

2022 N⁴WPP Water Challenge

Welcome students! Thank you for participating in our first ever N⁴WPP Water Challenge. **N⁴WPP** is the **Navajo Tech - New Mexico Tech - Navajo Nation Water Purification Project**. Navajo Technical University (NTU) and New Mexico Tech (NMT) have partnered to bring education and research opportunities for NTU and NMT students in a project with a long term goal of providing clean drinking water to the Navajo Nation. This partnership also strives to bring STEM projects to high school students to foster the growth of the next generation of hydrologists, water resource and civil engineers, and community planners and leaders. If you are interested in learning more about the N⁴WPP research project, please see more information at the end of this study material.

This water challenge will be broken into two sections:

Written Exam: The first part will be a written exam (multiple choice or short answer questions) focusing on basic hydrology concepts. Students will have an hour to complete the test and will be graded individually. No reference material will be allowed during the written test.

Problem Solving and Presentation: Following the written exam the students teams will present solutions to water problems commonly faced on the Navajo Nation today such as lack of infrastructure, water hauling, water quality concerns, etc. A challenge problem will be given one month prior to the competition to give teams time to consider the different aspects of the challenge and consider different strategies for solving the challenge. The presentation will be oral, though teams may use materials they have prepared for the presentation. The presentation to the judges should be short (5-8 minute). Teams will be given points according to the rubric provided in the challenge question.

Scoring: Teams will be scored by combining the individual test scores with the team presentation score to determine the team with the highest overall score. The total score will be an average of the total team score.

Example Score Cards -

Team A	Written Exam Score	Presentation Score	Total Score	Final Score
Student 1	75	80	$(75+80) = 155$	
Student 2	80	80	$(80+80) = 160$	
Student 3	95	80	$(95+80) = 175$	
Student 4	60	80	$(60+80) = 140$	
Team Score	$(75+80+95+60) = 310$	80	$(310+80) = 390$	$(390/4) = 97.5$

Team B	Written Exam Score	Presentation Score	Total Score	Final Team Score
Student 5	90	75	$(90+75) = 165$	
Student 6	90	75	$(90+75) = 165$	
Student 7	85	75	$(85+75) = 165$	
Team Score	$(90+90+85) = 265$	75	$(265+75) = 340$	$(340/3) = 113.3$

In this example, Student 3 was the individual winner, with a score of 175. Total team score is divided by the number of students on the team to keep scoring fair for different sized teams. In this example Team B was the team winner with a final team score of 113.

Study Materials

USGS

The USGS provides science about natural hazards that threaten lives and livelihoods; the water, energy, minerals, and other natural resources we rely on; the health of our ecosystems and environment; and the impacts of climate and land-use change.

- Water Resources Home Page with information on how we use water, measure and monitor water, and common water issues
<https://www.usgs.gov/mission-areas/water-resources/science>
- What is Hydrology?
https://www.usgs.gov/special-topics/water-science-school/science/what-hydrology?qt-science_center_objects=0#qt-science_center_objects
- What is Groundwater (OFR 93-643) <https://pubs.usgs.gov/of/1993/ofr93-643/>
- Sustainability of Groundwater Resources (Circular 1186)
<https://pubs.usgs.gov/circ/circ1186/pdf/circ1186.pdf>
- Ground Water and Surface Water A Single Resource (Circular 1139)
<https://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf>
- Aquifer and Groundwater Overview Website
<https://www.usgs.gov/special-topics/water-science-school/science/aquifers-and-groundwater#overview>
- Water Science School <https://www.usgs.gov/special-topics/water-science-school>

Science Olympiad

Hydrogeology (2014-2017 module)

<https://scioly.org/wiki/index.php/Hydrogeology>

Dynamic Planet: Fresh Water Hydrology (2022 module)

<https://www.noaa.gov/resource-collections/special-topics/2022-science-olympiad-freshwater-hydrology>

PBS

Free online water model. Use the model templates to explore the differing permeabilities of different sediment types, drill wells into model landscapes, explore the difference between confined and unconfined aquifers, discover how water moves around gaining and losing streams, and explore the difference between rural and urban area aquifers. Create your own landscapes to test ideas about water movement and sustainability of wells. Use the graphs to measure the amount of water from each well and monitor the level of water in streams.

<https://nm.pbslearningmedia.org/resource/8cfd4c05-5f24-40ab-aa0a-261263f4127f/water-model/>

NRCS

Hydrology 101

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082989.pdf

NASA

NASA Western Water Applications Office teamed with the Navajo Nation to create a Drought Severity Evaluation Tool. The tool aims to help the Navajo improve its ability to monitor and report drought through a combination of precipitation data from NASA satellites, drought indices and ground-based rain measurements. DSET will serve as a long-lasting resource for making maps and conducting time series analysis for climate variables and drought indices that can be used for water management and decision-making.

<https://wwao.jpl.nasa.gov/news-insight/articles/passing-baton-nasa-navajo/>

<https://app.climateengine.com/climateEngine>

Cultural Considerations for Sustainability

[Creating More Inclusive Spaces in STEM for Native Americans | by SACNAS | STEM and Culture Chronicle | Medium](#)

Water Quality

Water quality standards for drinking water are set by the US EPA. These standards are broken into mandatory (or primary) maximum allowable concentration levels and suggested (or secondary) concentration levels. A table showing these standards are below, but more information can be found at

<https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations>

<https://www.epa.gov/ground-water-and-drinking-water/drinking-water-activities-students-and-teachers>

<https://www.epa.gov/dwreginfo/drinking-water-regulations>

Water quality standards for livestock and agriculture are less clear cut as those set for human consumption. In most cases a range of water quality standards is given and will describe the level of impacts seen, but there is not one national standard set. A simplified version of these limits are presented in the table below. For more information see some of these sites:

Livestock suggested guidelines:

<https://www.ag.ndsu.edu/publications/livestock/livestock-water-quality>

https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf

<https://www.ag.ndsu.edu/publications/livestock/livestock-water-quality>

Poultry Guidelines:

<https://www.aces.edu/blog/topics/farming/evaluating-water-quality-for-poultry/>

https://www.agrolab.us/pdfs/AgroLab_Water_Interpretation.pdf

Agricultural Guidelines

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_051302.pdf

	Drinking water (mg/L)	Livestock (mg/L)	Irrigation (mg/L)
TDS	500	6000	2100
pH	6.5-8.5	5.5-9.0	
Aluminum	0.2	5	5
Arsenic	0.01	0.2	0.1
Barium	2	10	
Boron	7	5	0.75
Cadmium	0.005	0.05	0.01
Chloride	250	300	350(onion), 875(tomato), 1625(cotton)
Chromium	0.1	1	0.1
Copper	1.3	0.5	0.2
Fluoride	2	2	1 to 15
Iron	0.3	0.3	5 to 20
Lead	0.015	0.1	5 to 20
Manganese	0.05	0.05	0.2 to 10
Mercury	0.002	0.01	*
Molybdenum	0.2	0.5	1
Nickel	0.7	1	0.2 to 2.0
Nitrate(NO3)	44.3	150	
Selenium	0.05	0.05	0.13
Sulfate(SO4)	250	500-1500	
Uranium	0.03	0.2	*

Vanadium	0.1	0.1	0.1
Zinc	10	25	2 to 10
* not necessarily harmful to crops, but can accumulate in plant material over time			

Consumer Confidence Report (CCR), also known as an annual drinking water quality report from your water supplier. Your CCR tells you where your water comes from and what's in it.

<https://www.sjwd.org/files/247fb443f/2020+CCR.pdf>

Navajo Tribal Utility Authority provides CCR reports for Chapters it serves

<https://www.ntua.com/2020-ccr.html>

Typical Water Infrastructure

Infrastructure	Pros	Cons	Costs	Sustainability
New Well	Can provide a new supply of water.	Complex geology can make it difficult to predict the best place to drill a well. Water quality and flow rate can vary greatly.	\$\$\$ The deeper the well, and the larger the diameter, the more expensive the well.	Wells require regular maintenance of their pumps and equipment. Wells used for drinking water must be tested regularly for safety. Monitoring the depth of water in the well will help operators understand if the aquifer is being used at a sustainable rate.
Pipeline	Brings drinking water directly to homes, eliminating water hauling.	Right of way and permitting can be expensive and time consuming.	\$\$\$ Pipelines are typically evaluated by how many homes are connected per total mile of pipeline. Pipelines typically require large storage tanks to deliver water consistently.	Pipelines are subject to breaks and leaks, but are generally low maintenance once installed. Water tanks need maintenance to keep clean and in good working order.
Filtration System	Makes previously unusable water a new supply source. There are lots of different filters to meet different needs.	The complexity of the filter needed will depend on water quality and quantity. Wells with high flow rates will need larger systems than smaller wells.	\$\$ Initial system purchase and installation can be expensive. Annual costs include: power, filter replacement parts, maintenance staff.	Filters require regular maintenance and upkeep. Depending on the complexity of the system, the operator may require specialty training. A well maintained filter will last much longer than one that is not.
Cisterns	Cisterns provide localized places to fill water. They can be home scale or multi-home scale.	Water still needs to be hauled from the supply well to the cistern, and then a short distance from	\$ Cisterns are low cost to purchase and install. Costs to deliver the water to the cistern (by vehicle or	This is a low maintenance system, but still relies on water hauling to homes.

		the cistern to the home.	pipeline) should be considered.	
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Example steps for an infrastructure project.

General Project Steps	Description	Rough Timeline
Project Idea	Projects could be off the shelf solutions, new innovative ideas, or cultural ideas that have worked for centuries. This table outlines sample project steps for a typical construction project to install a new well, pipeline, tank, cistern etc.	
Community Buy-In	Water is a shared resource and the first step in any project is community discussion. Regular community planning to define the problems and to develop ranked priorities for improvement will help projects obtain funding and speed up the design process.	2-3 months to attend a planning meeting and a Chapter meeting with a resolution.
Check Land Status	Land in the 4 Corners region is typically a checkerboard of various land ownership. Projects that cross multiple parcels might need permission from each parcel owner.	2 months to work with local officials and online data
Project Design	If drilling a new well a hydrogeologic report to determine well depth and location is needed. If installing a filter system the water quality and flow rate will lead the filter design. A pipeline will require surveys of topography and estimates of size of lines and tanks are needed. Agriculture projects must evaluate soil and water conditions.	6 months - 2 years. Depends on the complexity of the project and available data.
Permits	Permits for any construction project will be needed to ensure no cultural or biological harm will occur, and that rivers or arroyos will not be impacted.	6-9 months. Weather and animal nesting/migration patterns can impact field work.
Obtain Funding	Applications for grants or project support can start much earlier, but are	1 year. Many grants

	often most successful once the permits are ready. There are many agencies that fund rural community planning and development. Such as USDA Rural Development, NM Indian Affairs Tribal Infrastructure Fund, Capital Outlay, etc.	open their application window at the same time frame each year. The review process can take several months, and money in hand to start work usually takes several more months after the award.
Construction	The project will be advertised, bids placed and reviewed, and contracts signed before construction can begin. Construction funds may be managed by the organization that granted the money for the project.	1-5 years depending on the complexity
Operation and Maintenance	Any project will require some level of long term maintenance to keep it running. Make sure that these costs are considered when designing the project and applying for funding.	Entire project lifetime

Glossary of Terms

acre-foot: volume of water that would cover 1 acre of land to a depth of 1 foot, the equivalent of 325,581 gallons.

aeration zone: the zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. Plant roots can capture the moisture passing through this zone but it cannot provide water for wells. Also known as the unsaturated zone.

alluvial: deposited by running water

aquiclude: A saturated geological formation that may contain water but does not transmit significant quantities.

aquifer: an underground geologic formation that is able to store and yield water

principal aquifer: The geologic unit that serves as the primary source of groundwater in a region.

sediment aquifer: an aquifer formed in loose sediments such as gravel or sand.

karst aquifer: an aquifer formed when water dissolves limestone rocks, creating interconnected caverns underground that hold water.

fractured rock aquifer: an aquifer where water resides in fractures in bedrock.

confined aquifer: A permeable formation whose upper boundary is an aquitard; water in a well within a confined aquifer will rise above the top of the aquifer.

unconfined aquifer: a permeable formation whose upper boundary is the water table. Also called a water-table aquifer.

leaky aquifer: an aquifer that is not perfectly confined but that has leakage across the surrounding confining layers.

aquifuge: a geological formation that is not porous or permeable so it neither contains nor transmits significant quantities of water.

aquitard: a geological formation that is of relatively low permeability and often acts as a barrier to water flow.

artesian well: a well in which water rises to the surface on its own.

cone of depression: the spatial pattern of drawdown in an aquifer as a result of pumping. The downward-pointing, cone-shaped surface of the water table in a location where the water table was previously saturated but has become unsaturated due to pumping. The shape of the cone is influenced by porosity and the water yield or pumping rate of the well.

confining layer: geologic material with little or no permeability or hydraulic conductivity. Water does not pass through this layer or the rate of movement is very slow.

depletion: the loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge.

dewatered area: area around a well where water is pumped out, resulting in the formation of a cone of depression and drawdown of the water table to the pumping level.

discharge: loss of water from the surface water reservoirs or groundwater through natural processes such as springs and rivers, or artificially by pumping wells. The opposite of recharge.

drawdown: a lowering of the groundwater level caused by pumping.

ephemeral: a term used to describe streams and arroyos that only flow in response to local rainfall or snowmelt events.

evaporation: the physical process involving a phase change from liquid to vapor from soils, lakes, streams and oceans.

evapotranspiration: The sum of evaporation from bodies of water and the ground surface and transpiration from plants and animals.

flow rate: the time required for a volume of groundwater to move between points. Typically groundwater moves very slowly, sometimes as little as inches per year.

gaining stream: a reach of a river or stream where groundwater is entering the channel through the riverbed and increasing the flow in the river and the volume of surface water.

groundwater: water that resides under the water table in a saturated zone of the subsurface, mostly in pores or cracks of rocks and sediments.

groundwater mining: prolonged pumping of groundwater at rates that exceed the rate of replenishment by recharge in an aquifer.

hydraulic conductivity: volume of water that will move through a unit area of saturated material, typically expressed as gpd/ft^2

hydraulic gradient: the slope of the water table.

hydrograph: a continuous record of streamflow (stage or discharge) or groundwater level in a well as a function of time.

hydrologic cycle: the global-scale, endless circulatory process linking (vapor) water in the atmosphere, to the (solid) ice in polar caps, to the (liquid) water in the oceans and lakes; also known as the water cycle.

hydrology: the study of the occurrence and movement of water on and beneath the surface of the Earth, the properties of water, and its relationship with the living and material components of the environment.

hydrosphere: the Earth's water, including surface water (lakes, rivers, and oceans), groundwater, and liquid water in the atmosphere.

impermeable: said of a water-bearing material that does not readily transmit or yield water to wells (such as clay).

infiltration: the movement of rain or melting snow into the subsurface.

infiltration capacity: the maximum rate at which water can infiltrate into a soil.

karst: a type of topography formed where groundwater dissolves limestone, dolostone, or gypsum to form underground opening or caverns, the roofs of which have collapsed in places to form closed depressions at the surface known as sinkholes.

land subsidence: the decline of the land surface produced by pumping groundwater wells slowly draining an aquifer and decreasing in volume because of pore collapse. May result in the formation of earth fissures on the land surface.

losing stream: a reach or stretch of a river or stream where the flow in the river is entering the groundwater by percolating through the riverbed and into the subsurface, decreasing the volume of surface water in the river.

mining: see overwithdrawal.

monitoring well: a non-pumping well, generally of small diameter, that is used to measure the elevation of the water table of the water quality. A piezometer, which is only open at the top and bottom of its casing, is one type of monitoring well.

overwithdrawal: withdrawal of groundwater over a period of time that exceeds the recharge rate of the supply aquifer; also referred to as overdraft or mining the aquifer.

perched water table: a quantity of groundwater that lies above the regional water table because an underlying lens of impermeable rock or sediment prevents the water from sinking down to the regional water table.

percolation: the process by which groundwater meanders from the surface, through the soil and unsaturated zones, down to the groundwater.

perennial: said of a stream that flows year-round.

permeability: the degree to which a material allows fluids to pass through it via an interconnected network of pores and cracks.

permeable layer: a layer of porous material (rock, soil, unconsolidated sediment); in an aquifer, the layer through which water free passes as it moves through the ground.

pH: measure of hydrogen ion concentration in a liquid; 1-7 is acidic, 7 is neutral, 7-14 is alkaline.

plume: a groundwater plume is an underground pattern of containment concentrations created by the movement of groundwater beneath a contaminant source. Contaminants typically spread laterally in the direction of groundwater movement.

pores: a small, open space within sediment or rock; may be voids between grains or along cracks and solution channels.

pore collapse: the closer packing of grains that occurs when groundwater is extracted from pores, thus eliminating the support holding the grains apart.

porosity: the ratio of empty or air space (pore space) in a material such as rock, sediment, or soil to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated sand contains about 20% water.

potentiometric surface: level to which groundwater will rise in wells.

precipitation: the dominant process by which water vapor in the atmosphere is returned to the Earth's surface either as liquid drops (e.g. rain) or solid particles (e.g. snow) under the influence of gravity.

produced water: water that is produced during the extraction of petroleum from underground reservoirs. These reservoirs contain a mixture of water and petroleum so produced water is an inevitable byproduct of the extraction process.

pumping water level: the level of groundwater in a well after pumping has lowered the water table by creating a cone of depression.

recharge: when water enters the ground and infiltrates into an aquifer.

diffuse recharge: when water infiltrates into an aquifer across a broad area through the soil.

focused recharge: when water infiltrates into an aquifer at a discrete location, such as through a stream channel bed or artificially through an injection well

recharge area: a location where water enters the ground and infiltrates down to the water table; also called a recharge zone.

remediation: containment, treatment, or removal of contaminated groundwater or the contaminated soil above the water table.

residence time: the period of time that groundwater remains in the aquifer.

runoff: water flowing over the land surface.

safe yield: the annual amount of water that can be taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally.

salt water intrusion: process by which an aquifer is overdrafted creating flow imbalance within an area that results in salt water encroaching into fresh water supply.

saturated thickness: total water-bearing thickness of an aquifer.

saturated zone: a region of the subsurface where pores are completely filled with water; the saturated zone is bounded at the top by the water table.

seasonal well: a well that provides water only during the rainy season when the water table rises below the base of the well.

sinkhole: a circular depression in the land that forms when an underground cavern collapses. Common in areas with karst aquifers.

soil moisture: water that is held in soils and rocks in the unsaturated zone.

solution channel: underground passage formed by the widening of cracks through dissolution of limestone, dolostone, or gypsum.

spring: a natural outlet from which groundwater flows up onto the ground surface.

static water level: the water table elevation under natural, stable conditions, i.e. when there are no pumping influences

stratum, pl. strata: a layer within the earth's crust that generally consists of the same kinds of soils or rock material.

sublimation: the physical process by which water in the solid phase (snow or ice) changes to water vapor and is directly returned to the atmosphere.

subsidence: a depression of the land surface as a result of groundwater being pumped. Cracks and fissures can appear in the land. Subsidence is a virtually irreversible process.

surface water: water above the land surface, including lakes, rivers, streams, ponds, floodwater, and runoff.

surface runoff: water from rainfall or snowmelt that runs over the surface of the Earth in sheets, rivulets, streams, and rivers.

sustainable yield: see safe yield.

transpiration: the physical process by which water changes phase from liquid to vapor, is released through the stomata of a plant, and returns to the atmosphere.

unsaturated zone: the zone in a soil or rock between the Earth's surface and the water table; pores in the unsaturated zone are partly filled with water and partly filled with air. Also called the vadose zone.

water table: The boundary, typically parallel to the Earth's surface, between saturated subsurface layers (the pore spaces are filled with water) and non-saturated layers (the pores are filled with mostly air and some water).

well: a bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies to inject, extract or monitor water.

well casing: a pipe, typically steel or PVC, that serves to line a well.

well closure: the process of sealing a well that is no longer being used to prevent groundwater contamination and harm to people and animals; also referred to as well plugging, or plugging and abandoning.

well screen: a section at the end of a well casing that allows water to enter the well; construction may be holes drilled or slots cut in a pipe or may be a wire mesh material.

well siting: location of a well placed to best protect water quality, access adequate water quantity, and allow for inspection and maintenance of the well.

wellhead protection area: a protected surface or subsurface zone surrounding a well or well field supplying a public water system to keep contaminants from reaching the well water.

withdrawal: the quantity of water extracted from a ground- or surface-water source.

zone of influence: the area of the cone of groundwater depression formed when the well pump is operating.