17. Working Water

Agriculture Along the River

Description: With a concentration on the agricultural aspect of the Middle Rio Grande Valley, students focus on creating an irrigation system on the "River of Change" model, expanding on and exploring human influence on the Rio Grande created in the Rio Manso river model.

Objectives: Students will understand:

- one of the main human uses of the river, agriculture;
- the physical characteristics and layout of an agricultural district;
- science and engineering elements in an irrigation system; and
- impacts of agricultural system on the bosque ecosystem.

Phenomenon: Irrigation water flows from the river through ditches to the fields.

Lesson Questions:

- *How does irrigation water work?*
- *How does it get here, and where does it go?*

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Grades: 2–12

Time: initial materials preparation about 30 minutes; another hour to assemble the river, learning where each component goes and how it affects the river system

Subjects: science, social studies

Terms: *acequia, check, dam, ditch, gaging stations, high-line canal, irrigation district, lateral, real-time data, riverside drain, suspended sediments, turnout*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

5.ESS3.C Human Impacts on Earth Systems

5.PS2.B Motion & Stability: Forces & Interactions

MS.ESS 3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems

MS.ETS2.B (MS-ESS3-3 NM) Influence of Engineering, Technology & Science on Society & the Natural World

NGSS CCCs

Cause & Effect: Mechanism & Explanation; Systems & System Models

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions*; Obtaining, Evaluating & Communicating Information*

Materials:

- River model set up as Rio Manso. It helps if there is something underneath the model so students can see a slope from foothills to river, and imagine the force of gravity helping the irrigation system work.
- One copy of Working Water student cards
- Scissors
- Envelopes or sandwich bags to hold the pieces and information cards
- Colored pencils or markers (optional)
- Material (listed by color) for various waterways:
  - Rectangular piece of paper or felt for the diversion/utility dam; cut at least the width of the river
  - Two long strips of light-blue fabric or ribbon approximately the length of the river for the high-line canal (these are in addition to the strips or flagging used in "Changing River" to represent the drains alongside the levees described below)
  - Eight shorter strips of blue fabric or yarn for the laterals, acequias, and ditches; they should be about one-fourth the length of the river
  - 20 or so circles, about an inch in diameter, for turnouts
  - Trapezoids or rectangles to represent checks
  - Two long thin strips of fabric the length of the river for the river-side or interior drains (or use the Rio Manso drains)
  - Six to eight small cylinders, cups or film canisters for the gaging stations
  - Distinctive yarn to outline the conservancy district's boundaries

Background:

Irrigation districts, or conservancy districts, are groups of farmers who have come together and pooled their resources so as to reduce the time, money and effort required for profitable irrigation-based agriculture. Instead of trying to maintain their own individual ditches and diversion structures and manage their own allotments of water, farmers can form an irrigation district that is responsible for all the aspects of irrigation for an agriculture community. These aspects can include ditch maintenance, water delivery scheduling, system improvements, water managing and possible legal actions, to name a few. Typically, taxes and water delivery fees are collected by the irrigation district for these uses. The benefit of an irrigation district is obvious in a place like the Middle Rio Grande Valley. It is much more efficient for 10,000 individual farmers to work together, as they do here, than for each one to work on his or her own.

The major purpose of an irrigation district is to efficiently deliver water from a given river to farmers who have water rights on that river. Irrigation districts use gravity as the key force to move water efficiently. Gravity is the force that one body, the earth, has on a second body, in this case water. The important idea to remember here is that the force of gravity on earth pulls all objects towards the center of the earth, and thus always pulls downhill. This being the case, irrigation districts can use gravity to their advantage to convey the water to the desired fields. **Diversion dams**, the structures that divert water from the river, are located at the highest point in the district. Diversion dams feed high-line canals, which are the major artery of the irrigation district. **High-line canals** tend to follow the highest points in the valley that are possible while the water is still flowing downhill, so that as much land as possible can receive water. **Laterals, ditches** and **acequias** branch off the high-line canals and run downhill towards the farmer's fields. Often a farmer will have a personal ditch that delivers water to particular fields the farmer irrigates. These also move water via gravity. In general, all the ditches in an irrigation district drop in elevation more slowly than the river from which the water came. This way, water that is not used by the farmers can return to the river downstream via the force that originally removed the water.

Sometimes the level of water at a particular point in a ditch is too low to feed a turnout to an offshoot ditch. A **turnout** is basically a pipe coming off a ditch which can be open and closed as is needed. This problem is easily solved by the use of a **check** structure. A check is a miniature dam that can be put in place and removed as needed. By placing a check in a ditch that would otherwise have a water level too low to feed a turnout, the level of water above the check will rise and eventually force water into the desired turnout. This is a major way the irrigation engineers can manipulate gravity.

The lowest part of the system are the drains. These lower the ground-water level so that irrigation water will move through the soil and away from plants' roots. An analogy is a house plant in a pot. There is always a hole in the bottom of the pot for excess water to drain out so the roots don't get saturated. Drains in irrigated lands flow into the river, returning water to the Rio Grande.

Irrigated agriculture has been going on in the Middle Rio Grande Valley since the 1600s. The Middle Rio Grande Conservancy District (MRGCD) was formed in 1923 combining more than 70 individual community acequias, or small irrigation districts. An entirely new irrigation network was created to better irrigate the land in the Middle Rio Grande Valley. The MRGCD has four diversion dams (Cochiti, Angostura, Isleta and San Acacia) and more than 1,200 miles (1,920 km) of ditches. The district encompasses about 300,000 acres (120,000 ha) of total area. The MRGCD has rights to about 130,000 acres (52,000 ha) of irrigable land, which means that not every acre in the district is irrigable. For example, the district owns almost all of the bosque, but does not irrigate it. Often, as is the case in Albuquerque, the MRGCD lets other agencies manage their lands. Albuquerque Open Space manages the bosque between the Sandia and Isleta Pueblos. The MRGCD is an agency of the State of New Mexico, and thus has a governing board of directors who are elected in local elections. The MRGCD has its own tax base with which to run its operations.

Procedure:

- Begin with a **KWL** activity. *What do the students **Know** about irrigation? What do they **Want** to know about irrigation?* After the activity, ask *What have they **Learned** about irrigation?* **(Asking Questions & Defining Problems)**

- Discuss students' experiences with irrigation, ditches, etc. *Do their families irrigate? Do they walk along ditches in the valley? What do they know about the flow of water and irrigation? What do they notice about how the water flows in the ditches and drains? How does it compare/contrast to the flow of water in the Rio Grande?*

  What causes rivers to flow?(Gravity) **(5.PS2.B)**

  How do many farmers in the valley irrigate their fields? (From ditches. Some use pumps to bring up ground water, but our focus will be those who use ditches/acequias/laterals to irrigate.)

  What powers the system of ditches and drains? (Gravity) **(5.PS2.B)**

  Making use of the laws of gravity, irrigation water is distributed throughout the valley. Remember as you work on this activity that water does not flow uphill!

  Where would you place the high-line canal? Think about how to use gravity to water fields. (You want to keep the canal along the far edge of the mesa, so it slowly flows downhill. This way you can use gravity to drain into fields toward the river.)

- Think in terms of Systems (see Appendix K). The network of acequias and ditches forms a system to irrigate farmers' fields. *What are the boundaries, components, interactions, inputs and outputs, and properties of this system?* **(Systems & System Models)**

Start with the Rio Manso model set up

- Divide the class into eight groups and pass out one Working Water card and appropriate items to each group.
- Have students read the cards and place their items on the Rio Manso model when instructed to do so.
- Tell the students to place items on the model in the order given below. Each group should describe what they have placed to the entire class and why they chose to place it where they did.
    - irrigation district
    - diversion dam (at the most upstream location in the district)
    - high-line canal (take in the widest section of the valley to maximize available farmland)
    - lateral ditches and acequias
    - farm fields
    - turnouts for fields
    - check dam to make turnouts work
    - gaging stations where you want to know how much water is being used (at the diversion and other places)
    - drains if they are not already in place

Discussion Questions / Assessment

Look back at the KWL charts. *What have students **Learned**? What additional questions do they have?*

Have students think about these ideas:

How has agriculture affected the Rio Grande Valley? **(Cause & Effect)**
How have farming practices changed over the last century?
What engineering projects have been built to provide water for irrigation for farmers?
What engineering projects protect our communities from flooding?
What engineering projects help farmers conserve water? **(5.ESS3.C; MS.ESS3.C; MS.ETS2.B)**

Extensions:

- Challenge students to build their own gravity-driven water system (they cannot use a running hose for power!) A tub of water could be their source. They could devise a system to divert runoff water from a roof or parking area to water native landscaping. **(Constructing Explanations & Designing Solutions)**
- Students can research traditional agricultural practices and compare those to more modern agriculture. What are advantages or disadvantages of each system? Have students present their findings using posters, written papers, or other formats. **(Obtaining, Evaluating & Communicating Information)**
- Oral history extension: have students talk with elders about agriculture and specifically about irrigation methods. Students may present their findings using posters, written papers, or other formats. **(Obtaining, Evaluating & Communicating Information)**

NGSS Connections to Working Water: Disciplinary Core Ideas

5.ESS3.C Human Impacts on Earth Systems *Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.*

Humans have made many changes to the Rio Grande Valley, some of them to help farmers get dependable water for their crops. Diversion dams direct water from the river into highline canals and irrigation ditches; deep trenches called drains ensure fields are not water-logged. Levees keep the river from flooding homes and agricultural fields. Water in ditches may help cottonwoods and other native plants grow in places away from the river. While flood irrigation is common in the valley, farmers typically have their field laser-leveled, which reduces water use.

How has agriculture affected the Rio Grande Valley, including the local floodplain ecosystem?
How have farming practices changed over the last century?
What engineering projects have been built to provide water for irrigation for farmers?
What engineering projects or agricultural practices help farmers conserve water?

5.PS2.B Motion and Stability: Forces and Interactions; Types of Interactions *The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.*

The force of gravity acts on water on the Earth's surface, resulting in the movement of water "downhill", toward the center of the Earth. This drives the flow of rivers and the movement of water in irrigation ditches. Farmers use this simple but powerful force to irrigate their fields!

What causes rivers to flow?
What powers the system of ditches along the Rio Grande?

MS.ESS3.C Human Impacts on Earth Systems

-Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

-Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

-The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

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How has agriculture affected the Rio Grande Valley?
How have farming practices changed over the last century?
What engineering projects have been built to provide water for irrigation for farmers?
What engineering projects protect our communities from flooding?
What engineering projects help farmers conserve water?

What are positive and negative impacts from agriculture—brainstorm lists of each.

MS.ETS2.B Influence of Engineering, Technology, and Science on Society and the Natural World

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

After years of building structures in the Rio Grande and its floodplain with the goals of reducing flooding, drying out waterlogged soils and delivering water for irrigation, biologists began to see impacts on the bosque ecosystem that were not intended or expected. The cottonwood forest corridor of the river was getting old, with few seedlings growing to replace them. Fish species like the Rio Grande silvery minnow were not finding the shallow, muddy, backwater areas needed to lay their eggs and produce successful fry. Use any of the following ideas after the "Changing River" activity to explore how New Mexicans have urged changes to the management of the river over time and how they are urging preservation of the bosque into the future.

How does the public influence/impact the management of the bosque?
How has the management of the bosque changed from the early 1900s to today? Describe who has influenced changes in management over these decades?

List long term impacts of major engineering projects concerning Rio Grande water, including original intent and unexpected results. Examples: dams, levees, sewage treatment plants, irrigation, agriculture, city water use, straightening the river, jetty jacks, San Juan-Chama diversion, growth of cities, pollution, industry, and mining.

Acequia Terms

Acequia: (n) a hand-dug, gravity-fed, canal that diverts water from a stream or other natural water source to irrigate fields, orchards and gardens

Acequia madre: (n) literally "mother ditch" this is the main canal that takes water from the river and divides into each acequia

Atarque: (n) a temporary dam built across a river to divert water into the acequia madre

Compuerta: (n) a headgate that regulates and divides the flow of water

Desagüe: (n) a drainage ditch that channels surplus irrigation water back into a stream

Limpiar: (v) to clean, spring cleaning of the acequias, limpia: (n) community cleaning event

Lindero: (n) also known as sangria, a lateral canal that channels water from the acequia madre to individual properties

Mayordomo/a: (n) a ditch boss who allocates water and oversees canal maintenance

Milpa: (n) a plot of cultivated land used for growing maize

Parciante: (n) a ditch member/irrigator, who works the acequias

Presa: (n) an out-take or diversion dam that diverts water from a stream or other natural water source to move it down- hill via the main canal

Regar: (v) to irrigate

Repartimiento: (n) the partitioning or dividing of waters between ditches that share the same stream or among the parciantes within a single acequia

Sangria: (n) also known as lindero, a lateral canal that channels water from the acequia madre to individual properties

Tiempos: (n) a rotating period of time in which ditch water is allocated

El Agua es Vida, Acequias in New Mexico, Loan Kit Teacher's Guide. Grochowski, A.L. Maxwell Museum of Anthropology, University of New Mexico. 2019.

Working Water Cards

Diversion Dam

A diversion dam is a restrictive structure that is built in a river or waterway so that water can be diverted into irrigation canals for agricultural use. Dams have many uses and not all dams are the same. An agricultural diversion dam typically does not create a reservoir behind it. Diversion dams reduce the flow of the river below the dam structure, trap sediment, and sometimes act as barriers to movement of biological organisms.

- Place the dam at the top of the river system where the high-line canals begin.

High-line Canal

A high-line canal (called an acequia madre (a-SAY-key-a MOD-ray) in northern New Mexico) is the main artery of the irrigation district. It is the large channel that carries water from the diversion dams on the river out across the valley floor by the force of gravity. High-line canals usually fan out from the river and move to the highest points in the valley that are possible while still having the water flow downhill. This way land that is a good distance from the river can still receive water. Once away from the river, the high-line canal usually runs parallel to the river. The high-line canal feeds smaller channels called laterals and acequias.

- Use the lightest blue ribbon or yarn to show the high-line canal.

Lateral, Ditch, and Acequia

These are all terms for smaller channels that spread out like a spider's web from the high-line canal. Typically farm land will be irrigated directly from one of these channels. Larger farms may also have many small channels to deliver water to individual fields. All of these names are interchangeable depending on the local tradition. Note: the term acequia (a-SAY-key-a) can be applied to an actual channel, but is also the term used for the small group of farmers who manage a small irrigation district. The term tends to be used in historical contexts and in upper watershed areas. Farmers' fields are usually clustered around these channels. Remember that gravity is needed to move the water, so the field should be lower than the acequia.

- Use blue yarn to show the laterals/ditches/acequias.

Turnout

A turnout is an irrigation structure that allows a farmer to pour water on a field from a lateral, ditch or acequia (a-SAY-key-a). Often a turnout is located above a check (mini-dam). Turnouts should be placed in irrigation channels where fields are located. A single field usually has multiple turnouts.

- Use small circles to represent the turnouts.

Check

A check is a mini dam on a high-line canal or lateral that causes the water upstream to build up, thus forcing it through turnouts into laterals or onto farmers' fields. Typically, there must be a check for a turnout to function properly.

- Place a check just downstream from any lateral on the high-line canal and a check just below each turnout to a field on a lateral.

River-side Drains

River-side drains (interior drains) closely follow the contours of the river and serve to lower the water table and collect groundwater, which is eventually returned to the river. Although they are also used by agriculture, the river-side drains' main job is to collect excess groundwater and lower the water table in the valley so it is not just a big swamp. They are also called "clear ditches" because the groundwater they collect is free of suspended sediments. These drains generally begin just after the diversion dams and gradually increase in size the further downstream they go. Like levees, they tend to confine the bosque within them. These may already be in place with the Rio Manso setup.

- Place the river-side drains just outside the levees.

Gaging Station

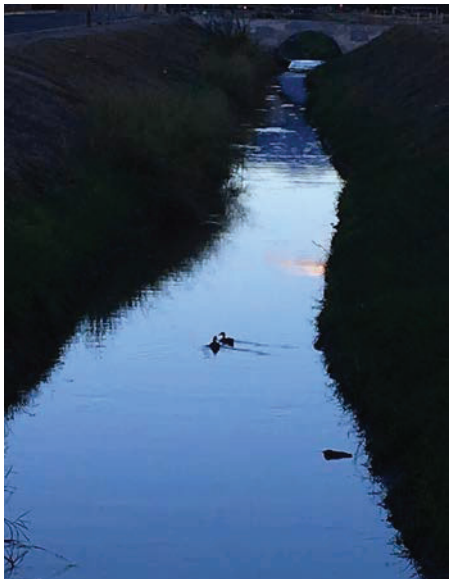
Gaging stations are used by hydrologists for continuous measurement of flows in both the river and the irrigation channels. Older models use physical recording devices to record flow levels over time, while newer radio and satellite-based gaging stations provide real-time data to be used in managing river and irrigation operations. Typically only large canals and drains, as well as the river, have gaging stations. A good rule of thumb is "the scarcer the water, the more gaging stations."

- Place gaging stations near the banks of major waterways and critical junctions in the irrigation system.

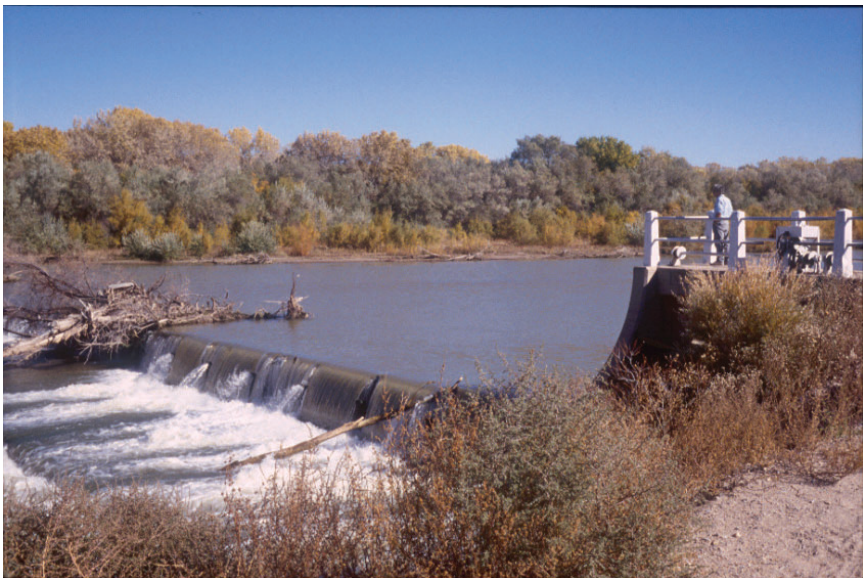
Irrigation District

An irrigation district, like the Middle Rio Grande Conservancy District, consists of citizens who live in the river valley on land that has the possibility of being irrigated. Not all land in the irrigation district actually receives water, but all residents in the district's boundaries pay taxes and can vote for the district's governing board. Those who receive water pay only a delivery fee because, if they still own their land's water rights, then they legally own the water. The irrigation district should include any land that can be watered via gravity.

- Use thin black yarn to outline the irrigation district's boundaries.



A drain in the valley lowers the groundwater levels.
Photograph by Mark Higgins



A diversion dam of the Middle Rio Grande Conservancy District near Algodones.
Photograph by Letitia Morris

The metal structure on the left is a check. When it is closed the water in the high-line canal or lateral builds up to a level that will flow through the turnout, shown at lower right, into a farm field or smaller ditch.
Photograph by Anders Lundahl

Schematic of Middle Rio Grande Conservancy District Water System