Topic: Mexico City's Water Crisis, a case study in hydrology, urbanization and water resources
Grade Level: 11-12
Courses: Designed for AP Environmental Science with possible modifications for the hydrology unit of Earth Science
Lesson Duration: 6-8 48 minute class periods

Justification

The world is becoming increasingly urban. Currently, 55% of the world's population lives in cities and by 2050 it will be 68%. Most of the recent growth in urbanization has taken place in the Global South in what are known as Megacities, cities with over 10 million inhabitants. Mexico City is the 2nd most populous city in the Western Hemisphere with 22 million inhabitants.

Providing city residents with adequate water, sanitation, energy, food and housing represents a tremendous challenge. In Mexico City, these challenges are compounded by its geological and political history and inadequate infrastructure, planning and maintenance of its systems. Present day Mexico City is built atop what was once the Aztec capital of Tenochtitlan, an island surrounded by wetlands and a large lake rimmed by mountains. As the Spanish conquered the Aztec empire, they converted this water-based indigenous city into a dry Spanish city. Over the last few hundred years, the water has been filled in and paved over so that now only a small remnant of this water city remains in the UNESCO World Heritage site of Xochimilco.

Mexico City's water crisis is very different than the water crises faced in other parts of the world such as Cape Town, South Africa or Chennai, India where there is water stress due to a decreasing per capita water supply. In Mexico City, there are three main issues: 1) the development of land in the valley with paved surfaces and storm water drainage means that most rain does not recharge the aquifer 2) the resultant overdraft of groundwater means that there is a decreasing water supply and the city is sinking which further stresses an outdated water system and 3) when it rains, there is flooding and the flood control measures unfairly impact poorer neighborhoods. The water supply issue is exacerbated by the inadequate maintenance of the system and the massive loss of water to leaks.

The case study of Mexico City's water crisis allows students to learn about groundwater over-pumping, permeability and infiltration of different substrates, wastewater management, flooding and environmental justice issues surrounding water management. This case study is also relevant culturally to many of my students who have family in the state of Michoacan, which is providing part of its surface water to Mexico City from the Cutzamala Water System. Some of the resources for this unit are in Spanish with English subtitles, which will make the information more accessible for my students who are native Spanish speakers.

Overall, the case study of the Mexico City Water Crisis creates a framework for teaching about multiple aspects of hydrology within the context of a relevant current event. Students can explore the possibility of engineering solutions that would be potentially transferable to other populous urban areas.

Standards: All standards are from the Next Generation Science Standards.

Students who demonstrate understanding can:

HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ESS3.C: Human Impacts on Earth Systems** • Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary)*	**Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. - - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Students who demonstrate understanding can:

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, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	- - - - - - - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Students who demonstrate understanding can:

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.**

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.	

Students who demonstrate understanding can:

HS-ESS2-5. **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	**Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

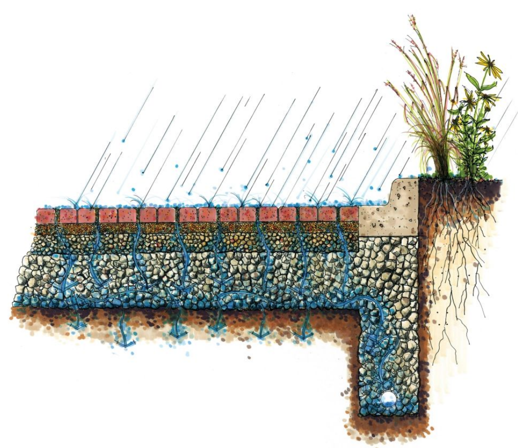
Measurable Objectives:

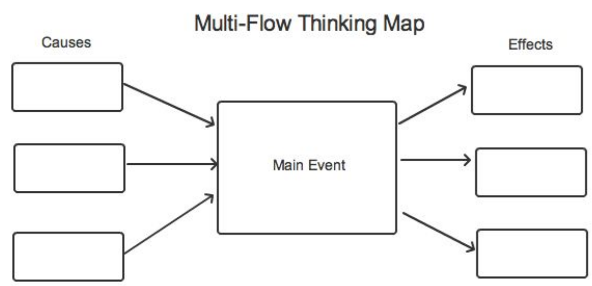
Students will be able to:

1) Identify a natural resource challenge from a variety of media sources
2) Design, construct and test a model landscape to illustrate hydrological principles
3) Summarize and analyze multiple sources and types of evidence related to an environmental problem (anthropological, government, scientific)
4) Use hydrological concepts to explain why an environmental problem exists
5) Evaluate water problems and potential solutions using a cost-benefit analysis while looking at political and technological constraints

Lesson Procedure:

Engage: Students are shown multimedia about the Mexico City water crisis and the topography of the city. They ask questions and identify problems that are occuring	Students look at Mexico City on Google Earth and discuss topography, location and density of urbanization Students listen to "Mexico City Keeps Sinking As Its Water Supply Wastes Away," a five minute audio clip by Carrie Kahn on NPR from September 2018 (https://www.npr.org/2018/09/14/647601623/mexico-city-keeps-sinking-as-its-water-supply-wastes-away) Students watch a 7 minute PBS Newshour video clip "Mexico City faces growing water crisis" from November 2014 (https://www.pbs.org/video/mexico-city-faces-growing-water-crisis-1422917376/) Students make a list of problems that are occurring and create a list of questions they have about why the problems are occurring

Explore: Students design and conduct experiments to understand the relationship between land use and the amount of water that infiltrates the ground vs. runoff. Students investigate the particular history and geography that affects Mexico City's water supply.	Students will be shown hydrological cycle diagrams and animations that illustrate concepts such as infiltration, groundwater, runoff and precipitation. (https://www.youtube.com/watch?v=ts19O41kwDA) There will be a class discussion of how the hydrological cycle was impacted by urbanization in Mexico City with a focus on impermeable and permeable surfaces. Students will design experimental models that allow them to show how urbanization affects hydrology. They will build 3D models that contain sediments and impermeable surfaces, have a source of water and will absorb groundwater and collect runoff. They can weigh the model before and after to show groundwater absorption. The models will be constructed on a slope to allow runoff to occur. Students will use materials to construct two test landscapes that will vary in the amount of permeable surfaces they have. They will design an experiment that shows how surfaces affect percolation, groundwater production, infiltration or permeability.  (https://ahbelab.com/tag/pervious-pavers/)

	Students work in groups to design a model on a white board that includes an explanation of the relationship between surfaces and hydrology using quantitative test results and drawings. Students share their models and come up with class understandings. They will apply this knowledge to explain what has happened in Mexico City as a result of urbanization. Students read about the causes and effects of the water supply problems in Mexico City (https://www.nytimes.com/interactive/2017/02/17/world/americas/mexico-city-sinking.html) and they use this information to make a multi-flow thinking map to show the causes and effects of the problems. 
Explain: Students explain how Mexico City's water system is functioning using hydrology vocabulary	Students will work in groups of 2 or 3 to create a text-based definition of hydrology vocabulary in the context of Mexico City's water management system. Each group will be assigned one or two terms and they will present their work to other students through a jigsaw. Groundwater Overdraft land subsidence Ground water Infiltration Permeability Flooding Combined sewers Students use previously viewed resources, group work and notes to help them form their explanations. Vocabulary

	definitions can include visual models if appropriate. Optional: View documentary on the Mexico City water crisis in sections to help students visualize the problems H20 MX documentary https://vimeo.com/103780777
Elaborate: Students apply their knowledge of hydrology and the Mexico City water management system working in groups to evaluate the impact of one aspect of the crisis. Students review various sources from journalists, anthropologists and water professionals working in Mexico to deeply understand the opportunities and constraints related to each issue	Students work in groups to understand how the water crisis affects people that live in Mexico City and its surrounding area. Each group focuses on one aspect of the problem and review the resources assigned to them: 1) **Unequal water distribution** Download PowerPoint and read the personal accounts on Day 3 (http://readinquirewrite.umich.edu/investigations/interpretation-mexico-city/) 2) **The Grand Canal and the sewage problem** "Mexico City's Water Crisis from Source to Sewer" by Jonathan Watts (https://www.theguardian.com/cities/2015/nov/12/mexico-city-water-crisis-source-sewer) 3) **Flooding** "Engineers Don't Solve Problems" by Dean Chahim (https://static1.squarespace.com/static/5259ce6ee4b05804955e2799/t/5b8435f6b8a045dc286d15ee/1535391233453/Chahim_Logic_Issue_5_Failure.pdf) A general resource for all topics: " Water Management in Greater Mexico City," Wikipedia (https://en.wikipedia.org/wiki/Water_management_in_Greater_Mexico_City) Each group creates a cost-benefit chart showing the impacts on people, the environment and political stability of using the current management practices. Charts are shared with the class orally.

Evaluate: Students return to the original questions they posed, propose and evaluate solutions based on their knowledge of the hydrology and social constraints of the crisis.	Students review the question list they created at the beginning of this unit. Each student will share a question and answer they have uncovered during this unit. Students will decide on one question or issue to try to solve. Students will create a 2-3 slide presentation with the following information: 1) What is the problem and who is affected by it? 2) How does this solution work? 3) What are limitations to being able to implement this solution? Students present their slides to the class and they are evaluated using the presentation rubric (see below) Additional Resources: Isla Urbana: Rainwater Harvesting https://islaurbana.org/english/ "Depave Paradise," 99% invisible podcast (https://99percentinvisible.org/episode/depave-paradise/)

Materials:

1) Chromebooks and WIFI
2) Landscape construction materials: trays, rocks, sand, impermeable layers, water, beakers or graduated cylinders, grass patches (sod), cardboard

Assessment/ Rubrics:
Final Slide Presentation Rubric: Solutions to the Water Crisis in Mexico City

Slides	Exceeds expectations (4 pts)	Meets expectations (2.5-3.9 pts)	Does not meet expectations (<2.5 pts)
What is the problem and who is affected by it?	Student demonstrates an understanding of the complexity of the problem. Multiple sectors of society or geographic locations are identified. The impact on different groups is identified by including the scope and scale of the problem.	Student understanding repeats already presented information. At least one affected group is correctly identified and the scope and scale of the problem is identified.	Student incorrectly describes why or where the problem is occurring. The impact is not correctly described or is incomplete.
How does this solution work?	The solution is clearly described and includes the logistics and costs of implementation. Visual aids make the solution more clear.	The solution is clearly described.	The solution is not clearly described.
What are limitations to being able to implement this solution?	The limitations show critical thinking about the feasibility of the solution. The underlying issues: lack of governance, policies, social inequality, etc are used to explain the limitations.	The limitations are repeated from previously mentioned ideas. They accurately describe what is going on.	The limitations are inaccurate or based on improbable situations.
Total Score ____/12 pts.			

Resources:

“Depave Paradise,” 99% invisible, Podcast.
https://99percentinvisible.org/episode/depave-paradise/

“Engineers Don’t Solve Problems” by Dean Chahim, Logic, Issue 5
https://static1.squarespace.com/static/5259ce6ee4b05804955e2799/t/5b8435f6b8a045dc286d15ee/1535391233453/Chahim_Logic_Issue_5_Failure.pdf

Enrique lomnitz, Isla Urbana founder
https://www.technologyreview.com/lists/innovators-under-35/2013/humanitarian/enrique-lomnitz/

H_20 MX documentary
https://vimeo.com/103780777

Hydrological Cycle Animation
https://www.youtube.com/watch?v=ts19O41kwDA

Isla Urbana: Rainwater Harvesting
https://islaurbana.org/english/

“Mexico City faces growing water crisis,” PBS Newshour video clip, from November 2014
https://www.pbs.org/video/mexico-city-faces-growing-water-crisis-1422917376/

“Mexico City keeps sinking as its water supply wastes away,” NPR Audio Clip
https://www.npr.org/2018/09/14/647601623/mexico-city-keeps-sinking-as-its-water-supply-wastes-away

“Mexico City Water Crisis from Source to Sewer,” The Guardian Newspaper
https://www.theguardian.com/cities/2015/nov/12/mexico-city-water-crisis-source-sewer

“Mexico City Sinking,” New York Times
https://www.nytimes.com/interactive/2017/02/17/world/americas/mexico-city-sinking.html

Permeability Labs
https://www.teachengineering.org/activities/view/cub_rivers_lesson01_activity1

Permeable Pavement
https://ahbelab.com/tag/pervious-pavers/

Water Management in Greater Mexico City
https://en.wikipedia.org/wiki/Water_management_in_Greater_Mexico_City

http://readinquirewrite.umich.edu/student_writing/interpretation-mexico-city/