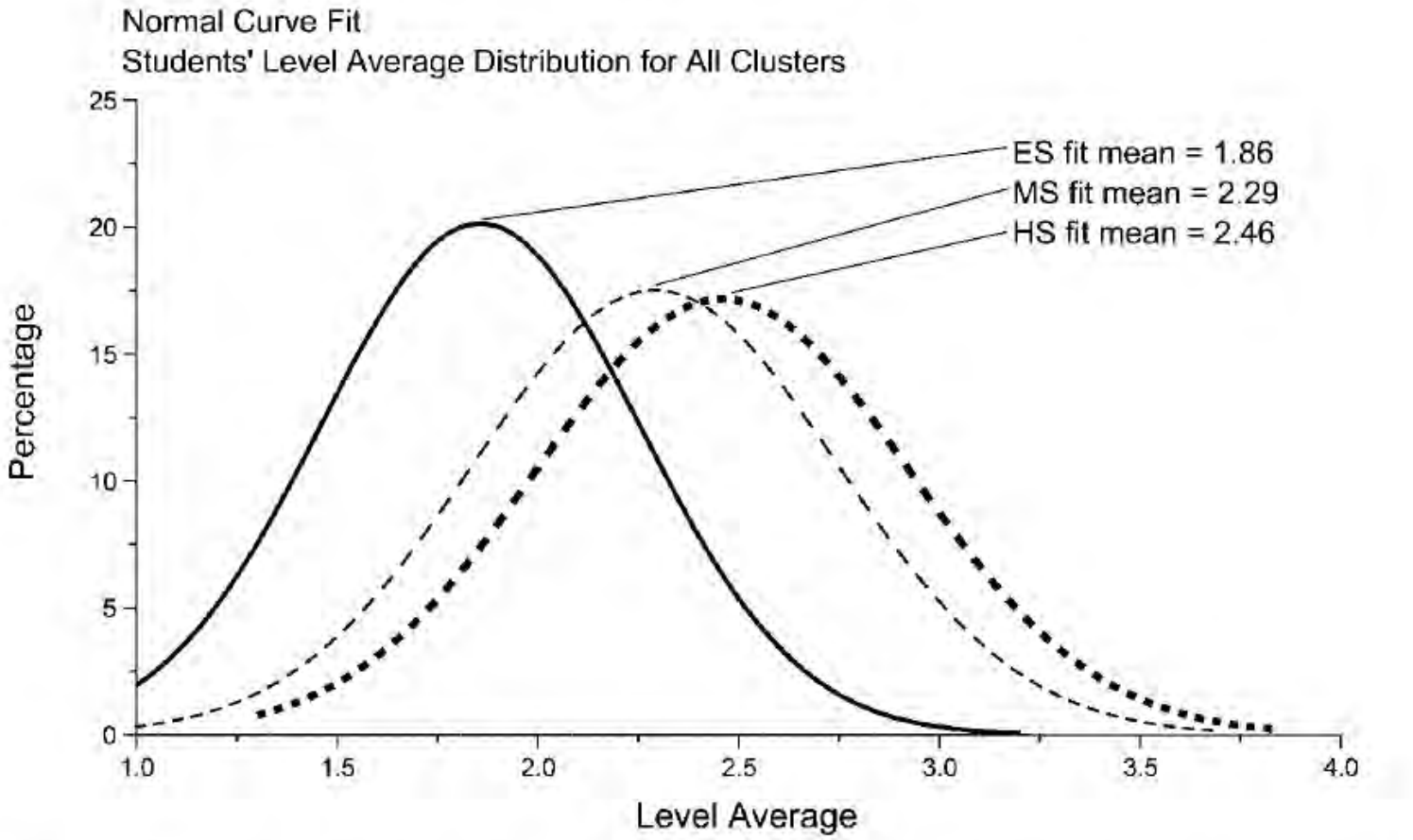
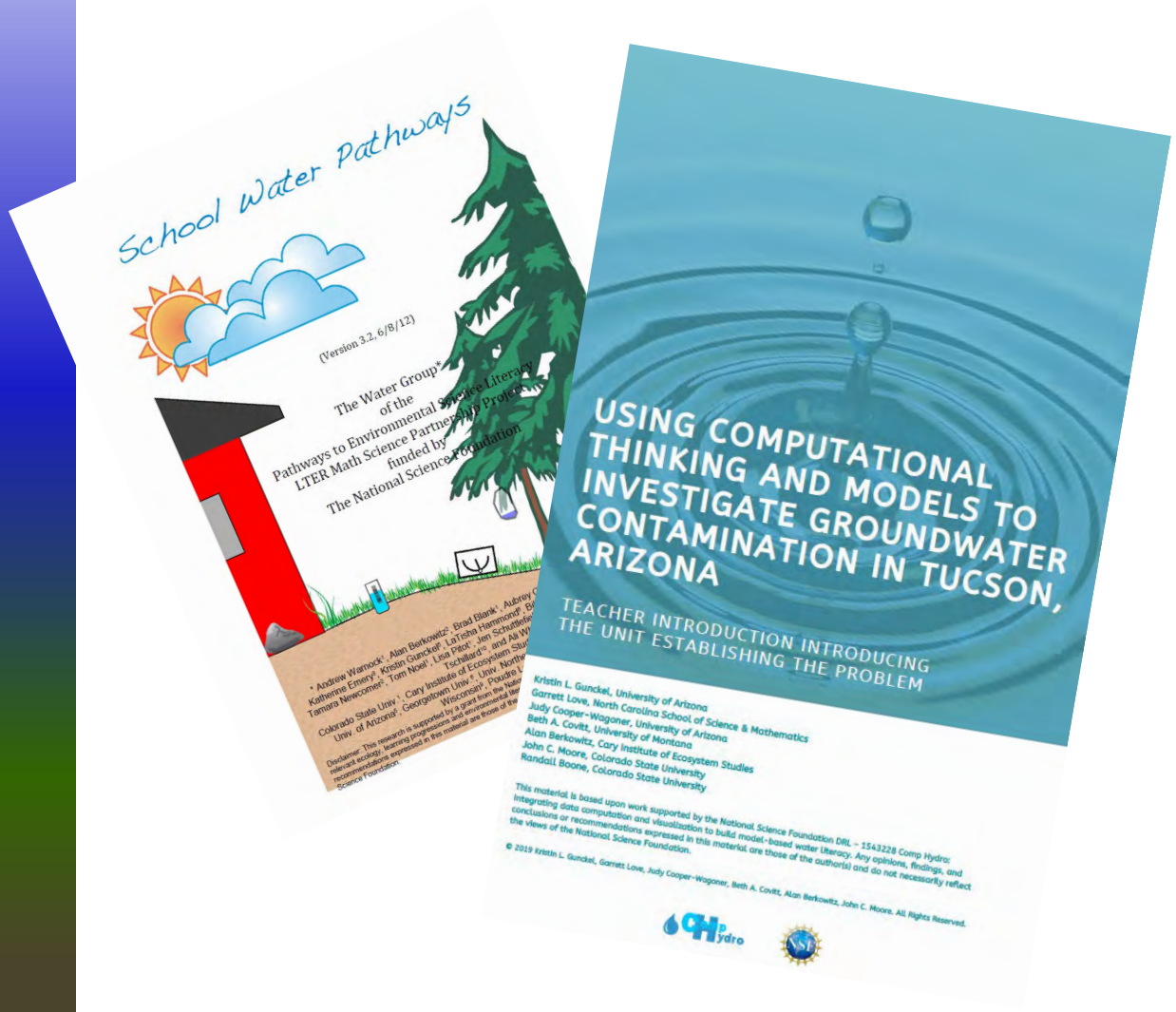


Figure 3. Gaussian fit curves for grade bands across average levels of achievement for all clusters.

Curriculum: Learning Progression-Based Curriculum Materials

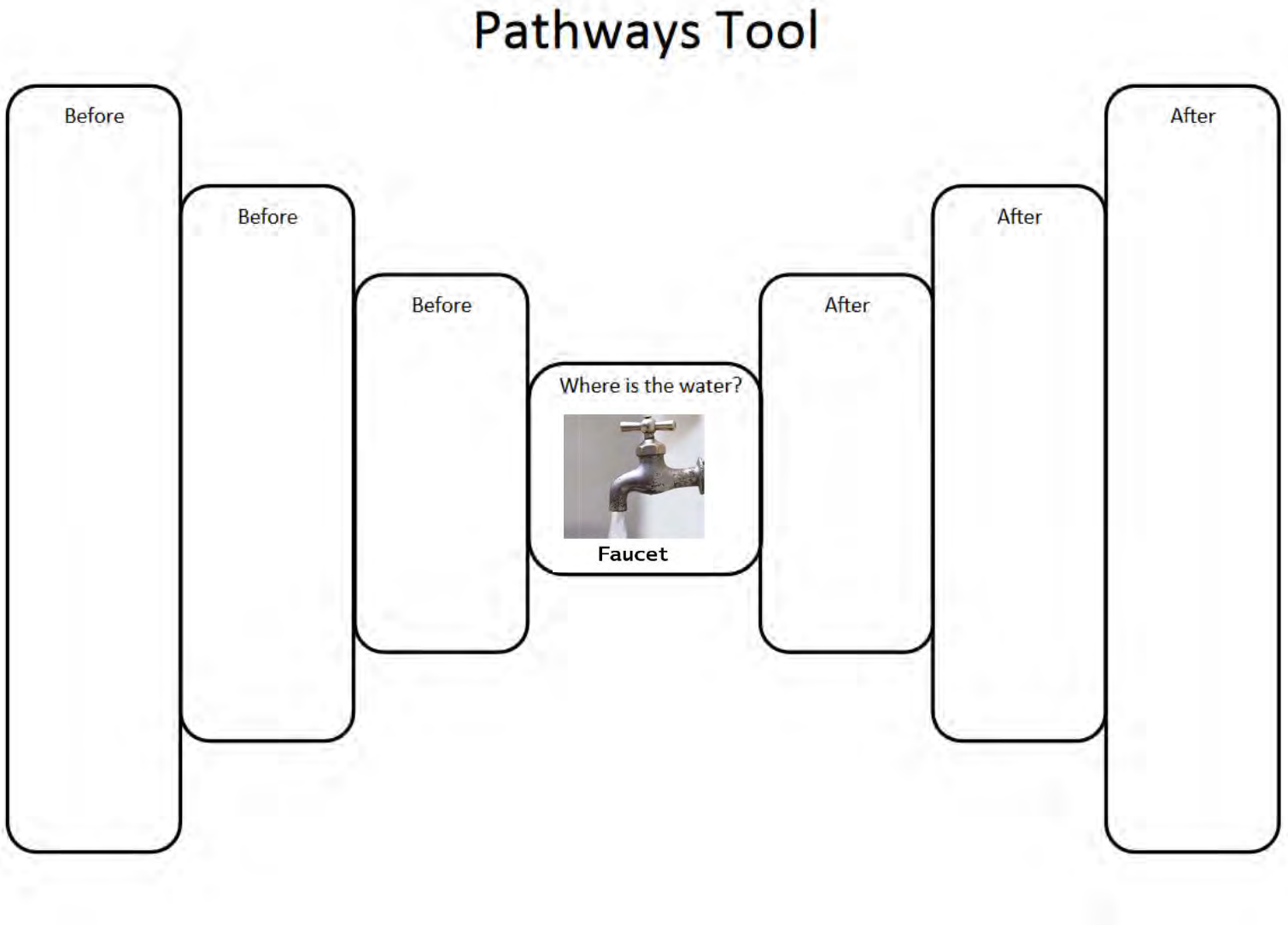


- Have multiple entry points to engage students performing at different levels of achievement in meaningful ways.
- Connect to students' primary Discourse and provide opportunities to use an develop scientific Discourse and engage in scientific practices.
- Provide experiences and supports that address the challenges students encounter moving from one level to the next.
- Are grounded in place-based phenomena that build on student funds of knowledge.
- Provide language-rich activities and supports.

http://ibis-live1.nrel.colostate.edu/CompHydro/

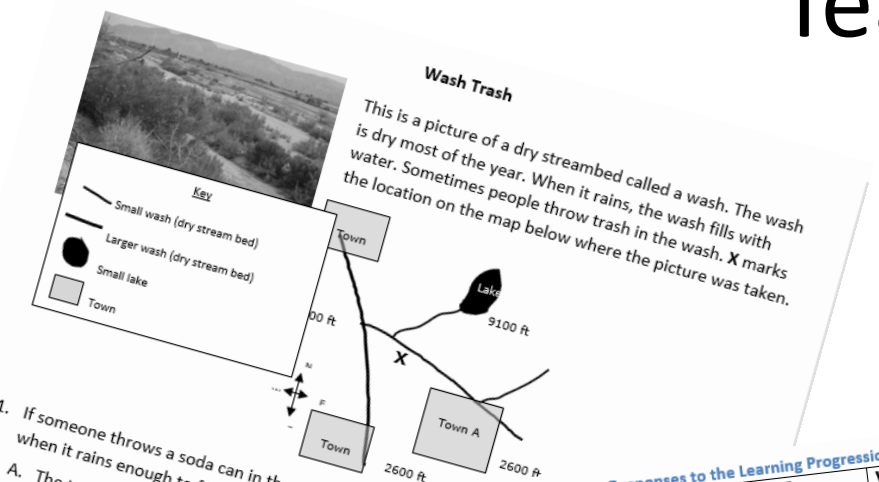
Instruction: Reasoning Tools for Water

Tools in the form of graphic organizers that support students in progressing from level 2 to level 3 and level 3 to level 4.



http://www.umt.edu/watertools/

Assessment: Formative Assessments with Teachers' Guides



Wash Trash

This is a picture of a dry streambed called a wash. The wash is dry most of the year. When it rains, the wash fills with water. Sometimes people throw trash in the wash. **X** marks the location on the map below where the picture was taken.

Key
Small wash (dry stream bed)
Larger wash (dry stream bed)
Small lake
Town

Town
Lake
9100 ft
X
Town
Town A
2600 ft
2600 ft

1. If someone throws a soda can in the river at the place i when it rains enough to fill the wash with water?
   A. The trash will not go anywhere.
   B. The trash will float to Town B.
   C. The trash will float to Town A.
   D. The trash will float into the Lake.
   E. The trash will float to Town C.
2. Which choice best describes your reason for where you think the t
   A. It flows south.
   B. Lakes flow into streams.
   C. Streams flow into lakes.
   D. It is lower in elevation.
   E. There is water.
   F. Water flows to connected washes or streams.
   G. It flows to the bottom of the picture
   H. None of the above
   I. The rule of Vs
   J. Tributaries flow into larger rivers.

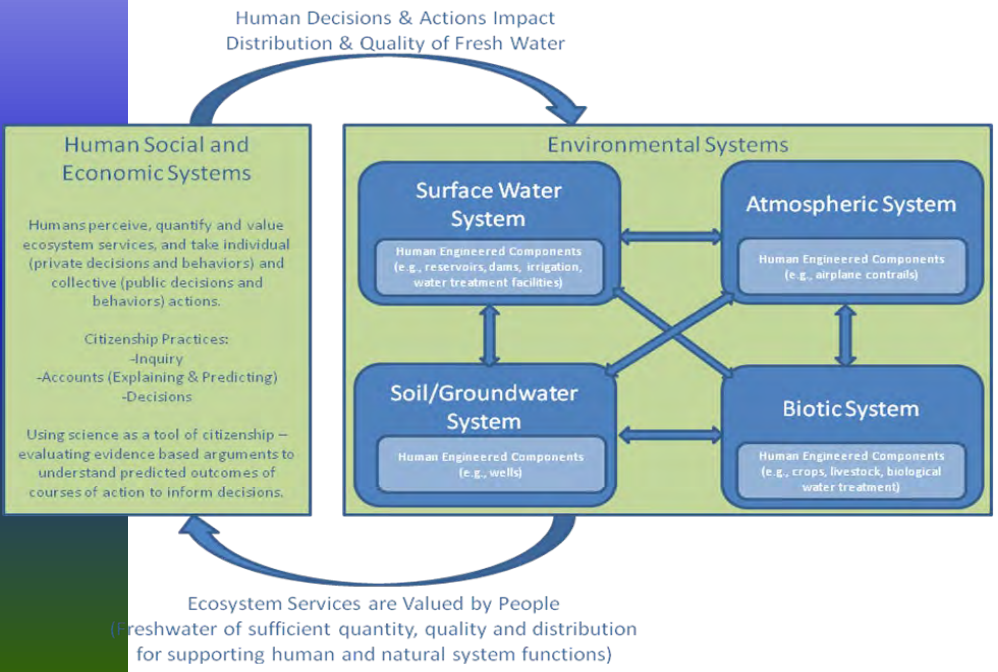
Connecting Student Responses to the Learning Progression (LP)

Level	Where will the trash go?	Why?	Interpretation & Implications
4 Model-based accounts	E. The trash will float to Town C.	D. It is lower in elevation	Recognizes that gravity pulls water down in elevation and correctly interprets map to identify that the lower elevation is to the northwest.
3 Incomplete school science stories	Any of these responses B. The trash will float to Town B. C. The trash will float to town A. D. The trash will float into the Lake. OR E. The trash will float to Town C.	D. It is lower in elevation OR Any of these responses I The rule of Vs H. Tributaries flow into larger rivers	Recognizes that flows downhill, but misinterprets downhill on the map. Correctly identifies the direction, but uses school rules for determining direction of water flow on a map rather than a causal definition that includes drivers of water flow.
2 Force-dynamic with mechanisms	Any of these responses B. The trash will float to Town B. C. The trash will float to town A. D. The trash will float into the Lake	Any of these responses F. Water flows to connected washes or streams C. Streams flow into lakes. A. It flows south. G. It flows to the bottom of the picture.	Recognizes that water moves from one place to another and provides a mechanism. Uses informal and often incorrect rules to reason about water flow.
1 Force dynamic	Any of these responses: A. The trash will not go anywhere F. The trash will float away	Any of these responses: E. There is water. J. None of the above.	Does not trace water moves from one place to another. Recognizes only what is immediately visible. Does not include a mechanism.

- Prompts to quickly assess student level of performance.
- Teacher's guides to interpretation of student responses.
- Suggestions for next instructional steps.

http://www.umt.edu/watertools/

Implications



- Even if you don't teach science, it is necessary to be responsive to how students make sense of water moving through environmental systems in order to teach about water issues.
- Connect the social science to the natural science. Help students recognize the ways that water is part of a socio-ecological system.

Questions