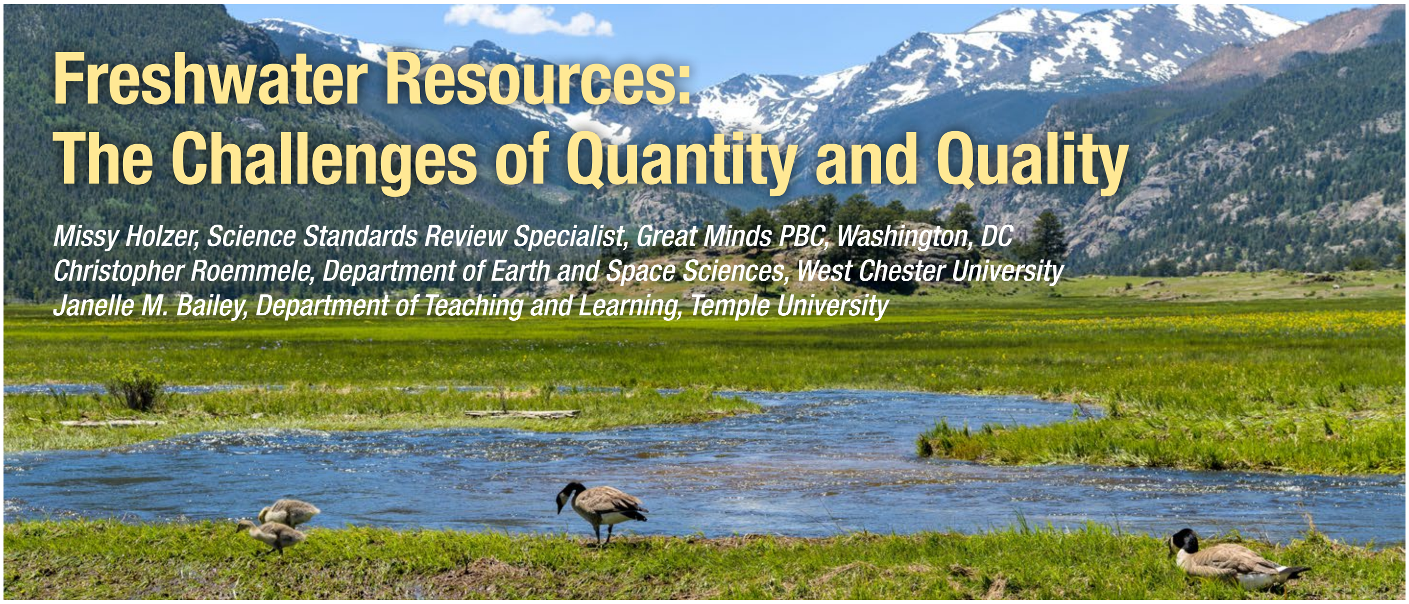

Freshwater Resources: The Challenges of Quantity and Quality

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Abstract

Freshwater resources are limited due to issues related to water quality and/or quantity. This article introduces a build-a-MEL that challenges students to address this socioscientific issue by considering the plausibility of three models: A) Earth has a shortage of freshwater, which will worsen as our world's population increases; B) Earth has a shortage of freshwater that can be met by engineering solutions; and C) Earth's freshwater is abundant and will remain so even in the face of global climate change. The eight lines of evidence in this build-a-MEL are data-rich and challenge students to think critically as they connect the evidence to the models. As a result of this activity, students develop an understanding of the spatial complexity of access to freshwater resources.

Since the publication of *A Framework for K-12 Science Education* (National Research Council, 2012, pp. 14 and 212), socioscientific topics have been brought up more often in science classes in general, and in Earth, environmental, and space science more specifically. When considering Earth and human interactions with the environment, human needs cannot be divorced from the science of natural resource management, climate change, and sustainability. However, when it comes to decision making around how we use our natural resources, scientific evidence plays the most important role in the decisions on how we, as humans, should interact with our Earth. An excellent example of a socioscientific issue worthy of consideration is that of freshwater resource management. This article describes an instructional model that challenges students as they grapple with competing viewpoints on this important issue.

Concerning Freshwater Resources

Water is essential for life; indeed, all ecosystems and organisms rely on water to function. Earth has a finite amount of freshwater to quench the needs of our growing population. Although we live on a water planet covered by more than 70% water, we find that nearly 97% of that water is in our oceans, rendering it close to unusable. Availability of freshwater is heavily dependent on the water cycle, which is influenced by global climate patterns.

Anthropogenic climate change is already impacting both the quantity and quality of Earth's water resources. Precipitation patterns are changing, and if there is no curtailing of greenhouse gas emissions, then the intensity and frequency of these patterns will continue to change in ways that we cannot yet predict. The inevitable outcome will be a reallocation of water resources away from some locations leading to droughts, and into other locations, which could result in persistent flooding.

Another limitation on the availability of Earth's freshwater is an ever-increasing human population on our planet, especially in areas that are already stressed from the lack of easy access to potable water. As populations in urban areas increase, the need for water in those areas also increases. To get water to places with the greatest need, a costly infrastructure system is required to divert or extract water from one place and transport it to another. In addition, agriculture requires the greatest use of potable water for food production, which is expected to increase nearly 70% over the next 15-20 years as our world population increases.

A great deal of our water currently comes from aquifers. Although these aquifers can often extend great distances and depths, the water available in them is finite and the continuous use of this water can lead to issues such ground subsidence or soil salinization. Therefore, access to groundwater should not serve as an invitation to populate regions where climates are typically very dry. The great quantity of water stored in aquifers can be easily depleted without proper management. Places where groundwater is extracted for agriculture have experienced ground subsidence caused by the loss of stability from over-extraction of water. This is another issue that will only get worse as our population increases across the planet.

Snow cover and glacier meltwater contribute to the supply of potable water for nearby communities, as well as those downstream from the flow of the meltwater. Despite climate change accelerating the loss of glacial mass and volume, this meltwater may only provide a short-term increase to the water supply. Even this supply of freshwater will eventually diminish as the glaciers continue to shrink and their meltwater becomes but a trickle. Snow cover in mountainous regions such as the Rockies has been unstable lately, as our climate has become more variable; this lack of snow cover translates into a decrease in freshwater supplies for the region and downstream the following year.

All the above challenges to water quantity and quality provide the basis for the Freshwater Resources build-a-MEL (baMEL), where students consider connections between eight lines of evidence and three models related to these challenges. The three competing models are: A) Earth has a shortage of freshwater, which will worsen as our world's population increases; B) Earth has a shortage of freshwater that can be met by engineering solutions; and C) Earth's freshwater is abundant and will remain so even in the face of global climate change. During this activity, students evaluate how eight lines of evidence connect to the three models to determine which model aligns with current scientific consensus. Three evidence statements (#1, 2, and 3) and associated texts lead students to consider the effects of land use changes brought about by global population increases. With surging numbers of people living in already stressed regions on our planet, the amount of freshwater (both groundwater and surface water) is severely compromised and being used a rate faster than local or regional recharge allows. Two lines of evidence (#4 and 5) are related to engineering solutions for water quantity and quality, and the final lines of evidence (#6, 7, and 8) reflect the issues climate change is having on our regional and global water supply.

Build-a-MEL Implementation

The content of this baMEL connects with *Next Generation Science Standards* (NGSS) performance expectations from ESS2 - Earth's Systems and ESS3 - Earth and Human Activity in middle school and high school (see Table 1; NGSS Lead States, 2013). Moreover, the content is a natural fit for AP Environmental Science (Unit 5, Land and Water Use), physical geography, and introductory college level science and socioscientific courses.

The Model-Evidence Link (MEL) and build-a-MEL activities can be accessed on our project's website, https://serc.carleton.edu/mel/index.html.

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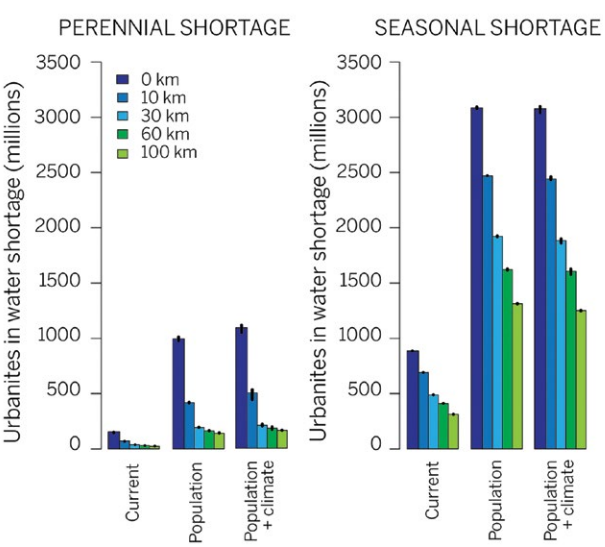
Table 1. *Next Generation Science Standards (NGSS)* Performance Expectations (PE) Related to the Freshwater Resources Build-a-MEL

PE Code	PE Description
MS-ESS2-4	Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
MS-ESS3-1	Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
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-ESS3-1	Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

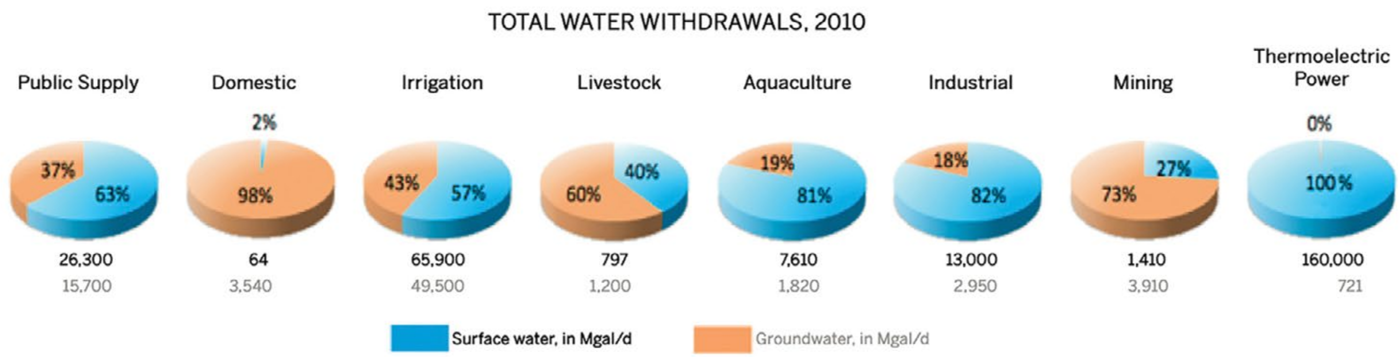
As with the previously developed MELs (see Bailey et al., this issue, and the Spring 2016 issue of *The Earth Scientist*), implementation of baMELs can vary from one class to another depending on the goals of instruction. There is quite a bit of flexibility in how baMELs are embedded in a course and how they are orchestrated within a class. They may be incorporated into the introduction of a new unit, challenge students in the middle of an instructional sequence with new ideas for a topic they are learning, or used as part of a summative assessment activity to check for understanding.

When implementing a baMEL in class, ideally students should have the ability to select two of the three models and four of the eight lines of evidence after surveying the evidence text for each line of evidence. Arguments for the selections students make may be based on a variety of reasons, such as the comparability between two of the models or how data is presented or interpreted in the evidence text. Another instructional option that is not recommended is for the teacher to preselect the scientific model, and allow students the freedom to select the second model from the remaining two. Modifying the activity in this manner would ensure there is a student voice in the selection process and that the scientific consensus model is included. However, the results of the activity may not provide the formative assessment information a teacher needs to check for understanding of the topic. Finally, to simplify the activity another suggestion for implementation is to have the teacher select the two models and narrow the options for the lines of evidence to fewer than the eight provided. By limiting the activity to four lines of evidence instead of the eight, the baMEL is converted to a MEL activity. However, with this implementation model, the opportunity for rich student discourse around the choice of models and lines of evidence is limited.

Figure 1. This figure from the text for Evidence #2 shows urban populations with either yearly on the left, or seasonal water shortages on the right. The bars show different distances from urban areas, and take into account current conditions, with an increase in population, and an increase in population coupled with climate change.



Scientists in the fields of Earth and space science employ a variety of data representations and figures in their work, and this baMEL includes a variety as well. The types of data and figures presented in the evidence texts of the Freshwater Resources baMEL may be new to students who are typically used to analyzing data in graphical forms only. Therefore, we suggest that you take time to discuss and interpret the data and figures in each evidence text. For example, the bar charts in Evidence #2 (Figure 1), or the coupling of the data in the pie charts with the multi-line graph in Evidence #3 (Figure 2), may not be as straightforward as they appear, and taking time to assist students may result in an improved instructional experience when engaging in a baMEL activity. One way to support students in their interpretation of the data and figures is to use the pedagogical tool called *Identify and Interpret* (I^2) *Strategy* (BSCS, 2012). In it, students first identify three "what I see" components of the figure, then determine "what it means" for each graphic, and finally craft a caption about the figure. Since there are eight lines of evidence, using a "jigsaw" approach may reduce the need to have all students perform this strategy for each figure. Learning how to interpret the charts and graphs embedded into the MEL or baMEL evidence texts is a necessary skill that will carry over to other science activities.



Closing

Access to freshwater resources has been in the public eye quite a bit lately as communities wrestle with contaminated water and droughts. When students feel connected to the content either personally or peripherally, they enjoy working through socioscientific issues such as this one. By considering various models and data-rich lines of evidence, students develop an awareness of the vast reach of this issue, and therefore are empowered to consider viable solutions for better use of Earth's natural resources (Medrano et al., 2020).

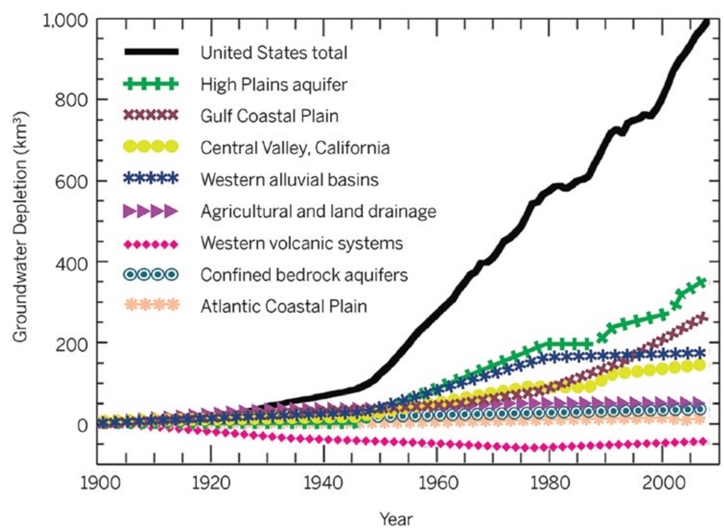


Figure 2. These figures from the text of Evidence #3 are combined to connect groundwater uses and rate of usage.

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