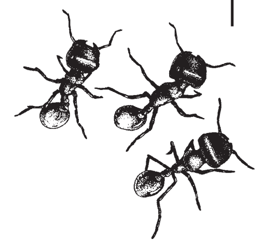


Chapter 5

Meandering Channels: School-based Activities

19. The Web

Interactions in the Bosque Ecosystem

Description: Students choose a plant or animal in the bosque; then, while standing in a circle, they show connections with other plants or animals by passing a string from one to another.

Objective: Students will learn that:

- there are many species which depend on each other in the bosque ecosystem; and
- that the loss of one will affect other species.

Materials: large ball of string

bosque animal cards (pictures only) from the "Who Lives Where?" activity

bosque plant cards from "Who Grows Where?"

Prerequisites: This activity is best done after the students have completed the "Who Lives Where?" activities.

Procedure: Select an assortment of bosque plants and animals so that there is one for each student. Use the pictures of animals from the "Who Lives Where?" activity and pictures of plants from "Who Grows Where," all of which are in this guide. Include a cottonwood and an insect, such as the mosquito. Pass out the plants and animals. Have all the students stand in a circle, and state what plant or animal they are. Then challenge them to make connections between themselves and another plant or animal.

The discussion might go as follows:

"All the energy for plants and animals on the Earth comes from what? (*the sun*) What organisms on Earth make use of that energy directly? (*plants*) So let's start with a plant. *(Give one end of the string to a plant.)* What eats the plant? *(Send the string to an herbivore.)* What

19. The Web

Grades: 1–8

Time: 20 minutes

Subjects: science, extensions in language, writing, drawing

Terms: *food web, herbivore, carnivore, ecosystem, threatened/endangered species* eats an herbivore? *(Send the string to a carnivore.)* Now let's make as many connections as we can think of between everything here. We also want to get beyond just what eats what. Think about as many ways as you can in which one organism might need another: Where will its home be? Does it need a place to perch to find food? Does it need the droppings of something to fertilize it? Be creative in thinking of connections."

Pass the string between all organisms to which they are connected. Make sure everyone is included. You will have created quite a web.

Continue the activity by asking:

"What happens when we lose a piece—one of the organisms in an ecosystem? How about the mosquito? I don't like mosquitoes. I would prefer not to be bitten by any more mosquitoes, so I am going to spray pesticides to get rid of them. Mosquito, you shake your string(s) to show that something is happening to you. Who feels the shaking? You have been affected by the loss of the mosquito. Now everyone who feels the shaking, shake your strings to pass it on. In this way the loss of one species is felt by many others. One change in an ecosystem ripples throughout. In real life there are many connections between organisms, connections that researchers are just now learning about. Sometimes we find out about a species only when it is too late to do anything to save it.

"In New Mexico, the state flower is the yucca. There is only one kind of insect that can pollinate the yucca flower—the yucca moth. Other insects may visit the flower, but only the yucca moth has the ability to pollinate it. If something were to happen to yucca moths and no more were alive, we would not have any more yucca plants starting, and once the old ones die off we would have no more yuccas. The yucca fruits are eaten by people and animals; birds nest within the spiny leaves; pueblo people have used this plant for generations to make string and rope for sandals, nets, etc., and a soap from the roots. So without one kind of insect, one kind of plant would be lost. The loss of that plant would affect many, many other organisms. It is for these reasons that we talk about threatened and endangered species.

"Along the Rio Grande, the large cottonwood trees will sometimes have holes where a branch has died or a woodpecker has excavated a nest hole. These cavities are used by many other birds for their nests. Woodpeckers can make their own holes, but other birds must find a hole already prepared. Starlings, birds introduced to America from Europe, have moved into the bosque and are very aggressive about claiming holes for nesting. They start early in the year before native birds nest or they push out the native birds and claim a hole for themselves.

"Another factor that is reducing the holes available for nests is that there are fewer and fewer large cottonwoods and more and more small trees like tamarisks and Russian olives. These trees are not native to North America but, since their introduction along the Rio Grande, they are the most common plants in some areas. They never get to be very large and are not big enough for woodpeckers to make their nest holes. Without cavities in the trees, many species are not able to nest and raise young.

"These are examples of changes in the natural system that cause effects no one even thought of before . . ."

Assessment: Have students draw their plant or animal along with other things it needs to survive. Do a group mural showing all the parts of the bosque ecosystem they have learned about.

Extensions: Have the students write about the plant or animal they have been in this activity. What would a day in the life or a year in the life of this organism be?

20. Bosque Leaf Hunt Relay

This activity was adapted from the activity "Leaf Hunt Relay" from Project Learning Tree and the Insect Variation developed by Bob Cain, Forest Entomologist for New Mexico State University Extension Service.

Description: Students participate in relay teams to identify leaves of bosque plants. For each race, the student team mimics a bosque arthropod and learns about the relationships between these animals and plants.

Objective: Students will:

- learn characteristics of arthropods;
- be able to identify some bosque plants by their leaves; and
- learn about plant/insect relationships in the bosque.

Materials: eight boxes or large paper grocery bags (fit over team members' heads)

two or four "bug eyes"—compound eyes—or poke several holes in the base of two paper cups, a set for each team

Background: Plants and insects are highly dependent on each other. Many plants rely on insects for pollination in order to make seeds and reproduce. Likewise, many insects rely on plants for food from leaves, pollen, seeds, roots, etc. This activity helps emphasize the importance of this dependence between the plant and insect world. It is also a "fun" environment to present some basic information about insects and build some appreciation for the insect world. Here are some general concepts on arthropods. Specific information on arthropods in this activity can be found in the ***Procedures*** section or Appendix E.

All insects have six legs.

Insects are the largest group of animals. One million species have been named, which is probably only one percent of the estimated number of insects.

20. Bosque Leaf Hunt Relay

Grades: K–6

Time: 30–45 minutes

Subjects: science

Terms: *pollination, arthropods, compound eyes*

Most insects have wings.

There are insects that humans consider good and bad:

- some of the negative things insects do are: spread disease, kill crops, cause discomfort, destroy homes (termites), kill trees; and
- some of the positive things insects do are: pollinate flowers, kill other insects, provide food for birds, fish, etc., provide honey.

Spiders, isopods (pillbugs), centipedes, and millipedes are not insects. Spiders have eight legs. Pillbugs have 14 legs. Centipedes and millipedes have many legs.

Procedure:

1. Collect leaves from plants in the bosque as a classroom project or on your own. Avoid stripping live leaves if at all possible; use leaves which have fallen beneath the tree, shrub or herb. For future use, you may want to press the leaves, mount them, and laminate or cover with contact paper. Here are the plants that are suggested for this activity, but other plants can be substituted depending on what is available (or you may use plant cards from the "Who Grows Where?" activity):

saltgrass	Russian olive	cattail
coyote willow	saltcedar	cottonwood (2)
sunflower	New Mexico olive	yerba mansa
false indigo bush	prickly pear	

2. Review the names of each plant and leaf identification characteristics with students.
3. Divide the class into at least two relay teams. Ideally, each team should have at least ten members. Team members should line up single file, with teams side-by-side.
4. Separate the leaves into piles so there is a pile of each kind of leaf for each team. Set the piles approximately 75-100 feet (22.5–30 meters) from each team.
5. Explain to the students that each team will supply a particular "arthropod" to find a particular plant. Arthropods are animals that have jointed legs and exoskeletons (skeletons on the outside). Arthropods include insects, spiders, crustaceans, centipedes and millipedes. Each team will need to determine how many legs the assigned arthropod has, and how many students they need to make a team with that many legs. For each round, have a short discussion about the animal, have students form teams, and tell them which plant they are looking for. The team that stays together, moves in the described manner, and selects the right plant first wins that round.

For younger students: Do only the arthropod/insect part, skipping the search for plants.

Arthropods

Harvester Ant

Description: Six legs requires three students. Two eyes means that the back two students must keep their heads down; three body segments requires that the back students keep their hands on the hips of the student in front of them.

Background information: Harvester ants live in large colonies in burrows that can be nine feet deep or deeper. The entrance is usually on the south side of their mounds. They mostly eat small seeds but eat an occasional insect for protein.

Situation: The harvester ant is looking for seeds from a saltgrass plant.

Robber Fly

Description: Six legs requires three students. Two eyes means that the back two students must keep their heads down; three body segments requires that the back students keep their hands on the hips of the student in front of them. Compound eyes means that the front student must look through a "bug-eye" or paper cup with several holes punched in the bottom. One pair of wings requires that the first student flaps his/her elbows while holding the bug-eyes.

Background information: Flies are a large group of insects with only one pair of useful wings. The robber fly is a fairly large fly that captures other insects as it flies. Its young develop in decaying vegetation.

Situation: This fly is waiting for food on a cattail.

Cicada

Description: Six legs requires three students. Two eyes means that the back two students must keep their heads down; three body segments requires that the back students keep their hands on the hips of the student in front of them. Compound eyes means the front student must look through a "bug-eye" or paper cup with several holes punched in the bottom.

Background information: The winged adult cicada is a robust insect often heard buzzing in the bosque. The larvae live and grow underground for several years. In their final nymph stage, they climb up trees and emerge as adults.

Situation: A cicada nymph is climbing up a saltcedar trunk.

Tarantula

Description: Eight legs requires four students. Eight eyes; the male is near-sighted, so the students must wear a box or bag over their heads so it is hard for them to see; back students keep their hands on the hips of the student in front of them.

Background information: Tarantulas are not aggressive and have only a mild poison. Males live eight to ten years in burrows. When the male is sexually mature, it goes looking for a mate. The male is very near-sighted and can see only about two feet. The females generally never leave their burrows.

Situation: The male tarantula is looking for a female with a burrow under the New Mexico olive.

Field Cricket

Description: Six legs requires three students. Two eyes means that the back two students must keep their heads down; three body segments requires that the back students keep their hands on the hips of the student in front of them. All of the team must jump.

Background information: Crickets eat dead leaves and, before the arrival of isopods to the bosque, may have been the major consumer of cottonwood leaves.

Situation: A cricket is looking for cottonwood leaves to eat.

Eight-eyed Jumping Spider

Description: Eight legs requires four students. Eight eyes; have students line up side-by-side, with arms linked across shoulders; students must jump to move forward.

Background information: The eight-eyed jumping spider is an aggressive predator and doesn't make webs.

Situation: The spider is hungry and looking for food on a false indigo bush.

Pinacate Beetle or Desert Stink Beetle

Description: Six legs requires three students. Two eyes means that the back two students must keep their heads down; three body segments requires that the back students keep their hands on the hips of the student in front of them. Compound eyes means that the front student must look through a "bug-eye" or paper cup with several holes punched in the bottom.

Background information: The pinacate beetle is a large black beetle that lives under stones and logs. When agitated, it will stand on its head and release a foul-smelling vapor.

Situation: The beetle is looking for food under a prickly pear.

Pillbug or Isopod

Description: Fourteen legs requires seven students. Two eyes means that the back six students must keep their heads down; the back students keep their hands on the hips of the student in front of them.

Background information: Pillbugs were introduced to this continent over 500 years ago with dirt that was used to stabilize sailing vessels but removed to make room for cargo space on return trips. Today these little animals are the major consumers of dead plant material in the bosque.

Situation: A pillbug is looking for dead coyote willow leaves to eat.

Black Widow Spider

Description: Eight legs requires four students. Eight eyes.

Background information: The bite of a black widow spider is poisonous to humans, but usually will not kill a person. Most black widow bites occur in outhouses. Black widows catch their prey in webs.

Situation: The female black widow is spinning a cobweb in a Russian olive tree.

Fall Webworm

Description: Has three pairs of true legs and five pairs of prolegs (leg-like appendages); requires eight students. The fall webworm moves like an inch-worm; students have hands on hips of team member in front of them. The first student moves forward as far as possible without the back team member moving. Then the first student stops, while the remainder of the team moves as close to the first person as possible. Once the back person stops, the first person can go again and the process is repeated.

Background information: The fall webworm is a late-season caterpillar that feeds on foliage from July through September. Because they do not emerge until July, their presence does not usually impact the tree's long-term health. They live gregariously in large webs where they stay all the time to eat, sleep and even poop!

Situation: A fall webworm is returning to his tent on the limb of a cottonwood.

Millipede

Description: Has many legs; all team members participate. A millipede has two pairs of legs per body segment; the back students keep their hands on the hips of the student in front of them. All students must shuffle their feet to move.

Background information: Millipedes are round, and eat plants. They do not bite or sting people.

Situation: The millipede is eating decomposing sunflower leaves.

Centipede

Description: Has many legs; all team members participate. Since the centipede is flat with one pair of legs per body segment, students will bend over at the waist, the back students holding onto the waist of the student in front of them. The legs are extended to the sides of the centipede, so students run with their legs spread wide apart.

Background information: Centipedes are predators that eat small insects and other arthropods. They paralyze their prey with poison in their jaws. This poison is also venomous to people and can cause a painful bite. Centipedes are flat because they spend a lot of time crawling underneath rocks and logs.

Situation: The centipede is looking for insects beneath the yerba mansa plant.

21. Cottonwood Quiz

Description: Students take a true/false quiz of their knowledge of cottonwoods and the bosque, then administer the quiz to others and analyze the response data.

Objective: Students will:

- know about surveying techniques by conducting, collecting data, organizing and displaying data and analyzing the results of a simple survey;
- learn what others know about the bosque; and
- educate participants in the quiz about cottonwoods and the bosque.

Materials: copies of the Cottonwood Quiz

pencils

calculator

Procedure:

1. Administer this quiz to all of the students. Each student should answer the questions him/herself first and record the answers in the first column on the Cottonwood Quiz sheet. Discuss the answers as a class. Statements 1 through 5 are false; 6 through 10 are true (see answers following the quiz).
2. Prepare for conducting a survey using the quiz. Go over the instructions on the quiz. Discuss how many people will be questioned by each student. Your goal is to survey 100 people. (A class of 20 will survey five each, when their own quiz results are included.) After each survey, students should go over the correct answers with those they have surveyed and tell them the percentage answered correctly. In teaching about the bosque in this way, students solidify their own knowledge.

21. Cottonwood Quiz

Grades: 5–8

Time: two class periods plus administration of quiz

Subjects: science, math

Terms: *germinate, saplings, seedlings, evolving, levee, introduced species*

3. Students will return with all of their surveys completed, correct answers recorded and percent correct calculated. Now they combine their results with the rest of the class.

   Go through each question and record the total number of correct answers of all the people surveyed. Since you surveyed 100 people, this number represents the percent of correct answers for each question.

   Sum the totals for each question and divide by 10 to calculate the average score of all people taking the quiz.

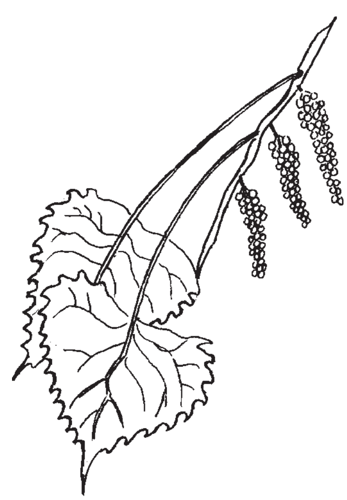
4. Students display the data in some way, a graph, chart, etc.
5. Students then answer the analysis questions.

Analysis questions:

1. Which questions were answered correctly by most participants?
2. Which question(s) were answered incorrectly by the most number of participants?
3. Make a general statement about the level of knowledge and understanding of cottonwoods and the bosque among the people surveyed.
4. Do you think these results will be true for the general public? Why or why not?

Extensions: Write a news article about your findings.

Take the questions that were answered incorrectly by the most number of people and design something to teach that information. This could be posters, videos, leaflets, etc.—an "ad campaign."



Cottonwood Quiz

1*	2	3	4	5	True or false?
					1. A Rio Grande cottonwood lives about 300 years.
					2. Most cottonwood seeds germinate and start new trees.
					3. Russian olive trees and elm trees have always been a part of the Rio Grande bosque.
					4. Rio Grande cottonwood trees get all the moisture they need from rain.
					5. We don't have to be concerned about the bosque. It will always be the way it is now.
					6. The cottonwood has been the most important tree in the bosque for thousands of years.
					7. Cottonwood seeds need sunlight, clear space, and soil that stays wet to start to grow.
					8. Historically, annual floods provided the wet ground that cottonwood seeds needed to grow and develop.
					9. Cottonwood trees have either female or male flowers but not both on the same tree.
					10. With river conditions today, cottonwoods do not naturally regenerate on a large scale. For the cottonwood to be a significant tree in the future forest, people need to plant the trees or manage the river for flooding over the banks.
					Number of correct answers
					Percent correct (multiply by 10)

*Student's name ______________________________

Instructions

- Answer all ten questions yourself and record your answers (T for true, F for false) in Column 1.
- Read the questions to four more participants and record their answers in Columns 2 through 5.
- Go over the correct answers (on the next page) with each participant.
- Count the number of correct answers for each participant and record the number in the participant's column.
- Compute the percentage of correct answers by multiplying the number of correct answers by 10. Write the percentage in the column.

Answers to Cottonwood Quiz

1. False: Cottonwood trees are like people—not many grow to be more than 100 years old. Cottonwoods are not long-lived trees.
2. False: Very few seeds germinate. Even fewer find the conditions they need to develop into trees.
3. False: Russian olive and elm trees came to the bosque in the 1930s. Saltcedar (tamarisk) was also introduced about the same time.
4. False: Large trees like cottonwoods need much more than the 10 inches (25 cm) of rain that make our area a desert. We often get even less than that. Cottonwoods tap the water table for their needs.
5. False: The bosque has always been changing following natural cycles. But today's changes are not cyclical. Instead they represent a progression from one type of habitat to another. Without responsible management the bosque may not survive as a cottonwood forest.
6. True: The Rio Grande cottonwood has been evolving with the river for thousands, perhaps more than a million years.
7. True: Cottonwood seeds need sunlight, a clear space, and soil that stays wet until the seedling roots reach the water table.
8. True: Annual floods kept the soil wet long enough for this to happen. Because the river is now controlled by levees and dams, it no longer floods unless managers allow it.
9. True: Cottonwoods with male flowers release pollen in the spring. It floats in the air to the trees with female flowers which later produce the cottony seeds.
10. True: Without flooding to provide a start for new trees, existing cottonwoods will die off and introduced species will take over. Changing management goals to manage for the entire ecosystem are setting an optimistic outlook for the bosque.

22. Mapping Species Richness

Description: Students color a map that shows how many species of birds live in different areas of New Mexico, then overlay other maps to learn what factors are important to species richness.

Objective: Students will learn that in the arid Southwest, the highest number of kinds of birds (species richness) live along rivers, i.e. places with water.

Materials: Mapping Species Richness map for each student to color

Mapping Species Richness data sheet for each student

colored pencils

copies of the following maps: New Mexico Rivers and 1,000-foot Elevation Contours (included in this activity). These could be on clear acetate, to overlay on the students' maps and/or show on an overhead, or student can hold paper copies up to a window to compare. Other maps such as the New Mexico highway map or other New Mexico maps may be used as reference.

Background: Terms:

Biodiversity: biological diversity. In considering the ecological condition of an area, biological diversity refers to the variety of organisms present, looking at all levels of classification as well as genetic variability, and the variety of ecosystems in which the organisms occur.

Community: an association of interacting species inhabiting an area. An example would be a pond community with all the animals and plants that depend on the pond and live in or near the pond.

Flyway: the path taken by birds during their annual migrations. Many birds will take the same route following a river or mountain crest as landmarks for their journey.

22. *Mapping Species Richness*

Grades: 6–12

Time: two class periods, plus homework

Subjects: science, math extension

Terms: *biodiversity, community, flyway, riparian, species, species diversity, species evenness, species richness*

Riparian: relating to, living near or located on the bank of a natural fresh watercourse such as a river, stream, pond or lake.

Species: a population of organisms, such as one type of bird, that is able to interbreed and produce fertile offspring.

Species diversity: a combination of the number of species in a community (species richness) and the relative abundance of the species in the community (species evenness).

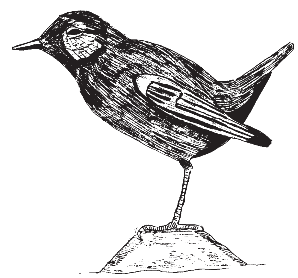
Species evenness: the relative abundance of a type of organism in the community, or how many individuals of each type (species) there are. For example, a site with five individuals each of 10 species has a greater evenness than a site with 41 individuals of one species and one individual of each of nine other species.

Species richness: the number of species in a community or location. This contrasts with the abundance or numbers of individuals. Species richness is simply a measure of the number of *types* of organisms present without regard to the number of *individuals*. Thus a site with 10 different types of birds present has a higher richness than a site with five species present, even if the latter site has 100 individuals and the first site has 50 individuals. Caution: Be aware that identical richness numbers don't mean that the same species of birds occur at different sites with the same richness value.

Scientists in many fields use color to look for patterns. For example, geologists create colorful maps of where different types of rocks are found and then study the patterns that appear in order to understand the geology of an area. In this activity, students illustrate the number of species of birds found in different areas of the state by coloring a map in a "color-by-number" style. Then students may compare their species richness maps to other types of maps to look for patterns.

When scientists and resource managers prioritize which natural places on Earth to preserve, one factor they are particularly interested in is the number of species of organisms present at a given site. Biological diversity, or biodiversity, includes species richness—sites with more species are said to have higher biodiversity. Although sites with fewer species can also be ecologically quite important, sites that support more species are especially valuable and these are typically targeted for conservation. Habitats that have been greatly reduced in extent and are now rare are also important conservation priorities, since they often support species found nowhere else.

Animals live throughout the state, but if you look specifically where those animals live, far more kinds are found along the streams, rivers and lakes of New Mexico than in drier uplands. In New Mexico, less than 1% of the state is riparian, but large numbers of vertebrate animal species depend on those riparian areas for at least part of their lives.[1] For example, deer will wander far and wide, but they must come to water to drink regularly. This is particularly noticeable with species of birds. More species of birds are found in riparian habitats than in all other vegetation types combined. This activity is designed to demonstrate the importance of the bosque ecosystem to birds in New Mexico. In 1984, the report of a study of animal life along the Middle Rio Grande Valley counted 277 species of birds sighted during two years. This was over 60% of the total number of birds known from New Mexico.[2]



American dipper

Around 500 species of birds have been seen in New Mexico. For this activity, birds that appear irregularly or infrequently are not considered; they are not a substantial part of the ecological community. There are at least 324 birds routinely seen somewhere in the state, and these are the ones included in this activity. The numbers in the chart are extrapolated from actual records compiled by the United States Geological Survey's GAP Analysis Project and simplified in some cases to easily demonstrate ideas to students. One or two sites are used to illustrate larger regions. For each site we have grouped the total numbers of bird species that can be seen in the area if you observe regularly throughout the year. Some birds may live there in the winter and migrate in the spring; some may only be seen in the spring or fall migration; some will nest in that area; still others will live in one spot all year long.

Procedure: Introduce the activity with a question, "Where do most birds in New Mexico live?" Then have students develop a hypothesis about their answers; write them down. Think about testing the hypotheses: "How would we find out?"

Begin with the following scenario: "Biologists have studied birds all over the state and recorded the numbers of birds in many different habitats and geographic areas of the state. Your task is to use these data to determine what areas in the state are most important to birds. To do this, you will make a map of species richness. Start by looking at the locations and number of species found at each location and then color that area of the state with the appropriate color-coded number."

1. Give the students the Mapping Species Richness data sheet and map showing statewide locations and the number of bird species found at each location.
2. Instruct students to match locations on the map to the number of birds found.
3. Students assign a color to each of the categories in the map key. We recommend that a bright red or orange be used for the highest number of species. Official maps go through the color spectrum with blue for fewest species, grading to green, yellow, orange and then red as the highest category—the largest number of species.
4. Have students color the Mapping Species Richness map. Some areas include more than one site, with a similar number of species. Remind students that numbers for the regions are extrapolated from data from one or a couple of sites within each region. Therefore students may find more than one site within the region they are coloring.
5. When the students have finished their maps, have them compare their maps to other maps. Pose the original question, "Where do the most species of birds in New Mexico live?" Can they answer that question? Ask, "What other questions could we ask from this data?" Assist them in comparing their maps to other maps and ask: "How does the species richness of birds relate to this?" For example, overlay the Rivers of New Mexico map. Is there a relationship between the rivers and the species richness? Overlay the elevation contour map. Ask students if there is a relationship between elevation and numbers of birds.

Discussion after maps are colored:

The main theme: where is the highest diversity of species of birds?

Where are the rivers on this map? Is there a relationship between rivers and the bird species richness? Overlay the Rivers of New Mexico map. *Students should be able to see that the rivers/riparian areas have a very high richness—therefore many different kinds of birds.*

Why? What is different there?

What are the most important things to determine where and why birds occur where they are?

What are those things all animals need to survive? Where are you safe from predators? *Food, water, shelter, and space in the proper arrangement. Water is extremely important in the dry Southwest*.

There is more water, but what else is there? When you look at the bosque compared to the dry areas above the floodplain, how is the floodplain different? *There are tall trees, a greater density of plants, larger plants. With taller plants, there are more nest sites for birds (canopy and cavity nesters), for example. More insects live on the large trees and over water, so insect eaters find more food there; more insect eaters and there will be more predators to eat them . . .*

Where are there the fewest species? Can we look at other maps to see why so few species live there? *Some types of areas have very few species—lava flow areas such as El Malpais and desert areas such as Chaco Canyon in the Great Basin desert.*

Look at Sites 2 and 4, which appear to have the same *number* of species. Do they have the *same* species? Look at the habitats. *These are very different environments; even though they may have similar numbers of bird species, the actual types of birds will be very different.*

belted kingfisher

Where do we find sandhill cranes in New Mexico? Why are they there? Why are they in this corridor? *Talk about migration flyways: many birds will follow rivers in their migration. Others, such as hawks, fly along mountain ridges as landmarks for their journey. Sandhill cranes fly from the northern U.S. and Canada to winter in a warmer place—New Mexico. They are abundant in the Middle Rio Grande Valley because there is food, water and safe places to roost. Several refuges plant crops for wintering birds to eat through the season.* (See the "Crane Migration" activity that follows for additional information.)

What does the number of species in an area say about the health of the local environment? *A large number of species indicates a healthy habitat—a high biodiversity. Be careful: even though there are few bird species at El Malpais, the plants and animals that live there have important adaptations that allow them to survive in the unique lava flow environment. Also, introduced/exotic species will increase the species richness but not the biological diversity.*

Assessment: Students can write a statement of conclusion regarding their original hypothesis and indicating the results testing that hypothesis. If the data did not address their hypothesis, have them state this. Then have them summarize the results of doing this activity.

Extensions: Students can research birds—where they are and which habitats they live in. What kinds of birds live in a particular area on their maps? There is a list of birds of the Middle Rio Grande in Appendix F.

Have students choose a species of bird that lives in the bosque to research.
Write about the habitats that species needs, the food it eats, the type of nest it uses, etc.
Why does it live in the bosque? Are there other places it could/ does live?
Does it migrate?
Where does it spend the summer and winter?

Math extensions: There are at least 324 bird species that routinely occur in New Mexico. Calculate the percent of statewide species at a few key locations on the maps they colored.
Figure the percentages of the map categories.

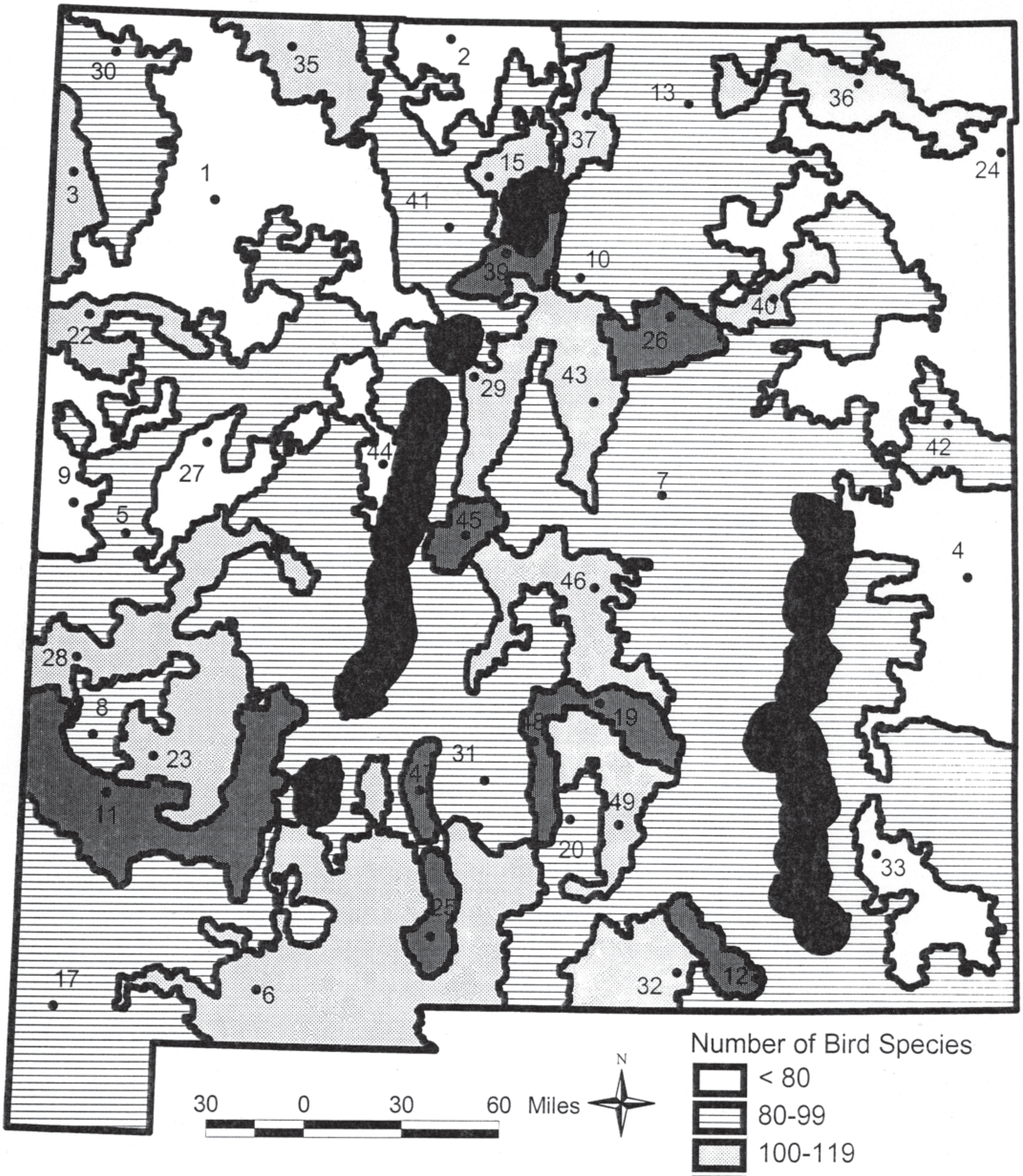
Adapting to younger students: You are a "birder" (you watch birds) and want to see wintering geese.
Where would you go? What about this area makes it a good place to see geese?
Why would you go to rivers to find ducks?
Many birds migrate, but not all; compare birds that migrate and those that do not.

References:

[1] Knopf, P.J., R.R, Johnson, T. Rich, and R.C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100:272-284.

[2] Hink, V.C., and R.D. Ohmart. 1984. Middle Rio Grande biological survey. Report submitted to U.S. Army Corps of Engineers, Albuquerque, NM.

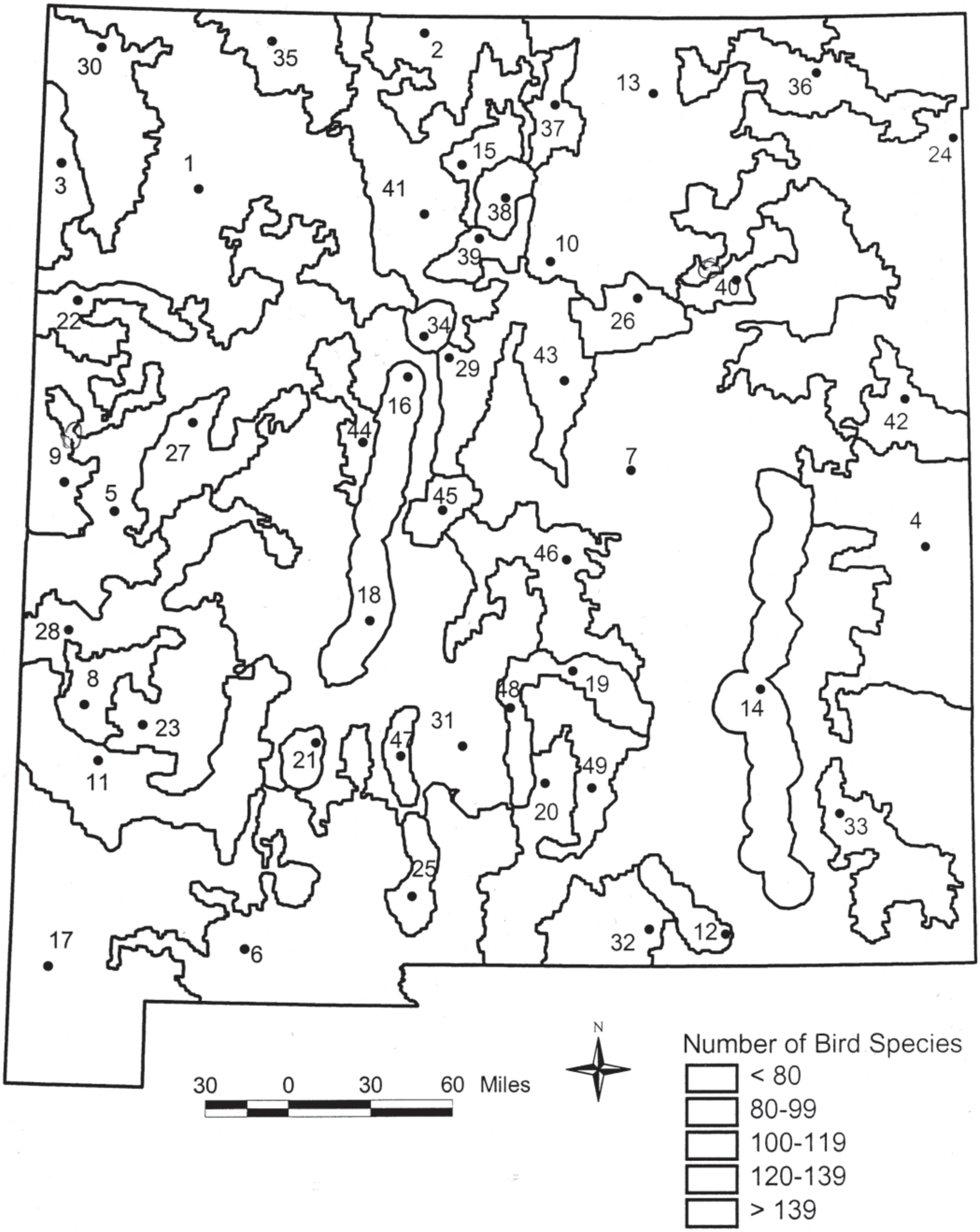
Teacher Key: Bird Richness



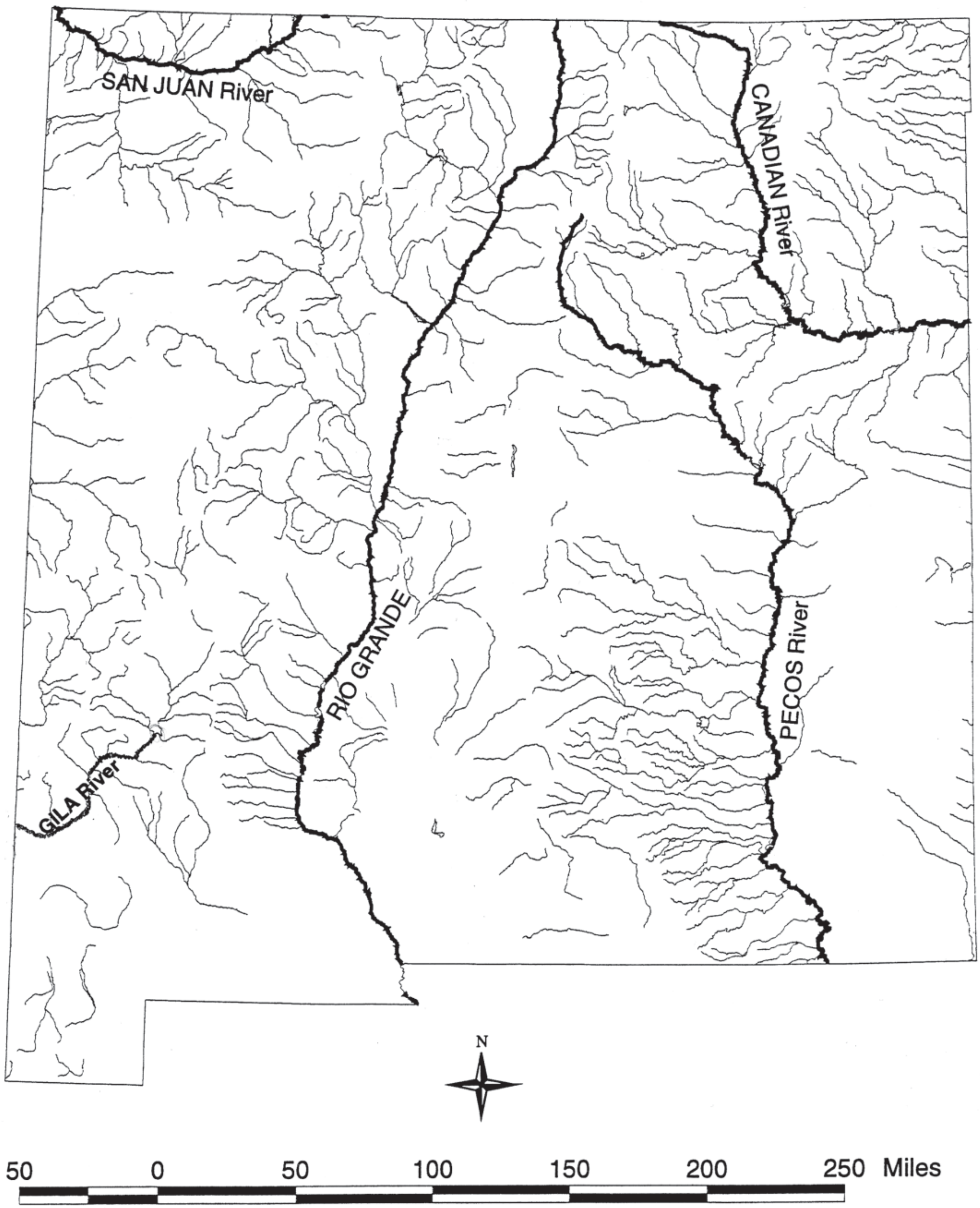
Mapping Species Richness Data Sheet

Site #	Name	Species Richness
1	San Juan Basin	43
2	Chama	65
3	Chuska Mountains	113
4	Portales	53
5	Quemado	94
6	Rock Hound State Park	103
7	Vaughn	92
8	Whitewater Baldy	86
9	Zuni Salt Lake	55
10	Randall Davey Audubon Center	94
11	Gila Riparian Preserve	124
12	Rattlesnake Springs Preserve	121
13	Philmont Scout Ranch	82
14	Bitter Lakes Refuge	159
15	Abiquiu	115
16	Rio Grande Nature Center State Park	143
17	Animas	98
18	Bosque del Apache National Wildlife Refuge	169
19	Capitan	133
20	Cloudcroft	82
21	Elephant Butte Reservoir	145
22	Gallup	103
23	Gila Cliff Dwellings National Monument	112
24	Kiowa National Grassland	52
25	Organ Mountains	125
26	Las Vegas National Wildlife Refuge	120
27	El Malpais	14
28	Reserve	117
29	Sandia Crest	106
30	Shiprock	84
31	White Sands National Monument	92
32	Crow Flats	102
33	Loco Hills	72
34	Santa Ana Pueblo	157
35	Navajo Lake State Park	114
36	Capulin	101
37	Arroyo Hondo	118
38	Alcalde	152
39	White Rock	123
40	Cañon Largo	116
41	Fenton Lake	86
42	The Caprock	92
43	Clines Corners	110
44	Rio Puerco	78
45	Mountainair	124
46	Corona	114
47	San Andres Mountains	134
48	Three Rivers Petroglyphs	126
49	Mayhill	118

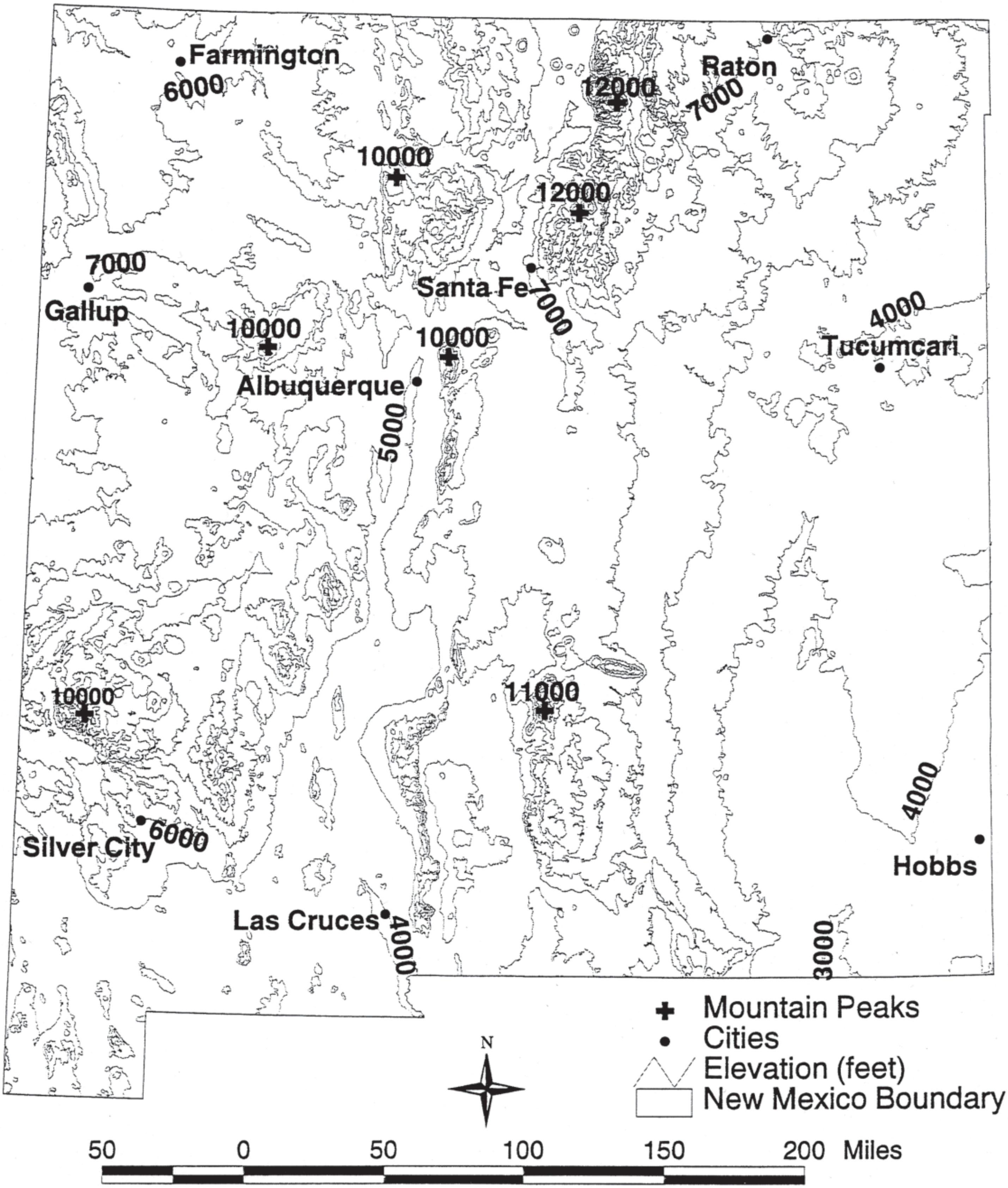
Bird Richness



New Mexico Rivers



1,000-foot Elevation Contours



23. Crane Migration

Adapted with permission from *Aquatic Project WILD* "Migration Headache"

Description: Students act out the trip sandhill cranes make between their nesting habitats in Idaho and their winter home in New Mexico. They experience the hazards cranes face at either end of the migration path as well as along the way.

Objectives: Students will:

- list the factors adversely affecting the population of sandhill cranes wintering in New Mexico;
- predict the effects of these restricting factors; and
- describe the effects of habitat loss and degradation on sandhill cranes and the importance of preserving wetland habitats for the cranes and other migrating water birds.

Materials: large playing field or gymnasium

two paper plates for every three students (clearly marked to differentiate top from bottom, i.e., paint one side blue to represent a wetland habitat and paint the other side brown to represent the loss of wetland habitat. Or write "habitat" on one side to represent wetland habitat. Alternative materials are 12" x 12" carpet samples from carpet retail stores or computer mouse pads).

Background: Migration is a fascinating and yet mysterious topic. How do migratory birds, fish, mammals and insects travel such huge distances with such precision, arriving at the same spot year after year? Although the answer isn't completely clear, visual clues of geographical features, the sun and the stars and even the earth's electromagnetism probably all play a role.

23. Crane Migration

Grades: 2–6

Time: two 30-minute sessions

Subjects: science, social studies

Terms: *degradation, migration*

What stimulates birds to migrate? Scientists have speculated that various factors contribute to the timing of migration. These include increases and decreases in daylight, endocrine interactions, gonad development, fat deposition, and the availability of food. Each species migrates at a particular time of the year and sometimes at a particular time of the day. Most sandhill cranes who winter in the wetlands of the Middle Rio Grande Valley begin their migration in September from wetlands like those at Gray's Lake National Wildlife Refuge in Idaho. By the end of November, the majority of cranes have arrived in New Mexico for their winter stay, and they start to leave in mid-February. Many migrating cranes stop in the San Luis Valley of Colorado, at what is termed a staging area, to spend several weeks. Here they feed, and in the spring they socialize and choose partners before flying on to their northern nesting areas. Unlike many smaller birds, cranes fly only during the day, usually at an altitude of about 2,500 feet (750 meters). They follow the same flyway they have used for centuries. Along the way they need wetlands where they can rest and eat before continuing their migration.

There are 15 different species of cranes worldwide. Only two species, the sandhill (*Grus canadensis*) and the whooping crane (*Grus americana*), live in North America.

The whooping crane is on the endangered species list. Whooping cranes never had a large population; probably fewer than 2,000 lived in the U.S. when the first Europeans began arriving on this continent. They reached a low of 19 in 1945. In 2001 there were about 185 migratory whooping cranes in the wild and another 100 in captivity, with only one whooping crane wintering at Bosque del Apache. There are current projects to increase their numbers and reintroduce them to historic ranges.

This activity focuses on sandhill cranes. Through the efforts of refuges like the Bosque del Apache National Wildlife Refuge the sandhill cranes have made a comeback from their status as rare. In 1941 there were only 1,000 greater sandhill cranes in the Rocky Mountain population, and 17 wintered at the Bosque del Apache. The population was estimated in 2001 at between 30,000 and 40,000 cranes. Today 12,000 to 17,000 sandhill cranes winter at the refuge, among some 23,000 in the Middle Rio Grande Valley, with the balance wintering in Mexico, and they are no longer considered endangered.

All cranes need habitat which include wetlands. These habitats have been reduced through degradation. Before the development of the 20th century, the natural flooding nature of the Rio Grande and the high water table in the valley created rich wetland habitats in the floodplain. Humans began to widely use the river for irrigation and began adding flood control to protect their crops and homes; these dams and irrigation canals changed the natural flooding regime of the Rio Grande. The installation of riverside drains lowered the water table and caused many wetlands to dry up. Many wetlands where cranes and other birds used to live or stop during their migration are now cities, towns and farms. Today the Rio Grande is confined, and many wetland habitats have been eliminated. Introduction of non-native plants such as saltcedar and Russian olive had a negative effect on the health of Middle Rio Grande wetlands. Increased pollution, through the use of pesticides and herbicides, has also affected the cranes. Evidence suggests that acid rain may be affecting insect populations, which in turn affects the cranes' food sources. In addition, predators, weather, disease and fire pose hazards to the birds and their habitats. In particular, disease is of concern at the Bosque del Apache refuge where the high concentrations of bird populations can create epidemic conditions.

In 1939, the Bosque del Apache National Wildlife Refuge was created as a safe place for birds (especially the sandhill crane) and wildlife that migrate to the wetlands of the Middle Rio Grande for the winter. The refuge is 13,000 acres (5,200 hectares) of bottomlands where the water of the Rio Grande has been diverted to create extensive wetlands. There are several other refuges in the valley, both state and local, that provide wintering wetland habitat as well. In the larger picture, there are international treaties and national laws affecting migratory species. State wildlife agencies share some responsibilities with the U.S. Fish and Wildlife Service, which is the regulating authority for managing and protecting migratory animals.

There are several sub-species of sandhill crane but the greater sandhill crane is the most abundant in the Middle Rio Grande Valley. They stand four feet (1.2 meters) tall with a wingspan of six to seven feet (2–2.1 meters). They fly at 25 to 35 miles per hour (40–56 kilometers per hour), often migrating 1,000 miles (1,600 km) or more each way.

Although sandhill cranes are no longer considered endangered, their habitat is. If their habitat disappears, cranes will disappear.

During this activity students, as cranes, will "migrate" between their winter habitat in the wetlands of the Middle Rio Grande Valley to their nesting habitat at Gray's Lake in Idaho. Discuss migration hazards with your students before the activity; these are: predators, highline wires, hunters and bad weather. Each student (assuming a class size of 25 to 30) represents 1,000 sandhill cranes.

Thus occasional losses due to predation and other minor events are not emphasized in the role play. The emphasis of the activity is on habitat loss. The major purpose of this activity is for students to dynamically experience some of the major destructive factors affecting sandhill crane habitats and the survival of the sandhill cranes as a species.

Procedure:

1. Begin by asking the students what they know about sandhill cranes. If available, show one of the videos listed in ***Resources/ References*** in this activity. Discuss the information from the ***Background*** section to supplement their knowledge.
2. Explain to the students that many factors can limit the survival of sandhill cranes. These include elimination of wintering and nesting habitats because of development (houses, industry), times of abundance or lack of food, drought, or flood.
3. Select a large playing area about 70 feet (21 meters) in length. Place one plate for each three students at each end of the field. Designate one end as the "winter habitat" and the other as the "nesting habitat."
4. Explain to the students that they are sandhill cranes which will migrate between the two areas at your signal.

   To increase interest, teach them the dance of the cranes. They bow their heads, flap their wings and leap high in the air. The cranes' dancing activity increases at the end of their stay at their winter habitats and then increases even more upon arrival at their nesting habitats in Idaho. Younger students can dance while waiting for the signal to migrate.

   Tell them the paper plates represent wetlands. These wetlands provide a suitable habitat for the sandhill cranes.

   Have them flap their wings. Cranes make a slow downbeat with a quick upbeat as they fly. They fly with their necks extended as they make their journey.

   At the end of each trip, the students will have to have one foot on a paper plate in order to be allowed to continue. If they cannot get their foot on a plate, they have not found any suitable habitat, so they die and have to move, at least temporarily, to the sidelines and watch.

Only **three** sandhill cranes can occupy a "habitat haven" (paper plate) at any one time.

Two students can be made permanent monitors to turn over the paper plates as per your instructions.

5. Begin the activity at the wintering habitats in New Mexico. The students will be doing the dance of the cranes. Signal the start of the first migration. Have the students migrate in slow motion until they become familiar with the process. Then they can speed up. On the first try, all the birds will migrate successfully to the nesting habitat.
6. Explain that there has been no loss in the nesting habitat. Thus, the students can do the crane dance and begin a successful nesting season.
7. Turn over one plate in the wintering region. Explain that a large wetland area has been drained and used for agricultural purposes. Repeat the signal to migrate and send the cranes on their journey to southern and central New Mexico for the winter. Have the three displaced students stand on the sidelines. Remind the students that these three represent 3,000 cranes. Thus these 3,000 died as a result of habitat loss. Let the students playing dead birds know that they can get back in the activity as surviving hatchlings when conditions are favorable and habitat is available in the nesting ground.
8. Before the next migration to the northern nesting area, turn over four plates in that area. Tell the students this is a catastrophic forest fire which has severely polluted and damaged wetlands. Give the dancing cranes the signal to migrate. At least 12 students will not find nesting habitat. Note: this results in a large number of students waiting on the sidelines. Before many cycles are repeated, provide them with an opportunity for re-entry in the nesting habitat. Each time, give the students examples of changes in habitat conditions that make increases in population possible. For example; the Rio Grande Nature Center State Park has constructed a new wetland habitat for wading birds and shore birds.
9. Repeat the process for eight or 10 migration cycles to illustrate changes in habitat conditions that affect the cranes. See the lists below for suggestions of factors that might influence the sandhill cranes' survival.

Factors limiting the survival of sandhill cranes:

* wetland drainage
* drought, causing less available food and drying out of wetlands
* pollution and contamination of water
* pollution of food on which cranes feed
* urban expansion
* conversion of wetlands to farm lands
* conversion of natural waterways to canals
* illegal hunting (poaching)
* crane flies into power line and is killed or severely injured
* diseases such as avian cholera
* conversion of wetlands to industry or residences
* not wanting wildlife to feed in agricultural fields

Factors favoring the survival of sandhill cranes:

* preservation of wetlands
* wildlife forage crops, corn or alfalfa left for wintering birds (such as at Los Poblanos and Candelaria farms in Albuquerque)
* habitat restoration (such as a new refuge)
* human action aimed at protecting and restoring wetlands including education programs
* regulation of hunting and reduced poaching

Although some limiting factors to the cranes' survival are a natural part of any environment, the largest threat to these big birds seems to be the loss or degradation of suitable habitat, most often as a result of human intervention, draining of wetlands, and pollution.

Be sure to create one or more "disaster" years to illustrate catastrophic loss of large areas of available habitat. Remember that wetland habitats are diminishing both locally and worldwide, so the activity should end with fewer areas of available habitat than can accommodate all the cranes. The result is a smaller population of cranes locally and worldwide.

Play several rounds of the game noting population changes for each round.

Assessment:

1. Have students choose among the following:
   a. Write a story as if you were a crane. Explain what happened to you and your flock over your many migrations.
   b. Draw a series of pictures about what happens to you and your flock.
   c. Give a presentation to someone in your family about crane migrations.

2. Have the students write a summary of the ideas generated in the discussion. Be sure to have them distinguish between the human-caused factors and the environmental factors involved in the success or decline of the crane's population. Working from the students' summaries, generate a class list of population increases or declines. Compare the similarities and differences between these limiting factors. Finalize the discussion by having the students identify the factors which pose the most significant long-term threat to the survival of the cranes.

3. Finally, discuss what kind of things can and should be done to protect the wetland habitats necessary to the survival of the sandhill cranes and all migratory birds. Discuss the compromises and trade-offs related to these recommendations.

Extensions

1. For variation set the activity back in time. Start in the early 1900s before the urban and agricultural development changed the natural flooding nature of the Rio Grande. At this time the sandhill crane population was between 30,000 and 40,000. Bring the student crane population down to the low of 1,000 and then show how the creation of the Bosque del Apache National Wildlife Refuge helped increase the sandhill crane population, and removal from the endangered species list. Continue to the present time highlighting current problems facing the sandhill cranes.

2. Use a graph to chart the cycles of declines or increases in crane population. Use this chart for further discussion after the activity. The students can be asked to:
   a. identify the apparent causes of any changes in population from year to year;
   b. identify the major factors contributing to habitat loss and degradation;
   c. make predictions about the effects of these factors;
   d. distinguish between short-term and long-term effects;
   e. distinguish between catastrophic and gradual changes; and
   f. support their ideas with evidence, engaging in research if necessary.

3. Take a trip to Bosque del Apache National Wildlife Refuge.
4. Make videos of cranes at the refuge or other locations.

Resources/ References:

Elphick, C., J.B. Dunning, D.A. Sibley, eds. 2001. The Sibley Guide to Bird Life and Behavior. National Audubon Society/ Alfred A. Knopf, New York.

Aquatic Project WILD—Aquatic Education Activity Guide. 1992. Western Regional Environmental Education Council, Inc., Bethesda, MD.

Price, Alice Lindsay. 2001. Cranes the Noblest Flyers—In Natural History & Cultural Lore. La Alameda Press, Albuquerque, NM.

Bosque del Apache National Wildlife Refuge. 1996. Southwest Natural and Cultural Heritage Association, Albuquerque, NM.

The International Crane Foundation at http://www.savingcranes.org

Video: "Back to the Bosque." Educational Products from Educators, Leading Object ™, Box 30003, MSC 3AI, Las Cruces, NM, 88003-8003; 505-646-5368 or 1-888-750-4156; www.leadingobject.com/products/videos/#southwest

Video: "Birds of the Bosque." Agricultural Information Video Studio, New Mexico Cooperative Extension Service, College of Agriculture and Home Economics, New Mexico State University, Department 3AL, P.O. Box 3003, Las Cruces, NM, 88003-0003.

Video: "Sandhill Cranes—Wintering in New Mexico." Judith Shaw Productions. 2002. Albuquerque, NM. (16:30 min).

24. WebQuest: Invasive Species

Description: Students work in teams of two to complete a WebQuest about invasive species in the bosque, to develop a management plan with their recommendations for improving the situation and to produce a presentation demonstrating what they have learned.

Objectives: Students will:

- know how the Internet can be used to search for biological resource information;
- understand how invasive species affect an ecosystem; and
- know how to prepare a basic species management plan.

Materials: Computers with Internet access (one for each team of two students)

copies of student activity pages

supplies for making posters or software for creating computer presentations

Background: Terms:
Invasive species: a species non-native (or alien) to the ecosystem and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. They can be plants, animals or microbes. Human actions are the primary means of invasive species introductions.

Refer to the "Changing River" activity for more information on non-native species.

This WebQuest is based on a lesson format designed by Bernie Dodge at San Diego State University. A WebQuest is an inquiry-oriented activity in which nearly all of the information that students interact with comes from resources on the Internet. For more information about WebQuests and examples of other WebQuests, visit http://webquest.sdsu.edu/webquest.html.

24. WebQuest: Invasive Species

Grades: 6–12

Time: three hours for Internet research; two hours for writing management plan; time for class presentations

Subjects: science

Terms: *invasive species*

Depending on the time available and the skill level of the students, the activity pages can be used independently of each other. For instance, Activity Page 1, "Introduction to the Bosque Training Course," might be used to give students an introduction to using the Internet to find information about the bosque.

Procedure: Preparation:

1. Make sure that computers are available, working, and connected to the Internet.
2. Assign students to teams of two and assign each team an invasive species:

   Saltcedar, *Tamarix chinensis*

   Russian olive, *Elaeagnus augustifolia*

   Tree of heaven, *Ailanthus altissima*

   Cheat grass, *Bromus tectorum*

   Kochia, *Kochia scoparia*

   Sweet clover, *Melilotus alba*
3. Make copies of student activity pages.

Doing the activity:

1. Introduce the concept of a WebQuest. Directions are included on the Student Activity Sheets.
2. Provide students with a time-line for completing the WebQuest.
3. Discuss guidelines for using the computers and internet.
4. The teacher should act as a facilitator, helping to trouble-shoot technology problems, asking questions, and helping students to organize their work.

Assessment: Use the rubric found at the end of this section to evaluate the students' work. The rubric can also be used by the students as a self-evaluation.

Extension: Research additional non-native species in the bosque. Some examples are: camel thorn, perennial pepperweed, hoary cress, Russian knapweed, musk thistle, Siberian elm, mulberry, cheat grass, cocklebur, tumbleweed.

Reference: Krasny, Marianne. 2003. *Invasion Ecology.* National Science Teachers Association (NSTA) Press. Available in both student and teacher editions designed to show students how to apply scientific knowledge to solving real-life problems.

Note about Webography:

There are many formats and styles for citing web sites, but the MLA (Modern Language Association), APA (American Psychological Association), and CBE (Council of Biology Editors) are the most common. The choice of style is generally governed by the content matter of the work. Since this WebQuest is science-based, a sample citation using the CBE style is below:
Stevens, Larry E. 2002 Jan 30. Exotic Tamarisk on the Colorado Plateau. Canyons, Cultures and Environmental Change. <http://www.cpluhna.nau.edu/Biota/tamarisk.htm>. Accessed 2002 July 9.

The citation should include the following information:

Author's name (if known)

Date of publication or last revision

Title of document

Title of web site (if relevant)

URL, in angle brackets

Date of access

Answers to the Bosque WebQuest Training

1. Where is the cottonwood found?
The Rio Grande cottonwood grows near water and in places where it can get its roots wet, in the lower valleys, from 4,000 to 7,000 feet or so in elevation, the lower limit of the narrowleaf cottonwood, along the Colorado, San Juan, Yampa, White, and Gunnison Rivers; in the southwestern corner of Colorado; and especially near the old Spanish settlements along the Rio Grande in Colorado and New Mexico.

2. Describe one interesting thing you found out about the cottonwood.
Answers will vary.

3. Name at least two reasons cottonwood/willow forests have been reduced.
Levees and dams were built that disrupted the flow of the river which altered the conditions needed for cottonwood reproduction and growth. Cottonwood-willow forests have also been reduced by land clearing, tree harvesting, water diversion, and agricultural uses.

4. Which two non-native trees have replaced the cottonwood?
Saltcedar and Russian olive.

5. What is a native plant?
The resident plant species that evolved within, or naturally dispersed to, a region are "native" or "indigenous" species.

6. What is an invasive species?

An invasive species is defined as a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

7. How are most invasive species introduced?
Human actions are the primary means of invasive species introductions.

8. Tour the Rio Grande from Santa Fe to Elephant Butte. What kinds of restoration projects are the Pueblos involved with?
Several Pueblos are working on restoration projects to lower the riverbanks, widen active channels, eliminate exotic species, and replant native vegetation.

9. What is the goal of the Bosque del Apache National Wildlife Refuge?
The goal of refuge management is to provide habitat and protection for migratory birds and endangered species and to provide the public with a high quality wildlife and educational experience.

10. What are some of the management tools used on the refuge?
Management tools used on the refuge include farming, prescribed burning, exotic plant control, moist soil management, and water level manipulation.

WebQuest: Invasive Species

Introduction

There are aliens in New Mexico! No, not UFOs, but alien, non-native plants. Non-native plants that cause environmental harm are often called “invasive species.” These species, like tamarisk (saltcedar), are threatening the health of the bosque ecosystem by taking over from the species that have lived there for thousands of years.

Here is the scenario: The state legislature of New Mexico has established a new wildlife refuge along a five-mile stretch of the Middle Rio Grande. According to the legislation, the mission of the refuge is to preserve the beauty of the bosque and to provide habitat for bosque plants and animals, for the enjoyment of all New Mexicans. What should be done about the invasive plants?

Task

You and a partner have been hired by the refuge manager as invasive plant consultants. You will work together as a team to complete training about the bosque ecosystem and become experts on a particular invasive plant. Your team will then determine a management plan for this plant and present it to the class during a “public hearing.” It will be your job to learn more about these plants and about ways to manage them.

Process

1. Before being trusted with the responsibility of making a decision about the new refuge, the team must complete an Introduction to the Bosque Training Course. Use Activity Page 1 for your training.
2. Your teacher will assign your team an invasive plant species to research. As a team, you will locate web sites or web pages about your species, and you will prepare a species profile. Use Activity Pages 2 and 3.
3. Write a management plan. Use Activity Page 4.
4. Present your management plan to the class. You may present a poster with appropriate drawings and illustrations or a computer presentation (web page, PowerPoint slide show, or hyper-studio slide show).
5. Evaluate your team’s work.

Activity Page 1: Introduction to the Bosque Training Course

Visit the following web sites to find answers to the questions listed below. Answer the questions on a separate sheet of paper.

www.iws.net/wier/RioGrandeCottonwood.html
native trees of the southern Rocky Mountains

1. Where is the cottonwood found?
2. Describe one interesting thing you found out about the cottonwood.

biology.usgs.gov/s+t/SNT/noframe/sw155.htm
changing landscapes of the Middle Rio Grande

3. Name at least two reasons cottonwood/willow forests have been reduced.
4. Which two non-native trees have replaced the cottonwood?

npsnm.unm.edu
Native Plant Society of New Mexico

5. What is a native plant?

www.invasivespecies.gov/index.shtml
federal invasive species web site

6. What is an invasive species?
7. How are most invasive species introduced?

www.rioweb.org/tour/
Rio Grande/Rio Bravo Basin Coalition

8. Tour the Rio Grande from Santa Fe to Elephant Butte. What kinds of restoration projects are the Pueblos involved with?

southwest.fws.gov/refuges/newmex/bosque.html
Bosque del Apache National Wildlife Refuge, U.S. Fish and Wildlife Service

9. What is the goal of the Bosque del Apache National Wildlife Refuge?
10. What are some of the management tools used on the refuge?

Activity Page 2: Web Site Identification

Find at least three web sites that have descriptions of the invasive species you have been assigned. (A web site may contain multiple web pages—you can count each page separately.) Fill out the information for each web page you find. You may add additional web sites if you find more than three that seem especially useful.

The following web sites are good starting points for invasive species information:

www.nbii.gov
National Biological Information Infrastructure

www.invasivespecies.gov
look at species profiles

www.invasivespecies.gov/databases/tpdb.shtml

All the above web sites have good search tools. Click on the search feature on the page and then enter either the common or scientific name of your invasive species.

You may also want to search the Internet using a search engine such as Google or Yahoo. Be aware that this method may return thousands of web sites, and you will have to decide which ones best suit your needs. Also, sites with addresses that end in .gov (government) or .edu (education) tend to have more credible information than ones that end in .com or .net. Ultimately, it is up to you to decide which sites provide the best information for your purposes.

Web Page 1

URL (address):

Who sponsors or hosts this web page?

Who is the intended audience?

One thing you learned about your invasive species is:

Web Page 2

URL (address):

Who sponsors or hosts this web page?

Who is the intended audience?

One thing you learned about your invasive species is:

Web Page 3

URL (address):

Who sponsors or hosts this web page?

Who is the intended audience?

One thing you learned about your invasive species is:

Activity Page 3: Species Profile

Using the web sites you have identified, complete a profile of your species. You should incorporate information from all of the web sites you find.

Common name:

Scientific name:

Physical description (including size, leaf description, flower description, color):

How propagated (how does it reproduce?):

Distribution (where is it found?):

Effect on natural areas:

Three methods for management:

List three terms (words you didn't know) and definitions:

Activity Page 4: Management Plan

Now that you have researched your non-native species, it is time to make your recommendation to the refuge manager. Your management plan should be one to two typed pages in length.

Your management plan needs to include the following elements: statement of the problem, species profile, description of various alternative management strategies, recommendation, definition of terms, and a webography. Use this outline to help you prepare your management plan.

I. Statement of the problem (two or three sentences about why this plant is an invasive species):

II. Species profile (one or two paragraphs describing where this plant is found in the bosque, what it looks like, and how it affects the bosque ecosystem)

III. Description of various alternative management strategies and consequences of the alternatives (one paragraph for each alternative). One of the alternatives must be a do-nothing alternative.

  A. Description and consequence

  B. Description and consequence

  C. Do nothing and consequence

IV. Your recommendation for managing the invasive species (one paragraph)

V. Unfamiliar terms and definitions

VI. Webography of web sites you accessed for your information

Evaluation Rubric

student's name ______________________

Component	Beginning Level	Developing Level	Advanced Level	Student Score	Teacher Score
Bosque Web Site Training	0 points Didn't follow directions. Answered less than half the questions correctly.	3 points Followed directions. Answered more than half the questions correctly.	6 points Followed directions. Answered eight or more questions correctly.		
Web Site Identification	0 points Found fewer than three web sites. Did not identify sponsor and audience for each site. Did not answer question about particular invasive species.	3 points Found three web sites. Identified some sponsors and audiences. Showed basic understanding of particular invasive species (answers were repetitive or simplistic).	6 points Found three or more web sites. Identified sponsor and audience for each. Showed strong understanding of particular invasive species.		
Species Profile	0 points Completed fewer than half the components of the profile.	4 points Completed three-fourths of the components of the profile.	8 points Completed all components of the profile.		
Management Plan	0 points Addressed fewer than half the elements of the plan. Plan is messy, illegible and/or less than one page, with numerous grammatical and/or spelling errors.	6 points Addressed most elements of the plan. Plan is neatly hand-written and/or less than one page, with few grammatical and/or spelling errors.	12 points Addressed all elements of the plan. Plan is typed and one or two pages, with no grammatical or spelling errors.		
Presentation	0 points Presentation is incomplete and paraphrased words and/or no pictures. Presentation shows little understanding about invasive species in general and/or particular species.	6 points Presentation includes essential information with some elaboration. Presentation shows some understanding about invasive species in general and/or particular species.	12 points Presentation is complete with original words and pictures. Presentation shows understanding about invasive species in general and about particular invasive species.		
Teamwork	0 points Teammates often "did their own thing." Were not able to work together to accomplish task. Had difficulty getting along with each other.	3 points Teammates were mostly able to participate appropriately. Usually came prepared and accomplished the task. Avoided most conflicts and/or were able to resolve any that occurred.	6 points Team members contributed fairly and squarely to all aspects of the project. Always came prepared and accomplished the task. Worked well cooperatively.		
Total Scores				50	50

Geologic History of the Rio Grande Rift

By Jayne Aubele
New Mexico Museum of Natural History & Science

New Mexico is unique in many ways. One of the little-known reasons that it is unique is that it is the site of the Rio Grande Rift which extends from southern Colorado (the San Luis Valley) down the center of our state and into northern Mexico[*] (see map and diagram on following pages). Much of the landscape, geology, and vegetation of New Mexico is related to the development and location of the rift. The Rio Grande exists because of the rift. Without the rift, there would have been no Rio Grande and no Rio Grande bosque.

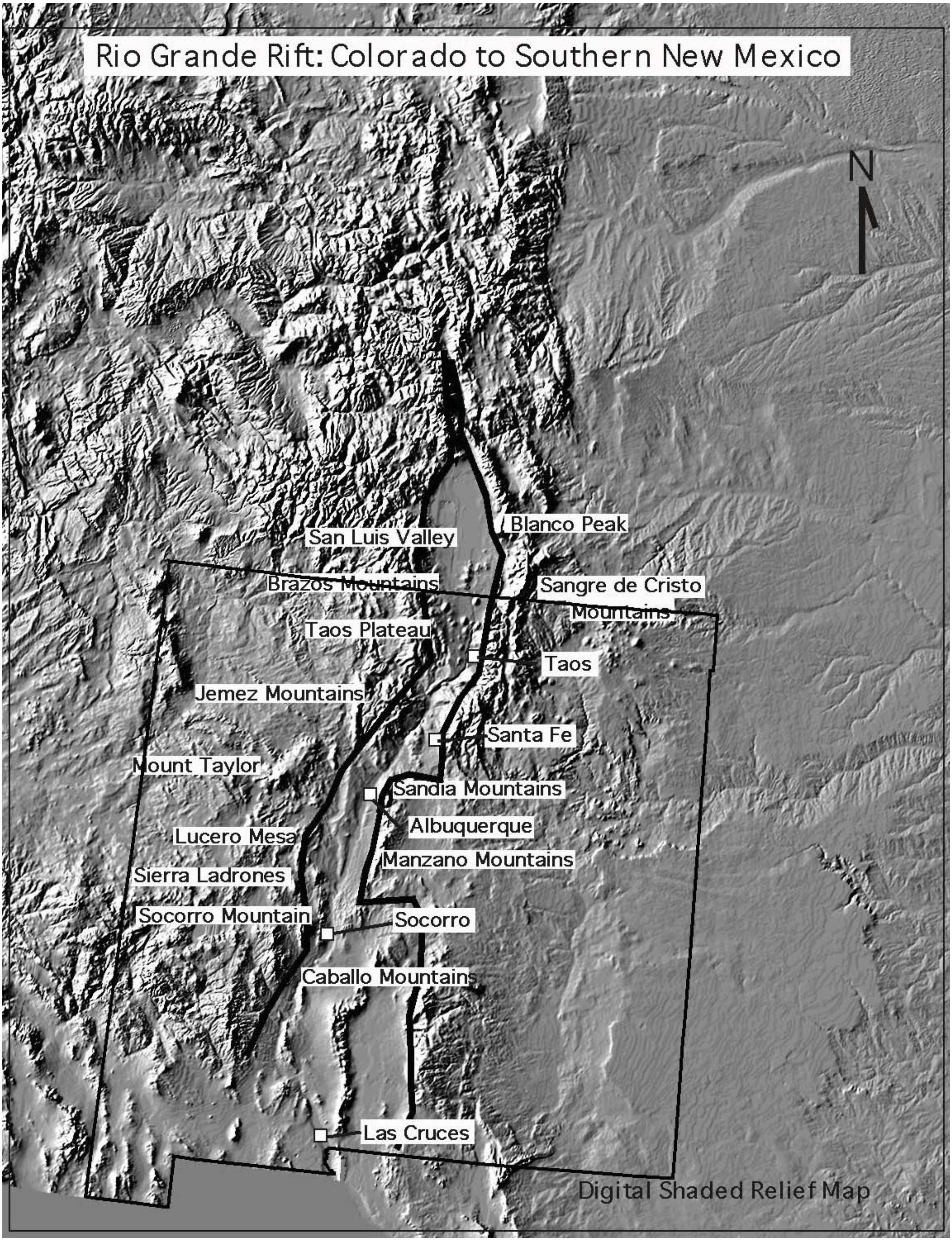
Imagine a New Mexico without the Rio Grande, without the central mountains that today border the Rio Grande on the east, and without the abundant young volcanoes that today parallel the river. This was New Mexico near the end of the Mesozoic Era (65 million years ago [mya]). Streams flowing from west to east carried sediment from western New Mexico onto a flat plain that existed where today Albuquerque and the Sandia Mountains are located. How did New Mexico get from there to here? How did the Rio Grande Rift and the Rio Grande form?

Pushing and Pulling

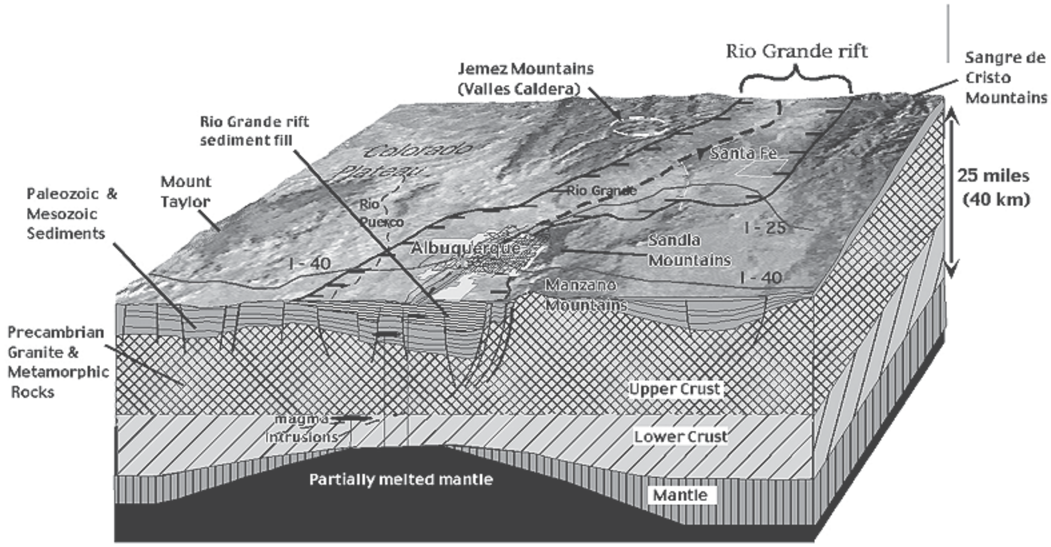
The Earth's crust is actually made up of many huge, separate pieces; geologists call these plates. Plates cover the Earth much like giant puzzle pieces, but they are not static. They move in relation to each other. Two plates can slide past each other, move toward each other causing mountain building or volcanism, or move apart from each other. New Mexico lies within a single plate, the North American plate, but our state has been affected by the movement of plates far away, along the western edge of the continent.

At the end of the Mesozoic Era, many small plates apparently began to crash into the western margin of the North American plate. These plates caused the continent to ripple like a rug being pushed from the edge. Geologists call this type of movement compression. The "ripples" became the modern Rocky Mountains, extending from Canada into northern New Mexico. The Sangre de Cristo Mountains in New Mexico are the southernmost expression of the modern Rocky Mountains.

[*] There are only five known young (active or recently active) continental rifts in the world, and the Rio Grande Rift is one of them. A continental rift is a linear area where the crust within a continent is thinning and pulling apart. It is not the boundary of two separate plates, but instead it forms within a plate. It can with time develop into a plate boundary. The other young active continental rifts in the world are: (1) the East African Rift; (2) the Rhine Valley in Germany; (3) the Baikal Rift in Russia; and (4) a recently identified rift beneath the ice in Antarctica.


Rio Grande Rift: Colorado to Southern New Mexico
N
Blanco Peak
San Luis Valley
Brazos Mountains
Sangre de Cristo
Mountains
Taos Plateau
Taos
Jemez Mountains
Santa Fe
Mount Taylor
Sandia Mountains
Albuquerque
Lucero Mesa
Manzano Mountains
Sierra Ladrones
Socorro Mountain
Socorro
Caballo Mountains
Las Cruces
Digital Shaded Relief Map

Rio Grande Rift
between Albuquerque and Taos

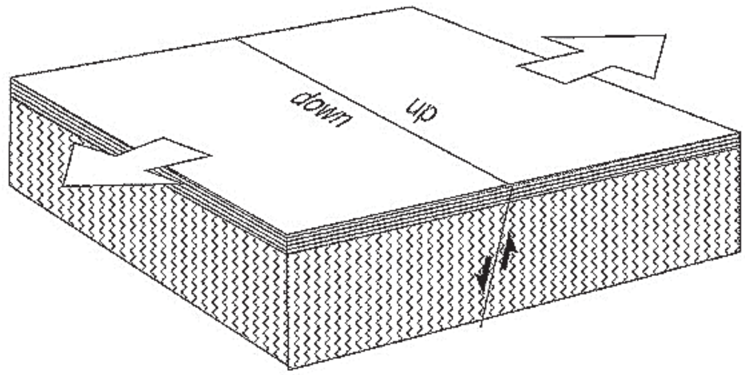


As plates continued to crash into the western edge of the continent, some pieces of plates attached to the edge of the continent. What we now call California was added to this edge. Apparently, at least one plate actually began to move beneath the continent. As this plate traveled from west to east beneath the continent, a wave of volcanic eruptions occurred throughout what would become the western U.S. These volcanic eruptions occurred from 60 to 20 mya and formed the Superstition Mountains in Arizona, the San Juan Mountains in Colorado, and the Mogollon–Black Range–Magdalena–Socorro–Organ Mountain province in New Mexico. Sierra Blanca, the Cerrillos Hills, the Ortiz Mountains, and a volcano that was eventually eroded partially away to form Shiprock also erupted during this time. The "Age of Volcanoes" in New Mexico began during this period and has continued to today.

It's All California's Fault!

About 20 mya something happened to the movement of the North American and Pacific plates. There may have been a redistribution or reorientation of their movements, as occasionally happens, and the compression of the North American continent ended. Instead of pushing the continent into mountainous "ripples," the plate bounding the western edge of the continent began to slide northward along the edge of the continent. This movement continues today and is the cause of the San Andreas fault zone in California. This sliding motion began to tear or pull apart the southwestern region of North America. Geologists call this type of movement tension or shear. As this movement continued, it caused the pulling apart of what is now the southwestern U.S. A series of roughly parallel, north-trending, deep, elongated valleys with intervening mountain ranges were created by this pulling apart of the continent. If you drive through southern Arizona or Nevada today, you see these parallel valleys and mountains in what is called the Basin and Range Province.

During this time, something strange happened in the Four Corners area of northwestern New Mexico, northeastern Arizona, southeastern Utah and southwestern Colorado. This region, which geologists named the Colorado Plateau, was a shallow circular valley during the Mesozoic Era (Triassic, Jurassic, and Cretaceous Periods) and had layer upon layer of rock units deposited on it in a flat layer-cake sequence. At the end of the Mesozoic Era, when the Rocky Mountains were uplifted, and during the Tertiary Period (60–20 mya), when the extensive volcanism was occurring in the western U.S., very little seemed to affect this region. When the continent began to pull apart 20 mya, the Colorado Plateau still was not affected. It stayed as a stable, layered piece of continental crust, while the rest of the continent broke apart into a series of valleys around it. If you pin a piece of paper to a bulletin board with a single pin and then pull on that piece of paper from one direction, the paper will begin to rotate and tear around the pin. That is what happened to the southwestern North American continent. As the continent began to pull apart and rotate around the Colorado Plateau, valleys were created to the south and west of the plateau, and a large valley began to form east of it. This "valley" is the Rio Grande Rift.

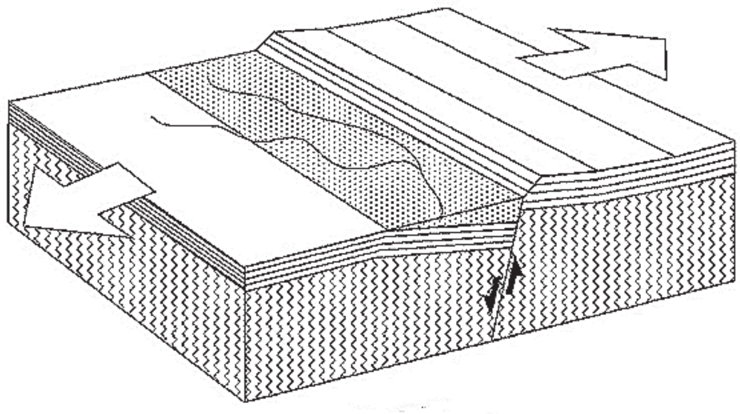


1. Rio Grande Rift 20 million years ago

Like Pizza Dough . . .

A geological rift forms by the pulling apart and thinning of the Earth's crust. You can think about it as though it was pie crust or pizza dough rolled out with a rolling pin and then pulling apart from both sides. If you have ever done this with dough, you know that it does not break in a straight line down the center. Instead, it breaks apart in a series of oval openings that occur as you continue to pull and the dough thins and breaks. This is exactly the way the Earth's crust responds to tension. In fact, the Rio Grande Rift has formed as a series of oval basins or depressions, outlined by faults, that extend in a slightly offset line from southern Colorado to northern Mexico. The escarpment known as La Bajada, between Santa Fe and Albuquerque, forms a margin between two of these basins. The city of Albuquerque was built on top of the eroded debris filling one rift basin to the south of La Bajada, and the city of Santa Fe was built in the basin to the north of La Bajada. A similar situation has occurred just south of Socorro.

As the basins began to form, the continental crust thinned and dropped down to form low areas. Thinner crust meant that it was easier for magma to reach the surface, so volcanoes began to erupt in the center of the rift. Volcanoes from Taos to Carrizozo erupted. In many places, such as west of Albuquerque or Los Lunas, these volcanoes form alignments that are called "fissure vents" where many small volcanoes erupt in a line. In the Albuquerque area, the width of the rift extends from the Sandia Mountains to the Rio Puerco, with the Albuquerque volcanoes right in the center of the rift.

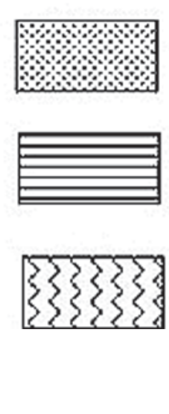


2. Rio Grande Rift 10 million years ago

The series of cracks in the crust at the edges of the rift, called boundary faults, became very complex. Some of the margins of the rift began to be uplifted into the modern central mountains of New Mexico, including the Sandia, Manzano, Manzanita, and Sierras de los Pinos Mountains. The Sandia Mountains near Albuquerque probably began to rise only 5–10 mya, making them geologically young and NOT part of the Rocky Mountains. The Rio Grande Rift and the mountains that form the rift's margins continue to be geologically active today.

The series of rift basins, with uplifted margins, formed a perfect low area for water to flow. As water runoff began to form in northern mountains, such as the San Juans, the water began to integrate into a permanent through-going river that took advantage of the low area. Most geologists believe that the Rio Grande formed as a major river 1–2 mya. *Most river valleys are eroded or cut by the rivers that flow within them. Unlike most rivers, the ancestral Rio Grande did not erode the broad, flat valley through which it now flows; it simply took advantage of this linked series of basins or low areas.*

Key to Illustrations



river sediments filling the rift valley (including sand and gravel from the river and eroded from nearby mountains)

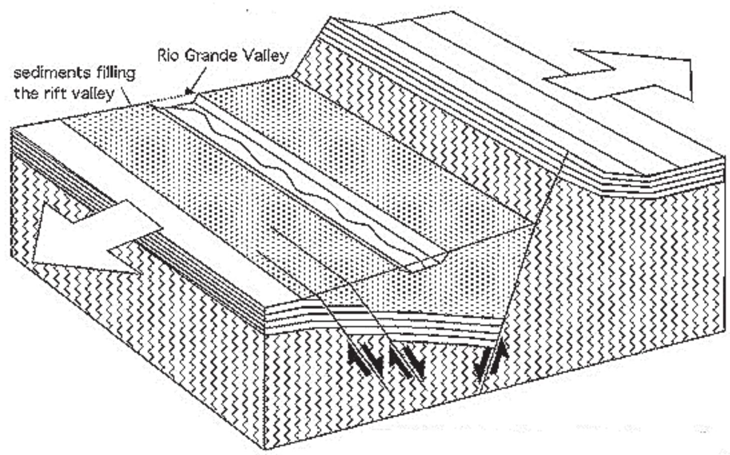
sediments from before rift valley formed (including Pennsylvanian limestone)

very old rocks (including Precambrian granite)

The modern river, of course, has eroded the small modern channel that you see today. In the Taos area, it eroded the Rio Grande Gorge, cutting down through the layered basalts filling that basin of the rift. Between Los Alamos and Santa Fe, the river cut White Rock Canyon, eroding the 1–3-million-year-old volcanic rocks in that area. Over time, the river channel has migrated and meandered from east to west. At one time the river was as far east as Eubank Boulevard in today's Albuquerque. From Albuquerque south, the river fluctuated between cutting a channel and depositing silt and sand carried down the river. At the end of the last ice age (12,000 years ago) when there was abundant water in the Southwest, the river probably eroded a deeper river channel than we see today. During the past 10,000 years, the river probably deposited material, in general, and actually filled in what was once a deeper, wider river channel. As the modern river flow rate and volume changes, the river bed can be slightly eroded or raised.

The Rio Grande is the Gift of the Rift

In New Mexico, more than in many other places, the landscape is directly related to and produced by dynamic and on-going geology. The rift has provided New Mexico with much of its beautiful landscape, its young mountains and its volcanoes. The rift has also given us the gift of a major river, an unusual phenomenon in our semi-arid southwestern region. As a result, the rift and the river have provided a home for a biologically diverse population of plants and animals, recognized today as the Rio Grande bosque.



3. Rio Grande Rift today

As you can see, the entire history of the Rio Grande is one of change. The river and bosque that we see today are very young, geologically speaking. The Rio Grande Rift is continuing to form. Marginal mountains continue to uplift. Small earthquakes occur within the rift. New volcanoes will someday erupt within the rift. One such place will probably be north of Socorro, where geologists know that molten magma is present beneath the surface, one of only three places in the American continent. For now, the ground is rising a few inches each year over this site. The uplift of the ground is actually causing the river to slow its flow in this area and pond in the Bosque del Apache region. The land and the river keep changing. The story of the Rio Grande Rift, and the river that flows through it, is not yet over.

25. Time Line Activity

One way to help students understand the concept of geologic time is to have them make a time line. Using this time line, choose items that are most interesting, with one for each student. Have the students make separate index cards for each one of the items. They can list the item or event and the time when it occurred or they can draw a picture. You then choose a unit of measure for each unit of time. For example, if you choose one centimeter = one million years then the age of the Sandia granite: 1.5 billion = 1,500 million = 1500/100 cm (and million years) per meter = 15 meters of string! If you go back to the beginning of the Earth at 4.6 billion years ago: 4.6 billion = 4,600 million = 4,600/100 cm per meter = 46 meters of string! If you used 1 millimeter for each million years and go back to the formation of the Earth, you will need only 4.6 meters of string.

Have the students stand up with their cards and arrange themselves in order from most recent item or event to oldest. Go down the line and have them state to the class what they are and the time. Then pull out the string and have them measure where they belong on the time line. You can pre-mark the string at each meter/100 million years. The students should then stand at the proper place along the string.

A Few Questions for Discussion

Were the Sandia Mountains here when dinosaurs lived here?
The dinosaurs went extinct 66 million years ago. The rocks that make up the Sandias had been formed, but they did not rise into mountains until 5–7 million years ago.

Are the Albuquerque volcanoes relatively old or relatively young?
They are young in relation to the geologic history of the Earth.

What things do we see together today that formed at very different times?
The Sandia granite and the limestone of the Sandia Crest are next to each other on the mountain, but over a billion years of time is missing.

What happened early in Earth's history? Why have we lost much of the record of it?
There has been erosion and plate tectonic activity to change the surface of the Earth; we have a much better record of more recent events.

Geologic Time Line

ya=years ago; mya=millions of years ago; bya=billions of years ago

Era	Period	Time	Event
CENOZOIC	QUATERNARY	12,000 ya	oldest known people in North America
		30–40,000 ya	modern humans first evolved: *Homo sapiens*
		150,000–1 mya	Albuquerque and Los Lunas volcanoes erupt; first bison in N. America
		1.1–1.6 mya	San Augustin Plain is a lake; Jemez Mountains (Valles Caldera) erupt
		1.6 mya	
	TERTIARY	1.5–2.5 mya	Rio Grande becomes a flowing stream; first mammoths in North America; Mt. Taylor erupts
		5–7 mya	Sandia/Manzanitas/Manzano/Los Pinos Mountains begin to form
		7–10 mya	Early Jemez Mountain eruptions
		10–20 mya	first bears; Sandias begin to uplift into mountains
		20–30 mya	Rio Grande Rift begins to form; Organ Mountains form; first camels
		35-55 mya	first grasses; first horses; Sierra Blanca erupts
		60 mya	first primates; primitive mammals; Tijeras Canyon fault activated
		65 mya	
MESOZOIC			extinction of dinosaurs, other species at Tertiary–Cretaceous boundary
		67–66 mya	rise and fall of *Tyrannosaurus*
	CRETACEOUS	70–90 mya	rocks formed in Rio Puerco valley; most of New Mexico covered by ocean mosasaur, *Albertosaurus*, *Pentaceratops;*
		100 mya	first flowers; ammonites abundant
		145 mya	
	JURASSIC	150 mya	NM a muddy floodplain (Late Jurassic); first bird, *Archaeopteryx; Stegosaurus, Allosaurus, Camarasaurus, Seismosaurus*
		170 mya	NM a “sand sea” similar to the Sahara (Middle Jurassic),
		200 mya	
	TRIASSIC		*Coelophysis* (NM state fossil); first mammals and dinosaurs; phytosaurs, aetosaurs, *Placerias*
		250 mya	
PALEOZOIC	PERMIAN		*Dimetrodon;* red sandstone deposited in northern NM
		290 mya	
	PENNSYLVANIAN		first reptiles; first seed plants; Crinoids (sea lillies); Madera Limestone (currently Sandia Crest) formed at bottom of ocean covering part of NM
		320 mya	
	MISSISSIPPIAN		shallow reefs cover New Mexico; Crinoids proliferate
		355 mya	
	DEVONIAN		first amphibians
		415 mya	
	SILURIAN		first insects; first land plants and land animals; scorpions
		440 mya	
	ORDOVICIAN		early jawless fishes
		495 mya	
	CAMBRIAN		first fish; trilobites and brachiopods
		545 mya	
PRECAMBRIAN	PRECAMBRIAN	1.5–2 bya	formation of granite in Sandia and Sangre de Cristo Mountains
		3.2–3.8 bya	oldest known rocks on Earth; oldest known fossils
		4.6 bya	Earth and other planets in our solar system formed

26. What is the Rio Grande Rift?

Description: Students will learn about the concept of a rift in general and about the Rio Grande Rift in particular. Two different diagrams of the rift can be used by different grade levels or can be used in sequence together for the same grade level. Students color the diagrams, analyze them, and answer in-depth questions about them.

Objectives: Students will:

- understand the geology of the Rio Grande Valley at Albuquerque;
- begin to understand the geological process of rifting and relate that process to the Rio Grande Rift;
- understand that the rock layers exposed in the Sandia Mountains to the east are the same ones over six miles (10 km) below the city; and
- understand that the Rio Grande exists because of the rift.

Materials: three Kleenex® boxes or three medium-sized wood blocks

DiagramA: "Development of the Rio Grande Rift in Three Time Snapshots" (one per student)

Diagram B: "Geologic Cross Section of the Rio Grande Rift at Albuquerque" (one per student)

colored pencils

a photograph of the Sandia Mountains with Rio Grande Valley (postcards work well)

Optional: samples of limestone and pink granite from the Sandia Mountains and a sample of volcanic basalt

Background: See overview explanation in this section, "Geologic History of the Rio Grande Rift."

26. *What Is the Rio Grande Rift?*

Grades: 3–8 and 6–12

Time: two class periods

Subject: science

Terms: *crystals, fault, granite, layer, magma, rift, sediment, slow-cooling/fast-cooling, strata, trough, volcano*

The Rio Grande Rift is one of only five young, active continental rifts in the world. The biodiversity and geodiversity of the Rio Grande Valley are related to the existence of the rift. Most river valleys are eroded or cut by the rivers that flow within them. However, the Rio Grande did not erode the broad flat valley through which it now flows; it simply took advantage of the presence of low areas along which to flow.

Diagram A, designed for Grades 3–8, presents simplified snapshots of the area around Albuquerque at different times in the geologic evolution of the landscape. Diagram B (more complete but still simplified), designed for Grades 6–12, is a cross-section drawn on the basis of many pieces of scientific information including drilled wells and geophysical measurements. It is as accurate as it can be at this scale.

Procedure:

1. Introduce the lesson by asking students to talk about the Sandia Mountains, and what they look like, either from their own experience or from viewing a photograph. Ask open-ended questions such as "Do you see different colors?" "Are there different kinds of rock?" "What color are the Sandias as the sun sets?" "Do the Sandias look different when viewed from Albuquerque and when viewed from the East Mountains?" Try to get students to relate as much of their own personal experience of viewing the mountain as possible.

2. Explain that the distinctive look of the Sandias is a result of their geology (both the result of rock type and the result of the way in which they were formed).

   Rock type: As you look at the western side of the Sandias, the bottom three-fourths of the mountain range is mostly made of very old granite. Granite is a rock that is composed of the minerals quartz, feldspar and mica. Granite forms from molten rock deep beneath the surface. The rock cools slowly underground, and the mineral crystals grow to be very big. The pink color at sunset and the eroded rounded appearance of the base of the mountains are both caused by the fact that the mountains here are made of granite. The layered rock at the top of the Sandias is a different kind of rock; it is sedimentary rock, mostly limestone with sandstone and shale. The limestone was formed as a mixture of sediment and fossils at the bottom of an ocean that covered New Mexico about 300 mya. Today the limestone forms the very distinctive layered cap at the top of Sandia Crest.

   In the middle of the rift, associated with the Albuquerque volcanoes, you can find a third type of rock that is very common in New Mexico: basalt. Basalt is a type of volcanic rock that forms when molten rock deep beneath the surface is erupted onto the surface to form a lava flow. Basalt cools very quickly when it reaches the surface and, therefore, the minerals making up the rock are very small and almost invisible without a microscope.

As water and wind eroded the landscape of New Mexico, the river has carried rocks from many areas. If you look closely at the rounded eroded cobbles along today's river channel, which have been carried downstream by the river, you will find granite, limestone, basalt and other rocks from the mountains and volcanoes adjacent to the Rio Grande Rift.

Formation of the mountains: The mountains that form the margin of the rift have been brought up along faults and tilted back, almost like the opening of a trap door. You can see this if you look at the difference between the appearance of the west side and the east side of the Sandias.

3. Demonstrate how the Rio Grande Valley in New Mexico was formed. Place three Kleenex® boxes or blocks of wood together, side-by-side. Then lift all three by holding the two outer boxes—pressing together to raise the middle box as you lift. You have a piece of the Earth's crust with two fault lines (the faults are where the boxes touch each other). Release the tension holding them together, and allow the middle box to drop a few inches, to illustrate the crust dropping in a rift.

   Note: The Rio Grande Rift is not a boundary between two plates; it is a place within the North American plate where the Earth's crust has thinned and dropped downward. Water has followed the low areas of the rift in New Mexico, carrying sand, silt and rocks (products of erosion) along with it over millions of years as the rift formed. Eventually the low areas of the rift were filled with sediment. In the center of the Rio Grande Rift the crust is thin; this becomes the easiest location for magma to come to the surface, such as at the Albuquerque volcanoes.

   Of course, this is a simplified demonstration. In the real situation, the rift would be bounded by many faults on both sides and the rift itself would consist of a series of oval low areas or basins.

4. For younger students, or as an introduction to older students, distribute the time-sequence Diagram A, "Development of the Rio Grande Rift in Three Time Snapshots," and discuss what the area would have looked like if the students could have visited here in a time machine. Are there mountains? How big are they? Was there a river? What direction was it flowing from,

north or west? Where are the volcanoes? Ask students to find and point out these features. Ask students when they would have liked to have lived in the Albuquerque area (20 million years ago [mya], 10 mya, today) and why. Have students color three types of rocks with three different colors:

a. Sandia granite and other rock types around 1.5 bya (billion years ago);
b. the sandstones, shales, and limestones from before the age of dinosaurs and during the age of dinosaurs (350 mya to 65 mya); and
c. the recent sediments filling the rift valley (20 mya to today).

As a group discuss Questions #1, 4, 5, and 6 below.

5. For older or advanced students, introduce the cut-away Diagram B, "Geologic Cross-section of the Rio Grande Rift at Albuquerque" in the student activity pages. Compare the geologic layers to a slice of cake with the levels being different kinds of rock. Ask students to find and point out: 1) the Rio Grande; 2) Albuquerque volcanoes; 3) top of the Sandia Mountains; 4) the largest fault/place of most offset; 5) the magma route to the volcanoes.

   Explain that there are many different types of rocks in the Albuquerque area and that by coloring each layer differently, we will be able to see some of the geologic changes that have happened in this valley.

6. Have students color the diagram and answer the questions.

Questions:

1. Which layer forms the top of the Sandia Mountains and is also buried below the river?
   Pennsylvanian Limestone —300 million years old
2. How many feet/meters of vertical displacement between those two layers?
   40,000 feet/12,400 meters
3. How many feet/meters of vertical displacement are present between the top of the Sandias and the Rio Grande itself?
   5678 feet/1732 meters
4. What happened to the layers of rock that used to be on the top of the Sandias that are still present in the Rio Grande?
   Eroded as the mountains uplifted, the sediments filled in the valleys
5. Which layers have been eroded from the top of the Sandia Mountains?
   Probably all of the Mesozoic units (see overview and geologic time line for more information about Mesozoic)

6. Why are the volcanoes located in the center of the rift?
   Because at the center of the rift, the crust is thinner (again, see overview essay, "Geologic History of the Rio Grande Rift)

Discussion: The colored diagram shows how the layers of rock have dropped down and are off-set in the Middle Rio Grande Valley. Explain that one of the layers of rock in the Albuquerque area was laid down by an ocean that covered this part of North America 300 million years ago; geologists call this Pennsylvanian limestone. This name refers to the time the rock unit was deposited and comes from the state of Pennsylvania, where rocks of this time period were first described. The Pennsylvanian rocks have been faulted in the Rio Grande Rift and are now displaced a great distance. The Pennsylvanian limestone forms the top—horizontal lines seen from Albuquerque—on the crest of the Sandias. The base of the Sandia Mountains contain some of the oldest rock in New Mexico, Sandia granite, which is 1.5 billion years old. The rocks are very old but were pushed up by the rift faults only 5–10 million years ago. Note, the age of the mountains is not the same as the age of the rocks that make up the mountains. (Contrast this to volcanoes where the age of the rock and time of formation are the same.) The Albuquerque volcanoes are very young: about 150,000 years old.

The rift illustrated in the cross-section has dropped deeply on the east side and less on the west. In other areas of New Mexico, the west-side has dropped further. Generally, the rift has large parallel faults, but the center area tips to one side or the other—called a "trap-door" shape, rather than a straight drop down.

Extension/ Assessment: For Grades 3–8, use the techniques described above.

For more advanced middle school students, use the geologic cross-section but have the students color only the Precambrian rocks, Pennsylvania/Permian and the volcanoes. Then have them color the Mesozoic rocks (the age of dinosaurs) and ask them why these rocks are not on top of the Sandias but occur to the east of the Sandias.

Answer: *They either eroded away as the mountains formed or rocks of this age were never deposited in that area. This might happen if it was a high-standing area during this time period.*

Then ask them where the rest of the sediments filling the basin beneath Albuquerque came from.

Sediment that has been eroded off of highlands surrounding the rift or carried down the rift valley by the river.

A few questions for older students:

Find the largest boundary of 'missing time,' between layers. This is the called an unconformity. What might have happened to cause this?

Between the Precambrian and the Pennsylvanian/Permian, either the layers eroded away before 355 million years ago, or the area was high and no material was deposited there.

Look at the faults in the diagram. What type of faults are there? What does this indicate?

They are all normal faults; no thrust or reverse faults are found. This is a signature of a rift valley.

Extension/ Assessment Activity: This activity is a fun evaluation for both younger and older grades. In small groups, students create a model of what they learned from the preceding activity.

Materials for small groups:
- paper and pencils for planning
- cross-section handouts, from this activity, for reference
- plates, trays or pieces of cardboard for the groups to mount their models
- paper for labels
- markers
- plastic knives
- One of the following sets of ingredients:
  - a) cake and icing: un-iced sheet cakes, one per group; frosting containers, one per group, or containers of different colors to be shared by whole group
  - b) peanut butter, jelly and bread for each small group
  - c) Play-Doh® in different colors, one set of at least three colors per small group

Time: two hours

Procedure: 1. Divide class into small groups.

2. After reviewing the rift formation, ask each group to plan how they will show the Rio Grande Rift. They should include the river, layers of rock below the river and the mountains, as well as the steps to form them. Students must identify different parts of the formation with labels. They should refer to their cross-section handouts.

3. Review each group's plans before handing-out one of the above ingredient sets, knives, and labeling paper. Allow students an assembly time of at least 30 minutes to create and label their

models. Encourage groups to add details to them like tiny houses, roads, trees, etc.

4. Have groups describe their model to the class. After the group presentations, plan a time for eating, or, in the case of Playdoh®, baking in the oven for taking home.

Resources/ References: An activity for Grades 6–12 is included in The Watercourse. 2001. Discover a Watershed: The Rio Grande/Rio Bravo. Bozeman, Montana: The Watercourse. "Which Came First the River or the Rift?" p. 195.

What Is the Rio Grande Rift?

Student Questions

1. Which layer forms the top of the Sandia Mountains and is also buried below the river?

2. How many feet/meters of vertical displacement between those two layers?

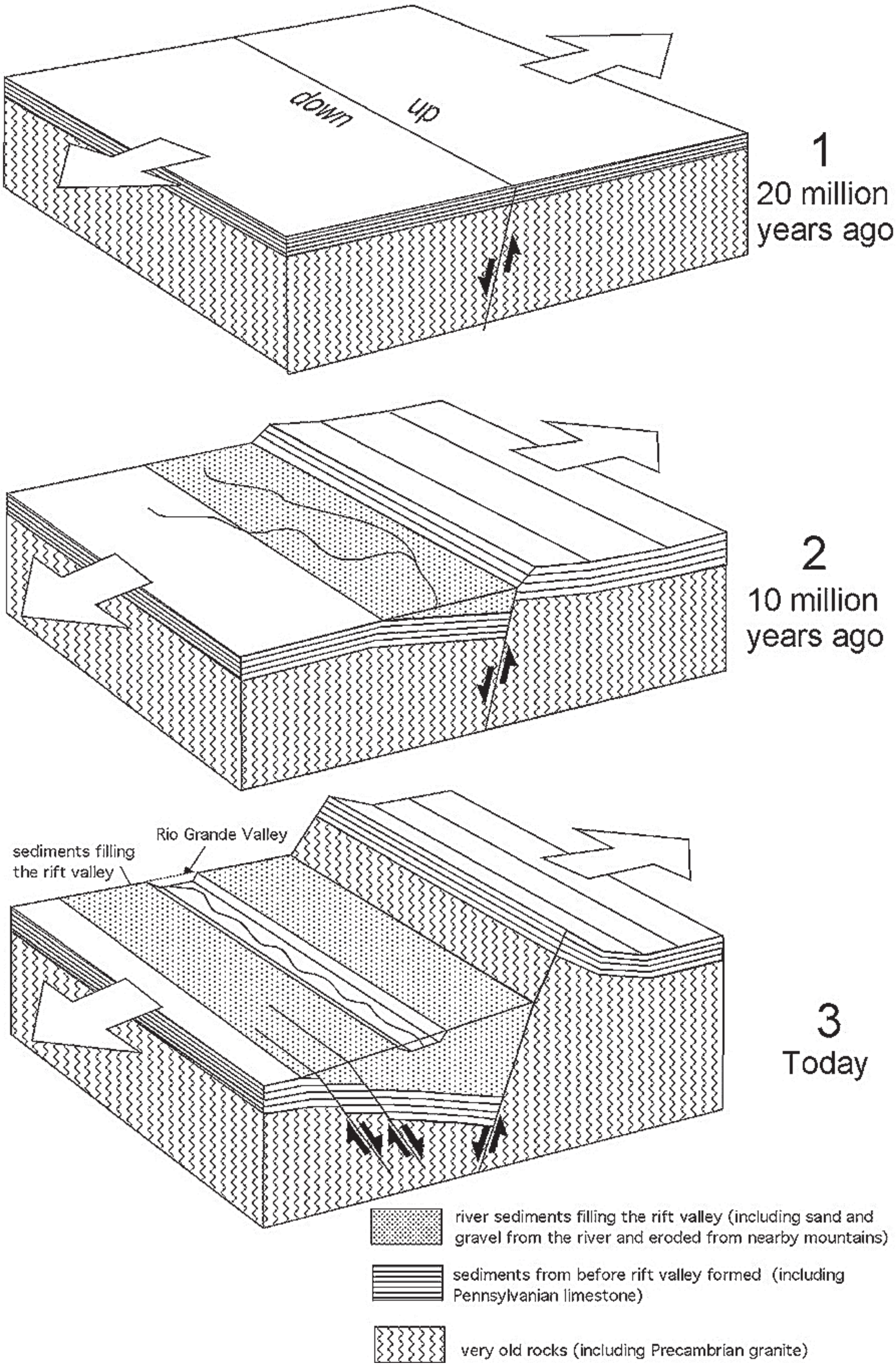
3. How many feet/meters of vertical displacement are present between the top of the Sandias and the Rio Grande?

4. What happened to the layers of rock that used to be on the top of the Sandias that are still present in the Rio Grande?

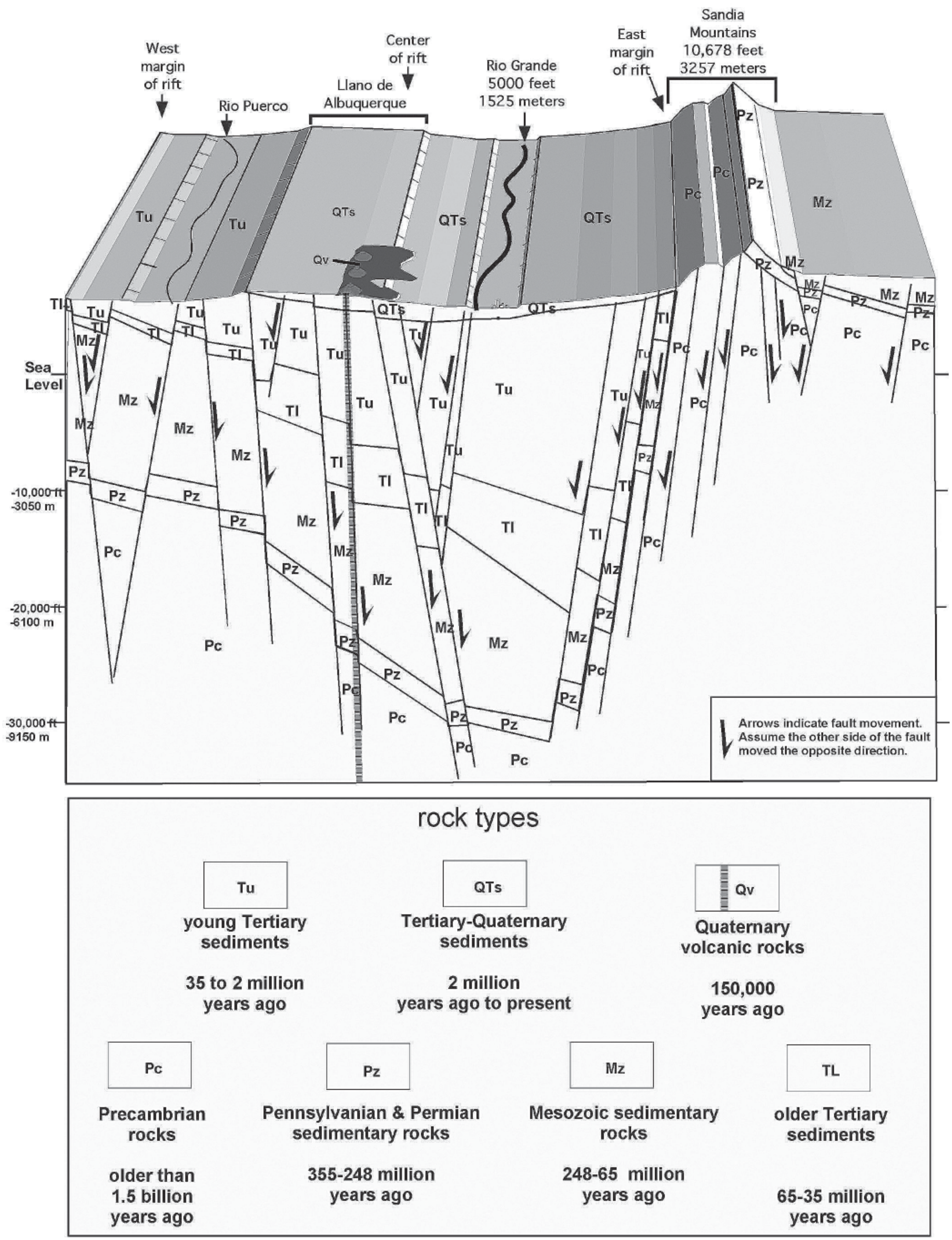
5. Which layers have been eroded from the top of the Sandia Mountains?

6. Why are the volcanoes located in the center of the rift?

A. Development of the Rio Grande Rift in Three Time Snapshots



B. Geologic Cross-section of the Rio Grande Rift at Albuquerque



27. WebQuest: Geologic History

Description: Students work in teams to complete a WebQuest about the geologic history of the Rio Grande and produce a team presentation displaying what they learned.

A WebQuest is a lesson format designed by Bernie Dodge at San Diego State University. This lesson follows that specific format. A WebQuest provides students with a task which can be accomplished using the World Wide Web. Specific web addresses are provided to help guide student research. However, the lesson is loose enough to require students to use research, critical thinking, and synthesis skills to complete the task. Students create a presentation after web research is completed.

Objective: Students will understand:

- that New Mexico is a unique geologic area;
- that the Rio Grande Rift runs north–south through New Mexico and is actively spreading;
- that earthquakes and volcanoes in New Mexico are related to the Rio Grande Rift, as well as other reasons;
- the Rio Grande followed the rift: the river did not cut a valley but rather filled in the rift; and
- the Rio Grande Rift provides the geologic setting for the Rio Grande and the bosque.

Materials: computers with Internet access (minimum one for each team).
PowerPoint, HyperCard, or Netscape or similar software
construction paper
markers, scissors, glue

27. WebQuest: Geologic History

Grades: 6–12

Time: preparation: 10 minutes
activity: three or four class periods

Subjects: science

Terms: *Rio Grande Rift, earthquake, earthquake magnitude, volcano, cinder cone, shield volcano, composite volcano, caldera, ash flow, dome volcano, lava flow, aquifer, sediment*

Procedure: Preparation:

1. Make sure computers are available, working, and connected to the Internet.
2. Assign students to teams of three.
3. Make copies of WebQuest student activity pages.

Doing the activity:

1. Introduce the concept of a WebQuest. Directions are included on the student activity pages.
2. Provide students with a time-line for completing the WebQuest. For example: Day 1–Read the WebQuest and prepare note pages. Day 2–Do web research. Day 3–Do web research. Day 4–Get together as a team and answer "Everyone" questions and design presentation. Day 5–Finish presentation.
3. The teacher should act as a facilitator, helping to trouble-shoot technology problems, asking leading questions, and helping students organize their work. This is a student-centered activity.

Assessment: Presentations—see student activity pages.

Extensions: Have students give oral presentations or show their web or PowerPoint presentations to other students who did not complete the WebQuest.

Teacher Answers to Questions in WebQuest

Volcanologist

1. Why is New Mexico called the Volcano State?
   New Mexico has examples of every type of volcano. New Mexico has a large number, variety, range of preservation, and best examples of volcanoes.
2. What type of volcanoes are in New Mexico?
   Types of volcanoes include cinder cones, stratovolcanoes (composite), shield volcanoes, calderas, ash flows, domes, and lava flows.
3. Why does New Mexico have so many volcanoes?
   The Rio Grande Rift is thinning the crust, making it easy for magma to rise through the crust to the surface.
4. Where will the next volcano likely erupt in New Mexico?
   The next volcano might be near Socorro, New Mexico, where a magma body apparently exists close to the surface.
5. Bonus Question: What other places in the world might be like New Mexico in terms of volcanic structures and activity?
   The mid-ocean ridges, Iceland and East Africa.

Seismologist

1. Does New Mexico have earthquakes? If so, how big are they?
   Yes, New Mexico has earthquakes. Most are fairly small (magnitude 1–3), but some large quakes have occurred in the past century (magnitude 5 –6), and there is evidence of very large earthquakes (magnitude 7) in geologic history.
2. What are some reasons why New Mexico has earthquakes?
   The Rio Grande Rift is still active, rising magma near Socorro, oil and gas drilling, pressure from large bodies of water (Heron and El Vado reservoirs).
3. What causes earthquakes?
   Earthquakes are caused by release of energy in the Earth's crust.
4. Where do earthquakes usually happen? Why?
   Large earthquakes are most concentrated near plate boundaries where tectonic plates are moving relative to each other, but earthquakes can happen anywhere.
5. Bonus Question: What other area of the world might be like New Mexico, in terms of earthquakes, volcanism and general landscape?
   The East Aftrican Rift is much like the Rio Grande Rift, but the East African Rift is actually pulling apart a little faster now than the Rio Grande Rift.

Hydrologist

1. Where did the sediment come from that forms the aquifer?
   The sediment was eroded off the rising Sandia Mountains and other nearby mountains and from volcanoes. The sediment was washed into the Rio Grande Rift and filled up the deep trough.

2. How did this sediment get here?
   Small streams and rivers from the west, as well as the early Rio Grande, washed the sediment into the deep Rio Grande Rift.
3. What did the Rio Grande follow in setting its course?
   The Rio Grande followed the Rio Grande Rift.
4. How is the Rio Grande different from a river that cuts a valley?
   The Rio Grande did not cut its valley. The Rio Grande followed the trough of the Rio Grande Rift. The Rio Grande filled up the rift with sediment instead of cutting down, although it has cut its present-day channel.
5. Bonus: What is wrong with the information given about the size/volume of the aquifer in the Albuquerque Environmental Story page?
   The page says that the aquifer is an underground lake that has large quantities of water. It implies that there is an unlimited supply of water under Albququerque. We now know that drinkable water is limited and we should not take its supply for granted.

Everyone

1. What is the linear feature that the Rio Grande follows that runs north–south through New Mexico?
   The Rio Grande Rift runs north–south and is pulling the crust apart. The center of the Rift is dropped down relative to the sides to form a trough. The trough is mostly filled in with sediment.
2. What is the relationship between this feature and volcanoes, earthquakes, and rivers?
   Earthquakes happen when energy is released from the crust as the rocks in the crust move along a fault. Volcanoes form when magma comes up through the relatively thin crust at the center of the rift. Rivers and streams have filled the trough with sediment. The Rio Grande follows the course of the rift.
3. How did this feature form?
   The Rio Grande Rift is a result of spreading and thinning of the continental crust in this region (see History of the Rio Grande Rift in this chapter). The rift continues to form actively today.

WebQuest: Geologic History

Introduction

Most rivers cut the valley through which they run, but the Rio Grande is very different. We might call it the Rio Grande Valley, but is it really a valley? How did the river get here? The Rio Grande is a unique river in a very unique place.

The Task

You and your teammates need to find answers to the following set of questions. You will use the World Wide Web to research the answers. Once you find the answers, you need to organize the information into an easy-to-follow presentation that explains the geologic history of the Rio Grande. You have a choice of the following options for presenting your answers.

1. Make a poster that has appropriate drawings and information.
2. Make a computer presentation, either as a web-page, PowerPoint slide show or a hyper-studio slide show.
3. Make a picture book.

Each person on your team will have a role and a specific set of questions to research. These are the roles:

Volcanologist: researches the volcanoes of New Mexico and finds out why New Mexico has so many volcanoes.

Seismologist: researches earthquakes in New Mexico and finds out why New Mexico has earthquakes.

Hydrologist: researches the aquifer and the sediments along the Rio Grande and finds out how they were deposited.

Process and Guidance

Each person will use the Internet to answer the questions assigned to her/his role. Follow this procedure.

1. Write down each question that pertains to your role at the top of a separate piece of paper.
2. Visit each web site listed for your role. When you find information that helps answer a question, write down the information on the piece of paper marked with that question. Include drawings. Write down the name of the web site from which you got the information so that you can go back to it if necessary. This part should take two class periods.

3. When everyone is finished researching, each person presents his/her questions and answers to other members of the team. Look for similarities in answers. Answer the “Everyone” questions. You may need to go back to some of the web sites for answers. Begin to put all the answers together to form a story that explains how the Rio Grande was formed and why.
4. Together, choose one of the presentation formats. Design your presentation. Write in your own words and make your own drawings. Do not copy from the web sites. Remember, each team member must contribute text and drawings that pertain to his/her role and questions. Each team member must sign the parts she/he contributed in order to get full credit for the presentation.
5. Grade your other teammembers on a sheet of paper and turn it in (unsigned). Be sure to explain your grade (give examples).
   5 = Team member was easy to work with, did all the work assigned, and was a positive team member.
   4 = Team member did all the work assigned and was mostly a positive team member.
   3 = Team member did all the work assigned but had to be told what to do and how to do it.
   2 = Team member only did some of the work assigned and was not a positive member of the team.
   1 = Team member hardly did anything.
   0 = Team member did nothing.

Questions

Volcanologist

1. Why is New Mexico called the Volcano State?
2. What type of volcanoes are in New Mexico?
3. Why does New Mexico have so many volcanoes?
4. Where will the next volcano likely erupt in New Mexico?
5. Bonus Question: What other places in the world might be like New Mexico in terms of volcanic structures and activity?

Seismologist

1. Does New Mexico have earthquakes? If so, how big are they?
2. What are some reasons why New Mexico has earthquakes?
3. What causes earthquakes?
4. Where do earthquakes usually happen? Why?
5. Bonus question: What other area of the world might be like New Mexico, in terms of earthquakes and plate tectonics?

Hydrologist

1. Where did the sediment come from that forms the aquifer?
2. How did this sediment get here?
3. What did the Rio Grande follow in setting its course?
4. How is the Rio Grande different from a river that cuts a valley?
5. Bonus: What is wrong with the information given about the size/volume of the aquifer in the *Albuquerque Environmental Story* page?

Everyone

1. What is the linear feature that the Rio Grande follows that runs north–south through New Mexico?
2. What is the relationship between this feature and volcanoes, earthquakes, and rivers?
3. How did this feature form?
4. When did this feature form?

Resources

Volcanologist

http://www.nmmnh-abq.mus.nm.us/nmmnh/nmmnh.html
Click on Research and then click on Volcanoes of New Mexico.

http://www.cabq.gov/aes/s1picgeo

Seismologist

http://tremor.nmt.edu

http://pubs.usgs.gov/publications/text/understanding.html
Be sure to read the part about Africa.

http://www.iris.edu
Click on the Seismic Monitor. You should be able to determine where most earthquakes occur.

Hydrologist

http://www.cabq.gov/aes/s1geol.html

http://www.cabq.gov/aes/s1picgeo.html

Assessment

You will receive a team grade and an individual grade. Team grades will be based on the overall completeness and appearance of your presentation. Team grades will also include how well your team worked as a team. Individual grades will be based on your research notes and your contribution to the team.

Team Grade = 40 points
- Completeness: 20 points
  - All questions are answered.
  - Questions are presented in an easy to read/follow format.
  - Information is correct.
  - “Everyone” questions are answered completely and correctly.
- Appearance: 20 points
  - Presentation is neat and pleasing.
  - Presentation includes original pictures and text.
  - Presentation is in easy-to-read format.

Individual Grade = 60 points
- Research Notes: 20 points
  - Each question has a note sheet.
  - Each question shows evidence of research from web sites
  - Each question has proper web site documentation.
- Presentation Answers: 20 points
  - Answers are in original words and pictures.
  - Answers are correct and show understanding.
- Contribution to the Team: 20 points
  - Student contributed fairly and equally to the team.
  - Student contribution to the presentation is signed.
  - Other team members grade your work.

Conclusion

Most people who live in New Mexico do not know why their state is so unique. New Mexico has many geologic features that are unusual and fascinating. Now you can explain some of those features to your neighboring New Mexicans, and you know how and why the Rio Grande formed.

28. Porosity and Permeability

Description: Students test the porosity and permeability of sand, gravel, and clay.

Objectives: Students will understand that:

All grades:

- water is stored underground in the spaces (pores) between grains of sediment; and
- the size of the grains of sediment affects how much water can be stored in the pore spaces.

Grades 5–8:

- the size of the grains of sediment affects how easily water can flow through sediment (permeability);
- sediment and sedimentary rocks that store water constitute an aquifer; and
- porosity and permeability are two characteristics that determine how much water is available in an aquifer.

Materials: Materials are per group of three or four students.

one small graduated cylinder
one dropper
five clear plastic cups—choose clear cups so that students can see the water filling pore spaces
gravel—should be as large as possible and preferably clean
sand—use playground-grade sand only; sand sold and used for mixing with cement (labeled silica sand) has too many fine particles that can harm the respiratory system

28. Porosity and Permeability

Grades: 5–12

Time: material preparation: 15–20 minutes
class time: 30–90 minutes, depending on how many sediment types are tested

Subject: science

Terms: *pore space, porosity, permeability, aquifer, sediment*

clay or very fine soil
sand/gravel mixture
nail
clock or watch with a second hand
four beakers (preferably plastic)
four large containers for holding sediment
four large containers for holding recycled sediment
water

Background: Water is vital to life. More than half of the world's human population uses ground water for survival; but until recently there has been little thought about the problems of depletion or contamination of ground water. More than 20% of the Earth's freshwater resources are in ground water reservoirs; and it is a vital resource, especially in arid areas.

Ground water is present in permeable rocks beneath many land areas; and is a replenishable resource. The problem in arid and semi-arid regions is that the rate of replenishment may be slow or periodic; and the resource can be depleted if ground water withdrawals exceed the local rates of replenishment. This is called ground water "mining." Ground water can actually be dated by the use of radioisotopes. Current work in the Rio Grande Valley indicates that in some areas the ground water we are mining is several thousand years old.

Ground water is created by precipitation. When rain falls, some is absorbed, some runs off into streams and rivers, some evaporates, and the remainder recharges the aquifer. Surface water and ground water are closely related. The water table often represents a reflection of the surface topography, and ground water provides much of the flow in streams and rivers during periods of low rainfall.

When the term ground water is used, many people visualize an underground cavern filled with water. But most ground water occurs in the interconnected pores between rock or sand particles or in fractures in rock. Gravity makes the water connect and flow toward an area where it can be discharged to the surface. Ground water occurs in the ground from the surface to almost 2,000 feet below the land surface and is divided into two zones. The zone where all of the voids in the sand and rock are filled with water is called the saturated zone and the water table marks the top of this zone. Above the water table is the unsaturated zone, where voids in the sand and rock are filled with either air or water.

Layers of rock, sand or gravel that are good ground water reservoirs are called aquifers, from the Latin words for "water" and "to bring." The best aquifers are loose sand and gravel. Sandstone is a good aquifer, while clay, shale and slate are not good aquifers at all. You might be surprised to discover that lava flows can also be good aquifers. The properties that make a good aquifer are those that increase the storage of water (porosity) and increase the flow of water (permeability) within that layer. **Porosity** is the proportion of empty space in a rock. **Permeability** is a measure of the ease with which liquids and gases can pass through a rock. All rocks have pore spaces and fractures; the greater the percentage of pores or fractures and openings in the total volume of the rock, the greater the porosity. In unfractured granite, the porosity may be less than 1%; in loosely consolidated sand and gravel (such as the fill of the Rio Grande Rift), the porosity may be as great as 30%. But it is not enough to have pore spaces; the pores must also be connected so that the ground water can flow. Clay, shale and slate frequently have pores that are not connected and therefore it is difficult for water to enter or leave these rocks. Lava flows frequently have bedding planes and fractures that allow water to flow; springs or seeps are frequently found at the margins of layered lava flows. Fractured granite and metamorphic rock aquifers are the principal sources of water for mountain communities. Because the fractures in these rocks are irregular, the grounwater movement and concentration are also irregular, making exploration for water difficult in these areas.

A type of geologist called a hydrologist studies water resources.

Procedure:

Preparation:

1. Pour sediment into large containers and label accordingly ("sand," "gravel," "sand/gravel," "clay"). Sediment should be dry and free of clumps.
2. Label four more large containers for students to dump used sediment.
3. Using a beaker, determine how much sediment a plastic cup will hold. Write this number on the board. Students must be sure to use the same volume of sediment for each test.
4. Place a beaker in each large container of sediment.
5. Assemble the rest of the lab equipment and divide equipment for each group.

Doing the Activity:

1. Lead a short introductory discussion using the following questions. You may want to write down all student answers on the board. Students can then look back at their answers after the activity to assess how much they learned.

   In New Mexico, where do we get most of our drinking water?

(Students may answer "the river." You should explain that most communities get all or most of their drinking water from underground, although this will change for Albuquerque in 2009.)

From where do the trees and plants get their water? In the bosque, from where do the cottonwoods get their water? How can there be water underground? Where does it come from? How does the water get underground? Have you ever poured water on the soil? Where does it go? How do we (and plants) get the water out of the ground?

2. Develop the questions this lab will examine. Preferably, lead students to develop these questions instead of just giving them the questions. Students may write the questions on their data sheets or in lab notebooks.

   Where is water stored underground?

   Which types of sediment can hold the most water?

   From which types of sediment is it easiest for people and plants to get water?

3. Have students hypothesize answers to the above questions. You may either write group answers on the board or have students write their own hypothesis on their data sheets or lab notebooks.

4. Demonstrate for students how to gather and test each type of sediment. Students will write data on their data sheets or in their lab books.
   a. Use a beaker to fill a plastic cup to the proper volume with gravel.
   b. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
   c. Pour the water SLOWLY into the cup of gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
   d. Record how many ml of water are now in the graduated cylinder, then discard.
   e. Complete the table to determine how many ml of water you poured into the cup.
   f. Hold the cup of gravel over the extra cup.
   g. Have someone ready to watch the clock.
   h. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail. (Note to teacher: sometimes the gravel you use may have lots of finer sediment mixed in. If you have not washed the gravel, your students will get better results

if they poke the hole on the side of the cup, about 3 cm from the bottom).

i. Time for 30 seconds as the water drips from the first cup into the second cup.
j. Pour the water into the graduated cylinder.
k. Record in the table how much water is in the graduated cylinder.
l. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
m. Repeat the above steps for the sand, clay, and the sand/gravel mixture. Use small cylinder for clay portion.

Note: The clay trial will take a long time.

5. Compile all class data. Make two charts on the board: one for porosity and the other for permeability. Have each group record their data for sand, gravel, sand/gravel mixture and clay. Calculate the means of each. Graph the means. This will give more accurate results and will illustrate experimental design and replication.

6. Use the following questions to lead a discussion about the data. Alternatively, you may wish to assign these questions for students to answer in written form.

Grades 3–5

a. What is porosity?
b. Which material above held the most water?
c. Why does the mixture of gravel and sand hold less water than either the sand or gravel?
The sand is taking up the spaces between the gravel.
d. What is permeability?
e. Which cup of material would dry out faster? Why?

Grades 6–8: add the following questions

f. What happens to the porosity when the particle size gets smaller?
You should see that porosity increases with smaller particle size. However, with the small volumes tested, the sand and gravel may show similar porosity values.
g. Which material was most permeable? Why?
h. What happens to permeability as particle size gets smaller?

You should see that permeability decreases with smaller particle size.

7. Re-examine the three questions from the beginning of the lab and the hypotheses. Did the data support the hypotheses? Have students develop a conclusion to these questions, based on their data. You may either write a group conclusion on the board or have students write their conclusions on their data sheets or in their lab notebooks.
8. Write the following question on the board. Have students develop an answer either as a group or as individuals.

What type of sediment would make the best aquifer? Why? (Think about which holds the most water AND which material is easiest to get the water out of).

Extensions: Have students bring in a sample of soil from their own home. Measure the porosity and permeability of these samples. Bring in two “mystery” samples to compare with the lab results. Are any results of the “mystery” samples similar to the lab results?

Related Activities: This activity was adapted from similar activities in the following publications:

Gartrell, J. E, Jane Crowder, and Jeffrey Callister. *Earth: The Water Planet.* Arlington, VA: National Science Teachers Association, 1992.

Lind, K. K, (ed). *Water, Stones, & Fossil Bones*. Arlington, VA: National Science Teachers Association, 1991.

Proyecto Futuro, “Earth and Space Science Supplemental Curriculum.” New Mexico Museum of Natural History & Science, 1997.

Assessment:

1. Have students draw a picture showing where water is stored underground.
2. Have students explain from where trees and plants get their water.

Thanks to Kristin Gunckel for this activity.

Drawings from the Earth & Space Science Supplemental Curriculum produced by the New Mexico Museum of Natural History & Science.

Porosity and Permeability

1. Use a beaker to fill a plastic cup to the proper volume with gravel.
2. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
3. Pour the water SLOWLY into the cup of gravel until the water reaches the top of the gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
4. Record in the data table how many ml of water are now in the graduated cylinder.
5. Complete the table to determine how many ml of water you poured into the cup. Pour the water from the graduated cylinder into the sink.
6. Hold the cup of gravel over an extra cup.
7. Have someone ready to watch the clock.
8. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail.
9. Time for 30 seconds as the water drips from the first cup into the second cup.
10. Pour the water from the second cup into the graduated cylinder.
11. Record how much water is in the graduated cylinder in the data table.
12. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
13. Repeat the above steps for the sand, the sand/gravel mixture and the clay.

    Note: The clay trial will take a long time.

Data Table

	A. beginning ml of water	B. end ml of water	C. ml water used = A - B: porosity	D. ml in cylinder at end	E. ml water dripped out in 30 sec: permeability
gravel					
sand					
sand/gravel					
clay					

29. Rio Grande Bosque Water Cycle

Description: Students roleplay water molecules going through a water cycle.

Objective: Students will understand that:

- water cycles through the Earth and the atmosphere;
- the processes involved in the water cycle include:
  precipitation,
  evaporation,
  runoff,
  transpiration (transpire),
  respiration (respire), and
  condensation;
- in the semi-arid climate of New Mexico, low precipitation amounts limit the quantity of water available for plant, animal, and human use; and
- human users of limited water resources must consider all water users.

Materials:

1. two large buckets, one labeled "Ocean" and the other labeled "Aquifer." Mark a fill line about 1" below the top of the aquifer bucket
2. six bowls with different labels—one each for "River," "Plants and Animals," "Lake," "Agriculture," "Industry," and "Residents"
3. seven paper cups (eight to 12 ounces) to take water from aquifer for agriculture, industry, and residents
4. 18 plastic spoons

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29. *Rio Grande Bosque Water Cycle*

Grades: 3–8

Time: Material preparation: 20 minutes

Class activity: 20-30 minutes

Subjects: science, social studies

Terms: *precipitation, evaporation, runoff, transpiration, respiration, condensation, aquifer, reservoir, ground water*

5. four small (four ounces) paper cups labeled "Clouds"
6. water
7. cards, copied and cut out (from following pages). Laminate them, if possible, since they will be around water.

Feel free to use cups, spoons, etc., that can be reused. Try not to create lots of trash.

Procedure: Preparation:

1. Label all buckets and bowls.

Note: On small cups (Clouds) mark a fill line at two-thirds of the cup capacity.

2. Copy and cut out game cards on the following pages.
3. Fill Ocean, Aquifer, Plants and Animals, River and Lake containers with water. Spread the containers around the room.
4. Place the Clouds (empty) together in another spot in room. Clouds should be as far as possible from the Ocean container because water moving from the ocean to form clouds in New Mexico must travel a long distance.
5. For Round 2, fill Agriculture, Industry and Residents bowls. During Round 2 these containers will also be placed around the room.

Doing the Activity: *Round 1—Rio Bravo*

1. Pass out game cards and appropriate equipment (spoons or cups). Have each student stand at the first station marked on the card. For example, the student with the "Cloud to River" card stands at the cloud station.
2. Explain the basic procedure. Students will move the water in the containers according to the directions on their card. For example, "River to Lake" moves one spoon of water from the River to the Lake, and returns to the River to take another spoon of water to the Lake. Each student/station continues the activity as directed on their card, if possible, for the time-period of the activity (see 4. below).
3. Announce the following special considerations.

   Clouds cannot dump the water as their card directs until their cups have been filled to the fill line.

   Players taking water from the Aquifer and moving to Plants and Animals may not take water if the water in the Aquifer falls below the marked line.

   The Ocean should never be empty.

If a container is empty, players must wait for water to be added by the appropriate process before they take water from the container.

4. Allow five minutes for students to do their assigned task. Switch cards and repeat the process for five more minutes so students may participate in another part of the cycle.
5. Use the following questions to lead a discussion of the process.

   Why do the clouds wait so long to dump their water?
   Air in New Mexico is very dry. Clouds must gather a lot of moisture before they are able to rain.

   Why are the cloud stations so far from the ocean station?
   New Mexico is a long way from the nearest ocean. Moisture must travel a long distance before it can rain on New Mexico.

   Is there enough water available for the plants and animals? Why is the water below the fill line in the aquifer bucket unavailable to plants and animals?
   This water is too deep to be reached by plants or animals.

   Is there enough water available for the river?
   In an undisturbed system, the plants and animals have adaptations for survival with the amount of water available.

   Where is the most water available for use?
   In the aquifer. The ocean certainly has a lot of water, but it is not available for use by freshwater plants or animals in New Mexico. The ocean is so far away, and it is saline/salty.

   Where is the least water available for use?
   In the clouds.

Round 2—Rio Manso

6. Add Agriculture, Industry, and Residents containers to the set-up. Pass out cards and equipment for Round 2.
7. Repeat the exercise as in Steps 3 and 4.
8. Use the following questions to lead a discussion on the process.

   How was this water cycle round different from Round 1?

   Was there enough water available for plants and animals?

   Why?

   Was there water in the river? Why?

   What do you use water for in and around your home?

   What does agriculture need water for?

How would you make changes to insure that everyone, including residents, agriculture, industry, plants, and animals, has enough water?

Where would pollutants enter into this system and where would they go? What would be affected by pollutants?

To the teacher: This is not a black-and-white easy-to-answer issue. There are many pieces to the problem and very good reasons for what each party wants to do with water. We encourage a discussion about the need for agriculture, industry and communities to use water. Who is allowed to use how much water has been an issue since the first people arrived in this area, with many fights between differing parties. We want students to be able to make responsible decisions about water use in the Southwest.

Extensions: Have students determine their daily water use and suggest what impacts they have on the New Mexico water cycle/water budget. See Project Learning Tree, "Every Drop Counts," or Project WILD, "Water's Going On?!"

Do an "imaginary field trip" through the water cycle. See Project WILD, "Stormy Weather," for general idea.

Related Activities: Project Learning Tree, "Water Wonders."

Assessment:

1. Have students draw a diagram or a picture of the water cycle, from memory.
2. Have students write a story about a water molecule that travels through the water cycle in New Mexico.

Water Cycle Cards

Part 1: Rio Bravo

1.
Cloud to River
small cup
rio bravo 1

2.
Cloud to Plants and Animals
small cup
rio bravo 1

3.
Cloud to Aquifer
small cup
rio bravo 1

4.
Cloud to Lake
small cup
rio bravo 1

5.
River Evaporates to Cloud
plastic spoon
rio bravo 1

6.
Plants and Animals Transpire and Respire to Cloud
plastic spoon
rio bravo 1

7.

Lake Evaporates to Cloud

plastic spoon

8.

Lake Evaporates to Cloud

plastic spoon

9.

Ocean Evaporates to Cloud

plastic spoon

10.

Ocean Evaporates to Cloud

plastic spoon

11.

Aquifer to Plants and Animals

plastic spoon

12.

River to Aquifer

plastic spoon

13.
Aquifer to River

plastic spoon

rio bravo 1

14.
River to Plants and Animals

plastic spoon

rio bravo 1

15.
River to Lake

plastic spoon

rio bravo 1

16.
River to Ocean

plastic spoon

rio bravo 1

Water Cycle Cards

Part 2: Rio Manso

17.

Aquifer to Agriculture

large cup

18.

Aquifer to Agriculture

large cup

19.

Aquifer to Industry

large cup

20.

Aquifer to Industry

large cup

21.

Aquifer to Residents

large cup

22.

Aquifer to Residents

large cup

23.

Evaporation from Agriculture

large cup

24.

Evaporation from Industry to Clouds

large cup

25.

Evaporation from Residents to Clouds

plastic spoon

26.

Agriculture Runoff to River

plastic spoon

27.

Industry Runoff to River

plastic spoon

28.

Residents Return to River

plastic spoon

30. Surface Water Demonstration

Description: Students observe what happens in a model of a watershed with a plastic-draped surface representing the mountains and spray bottles to simulate precipitation. Students observe and identify how water behaves on the land's surface.

Objective: Students will understand:

- what a watershed is;
- how different land areas (mountains, foothills, valleys, plains) can be part of the same watershed;
- how surface water collects together and flows only downhill; and
- the cohesive property of water.

Materials:

1. large, heavyweight plastic garbage bag, split open, or plastic drop cloth
2. four or more misters (squirt bottles with a fine mist)
3. lunch boxes or backpacks placed under the plastic sheet to make 'mountains'
4. optional: bucket to collect water that drains off the model, and towels to wipe up the inevitable wetness

Background: All the water on our planet is connected via the water cycle (or hydrologic cycle). The water cycle is a water circulation network. (See the "Rio Grande Bosque Water Cycle" activity in this guide.) The water in the Rio Grande is part of the water cycle. This activity explores the surface water part of the water cycle—precipitation and surface water flow.

30. Surface Water Demonstration

Grades: 3–8

Time: Set-up: five minutes; at least 10 minutes to explain, observe, and compare. Add clean up time for spills.

Subject: science

Terms: *precipitate, cohesion, gravity, watershed, surface water, divide, tributary*

The area of land from which water drains into a river is called its watershed. If you imagine that raindrops fall on your school, you might imagine them collecting with other drops and flowing downhill. All of the water that drains into one river system is part of that river's watershed. It is at the high ridges of mountains that the water dropping in one spot may flow east to one river, while a few inches away, the drops flow west ending in a different river system. Your students will set up a model of a mountain and look for the watersheds of their model. This easy, inexpensive model allows observation of what happens in part of the water cycle, how different land areas (mountains, foothills, valleys, plains) can be part of the same watershed, and how surface water collects together and flows only downhill.

Surface water:
collects together *(cohesion)*,
moves only downhill *(gravity)*, and
is used and needed by plants, wildlife, and people.

Procedure:

1. Using a large table, floor or outdoor space, spread the plastic sheet over lunch boxes or other objects forming a 'landscape' with higher mountains on one side or in one corner, some lower hills just below the mountains, and plenty of fairly flat areas. For a table display, arrange the plastic so that water, which collects and flows to the lowest point, will drain off the plastic in one spot where it can be drained into a bucket.

2. Explain that students will be observing behavior of surface water using a model. Ask your students how real land is different than plastic (it has soil, plants, animals, houses, and people). Real land also allows some water to soak into the ground. However, when the spaces in the soil are filled with water, additional water that falls will collect together and flow.

   Things to look for and identify are:

   Water drops—their size, location, and movement.

   Where on this landscape would our school be? (The foothills? The valley?) (Or where on the landscape would be a good place to build a school?)

   Answer these questions through observation: Where does the water come from? Where does the water go?

3. Select several students to be the clouds—the mister operators. The misters must be set on very fine spray. Other participants will be the scientists. Everyone will observe and describe what happens. The clouds should listen for when to precipitate (mist), when to stop, and when to start again. They need to pay attention for directions on where to mist and to be sure

mist falls on all areas of the 'land,' but not on the scientists. Ask the scientists to observe all areas of the land: the mountains, the foothills, the valleys, the plains, and to let us know what happens on all areas. Encourage students to explain their observations using terms such as **gravity** (the force of gravity causes water to move downhill); and **cohesion** (the property of water molecules connecting and pooling). Encourage students to describe everything observed. Much of the precipitation that falls on the landscape will be part of one watershed.

4. Tell the clouds to begin precipitating. Within a few seconds tell the clouds to stop. Ask the observers what they saw the water do. Guide your scientists to describe water falling through the air, tiny drops forming on the surface of the whole landscape—the mountains to the plains. Be sure to observe the entire landscape. Water should not be flowing yet. Focus on observing the drops appear, then grow, then collect.

5. Precipitate (mist) again. Within a few seconds tell the clouds to stop precipitating. What do students notice about the water? Notice the water flowing downhill on the steepest areas. What is happening elsewhere? Water drops are growing larger as more and more water flows downhill. A few puddles are forming. Guide your observers to watch all areas of the landscape.

6. Resume precipitating. Let the clouds keep going and encourage the scientists to describe what they see as it is happening. Direct scientists to report from all areas of the landscape: the precipitation that still makes tiny drops, the drops that still collect together, the movement downhill. Look for movement uphill or over obstacles—it can't happen! The only way for water to spill out of a mountain pond is to keep collecting together until it is higher than the edge of the pond and then overflow. Look for a lake forming in the valley or on the plains. Where is that water coming from? Water flows down from the mountains and also from land near the lake. The clouds continue precipitating until all scientists and observers have had a chance to observe action on all areas of the landscape, and until valley lakes have joined, finding a way to form a river and flow off the plastic. Most of the precipitation will form one main river; some observant scientists will note that the drops on the back of the mountains or on some parts of the flat areas do not flow into the main river, rather, they leak off the side somewhere. This water is part of a different watershed. Precipitation falls everywhere, not just in one watershed at a time. Some water will also move through the watershed as ground water; this is at a much slower rate of movement.

7. Stop precipitating. Share observations.
8. Define the boundaries of the main watershed with your class. Determine ridge tops and areas where the drops collect into the main watershed of the model. Locate land areas where drops form and do not join the main watershed. Guide students to recognize that there are two or more watersheds, depending on where the water flows. Encourage students to review all observations in summary.

Assessment: Depending on the age of students, have them write or draw what might happen to a raindrop.

How are mountain water and valley water connected?

List three things you observed about water on the surface water model.

Define these vocabulary words: precipitate, cohesion, gravity, watershed, surface water, flow.

Extensions: Do the "Watersheds in New Mexico" activity in this guide.

Connecting with the Watershed: Contact a school along another part of the Rio Grande and trade information. Imagine pen pals in another state, or another country, but in the same watershed! What would you like to tell students on a different acequia or arroyo or tributary about your part of the watershed? One school in Albuquerque hosted and gave tours to another local school investigating the bosque. Students can trade photos; monitor the river near their school and post the data; create a field guide to part of the bosque nearest your school or for use on a visit to the Rio Grande Nature Center State Park; visit a school in a different part of town for a tour of how they care for their part of our river.

Students can connect to another stretch of the river. Examples include a high school class from Las Cruces that planned a raft trip near Taos, to experience another reach of their river, and an elementary school in Santa Fe that visited the Rio Grande Nature Center and compared the Rio Grande to their reach of the Santa Fe River.

Mapping Fun: How can we tell if we're in a watershed? Where are we on the map? What map?

You might want to start by making your own map. Imagine a raindrop falling on your schoolyard, joining with other drops and flowing downhill. Where does it go? Is there a tiny arroyo from the canales or gutters of your school building? Does your parking lot drainage lead to an arroyo at the edge of your school grounds?

Does it have a name? Maybe that is as far as you want to draw your first map.

Where does it go from there? Perhaps you would like to get a topographic map including the area of your school. This will show the major arroyos or tributaries near you. How far does your raindrop have to travel to reach the Rio Grande? Locate your country, locate your state, and locate your town on a map. Then get a map of your town, and your part of town. Maybe you want to start with the big picture before you imagine your raindrop. (See "Watersheds" activity in this chapter.)

Watershed Health: How healthy is your section of the Rio Grande watershed?

We all share in the water quality and other resources of our watershed. One way to contribute to the care of our watershed is to collect data and monitor conditions. A **survey** is a collection of measurements, and to **monitor** is to take those measurements over time and compare them. This allows us to notice changes. We can be informed as to the quality of wildlife habitat, drinking water, and pollution issues. Investigate the activity "Kick-net Kritters" (in Chapter 3) for information on how sampling a stream's aquatic macroinvertebrates (water bugs) constitutes a rapid assessment and is an indicator of riparian habitat and water quality.

31. Watersheds in New Mexico

Description: Students will color the different watersheds in the Southwest to learn which rivers drain out of each area of the state/region. Extensions include making a pie chart to show the area of each watershed in the state, researching the watersheds in teams and presenting findings about the state's watersheds to the class in a poster presentation.

Objectives: Students will:

- understand the concept of watersheds; and
- be able to identify the watersheds in New Mexico and the Southwest and where they flow.

Materials: colored pencils or highlighters

a copy of the Define Watershed Boundaries worksheet for each student

a copy of the New Mexico Watersheds map for each student

physical map of North America (for finding where New Mexico's rivers flow)

Background: Precipitation that falls to the ground can have one of several things happen to it—it can evaporate, soak into the soil to become ground water, or flow downhill as surface water in rivers and lakes. In this activity, we consider surface water movement as we look at the watersheds of New Mexico. Watersheds are identified by surface water movement. Rivers, streams, creeks, and arroyos are formed where water flows when following gravity. A watershed, or drainage basin, is an area of land drained by a river, river system or other body of water. Except in closed basins, which have no outflow, all watersheds eventually drain into an ocean or sea. Thus you can follow a river from its mouth up to its headwaters, including all of the tributaries that flow into it, to get an idea of the size of the watershed.

31. Watersheds in New Mexico

Grades: 6–8

Time: two class periods

Subjects: science

Terms: *watershed, tributary, Continental Divide, closed basin, headwaters*

It is important for students to understand their place in the watershed. There are plants, animals and people living above them (upstream) and below them (downstream). Things that happen upstream in the upper watershed will flow down to affect them, and things that their community does in the river or drainages of their area will affect plants, animals and people downstream.

New Mexico also contains several closed basins. The water falling in these basins flows down into the basin, but does not flow out to other rivers. Thus, this water does not flow into an ocean. These basins are surrounded by mountains or highlands. The water either soaks into the ground, becoming an aquifer, or pools in surface lakes open to evaporation. In this activity, the closed basins are shaded so as not to confuse students in their search for the boundaries of the major river watersheds.

Terms:

Closed basin: a drainage surrounded by high land without a natural outlet; surface water does *not* flow out to a larger river and thus does not reach the ocean.

Continental Divide: the boundary that separates streams flowing toward the Atlantic or Pacific oceans. Along this divide, water falling within a few feet, such as at a mountain ridge, could flow to different oceans.

Headwaters: the upper reach of a watershed, where the water first collects and begins to flow as a stream.

Tributary: creeks, streams or rivers which feed into a larger stream, river or lake.

Watershed (drainage basin): an area or region drained by a river, river system or other body of water.

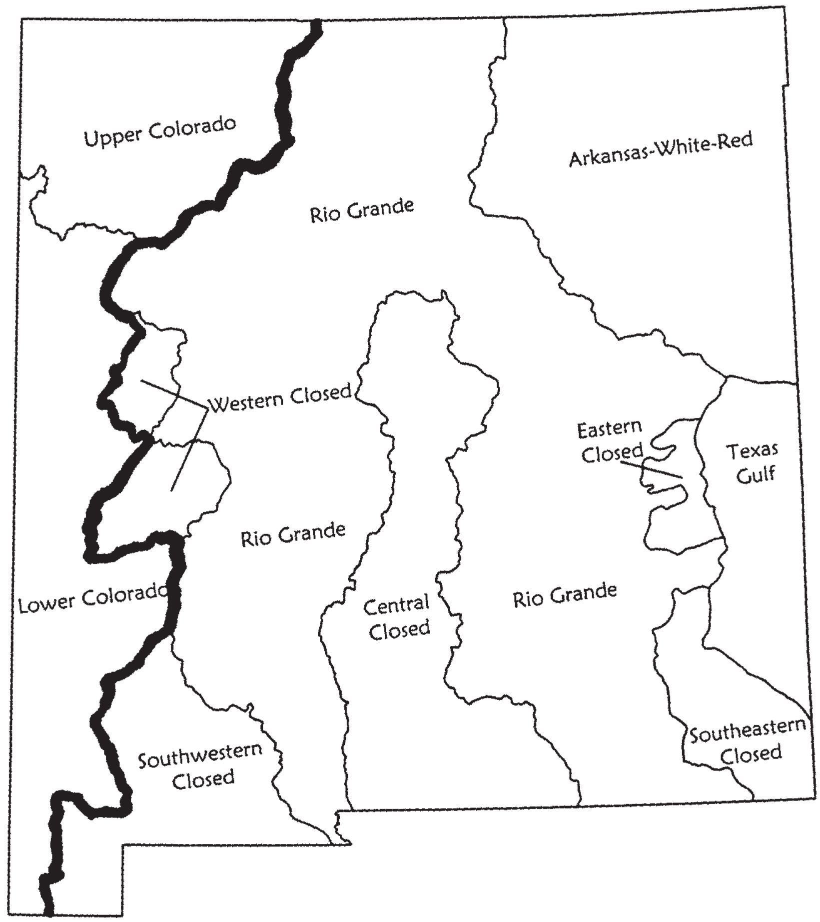
In the activity, the tributaries of the Colorado River are divided into the Upper Colorado Basin and the Lower Colorado Basin. They are all part of the Colorado River Basin, but are considered separately in dividing water for human use. The Glen Canyon Dam near the Arizona–Utah border marks the division.

Procedure:

Introductory questions:

What river do we live near?

Where does our river come from—where are the headwaters of that river? Where does it flow from here—in what direction? Does it flow into a larger river and where does that flow? We are going to look at maps to learn about all of the drainages in New Mexico, called **watersheds**. We will also identify all of the large rivers in New Mexico and where they flow.



River basins and Continental Divide in New Mexico

Do we live in the Atlantic or Pacific watershed? Do you know what the Continental Divide is? The Continental Divide passes right through New Mexico so some of the water that falls in New Mexico goes to the Pacific and some goes to the Atlantic.

Begin the activity: hand out the Define Watershed Boundaries worksheet. Ask students to choose a color of pencil or highlighter marker for each different river system in New Mexico. Begin with the Rio Grande. Start at the bottom of the map with the Rio Grande; begin outside the state boundary and trace upstream. Make sure everyone knows where to begin. Students should trace the main channel of the Rio Grande and all of the tributaries that feed into it with the same color. Color the rivers only at this point. Students must look closely for the sometimes-small space between the upper end of two streams—they almost meet in many locations and in reality only a few feet may separate one watershed from another. (Refer to the "Surface Water Demonstration" activity for a physical model of a watershed.)

After coloring the Rio Grande, color its tributaries in the same color. Then find the rivers below and color them and their tributaries in separate colors:

Pecos
Canadian/Beaver/Cimarron/Arkansas/Frio
San Juan
Little Colorado/Gila/Black

The boundaries of each watershed are between the differently colored river systems. Students can draw a line to divide each color from the other colors, then lightly color the entire area within that divide with the same color as the river. They now have a watershed map.

Use classroom or library resources to link the series of rivers from New Mexico to other rivers and into their respective ocean (the Atlantic/Gulf of Mexico and the Pacific/Sea of Cortez) as shown in the answer key below.

Answer Key:

Rio Grande Basin
Rio Grande—Gulf of Mexico—Atlantic
Pecos River—Rio Grande— Gulf of Mexico—Atlantic

Arkansas-White-Red Basin
Canadian River—Arkansas—Mississippi— Gulf of Mexico—Atlantic
Beaver River—North Canadian—Arkansas—Mississippi— Gulf of Mexico—Atlantic
Cimarron River—Arkansas—Mississippi— Gulf of Mexico—Atlantic

Upper Colorado Basin
San Juan River—Colorado—Sea of Cortez (Gulf of California)—Pacific

Lower Colorado Basin
Little Colorado River—Colorado—Sea of Cortez (Gulf of California)—Pacific
Gila River—Colorado—Sea of Cortez (Gulf of California)—Pacific

Texas Gulf Basin
No major streams are in New Mexico's portion of this basin, so it is shaded already.

Once they have defined the watershed basins of the state, the students can locate the Continental Divide. Ask the students which watersheds flow to the Atlantic and which to the Pacific. The divide is the line where those watersheds meet.
It runs north–south, in the western part of the state. Have them draw the Continental Divide on their map with a different color or type of marker.

Extensions: A. Follow up the mapping activity with the following open-ended questions/discussion.

Major John Wesley Powell was well-known for making the first scientific exploration by boat of the Colorado River through the Grand Canyon. He was politically influential in the late 1800s as a result of his extensive research trips in the western U.S. He maintained in written reports and congressional hearings that the West should be organized by watersheds. New political lines, such as state boundaries, should follow the natural watershed boundaries and not arbitrary lines such as the 37th parallel.

In 1876 Powell wrote: "Nature in its drainage network has indicated the pattern of rational settlement." He further wrote in a report to a special congressional committee, "I early recognized that ultimately these natural features would present conditions which would control the engineering problems of irrigation and which would ultimately control the institutional or legal problems."

What did Major Powell mean when he said this?

How would New Mexico be different if the state boundary followed watershed boundaries?

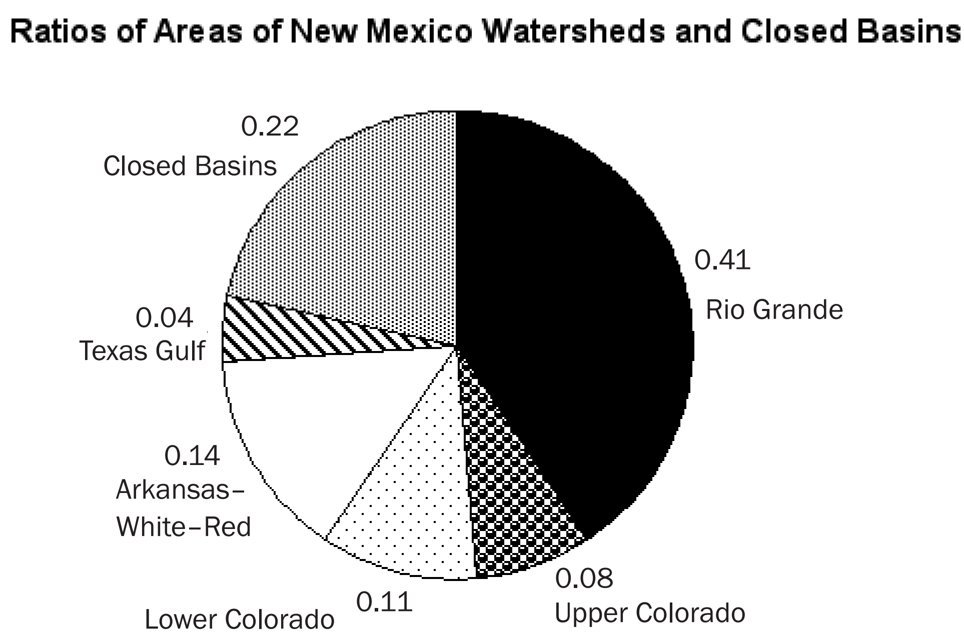
How does the upper watershed area affect areas downstream?
This can be answered in many ways. For example, ecologically plants and animals travel up and down watersheds. Hydrologically water flows downstream and any pollutants will travel down—what is upstream in terms of pollution possibilities? The volume of water—if too much is used, there won't be much downstream; each year the snow melt causes a flood pulse—the rise in water in the spring brings nutrients, moisture for seed germination, etc; sediment is moved—etc.

B. Here are the number of square miles and kilometers of the state that are drained by each watershed:

Basin (Watershed)	Square Kilometers	Square Miles
Rio Grande	127,718	49,299
Upper Colorado	25,241	9743
Lower Colorado	34,573	13,345
Arkansas-White-Red	45,539	17,578
Texas Gulf	13,695	5,286
Central closed	30,836	11,903
Eastern closed	3,115	1,202
Western north closed	2,942	1,136
Western south closed	5,136	1,982
Southwest closed	17,071	6,589
Southeast closed	9,002	3,475
Totals	**314,868**	**121,538**

Summary of New Mexico area:
Area NOT a closed basin: 246,766 km^2/95,251 mi^2
Area of closed basins: 68,102 km^2/26,287 mi^2

Make a pie chart to show how much of the state is in each watershed. This is easiest with a computer program.



The entire Rio Grande watershed is 920,389 square kilometers/355,500 square miles. What percent of the watershed is in New Mexico? *18.4%*

The entire length of the Rio Grande is (about) 3033 kilometers/1885 miles (depending on how finely one counts the changing meanders); 752 kilometers/470 miles of it is in New Mexico. What percent of the length is in New Mexico? *Almost 25%; 24.8/24.9% rounded*

C. Divide students into teams for each of the watersheds. Have them do a poster on that watershed and present to the entire class. Things to be included: hand-drawn map of the watershed showing at least three communities; descriptions of a watershed boundary, for example: where does it flow to—does it go to the ocean (and which ocean)? Research other statistics—length of each river? What dams if any are on this river? What wildlife refuges, if any, are on or near this river? What major industries are located along the river. What threats are there to the quality of water and natural areas along this river?

D. Discuss the City of Albuquerque's plan to use San Juan/Chama water for municipal use. This water is already brought from the Colorado watershed into the Rio Grande watershed as part of the Colorado River compact. What do students think about moving water from one watershed to another?

Assessment: The group project (C.) can be a final assessment. Have students draw a free-hand map of New Mexico showing the rivers and watersheds of the state or give them a different map to draw.

Resources/ References

maps (North America, New Mexico and NM Fishing Waters Map)

deBuys, William, ed. 2001. Seeing Things Whole: The Essential John Wesley Powell. Washington: Island Press/Shearwater Books.

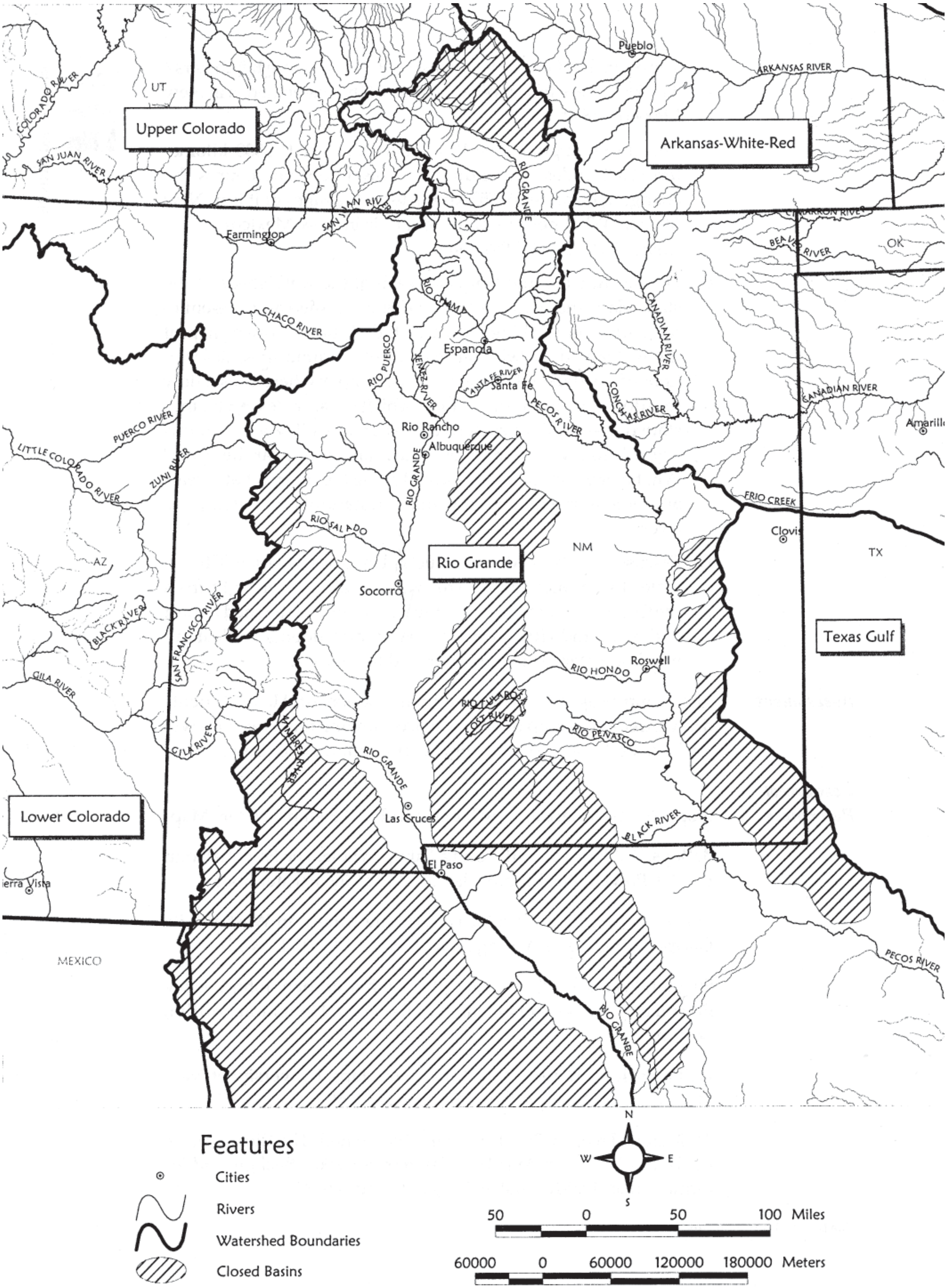
Reisner, Marc. 1986. Cadillac Desert: The American West and Its Disappearing Water. Viking Press, New York, NY (Powell)

Stegner, Wallace. 1954. Beyond the 100th Meridian: John Wesley Powell and the Second Opening of the West. Houghton, Mifflin, Boston.

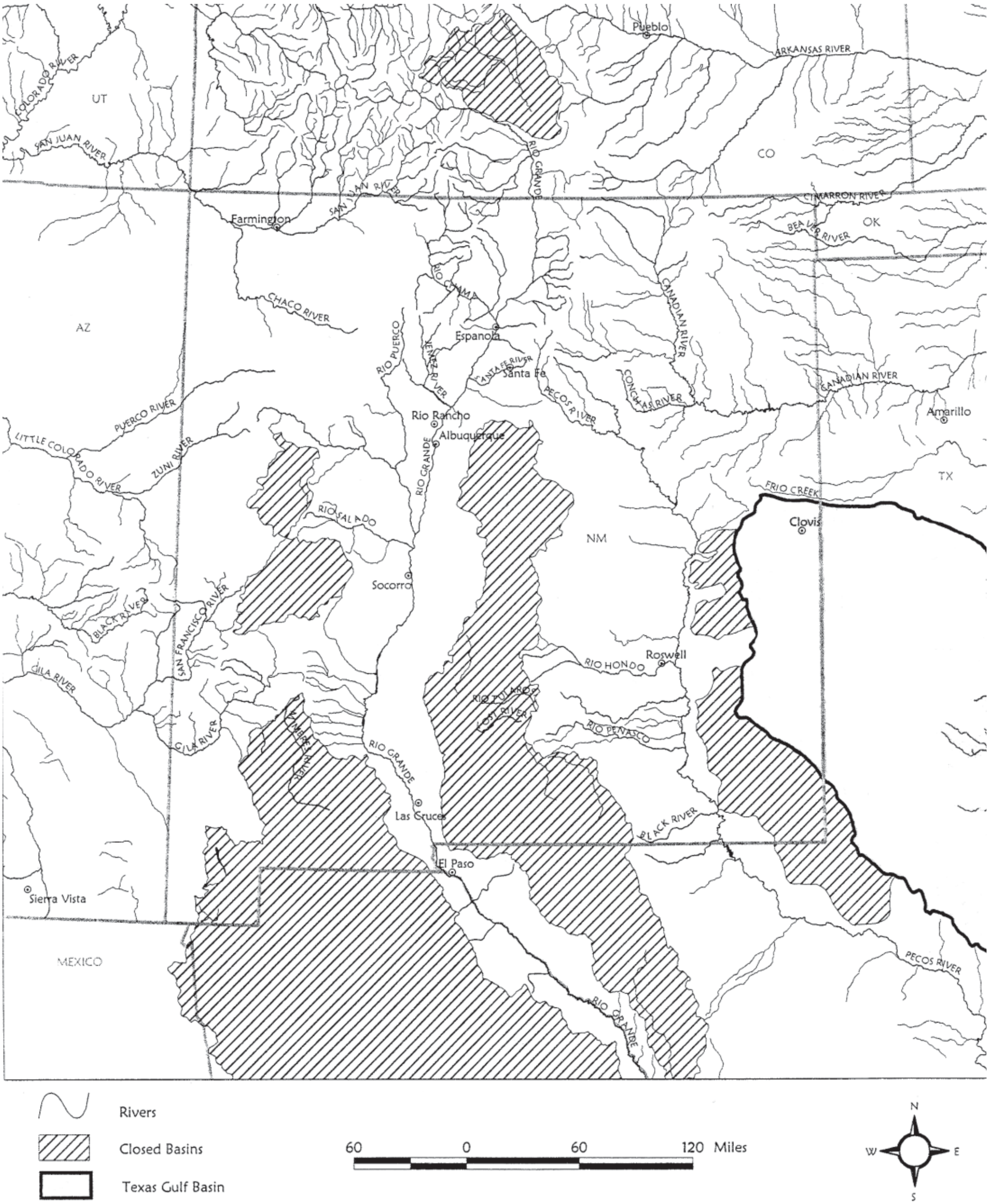
Williams, Jerry L. 1986. New Mexico in Maps. University of New Mexico Press, Albuquerque. "Surface Hydrology" p. 55–57.

"Tributary Tree," p. 201, Discover a Watershed: The Rio Grande/Rio Bravo. Bozeman, MT: The Watercourse. 2001. Background information and additional activity for Grades 6–12.

Teacher Key: New Mexico's Watersheds



New Mexico's Watersheds



Define Watershed Boundaries

Student Worksheet

1. Color these groups of rivers, choosing a different color for each group. Color the boxes next to the river groups below to correspond with how you colored the rivers on your map. Start with the main stem of one river: trace it all the way up, then color all the tributaries for that river system the same color as the river. Then use another color for the next river system, tracing the main stem and the tributaries. Look closely—some streams are very close together, but they belong to different watersheds. Often, they are separated by only a few feet on either side of a mountain ridge. Work your way upstream on each river.

- ☐ Rio Grande
- ☐ Pecos
- ☐ Canadian/Arkansas/Cimarron/Beaver/Frio
- ☐ San Juan
- ☐ Gila/Little Colorado/Black (AZ)

2. Locate the boundaries of the watersheds. Draw a line to show the edges of the watersheds.

Here are some hints to help you draw the boundaries.

A boundary separates different river systems. Look for rivers and tributaries that are almost connected, but not quite.

There are five watersheds in New Mexico.

The Texas Gulf Basin does not have any rivers or tributaries marked on your map. It is already colored for you.

3. Using the same color as the river system, lightly color in the watershed. Don't color the closed basins.

4. Using your map and a map of the United States, trace the path of the following rivers to the ocean; list all of the rivers between each river and the ocean.

Example: Rio Grande→Gulf of Mexico→Atlantic Ocean

Pecos→ ______________________________

Canadian→ ______________________________

Beaver→ ______________________________

Cimarron→ ______________________________

San Juan→ ______________________________

Little Colorado→ ______________________________

Gila→ ______________________________

5. The Rio Grande watershed includes another major New Mexico river. Which river is it?

6. Label the following watersheds on your map:

Arkansas-White-Red Basin

Texas Gulf Basin

Rio Grande Basin

Upper Colorado Basin

Lower Colorado Basin

7. Locate the Continental Divide and draw it on your map with a different color or type of marker. Add that to the map key.

8. Put a star where your community is on the map. List that on the key as well.

32. Rio Grande Stream Table

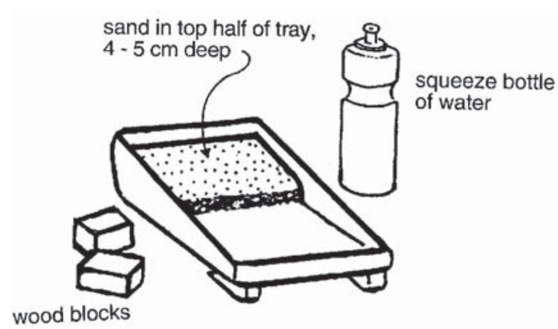
Description: Students will use stream tables to model river processes, especially as they relate to the Rio Grande and the Rio Grande bosque.

Objective: Students will understand that:

- rivers transport sediment;
- rivers shape the land through erosion and deposition;
- the Rio Grande does most of its erosion in the mountains and deposits the sediment along the flatter reaches;
- rivers generally erode on the outside of a meander and deposit sediment along the inside of a meander;
- in the bosque, the inside of a meander is prone to flooding; and
- levees and channelizing of the river have changed the river patterns and processes along the Rio Grande.

Materials: For each student group of three or four students:

paint tray or inexpensive paint tray liners
sand—use playground-grade sand only: sand sold and used for mixing with cement (labeled silica sand), has too many fine particles that can harm the respiratory system.
water bottle or plastic beaker
wood blocks 2” thick
Legos® or Monopoly® pieces to use as houses
paper towels



32. Rio Grande Stream Table

Grades: 3–12

Time: material preparation: 20–30 minutes
class activity: 60–80 minutes, depending on number of trials

Subject: science

Terms: *erosion, deposition, meander, levee, floodplain, sediment, sand bar*

Background: The landscape of our planet has developed by the interaction of two opposite forces: the force of erosion, wearing away landforms, and the geologic processes that build landforms, generally through volcanism and mountain building. Running water is the most important of the forces of erosion. Year after year, streams and rivers erode and move an enormous amount of rock, sand and gravel from topographically high areas and deposit it in topographically low areas.

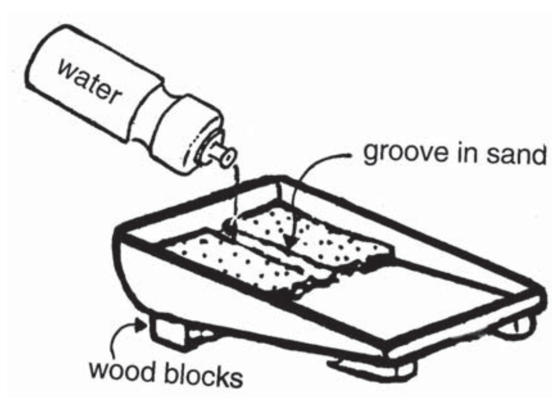
The same stream can: 1) carry and transport material that was eroded elsewhere; 2) erode its own channel and banks; and 3) deposit material along its channel and banks. Whether the stream does one or more of these depends on the energy of the stream. This energy, in turn, depends upon the amount of water in the stream and the gradient of the stream channel (the difference in elevation between the beginning and end of the stream).

Streams adjust themselves as changes occur in their channel and their gradient and in the velocity of their water. Streams attempt to maintain a constant gradient by increasing or decreasing stream velocity, which affects the deposition or erosion of sediment, which in turn affects the depth and width of the stream channel. As the velocity of the water increases, the size of the material that can be carried by the water and the energy of the stream increase.

Monitoring the volume and velocity of streams is very important in order to understand how much water is available downstream for agriculture, cities, flood control and other uses. The very first river gaging station built by the U.S. Geological Survey in 1889 was in New Mexico, at Embudo Station on the Rio Grande south of Taos.

Procedures: Preparation:

1. Poke a hole at the bottom (shallow end) of each paint tray for water to drain.
2. Fill each paint tray one-half to three-quarters full with sand. The deep end should be the top and the shallow end should be the bottom. Most of the sand should be in the deep end at the top.



3. At each student work station, place the paint tray on the table with the drain hole hanging just over the edge of the table.
4. Place a bucket on the floor underneath the drain hole in the paint tray to catch water.
5. Divide the rest of the equipment for student groups.

Doing the activity:

1. Begin by asking the following questions. Accept all answers as hypotheses. You may have students write down the question on their data sheets or in a lab notebook.

   "How do rivers shape the land?"

   "How does the Rio Grande shape the bosque?"

2. Demonstrate to students how to use the stream table. Show how to slowly pour water from the beaker or water bottle onto the sand at the top of the paint tray. Demonstrate how the drain hole must be over the bucket.
3. Allow students some time to play with the sand and water. Have students make streams with a finger in the sand and watch what happens as the water flows down the tray.
4. After students have had about 10 minutes to play, have students build the following models. Students should watch each model and note where the river erodes sediment and where it deposits sediment.
   a. Straight river.
   b. Straight river with the top of the paint tray propped up on the wood block (steeper).
   c. Straight river with most of the sediment pushed up to the top of the tray to form mountains at the top and a flat plain toward the bottom. Do not use blocks.
   d. Curving (meandering) river. Be sure to use a broad meander. Do not use blocks.
   e. Rio Grande–Rio Bravo: Push most of the sand to the top of the tray to form mountains and a flat plain toward the bottom. Make a broadly meandering river on the flatter, lower part of the tray.
   f. Rio Grande–Rio Manso, early: Repeat Trial e above but add houses along the river.
   g. Rio Grande–Rio Manso, later: Push most of the sand to the top of the tray to form mountains and a flat plain toward the bottom. Make a straight river on the flatter, lower part of the tray. Build levees next to the river. Add houses outside the levees.

Note: Make sure the students don't dump the sand in the sink at the end of the activity.

5. You may want to have students draw pictures of their river models, using different colors to mark areas of deposition and erosion (examples: red = erosion, green = deposition). Have students describe how each trial is different from the previous trial. You may either ask students questions after each trial or have them describe on their data sheets or in their lab notebooks what happened.
6. Discuss the results using the following questions. You may choose to write answers on the board or have students answer questions on their data sheets or in their lab notebooks.
   a. How did the river pattern change when you put the stream table up on the block? Was there more erosion or deposition? Why?
      There should be more erosion because there is more potential energy for the water to cut into the sediment.
   b. When a river meanders, where does erosion happen (the outside or the inside of the meander)?
      Students should see erosion happening on the outside of the meander.
   c. When a river meanders, where does deposition happen (the outside or the inside of the meander)?
      Students should see deposition happening on the inside of the meander.
   d. How did the river pattern change when you made the mountains and the plain?
      Students should see more erosion in the mountains and more deposition on the plain. This model reflects the modern Rio Grande.
   e. Based on what you know about cottonwood trees, where would new cottonwoods most likely sprout?
      New cottonwood trees would sprout on the inside of meanders where flooding and deposition happens.
   f. What happened to the houses in Rio Bravo Part II (Trial 4.f)?
   g. Did the levees protect your houses any better?
   h. Based on what you know about cottonwood trees and bosques, what would happen to the bosque after the levees were built?
      The river no longer meanders, floods are confined, and cottonwoods would not begin to grow as easily as before the levees.
   i. In Albuquerque, the Rio Grande is actually higher in elevation than the houses in the North Valley. What would happen if we didn't have levees or if the levees broke?

j. Based on what you know about bosques and river processes, what do you think we should do to help the bosque and protect homes and businesses?

Assessment: Have students draw the Rio Bravo and Rio Manso and show, on the drawing, how the river shapes the land and shapes the bosque. Alternatively, students could answer the question in written, paragraph form.

Extensions: During the activity, students may ask questions about "What would happen if . . .?" Allow students to write down their questions and a hypothesis and then test their hypothesis with the model.

Soil Conservation Districts throughout New Mexico have an outreach program where they bring their "Rolling River" trailer to schools. This is a large stream table where the whole class can see river dynamics in action. Call your local Soil Conservation District office to inquire.

Related Activities: This activity was adapted from similar activities in the following publications:

Gartrell, J. E, Jane Crowder, and Jeffrey Callister. Earth: The Water Planet. 1992. Arlington, VA: National Science Teachers Association.

Project Storyline: Science, the Changing Earth. 1993. The California Science Implementation Network, University of California, Irvine.

Proyecto Futuro. Earth and Space Science Supplemental Curriculum. 1997. New Mexico Museum of Natural History and Science.

Thanks to Kristin Gunckel for this activity.

Drawings from the Earth & Space Science Supplemental Curriculum produced by the New Mexico Museum of Natural History & Science.

33. How Deep is the Water Table?

Description: Students work in teams of scientists to analyze ground water data to determine how deep to plant cottonwood poles.

Objective: Students will understand:

- how to graph data in order to make interpretations;
- that Rio Grande levels fluctuate on an annual basis, generally peaking in the spring and early summer because of snow melt;
- that science is an ever-changing pursuit and scientists don't always know all of the answers; and
- that ground water levels are highly variable and ground water systems are complex.

Materials: For each group of four students:

copies of data tables
map of well sites
four rulers
graph paper
colored pencils (optional)

Procedure: Preparations:

1. Make copies of all data tables for each group.
2. Obtain materials for each group.

Doing the activity:

1. Lead an introductory discussion that summarizes what students should already understand about ground water. Points students should already understand:
   a. Cottonwood trees need floods in order to regenerate naturally.

33. How Deep Is the Water Table?

Grades: 7–12

Time: preparation: 10 minutes
class activity: 40–60 minutes

Subjects: science, math

Terms: *runoff, ground water, water table, pole planting, discharge, fluctuation, anomalous*

b. Cottonwood trees and other plants living in the bosque take up water through their roots.
c. Cottonwood trees, and some other trees, have their roots in ground water.
d. Ground water is water stored underground in the pore spaces between sediment grains.
e. Ground water can travel through sediment (permeability).

2. Set the scene for the activity.

   Each student group is a team of scientists. In this situation, the City of Albuquerque is concerned about the Rio Grande bosque. The city would like to plant cottonwood poles. Cottonwood poles are long, live branches off a large cottonwood. When stuck into the ground to the level of the water table, the cottonwood poles will sprout roots and become new cottonwood trees. The problem is, the city wants to know how deep to plant the cottonwood poles so that the roots will sprout. They have come to you for help. Your job is to analyze some data you have collected from wells in the bosque to determine the characteristics of the ground water table at each well site, so that cottonwood poles can be planted at each area. (There is more information on pole planting in the Rio Nuevo section of the "Changing River" activity and in Chapter 7, Service Learning.)

3. Pass out the data tables and graph paper to each group. Each person in the group should graph one set of data. Three of the data sets are measurements of water depth in the wells. Therefore, in order to make interpretation of the graphs easier, students should graph the data with the graph origin (0 feet below the surface) in the upper left-hand corner. Each team member should use the same scale for the graphs so they can be compared.

   Take time to review graphing with your students. If students are very familiar with graphing, you may need to make a few points about the location of the origin. If students are not accomplished with graphs, you may want to get them started by demonstrating how the graph is set up.

   Stress that these are *real* data and that the question about the depth to plant cottonwood poles is a *real* question the City of Albuquerque is investigating. Note that the data sets are incomplete. Equipment failures and logistics problems often contribute to incomplete data sets. In this case, it is permissible to connect all of the data points, except in places where the data skips more than four months. Completed copies of the graphs are included in this lesson as a key. Note that to reduce space all three well-depth data sets are combined into one graph.

In discussing the data, explain the term discharge. The volume of water in a river is measured in cubic feet per second (cfs). For example, if a river has a discharge of 300 cfs, at any given point, 300 cubic feet of water are flowing by each second. Another way to think about this measurement is that a cubic foot is approximately equal in size to a kitchen sink. At 300 cfs, have students imagine 300 kitchen sinks of water flowing by each second.

4. Once the graphs are complete, begin an analysis of the graphs. Teams should use all of their graphs together to make interpretations. You may either carry out the analysis as a class, or pass out the analysis questions to each group. Analysis questions are listed after each data set.
5. Have each group of student scientists prepare a summary of the well sites and determine how deep to plant the cottonwood poles.

Extensions/ Assessment:

1. For younger students: do the activity as a class.
2. Students can make more graphs using data available from the U.S. Geological Survey available at http://nm.water.usgs.gov/waterwatch
   Have students write an interpretation of the graph that characterizes the ground water table at the well site.
3. Transfer the individual team graphs to one graph for better comparison (see key).
4. Visit pole planting areas, assist on a pole planting project or take a trip to well sites with a researcher to see how he/she measures the water table. See Chapter 7, Service Learning, for more information.
5. Discuss or have students write answers to the following questions.

As recently as 1990, scientists and city officials thought that the aquifer beneath the bosque was one continuous layer of sediment with water filling all the pore spaces. People thought we could pump unlimited quantities of water from the aquifer and it would be refilled by water soaking in from the river. Based on the graphs you drew from the three wells in the bosque, what do you think is wrong with what people used to think about the ground water beneath the bosque?

In the Bosque Ecosystem Monitoring Program, students have been measuring ground water wells for several years. At sites with deep ground water, the plants under the trees are mostly shrubs. At sites with shallow ground water, grasses and sedges dominate. Do you think this is a coincidence or does the depth of the ground water affect the plants that grow there? Support your answer.

Resources: Data for this activity are real data obtained from "Analysis of the Groundwater Monitoring Program in the Rio Grande Valley State Park, February 1998 through December 1999," City of Albuquerque Parks and Recreation Department, Open Space Division.

Possible Answers to Analysis Questions

Rio Grande Discharge Questions

1. In which months is the river discharge (flow) the highest?
   May 1998, May 1999, June 1999, July 1999
2. List at least two reasons why river discharge would be highest in these months.
   Snow is melting from the mountains and flowing into the rivers.
   There is a release of water from upstream dams.
3. In which months is the river discharge (flow) the lowest?
   February 1998, November 1999, April 1999
4. List at least 2 reasons why river discharge would be lowest in these months.
   The temperatures are cool and no snow is melting into the rivers.
   There are no releases of water from upstream dams.

Well Questions

1. In which months of each year is the water table closest to the ground surface (the shallowest)?
   Rio Bravo—May 1998, June 1999, July 1999
   Zoo Burn—May 1998, July 1999, December 1999
   Rio Grande Nature Center—May 1998, February 1999, May 1999
2. Compare your graph to the Rio Grande discharge graph. Does your graph follow the patterns of the river? List two reasons why the water level in the well would be shallowest in the months that you listed in Question 1.
   More water in the river in May and June
   More water as rain in July (monsoons)
3. Compared to the graphs of the other well sites, does your well show lots of fluctuation (up and down movement), or little fluctuation?
   Rio Bravo—some fluctuation
   Zoo Burn—lots of fluctuation
   Rio Grande Nature Center—little fluctuation, except for anomalous readings in 1999.

4. Is the water table in your well shallower or deeper than the other well sites?
   Rio Bravo—shallowest
   Zoo Burn—deepest
   Rio Grande Nature Center—middle level

Site Characterizations

These are characterizations to be used as background information in helping your students interpret the graphs. Do not expect your students to write summaries this complex. You should encourage varying levels of response, depending on the level of your students' reasoning skills.

Rio Bravo Well
This well is located about a mile north of Rio Bravo in the South Valley on the east side of the river. It has the shallowest water table, with water depths ranging from 2.75 to 8.47 feet deep. It shows moderate fluctuation and does seem to go up when the river discharge is higher. This well is probably well-connected to the river. Cottonwood poles should probably be planted about 5 feet deep. Cottonwoods use the least amount of water in the winter, so 5 feet deep would ensure that their roots are in the water for most of the year, especially in the growing season.

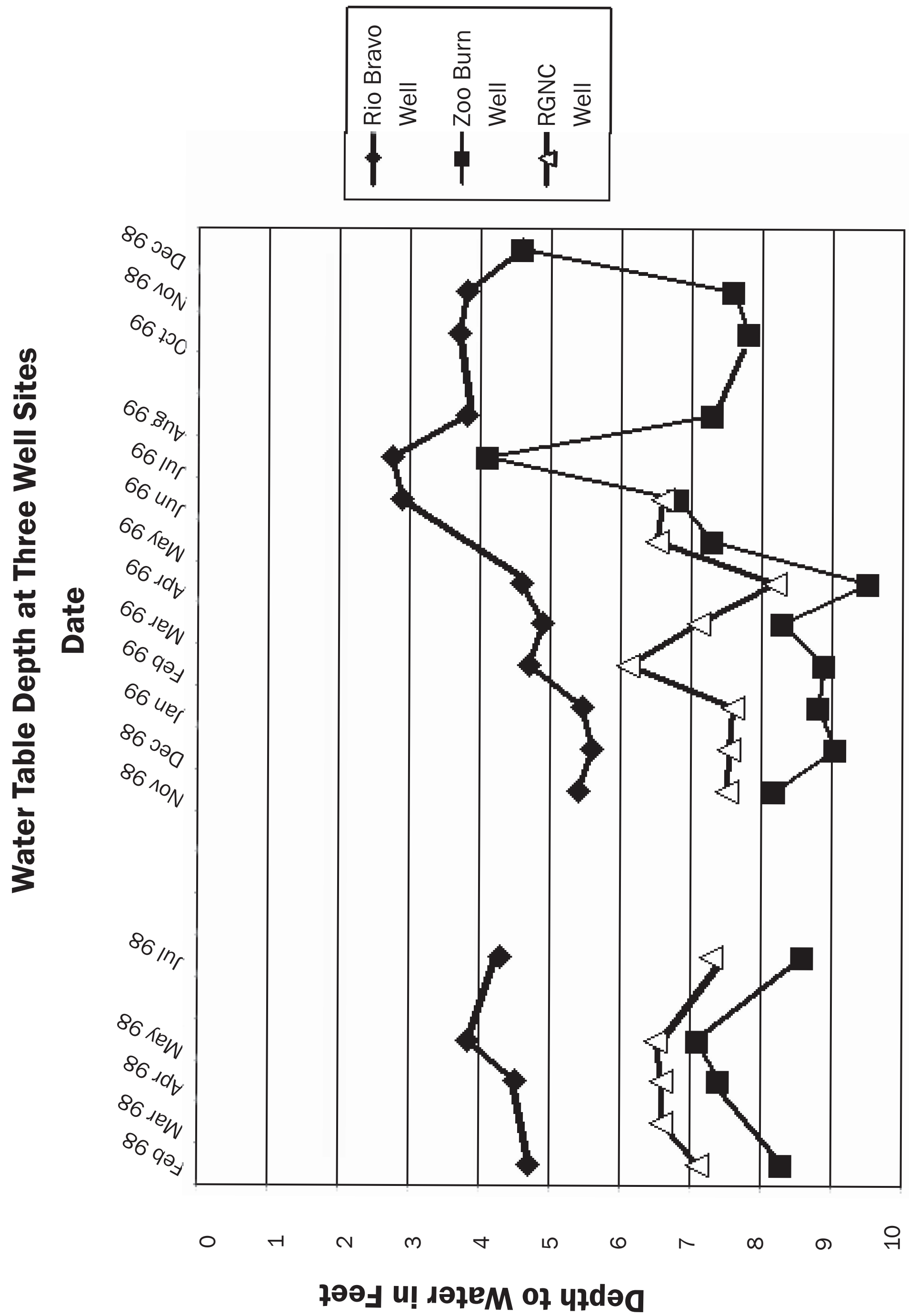
Zoo Burn Well
This well is located near the Rio Grande Zoo on the east side of the Rio Grande. It has the deepest water table, with water depths ranging from 4.1 to 9.5 feet deep. It shows high fluctuation and seems to go up when the river discharge is higher. This well is probably well-connected to the river. Cottonwood poles should probably be planted about 9 feet deep so that roots are in the ground water even when the water table is low.

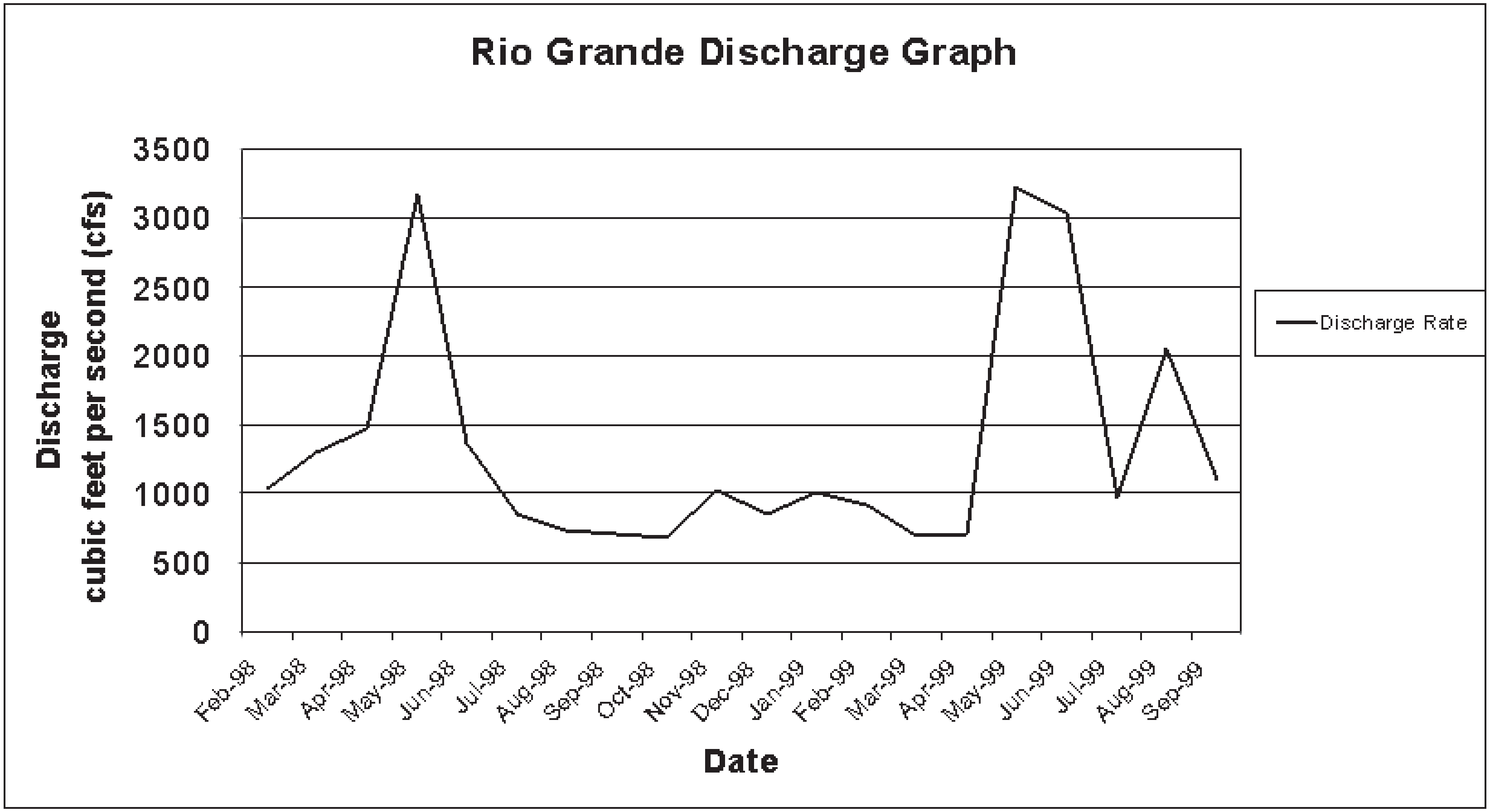
Rio Grande Nature Center Well
This well is located on the east side of the river in the Rio Grande Nature Center State Park. Its water table is deeper than the Rio Bravo well but shallower than the Zoo Burn well. It shows the least variability, although data is somewhat inconclusive. January 1999 and April 1999 seem like anomalous readings. This well does not follow the trends of the river. This well may not be as well-connected to the river as the other two wells, meaning that the depth to ground water does not vary with the amount of surface water in the Rio Grande. (This may mean that there are clay deposits that are a barrier to ground water movement or that the river channel is incised and the water does not infiltrate to that area.) Cottonwood poles should probably be planted about 7.5 feet deep.

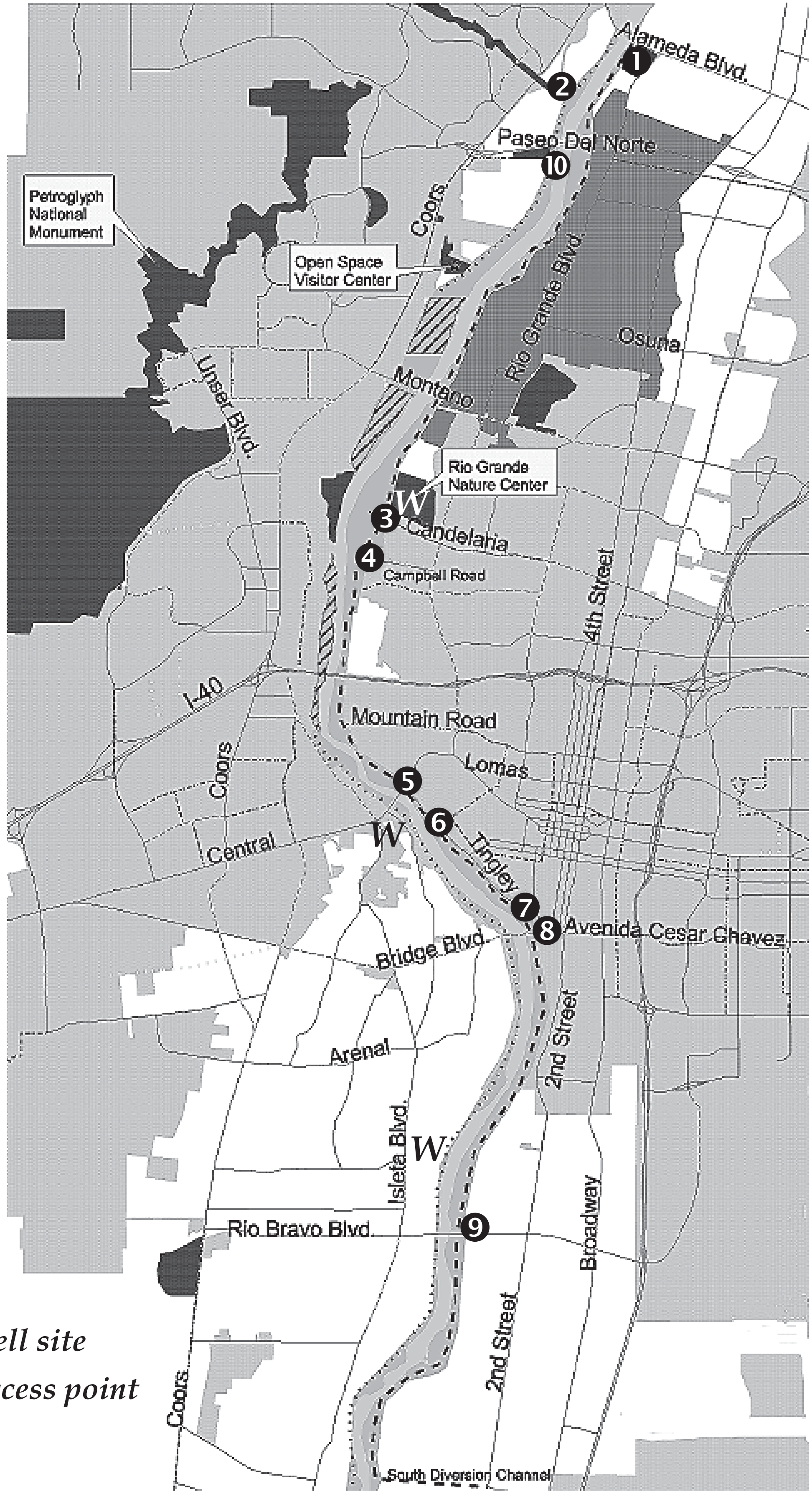
Extension Questions:

As recently as 1990, scientists and city officials thought that the aquifer beneath the bosque was one continuous layer of sediment with water filling all the pore spaces. People thought we could pump unlimited quantities of water from the aquifer and it would be re-filled by water soaking in from the river. Based on the graphs you drew from the three wells in the bosque, do you think this is true?
Based on the data from these three wells, the aquifer beneath the bosque does not seem like one continuous layer of sediment filled with water. Each site is different and appears independent. Researchers have found far less water in the aquifer than once believed. Some of that loss is due to more clay deposits that do not hold available water. Another part is that as ground water is pumped from the aquifer, and water is pulled out for irrigation and other uses, there is not enough water to recharge the aquifer. More research is needed to understand how the ground water, the river, and the bosque are connected.

In the Bosque Ecosystem Monitoring Program, students have been measuring ground water wells for several years. At sites with deep ground water, the plants growing under the trees are mostly shrubs. At sites with shallow ground water, grasses and sedges dominate. Do you think this is a coincidence or does the depth of the ground water affect the kinds of plants that grow there? Support your answer.
Grasses have shorter root systems and shrubs have deeper root systems. Where ground water is deeper, shrubs can out-compete grasses. Although shrubs can tolerate higher ground water, it is harder for them to become established due to competition with grasses.


Water Table Depth at Three Well Sites
Date
Depth to Water in Feet
0
1
2
3
4
5
6
7
8
9
10
Feb 98
Mar 98
Apr 98
May 98
Jul 98
Nov 98
Dec 98
Jan 99
Feb 99
Mar 99
Apr 99
May 99
Jun 99
Jul 99
Aug 99
Oct 99
Nov 98
Dec 98
Rio Bravo Well
Zoo Burn Well
RGNC Well


Rio Grande Discharge Graph
Discharge
cubic feet per second (cfs)
0
500
1000
1500
2000
2500
3000
3500
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Date
Discharge Rate



W = well site

▶ = access point

How Deep Is the Water Table?

1. Rio Grande Discharge Graph

Date	Feb 98	Mar 98	Apr 98	May 98	Jun 98	Jul 98	Aug 98	Sep 98	Oct 98	Nov 98
cfs*	1,034	1,288	1,471	3,177	1,366	858	732	700	682	1,032

Date	Dec 98	Jan 99	Feb 99	Mar 99	Apr 99	May 99	Jun 99	Jul 99	Aug 99	Sep 99
cfs*	851	1,001	913	689	703	3,220	3,042	973	2,047	1,103

*cubic feet per second

Analysis Questions

1. In which months is the river discharge (flow) the highest?
2. List at least two reasons why river discharge would be highest in these months.
3. In which months is the river discharge (flow) the lowest?
4. List at least two reasons why river discharge would be lowest in these months.

Now use your graph to help others in your team of scientists answer questions about the well sites.

How Deep Is the Water Table?

2. Rio Bravo Well

Date	Feb 98	Mar 98	Apr 98	May 98	Jun 98	Jul 98	Aug 98	Sep 98	Oct 98	Nov 98
Depth*	4.7	—	4.5	3.85	—	4.3	—	—	—	5.4
Date	Dec 98	Jan 99	Feb 99	Mar 99	Apr 99	May 99	Jun 99	Jul 99	Aug 99	Sep 99
Depth*	5.6	5.45	4.7	4.9	4.6	—	2.9	2.75	3.8	—
Date	Oct 99	Nov 99	Dec 99							
Depth*	3.7	3.8	4.6							

*depth to water in feet

Analysis Questions

1. In which months of each year is the water table closest to the ground surface (the shallowest)?
2. Compare your graph to the Rio Grande discharge graph. Does your graph follow the pattern of the river? List two reasons why the table table in the well would be shallowest in the months that you listed in Question 1.
3. Compared to the graphs of the other well sites, does your well show lots of fluctuation (up and down movement), or little fluctuation?
4. Is the water table in your well shallower or deeper than the other well sites?
5. Circle any points on the graph that seem like they don't fit. What reasons can you think of to explain this?
6. What difficulties did you have in reading this graph?

How Deep Is the Water Table?

3. Zoo Burn Well

Date	Feb 98	Mar 98	Apr 98	May 98	Jun 98	Jul 98	Aug 98	Sep 98	Oct 98	Nov 98
Depth*	8.3	—	7.4	7.1	—	8.6	—	—	—	8.2

Date	Dec 98	Jan 99	Feb 99	Mar 99	Apr 99	May 99	Jun 99	Jul 99	Aug 99	Sep 99
Depth*	9.05	8.8	8.9	8.3	9.5	7.3	6.8	4.1	7.3	—

Date	Oct 99	Nov 99	Dec 99
Depth*	7.8	7.6	4.6

*depth to water in feet

Analysis Questions

1. In which months of each year is the water table closest to the ground surface (the shallowest)?
2. Compare your graph to the Rio Grande discharge graph. Does your graph follow the pattern of the river? List two reasons why the table table in the well would be shallowest in the months that you listed in Question 1.
3. Compared to the graphs of the other well sites, does your well show lots of fluctuation (up and down movement), or little fluctuation?
4. Is the water table in your well shallower or deeper than the other well sites?
5. Circle any points on the graph that seem like they don't fit. What reasons can you think of to explain this?
6. What difficulties did you have in reading this graph?

How Deep Is the Water Table?

4. Rio Grande Nature Center Well

Date	Feb 98	Mar 98	Apr 98	May 98	Jun 98	Jul 98	Aug 98	Sep 98	Oct 98	Nov 98
Depth*	7.1	6.6	6.6	6.5	—	7.3	—	—	—	7.5

Date	Dec 98	Jan 99	Feb 99	Mar 99	Apr 99	May 99	Jun 99	Jul 99	Aug 99	Sep 99
Depth*	7.55	7.6	6.1	7.1	8.2	6.5	6.6	—	—	—

Date	Oct 99	Nov 99	Dec 99
Depth*	–	–	–

*depth to water in feet

Analysis Questions

1. In which months of each year is the water table closest to the ground surface (the shallowest)?
2. Compare your graph to the Rio Grande discharge graph. Does your graph follow the pattern of the river? List two reasons why the table table in the well would be shallowest in the months that you listed in Question 1.
3. Compared to the graphs of the other well sites, does your well show lots of fluctuation (up and down movement), or little fluctuation?
4. Is the water table in your well shallower or deeper than the other well sites?
5. Circle any points on the graph that seem like they don't fit. What reasons can you think of to explain this?
6. What difficulties did you have in reading this graph?

How Deep Is the Water Table?

Site Characterizations

For each well, write complete sentences that describe the following characteristics of the well. Work as a team to answer the questions. Share the writing responsibility.

1. Where the well is located (refer to the map).
2. How deep you would plant the cottonwood poles.
3. Two reasons why you would plant the poles this deep.

Rio Bravo Well

Zoo Burn Well

Rio Grande Nature Center Well

For the Rio Grande Discharge, write a short summary about:

1. What typical discharge levels are for spring, summer, fall and winter.

2. Reasons why flows increase and decrease.

3. How the river influences the water table level at the nearby well sites.

34. Water Budget Activity

Description: Students will predict and calculate how much water is used from the Rio Grande, both for an average year and for a drought year. Students will make water budget decisions and learn the consequences of those decisions.

Objective: Students will understand the concept of a regional water budget and its complexities.

Materials: calculator

worksheets

Background: Water is a scarce resource in the arid Southwest, and people rely on the river and aquifer for irrigation, livestock, personal consumption, and industrial and commercial uses. Because the Rio Grande flows through three states, Colorado, New Mexico, and Texas, and two countries, the United States and Mexico, the right to use water from the river is regulated by local, state, federal and international agencies. The treaty with Mexico that governs the use of the Rio Grande dates back to 1906. Tribal governments also have water rights.

The Rio Grande Compact (1938) allocates Rio Grande water between the states of Colorado, New Mexico, and Texas through a complex set of delivery schedules that relate runoff volumes to delivery obligations at set river index points. During normal water years, New Mexico must ensure that about 60% of the Rio Grande flow passing the Otowi Gage reaches Elephant Butte Reservoir (Crawford, et al. 1993). On average, this delivery requirement is 790,000 acre-feet per year. This requirement is significantly reduced during a drought year. To assure that each jurisdiction receives

34. Water Budget Activity

Grades: 6–12

Time: three one-hour class periods

Subjects: science, math, social studies

Terms: *acre-foot, aquifer, evapotranspiration, evaporation, riparian, water budget* its share of water, a water budget is developed. A water budget records the amount of water that goes into the system, which includes tributary and ground water sources (the inflow), and the amount of water that is taken out of the system (the outflow).

Although a water budget may seem simple at first glance, the reality is incredibly complex. A water budget is affected by forces over which humans have no control, such as precipitation, weather patterns, and evaporation, as well as by the interests of the environment, agriculture, industry, and national, state, municipal, and tribal governments. There simply is not enough water for all the competing interests that a water budget has to satisfy.

For the purposes of this activity, the Middle Rio Grande is defined as the reach between the Otowi Gage (near Los Alamos) to the Elephant Butte Dam.

Note: In order for students to gain an understanding of the complexity of water budgets, it is strongly suggested that all three sections of this activity be completed.

Terms:

water budget: A summary that shows the balance in a hydrological system between water supplies (inflow) to the system and water losses (outflow) from the system. It is a common reporting tool for water-resource systems.

riparian: relating to or living or located on the bank of a natural fresh watercourse such as a river, stream, pond or lake.

evapotranspiration: a term that includes the portion of precipitation being returned to the atmosphere either by direct evaporation or by transpiration through vegetation, with no differentiation being made between the two processes.

evaporation: the change from liquid or solid to vapor; water in a lake evaporates into the air.

acre-foot: a quantity of volume of water that covers one acre to a depth of one foot; equal to 43,560 cubic feet, 325,851 gallons or 1,233.48 cubic meters.

aquifer: the stratum or rock below ground that bears water, typically in a location capable of producing water usable by humans, such as from a well.

Procedure: **Part I**

1. Brainstorm with students where the water in the river comes from. Answers include:
   - rain (and all forms of precipitation)
   - melting snowpack
   - inflow from tributaries
   - run-off from urban storm drains
   - aquifer (shallow and deep)
2. Explain that the river and the aquifers are not closed systems, independent from one another, but instead are connected. The shallow aquifer discharges water into the river, and the water in the river flows into (recharges) the shallow aquifer. In Albuquerque, more water is "mined" from the deep aquifer than is recharged. The water table falls several feet a year as a result of this ground water mining.
3. Brainstorm with students the Rio Grande water consumers. Who takes water away from the river? Some possible answers are:
   - residential use (personal consumption, lawns, dishwashing, laundry, etc.)
   - agriculture
   - livestock
   - commercial (office buildings, stores, etc.)
   - industry (factories)
   - governments
   - evaporation
   - riparian evapotranspiration
   - aquifer recharge
   - downstream users
   - aquatic wildlife (fish, etc.)
   - terrestrial wildlife (deer, etc.)
4. Introduce the idea of a budget. When do people use a budget? What do you think a water budget is? How would you know if a water budget is balanced?
5. Assign students to work in groups of two or three. Pass out Worksheet I to each group. Have students predict the percent (%) and answer the first two questions.
6. Reveal the actual percent and have students record this on their worksheets. Have them answer the last two questions. Review each category and discuss results as a class.

Part II

1. Pass out Worksheet II.
2. Introduce the Rio Grande Compact.
3. Explain the definition of acre feet: quantity of volume of water that covers one acre to a depth of one foot; equal to 43,560 cubic feet, 325,851 gallons, or 1,233.48 cubic meters.
4. Review the procedure for calculating ac-ft using percentages. For example: 8.4% of 1,424,000, multiply .084 x 1,424,000 = 119,890.
5. Have students calculate and decide whether the requirements of the Rio Grande Compact are met.

Part III

1. Pass out Worksheet III.
2. Discuss drought conditions and how drought affects the water flow in the river.
3. Have students allocate the remaining water and figure out the percentages.
4. Discuss consequences using notes below.

   If "Agriculture" is less than 119,890 ac-ft: There is not enough water to support all the agriculture needs in the Middle Rio Grande Valley. Some farmers will have to leave their land fallow; others may have to sell land. Ways that farmers could adapt to less water are to plant crops that require less water or develop more efficient methods of watering (drip irrigation vs. sprinklers).

   If "Riparian Evapotranspiration" is less than 164,060 ac-ft: Riparian evapotranspiration cannot be controlled in the same way that human water consumption is controlled. There is no "switch" to turn off riparian evapotranspiration. In fact, during a drought year, riparian trees and plants may use more river water because they are receiving less water in the form of precipitation (rain). One way to reduce evapotranspiration is to remove water-thirsty non-native species like saltcedar and Russian olive. This work is already being done at Bosque del Apache, with water savings of 25 to 30 percent.

   If "Residential Use" is less than 69,410 ac-ft: Water-saving measures go into effect. Depending on the severity of the drought, people may only be allowed to water their lawns once a week, or even not at all. The cost of water may also increase. Building of new homes may be limited.

If "Business and Government" is less than 37,860 ac-ft: Golf courses might not be watered, swimming pools could be closed, restaurants might have to use paper plates to save water used in dishwashing.

If "Water Left in the River" is less than 350,000 ac-ft: The requirements of the Rio Grande Compact are not met and a debit is accumulated which will have to be met in future years. The Treaty of 1906 between the U.S. and Mexico may be violated because 60,000 ac-ft must be delivered annually to the border.

5. Discuss as a class who or what consumes water or needs the river but is not reflected in the water budget. Historically, water budgets have reflected the needs of people, and by extension the needs of agriculture. It is important for students to understand that many plants and animals are affected by water budgets even though their needs are not specifically addressed. What happens to fish and other aquatic animals during a drought? Do they have enough water? How about riparian plants like the cottonwood that are directly tied to the flow of the river? Students may also think about ways they use the river that are not reflected in a water budget—for recreation (boating, fishing, hiking along the bank) and quality of life (the existence of a riparian forest in an urban area).

Extensions:

1. Make a pie chart for an average year and a drought year to illustrate water use.
2. Develop the following scenarios and have students debate the pros and cons of each position.
   a. The City of Albuquerque has depleted significant portions of the shallow and deep aquifer and decides to rely on the river to provide a percentage of the city water supply. (Note: this is due to happen beginning in 2005.)
   b. The Rio Grande silvery minnow, an endangered species, is only found between Cochiti Dam and the headwaters of Elephant Butte Reservoir, in about 5% of its historic range. This fish requires that a certain amount of water be in the river at all times. During parts of the summer, the total flow of the river dips below the level that the silvery minnow requires.
3. Have groups take one water consumer and propose a way to reduce water usage, listing pros and cons.
4. Have students collect news stories about the Rio Grande's water users.
5. See the "How Deep Is the Water Table?" activity for information about how the river is connected to the aquifer.

6. Investigate these state and federal agencies to find out more about water decisions: N.M. State Engineer's Office, U.S. Bureau of Reclamation, Middle Rio Grande Conservancy District, United States Geological Survey, Army Corps of Engineers, U.S. Fish and Wildlife Service.

References:

NM State Engineer's Office Web site, "Summary of Water Use (in acre-feet) in Rio Grande Basin, 1995." www.seo.state.nm.us/publications/wrri/wateruse/basin95/rg.html

Middle Rio Grande Water Assembly Web site www.waterAssembly.org

Middle Rio Grande Water Budget Averages for 1972–1997, Middle Rio Grande Water Assembly, Inc. October 1999.

Crawford, Clifford et al. October 1993. The Middle Rio Grande Ecosystem: Bosque Biological Management Plan. U.S. Fish and Wildlife Service, District 2, Albuquerque.

Shupe, Steven, and Folk-Williams, John, 1988. The Upper Rio Grande; A Guide to Decision Making. Western Network.

Teacher Key for Water Budget Worksheets

Average Water Year

Use	Percent of Total	Acre Feet per Year	Note
Agriculture	8.4%	119,890	Farmers get water from the river via ditches and acequias.
Open-water Evaporation	4.9%	69,410	This is the water that evaporates from the moving part of the river, as well as from streams, wetlands, ditches and pools.
Riparian Evapotranspiration	11.5%	164,060	Riparian evapotranspiration occurs when plants lose water from their leaves as a natural part of their plant processes, as well as by direct evaporation from the forest.
Evaporation from Elephant Butte	12.0%	170,370	
Residential Use	4.9%	69,410	
Business and Government	2.7%	37,860	
Water left in the river (Rio Grande Compact)	55.6%	793,000	This portion is regulated by the Rio Grande Compact. See ***Background*** for more information.
Total	**100%**	**1,424,000**	

Data based on Middle Rio Grande Water Budget Averages for 1972–1997, Middle Rio Grande Water Assembly, Inc., October 1999; confirmed and adjusted in 2002.

Water Budget Worksheet I

In your group, estimate how much water is consumed in the Middle Rio Grande Valley in the following categories. The total percentage you predict must add up to one hundred percent.

Water Use During an Average Year

Use	Prediction	Actual Percentage
Agriculture		
Open-water Evaporation		
Riparian Evapotranspiration		
Evaporation from Elephant Butte		
Residential Use		
Business and Government		
Water Left in River (Rio Grande Compact)		
Total	100%	100%

In your prediction, who or what uses the most water? Explain your answer.

Who or what uses the least water? Explain your answer.

Answer the following questions after your teacher tells you the actual percentages for an average year.

How do your predictions compare with the actual percentages?

Were you surprised by any of the percentages? Why?

Water Budget Worksheet II

1 acre-foot (ac-ft) = a quantity of volume of water that covers one acre to a depth of one foot; equal to 43,560 cubic feet, 325,851 gallons, or 1,233.48 cubic meters.

Using 1,424,000 ac-ft as the total amount of water available (from the river, tributaries, ground water and storm drains), calculate the acre-feet allocated to each category. Round up to the nearest whole number.

Water Use During an Average Year

Use	Percentage	Acre Feet
Agriculture	8.4%	
Open-water Evaporation	4.9%	
Riparian Evapotranspiration	11.5%	
Evaporation from Elephant Butte	12.0%	
Residential Use	4.9%	
Business and Government	2.7%	
Water Left in River (Rio Grande Compact)	55.6%	
Total	100%	1,424,000

The Rio Grande Compact is an agreement between Colorado, New Mexico, and Texas that regulates the allocation of river water. As it relates to the Middle Rio Grande, the compact stipulates that during an average water year at least 790,000 ac-ft must be “delivered” annually from Elephant Butte for use downstream. Does the water budget above meet the Rio Grande Compact requirements?

Water Budget Worksheet III

Imagine that there is a drought and the water available is reduced to 753,000 ac-ft annually. In a drought year, the Rio Grande Compact stipulates that 350,000 ac-ft must be delivered. Recalculate how much water, in acre feet, is available for each use. Consider how water use will change during a drought year. Will households use more or less water during a drought? How about agriculture?

After you have allocated all the water (remember, it needs to add up to 753,000 ac-ft), calculate the percentages.

Water Budget for a Drought Year

Use	Percentage	Acre Feet
Agriculture		
Open-water Evaporation		
Riparian Evapotranspiration		
Evaporation from Elephant Butte		
Residential Use		
Business and Government		
Water Left in River (Rio Grande Compact)		
Total	100	753,000

Describe the consequences of this water budget on river users compared to an average year.

Who (or what) consumes water or needs the river but is not reflected in the water budget? How would a drought affect them?

35. Interpreting a Hydrograph

Description: Students interpret a graph showing the volume of flow of the Rio Grande in three different years and look on the Internet for current information to compare with the data presented.

Objectives: Students will:

- read and interpret a graph of the flow of the Rio Grande from three different years;
- see the difference between the uncontrolled flow and after dams and diversions were put in place; and
- be able to characterize the flow volume and timing over the course of a year.

Materials: copies of the hydrograph and worksheet for each student

Internet access for Part 2

graph paper for extensions

maps of New Mexico

Background: Terms:

cubic feet per second (cfs): the typical unit to record river flows; calculated by measuring the width and depth of the channel (area) times the velocity of the flow (feet per second)

discharge: in a stream or river, a measure of the amount of water passing a given point, measured as volume per unit of time (units typically cfs)

flood pulse: a predictable inundation of the floodplain from the river, which results in adaptations to flooding by local organisms; in this region, typically annual spring snowmelt sends a large volume of water downstream

35. Interpreting a Hydrograph

Grades: 6–12

Time: Part 1: one class period; Part 2: one additional class and Internet time

Subjects: science, math

Terms: *cubic feet per second, discharge, flood pulse, gage, hydrograph, overbank flooding*

gage: a device used for measuring or testing something, especially for measuring a dimension or quantity; in this activity we talk about stream-gage, which collects water data, especially the discharge of a stream or river; note that the spelling "gage" is typically used in technical applications rather than "gauge"

hydrograph: a graph showing the volume of flow of water in a river over time

overbank flooding: the water in the river increases so much that the river flows over its banks spreading water and sediment beyond its channel

real-time data: data available as soon as they are collected, continually sent from the collecting equipment to a central computer through some means such as a dedicated phone line, a radio or a satellite

The Rio Grande is the life-blood of central New Mexico. In this arid state, it is the source of water for the diversity of life along its native bosque and important irrigation for food production.

The Middle Rio Grande bosque is the result of the interaction between biological and physical processes. The native plant and animal communities evolved and adapted to a river that overbanked on a regular basis, probably every three to five years. These floods were a key component of the cottonwood–willow ecosystem, as well as the thriving aquatic environment. In the last century the river has undergone a disruption of the once-normal floods, narrowing of the floodplain and stabilization of the banks with jetty jacks and non-native saltcedar and Russian olive trees. This has had a dramatic effect on the native plants and animals. Of the five native minnow species found at the turn of the 20th century in the Rio Grande, only the silvery minnow remains, and it is listed as an endangered species.

Before dams and diversions there was a typical cycle over the course of a year. Starting with spring, the flow of the river began to increase as the snows that accumulated in the mountains began to melt. In wet years, the river flowed over its banks (**overbank flooding**) spreading water and sediment beyond its channel. Typically this was a low-intensity inundation that rose gradually and dropped nutrient-laden sediment. Water in the floodplain was critical for the decomposition of wood and leaves in the forest, breaking down nutrients that became available for other living things. Sometimes the river would change course or erode its banks, but it also would leave new sand bars that gave young cottonwoods a place to become established, since cottonwood trees release their seeds during high water. Cottonwood seed germination is best with a peak flow and rapid decline; extended flows favor saltcedar.

Aquatic systems benefited from this high flow as well. For example, the Rio Grande silvery minnow depends on a high peak flow when its eggs are laid and dispersed across the flood plain. Then a quick receding flow leaves them in quiet backwaters to grow. The longer but lower peak flows since the river was regulated mean less overbank volume, thus less backwater for minnows, so the eggs are moved downstream out of local habitats.

Such a predictable inundation of the floodplain from the river, which results in adaptations to flooding by local organisms, is called a **flood pulse.** Following the flood pulse, the late-summer to fall flows would vary, increasing with summer thunderstorms and then tapering off periodically. Winter flow in the region was typically low, providing habitat for birds.

Controls such as dams, irrigation diversions and levees have regulated the flow of the river. The result is lower peak flow, with high flows occurring later in the year, and higher minimum flows. Now the early snow-melt is held in reservoirs to be released over the growing season. This can be seen in the hydrograph in this activity. In 1920 the flow of the Rio Grande in June reached 18,000 cfs (cubic feet per second), whereas the peak flow in 1997 was 4,000 cfs. Although some regulation was already present along the river in Colorado, Cochiti Dam was completed in 1975 and most directly affects the river flow through the Middle Rio Grande Valley. There are also dams on tributaries of the Rio Grande that affect its flow.

Water managers now want to allow the overbank flow during wet years again. They want to maintain as many aspects of the early, uncontrolled river (Rio Bravo) as possible to provide the processes necessary for maximum biological diversity. Flooding the bosque now is difficult, however, in part because the volume of water needed for overbank flooding is different at different areas. Bosque del Apache National Wildlife Refuge, south of Socorro and just north of the San Marcial gage used in this activity, takes 3,500 cfs to breach the bank and flow into the floodplain. At Albuquerque it takes 10,000 cfs to do the same. This reflects differences in the structure and depth of the channel. For example, the southern end of the valley has high sediment deposition due to input from the Rio Salado and Rio Puerco, so it is shallow and floods relatively easily, while the channel along the upper reaches is down-cut (deeper) due to sediment retention behind Cochiti Dam. This makes it difficult to inundate the bosque through Albuquerque without flooding a much greater area to the south.

Water managers use stream gages to monitor the flow of water in rivers and streams. As the country developed, with an increasing need for reliable water sources, there was a need for streamflow data to aid in planning water storage and distribution facilities. The first stream-gaging station in the United States operated by the U.S. Geological Survey (USGS) was installed on the Rio Grande near Embudo, NM, in 1889. That gage is still active, with a total of 84 stations now in New Mexico, including nine on the main stem of the Rio Grande. As of 1994, 7,292 continuous-record stream-gaging stations were operating in the United States, Puerto Rico, and the Trust Territories of the Pacific Islands. About 4,200 of them are telemetered by an Earth-satellite-based communication station and so provide real-time data, which can be accessed through the Internet. The USGS stream-gaging program provides a resource for water managers, with uses including forecasting and managing floods, characterizing water quality, and operating reservoirs. This is a resource that is also readily available to teachers and students.

The gage called San Marcial has the name of a former community with a floodwater story of its own. It began on the east side of the Rio Grande but moved to the west side after a flood in 1866. The town grew after the railroad arrived in 1880 and was the second largest in Socorro County. The town suffered periodic floods, especially in the 1920s, when silt was deposited in many buildings, but residents cleaned up and continued on. One night in 1929, however, the water began to rise. Residents evacuated, but by morning they saw that floodwaters had reached the second-story level. The destruction was so great that the town was abandoned.

Procedure: Provide information from the ***Background*** about the historical pattern of stream flow along the Rio Grande, the beneficial aspects of an annual flood pulse, and the use of stream-gages to collect water data. Hand out the copies of the hydrograph and the worksheet. Have students interpret the graph and write their answers on the worksheet. Part 2 must be done with Internet access. Students look up current data from the United States Geological Survey web sites and compare current information to the hydrograph handout.

Have students find where San Marcial is on a map of New Mexico. The gage here is the last gage on the Rio Grande above Elephant Butte Reservoir.

Teacher Answer Key

Part 1

1. Was the river dry at any time(s)? List months and years.
Yes, flow at 0 in 1920 from early September to early October; in 1952 from early September to mid-November; in 1997 July and from mid-August to mid-September.

2. What were the flows on June 18 on each of the years shown?
1920: 10,000; 1952: 5,800; 1997: 3800

3. What causes these high flows at this time of the year?
High flows are caused by extra water from mountain snowmelt.

4. Count the number of days in each of the three years the water flowed over 3,500 cfs. This represents overbank flooding conditions in the area of Bosque del Apache National Wildlife Refuge just north of San Marcial.
1920: 80 days; 1952: 41 days; 1997: 33 days

5. What causes the smaller peaks in late summer?
Increased flow from thunderstorms.

6. Which year had the highest flows during the late fall/early winter?
1997

7. Describe in sentences the rhythm of flow of the Rio Grande over the course of a year.
This river begins the year with a low flow and spikes in May, climbing until June when it peaks. It then returns to a low flow for the remainder of the year, though there may be smaller, late-summer peaks.

8. Why has the hydrograph changed over the century?
Humans have controlled the flow of the river, building diversion dams, and specifically Cochiti Dam that holds the spring run-off and releases water more gradually over many weeks.

9. In this system, what effect have dams had on river flow?
Dams result in lower peak flows and higher minimum flows.

Part 2: Internet Access

1. Look up the river flow today at the San Marcial gage on the USGS web site http://waterdata.usgs.gov/nm/nwis/uv?08358400—"Rio Grande Floodway at San Marcial, NM" site. (The term "floodway" has the numbers you want for the river flow. There are two San Marcial gages; the other is the "Conveyance Channel.") Look at "Real time" data and the chart that shows "Discharge": this shows the current flow as well as the flow for the last few days.

a. What is the flow today? date_________ time__________ flow __________

b. Print out a hydrograph for the last week or last month—you define the number of days.

2. Look on the USGS web site for the gage that is closest to where you live. "USGS Real time data for New Mexico" http://waterdata.usgs.gov/nm/nwis/rt includes a map of the gages in the state. You can select the closest one. You can also type in the county or other location to help locate the closest gage.

a. Name of the gage site ________________________________

USGS Station # ____

Web address of the site _________________________________

What is the flow today? date_________ time__________ flow __________

b. Print out a hydrograph of the water flow at this location for the last week or month—choose the same days as the San Marcial hydrograph you printed above.

c. Compare the two hydrographs: write a paragraph comparing them.

Students should compare the flow of water: is one location higher than the other? What reasons might there be for the difference? Or are they about the same? Were there any changes over the week or month? Why might that be?

3. From other information in this unit and what the you have learned in this activity, write about the role/importance of spring run-off in the bosque ecosystem. The answer should include some of the following:
High spring flows bring nutrients and new sediments. Cottonwood trees release their seeds coinciding with the high water. In wet years, the river flows over its banks (overbank flooding) spreading water and sediment beyond its channel. When the water spreads to the floodplain, it slows its flow and drops sediment across the plain. Water in the floodplain provides the key component for decomposition, breaking down nutrients that will be available for other living things. Some species of fish (e.g., silvery minnows) spawn in response to the high flow. Sometimes the river would change course in the spring and erode banks while leaving new sand bars for new cottonwoods to establish themselves as well.

Assessment: All questions finished, accuracy, interpretation of the data.

Extensions: Use USGS site to relate the cubic feet per second information to acre feet and calculate acre feet.

Add to the San Marcial Floodway hydrograph the data for this year. Look under "Surface water—Measurements" option at the gage site; the term "stream flow" is the cubic-feet-per-second (cfs) value to graph. You can limit the data presented in the chart to the months you want with "reselect output format." How does this compare to the previous years shown on the San Marcial hydrograph hand-out?

You can use the same process above to create a hydrograph from the gage closest to your community. Compare this graph to the San Marcial hydrograph handout.

As students explore gage data, have them consider the climatic events for a current year. For instance, if they review gage data along the Rio Grande from 1930 to 1960, they will find dramatic peaks and valleys in gage readings. Refer them to the Western Regional Climatic Center's Historical Summaries website (http://www.wrcc.dri.edu/ > Historic Climate Information > Climate and Weather Information heading, Western US Historical Summaries (individual stations) > select New Mexico link). Red dots indicate climate reporting stations across New Mexico. Selecting one will bring up lists of average precipitation and temperature measurements over many decades, as well as listings for daily and monthly readings. Have students compare hydrograph readings with climatic data to see any corresponding trends. Returning to the 1930–1960 example above, students should discover a period of historic precipitation in the early 1940s which corresponds to higher river gage readings. Conversely, lower readings in the 1950s should correspond with climatic data that indicates an equally historic drought. What other trends might they discover?

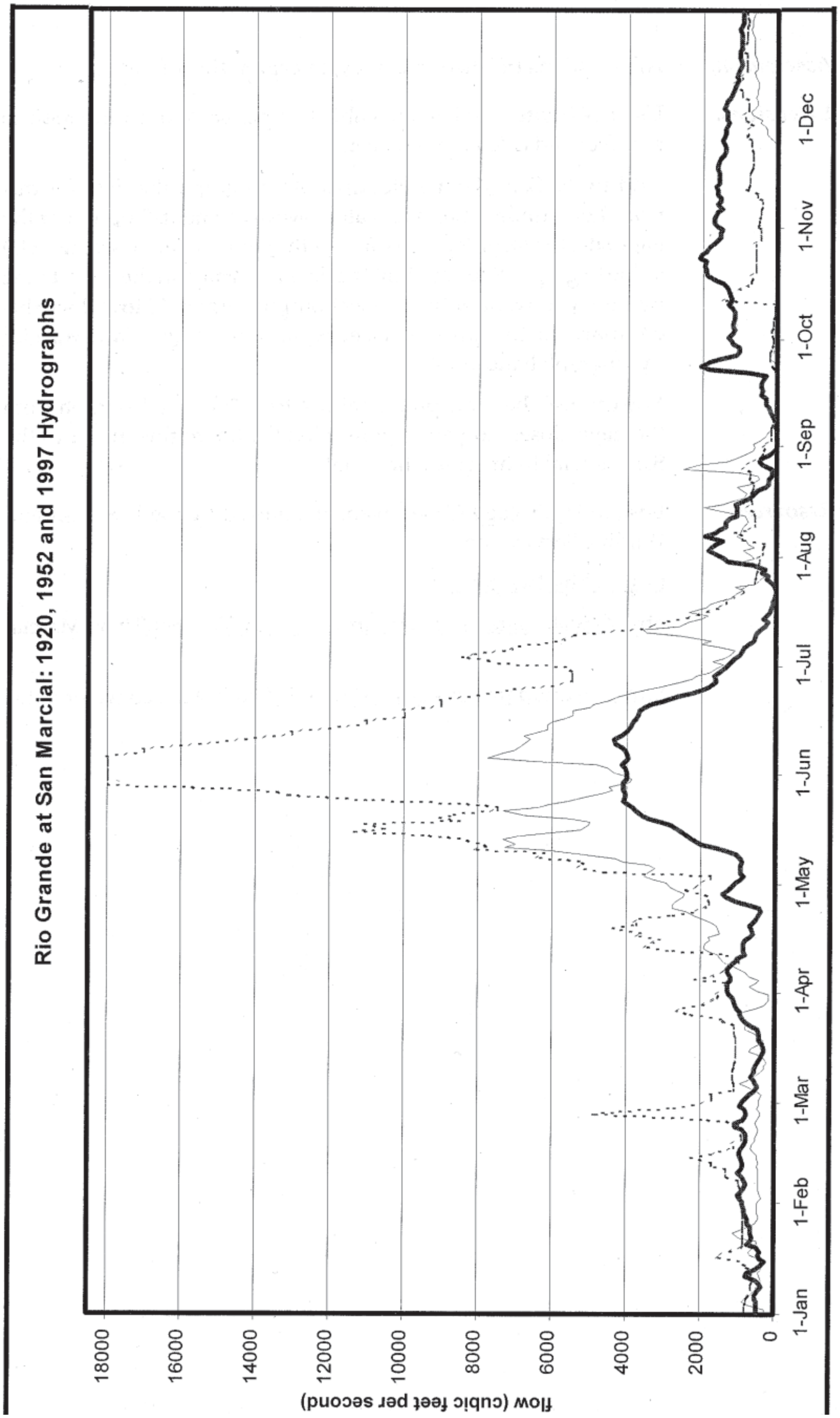
Resources: Bosque Hydrology Group web site, hosted by the U.S. Fish and Wildlife Service site

http://bhg.fws.gov/

http://waterdata.usgs.gov/nm/nwis/uv?08358400 (San Marcial site)

http://waterdata.usgs.gov/nm/nwis/ New Mexico water data

Western Regional Climatic Center http://www.wrcc.dri.edu


1920
1952
1997
Rio Grande at San Marcial: 1920, 1952 and 1997 Hydrographs
flow (cubic feet per second)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

Hydrograph Worksheet 1

Part 1

1. Was the river dry at any time(s)? List months and years.

2. What were the flows on June 18 on each of the years shown?

3. What causes these high flows at this time of the year?

4. Count the number of days in each of the three years the water flowed over 3,500 cfs. This represents overbank flooding conditions in area of Bosque del Apache National Wildlife Refuge just north of San Marcial.

5. What causes the smaller peaks in late summer?

6. Which year had the highest flows during the late fall/early winter?

7. Describe in sentences the rhythm of flow of the Rio Grande over the course of a year.

8. Why has the hydrograph changed over the century?

9. In this system, what effect have dams had on river flow?

Hydrograph Worksheet 2

Part 2: Internet Access

1. Look up the river flow today at the San Marcial gage on the U. S. Geological Survey web site by searching for National Water Information System, USGS Station #08358400—"Rio Grande Floodway at San Marcial, NM." (The term "floodway" has the numbers you want for the river flow. There are two San Marcial gages; the other is the "Conveyance Channel.") Look at "Real time" data and the chart that shows "Discharge": this shows the current flow as well as the flow for the last few days.

a. What is the flow today? Date__________ time___________ flow___________

b. Print out a hydrograph for the last week or last month—you define the number of days.

2. Look on the USGS web site for the gage that is closest to where you live. "USGS Real time data for New Mexico" http://waterdata.usgs.gov/nm/nwis/rt includes a map of the gages in the state. You can select the closest one. You can also look for a place to type in the county or other location information to help locate the closest gage.

a. Name of the gage site ________________________________

USGS Station # _______________________________________

Web address of the site_________________________________

What is the flow today? Date__________ time___________ flow___________

b. Print out a hydrograph of the water flow at this location for the last week or month—choose the same days as the San Marcial hydrograph you printed above.

c. Compare the two hydrographs: write a paragraph comparing them.

3. From other information in this guide and what the you have learned in this activity, write about the role/importance of spring run-off in the bosque ecosystem.

Acequia Culture

By Michael Miller
National Hispanic Cultural Center of New Mexico

The use of water irrigation systems to support agriculture in New Mexico and throughout the Southwest began with the Ancestral Puebloans. This ancient culture was centered around Mesa Verde and Chaco Canyon in present-day northern New Mexico and southern Colorado. These prehistoric people built communities for long-term occupation. Their indigenous technologies included solar-heated pithouses and kivas, cisterns for domestic water storage, and community outdoor hearths and ovens. They farmed on contour terraces, grid-bordered gardens, and canyon floors and eventually developed a sophisticated and water efficient system. That system depended on natural precipitation and runoff which the Puebloans captured, stored, and distributed to their crops via intricate systems of canals, diversion dams, and head-gates.

When these settlements were abandoned around 1100 AD, this unique agriculture technology did not disappear. In fact, it was passed on to modern Pueblo cultures who occupied the Rio Grande basin and its tributaries, and the agricultural and irrigation practices begun by the Ancestral Puebloans evolved into even more efficient methods of soil and water conservation.

This evolution in agriculture went beyond the dryland farming and water-harvesting techniques employed by the Ancestral Puebloans, which depended primarily on snowmelt moisture, direct precipitation, intermittent runoff, and floodplain irrigation in river-bottom lands. Pueblo agriculturalists invested an enormous amount of time, energy, and resources to construct a network of water-harvesting and conservation systems which were very innovative and ingenious. These remarkable conservation accomplishments and engineering techniques included dense coverage of low mesas by installation of gravel mulched fields, complexes of rock-bordered rectangular grids and cobble-step terraces on high mesas, stone-lined ditches to channel water from one depression to another, and placement of rock alignments as check dams to designated planting areas within the irrigated floodplain.

The Spanish were the first Europeans to enter the Southwest and discover these remarkable agricultural systems. Unlike the Ancestral Puebloans and the Pueblo farmers, the Spanish–Mexican agriculturalists did not limit their settlements to areas dependent on captured runoff and consistent rainfall. Spanish colonization and the establishment of *ranchos* (ranches) and land-grant settlements required much larger tracts of land, and the colonists had to engineer much larger diversions and water delivery systems from the Rio Grande, the Rio Chama, the Rio Pecos and their tributaries. These systems came to be known as *acequias* (a word, derived from the Moors, which means community ditch). If a ditch had been dug by the Pueblos in earlier times and later abandoned, the Spanish colonists reopened it and made improvements. Spanish law prohibited encroachment on Indian ditches that were still in use. Although this law was broken on occasion, colonists for the most part actively looked for locations where irrigation works could be constructed for new settlements and did not interfere with existing Pueblo systems.

These new irrigation systems were often sophisticated engineering projects that required unique skills and calculations. Using wooden hand tools the Nuevo Mexicano *parciante* (a member of the acequia association) would dig ditches and laterals off both banks of the river from the diversion dam using gravity to direct the water to his fields and pastures. Without the benefit of modern surveying equipment these early settlers continued to use gravity to create a water flow that followed the natural landscape and which often appeared to run upstream. With wooden spades, crowbars, hoes, plows, and rawhides pulled by mules or oxen they constructed an earthen *presa* or dam that pushed the water into the *acequia madre* (the "mother ditch," the main irrigation canal that runs through the community). *Compuertas* (head-gates) controlled the flow of water to the mother ditch, and a *desague* (a small outlet drain) helped clean debris from the main ditch and put water back into the main channel or stream flow. *Sangrias,* or lateral ditches, to irrigate individuals parcels were also built throughout the system, connecting ditches with *canoas* (a log that carries acequia water across an arroyo) and canyons to create an intricate and efficient irrigation system within the community. These remarkable human carvings in the earth defined the spatial boundaries of each settlement and provided life-giving water to the thirsty soil that nurtured their crops. Ultimately, this system of irrigation and sustainable agriculture tradition created a unique cultural region.

In populated areas such as Santa Fe, Albuquerque, and Las Cruces the management of water resources was carried out by *cabildos* or town councils. In isolated areas, on the ranchos for example, larger agricultural jurisdictions administered the water according to local custom under the general direction of the Law of the Indies which governed all the provinces in northern New Spain which were under Spanish rule. This sustaining and ingenious method of agriculture, combined with the techniques of the ancestral Pueblo and Pueblo cultures, has served the region for over 400 years, and it remains the principal method for sustainable agriculture and traditional soil and water conservation in the state today.

Parciantes clean the acequia madre and the sangrias each spring. Participation by young people is the key to the survival of acequia culture in New Mexico.
Photo by Carlos Vasquez

Modern Conservation in New Mexico

Modern conservation came to New Mexico in 1935 with the enactment of the federal Soil Conservation Act, which created conservation districts across the nation. Conservation districts are local government subdivisions established under state law to implement and supervise programs for the use and development of soil, water, and related resources.

Districts work with land owners, local government agencies and interested conservation programs in addressing a broad spectrum of concerns in resource management. Examples are: erosion control, flood prevention, wetlands protection, water quality and quantity control, waste-water management, forest land protection, water conservation and use, recreational development, forest land protection, wildlife protection and community growth and development.

The evolution of conservation districts began in earnest as a response to a national concern for the control of erosion, flooding and the "Dust Bowl" devastation and loss of topsoil in the 1930s. President Franklin D. Roosevelt sent the governors of all the states a recommendation for passage of local legislation. New Mexico was one of the first states to participate in this national effort. In 1937, the New Mexico Legislature adopted and passed the Soil Conservation District Act. In cooperation with the Department of Agriculture a policy statement was written which justified the creation of soil conservation districts as "a legitimate exercise of state police power to overcome the multiple ill effects resulting from unsound farming and grazing practices." This enforcement power helped move along the work of the statewide conservation committee that had the responsibility of cooperating and working with the federal government and assisting local communities with the organization of local soil and water districts. It also had the authority to call on state agencies and educational institutions for assistance and to employ administrative and technical specialists to assist these communities.

In 1961 the act was modified to eliminate enforcement of land-use regulations, and district supervisors were given authority to levy property tax assessments with voter approval. In the 1970s the soil and water conservation districts were given broader responsibilities for general conservation, wildlife protection, flood prevention and development of water resources for a variety of uses. The districts were permitted to borrow money and accept federal grants.

At the opening of the 21st century, New Mexico had 47 districts in six regions. About 300 people were serving on district boards. Slightly more than half of the district supervisors, who serve on a volunteer basis, were farmers and ranchers, a change from previous traditions and a reflection of the districts' changing roles.

36. Change Is All Around Us

Land-use Change in the Middle Rio Grande Valley

Description: Students look at land-use changes in the Rio Grande Valley in two ways: by coloring a 1918 land-use map of Corrales and comparing it to a 1992 map; and by graphing the cover type in the Middle Rio Grande Valley from surveys in 1935 and 1989.

Objectives: Students will:

- identify past and current land uses in the Middle Rio Grande Valley;
- identify the relationship between cultural (human) land use and natural land cover types within the landscape of the Middle Rio Grande Valley;
- gain experience in reading maps; and
- gain experience in analyzing data and determining historical correlations.

Materials: copies of 1918 and 1992 maps for each student or pair of students

color pencils and graph paper for each student

Background: We are completely dependent on our landscape. It supports our existence. We use the land to live, work, play, learn and shop. Our survival depends on the land, but does our use balance the needs of the landscape as well? Is human use sustainable? Taking too much from the land can cause environmental stresses which lead to environmental degradation. An unhealthy environment will affect humans as we depend on the land.

In most areas of the world, land use changes over time, either through natural or man-made processes or a combination of both. By looking at archaeological records, field survey data and

36. Change Is All Around Us

Grades: 6–12

Time: two class periods

Subjects: science, social studies

Terms: *land use, cover type, Middle Rio Grande Conservancy District, agriculture, commercial, residential, riparian, upland, range, urban, hectare, reach* accounts through oral histories, we have been able to determine historical land use in the Middle Rio Grande Valley. More recent documentation is gained from maps, aerial surveys and written documents. By looking at all the documentation, we are able to look for land-use patterns and identify changes.

The Village of Corrales is located just north of Albuquerque in the Middle Rio Grande Valley. In 1918 the Office of the State Engineer completed a formal survey of the Middle Rio Grande Valley. In 1992 the Middle Rio Grande Conservancy District completed a map showing contemporary land use. This activity uses those maps and survey data to examine how land use has changed over the last century.

Summary points—What changes have occurred in the Middle Rio Grande Valley?

We want students to consider how the use of the land changes over time. How might changes in transportation, technology, economy, farming, or social politics affect our use of the land? The trend from the early 1900s to today is of increasing residential and urban areas and decreasing agricultural and riparian areas. Agricultural lands are being converted into residential areas. Both agricultural and riparian areas are being chopped into small pieces surrounded by residential or commercial uses. This is happening fastest near growing cities such as Albuquerque.

The number of acres of forest has not changed appreciably over this time, though surveys record this forest changing from a primarily cottonwood forest to one dominated by introduced saltcedar and Russian olive trees. What has changed in area is the amount of wetlands. In 1918, from Cochiti Dam to San Marcial (the Middle Rio Grande Valley) there were 52,000 acres (21,053 hectares) of wetlands; these include marsh, open water, saltgrass meadow and alkali flats. In 1989, there were 14,780 acres (5,985 hectares) of river, lake, wet meadow, marsh or pond and most of those areas were in designated state or federal refuges. This amounts to a decrease of over 70%.

The Rio Grande bosque is a long, narrow habitat. Reduction in the extent of the bosque through construction of housing, shopping centers and clearing for agriculture has reduced the area that native plants and animals have to live. The interruption of habitat, called fragmentation, also affects the life of the bosque with power lines, bridges and roads cutting through the narrow bosque. Populations of plants and animals are separated; migration and dispersal of species is impaired. When a habitat is broken into small pieces separated by farmland or residences, some species may not be able to survive, although many species use farmland for habitat and are able to move across it.

Encourage students to look at both the maps and the data and compare cultural/human land use to natural land cover type. There are ways that these are separate, but many ways in which they are intricately connected. Have students think about how human land use is connected to natural land use.

Notes on maps—Part 1: These maps were prepared by the Middle Rio Grande Conservancy District (MRGCD) for this guide. The original 1918 map was made by the Office of the State Engineer in a survey of water use in the Middle Rio Grande conducted from November 1917 to September 1918. The maps were hand-drawn on 30 pages called "linens," a woven linen paper. The 1992 map is from a survey conducted by the federal Bureau of Reclamation and is part of the Land Use Trends Analysis (LUTA) data set from air photos.

Only the area of Corrales that is part of the MRGCD was included in the 1992 survey; the blank areas are outside of the district boundary.

Today, these maps are needed for the same reason as in 1918: to determine irrigated land and water use in the valley. Comparing 1918 maps to recent maps is what is done today by the Office of the State Engineer and the MRGCD, only with computer assistance—but is basically what the students are doing in this activity.

Notes on data—Part 2: The 1935 data is from the National Ecology Research Center, U.S. Fish and Wildlife Service; the 1989 data is from the National Wetlands Inventory by the U.S. Fish and Wildlife Service. Both data sets appear in the *Middle Rio Grande Ecosystem: Bosque Biological Management Plan.* One bit of trivia is that the 1935 aerial photo survey was done by Charles A. Lindberg (yes, that Lindberg). If you notice, the 1989 survey has a percentage of "no photo coverage," while Lindberg's 1935 survey has complete coverage.

Cochiti Reach	Cochiti Dam to Angostura Dam	21 mi (34 km)
Albuquerque Reach	Angostura Dam to Isleta Diversion Dam	38 mi (61 km)
Belen Reach	Isleta to Bernardo	39 mi (63 km)
Socorro Reach	Bernardo to San Marcial (just above Elephant Butte Lake)	62 mi (100 km)

Oral History

An Interview with Hector Gonzales by Rebecca Tydings

In the fall of 2002, Hector Gonzales and his eight brothers and sisters are looking for a buyer for their 23 acres in Corrales, NM. This bit of property is all that remains of his family's portion of the Alameda Land Grant. In 1710, Governor Marques de Penuela gave 104,000 acres to Captain Francisco Montez Vigil as a reward for military service. Two years later in 1712, Capitan Vigil sold his land to Juan Gonzales Bas or Vas. (Note: The Spanish B and V are pronounced the same. This part of the name was later dropped.) Juan Gonzales Bas built a home and a small chapel in honor of Our Lady of Conception. By 1744 eight families occupied the Alameda Land Grant centered around the house and chapel of the Gonzales family. This was the beginning of the Hispanic community Alameda. By 1770, Alameda had grown to 66 families containing 388 persons[*]. The story of why the Gonzales family is now selling their historical property is the story of how land has been used within the Middle Rio Grande floodplain for the last 400 years. It also addresses the current practice of selling fertile agricultural land along the Rio Grande for real estate development.

Born July 20, 1924, Hector Gonzales grew up in Albuquerque. His father farmed the land and until his late teens Gonzales and his brothers and sisters lived and worked there weekends and summers. Their main crop was alfalfa sold to dairies in Albuquerque. The children helped cut the alfalfa and rake it into rows to dry. Later it would be raked together and piled on a wagon, then carried to the front of the property, near the Corrales Road, where it would be stacked into haystacks. Here the dairymen from Albuquerque would purchase the crop for cattle feed. The Gonzales family also raised chili, corn, squash, apples, apricots and peaches. Much of their crop was canned or dried for their own use. A job Gonzales remembers from his youth was using a horse pulling a scraper to tear down and level what had once been part of the family's old home. It had been built of *terrones*, chunks of vegetative material cut from the bogs along the river and stacked into walls, much like adobe walls are built today. A stiffened cloth tacked to it covered the ceiling. At that time land was more valuable for raising crops than for a home. Hector's brothers eventually became sheet-metal workers and auto mechanics or worked in the construction industry, jobs for which they were paid wages. Hector himself became a plumber and operated the Eveready Plumbing and Heating until 1987 when he gave it to his son and daughter-in-law.

According to Gonzales the eastern boundary of the Alameda Land Grant was partially the hills on the east side of the river, where Edith Blvd. is now. The land grant extended west to the "Ceja de Rio Puerco," the drop-off of the lava escarpment of the Rio Puerco, 16 miles (25.6 km) west from the Rio Grande. The northern boundary was the Arroyo de la Barranca. The southern boundary was the small hills that designated the Land Grant of Louis Garcia de Noriega. Paseo del Norte represents this southern boundary nowadays. Gonzales stops his story to explain that at that time the village of Alameda was on the west side of the Rio Grande. "Remember now," he says, "that the river ruled the valley. When it flooded it went anywhere it wanted to." In 1874 the Rio Grande overflowed its banks and swept into an old channel on the west side of the valley. The river's course was changed and the village of Alameda was now on the east side of the river. Gonzales explains that the corrals where livestock were kept for the community of Alameda were separated from the village by the river's new course. "That," he continues "was the beginning of the area now called Corrales."

Continuing, Gonzales tells that people supported their families by raising sheep and cattle and growing squash, melons, corn, apples, alfalfa and native grass for the livestock. The *acequia madre* (mother ditch for irrigation) had to be reworked every year because the annual spring floods of the Rio Grande would clog or remove the point of diversion, the point where water was diverted from the river to be distributed to the fields. Hay was cut by hand and raked into rows in the field. Wood from the bosque was used for everything: fences, gates, ladders and vigas for houses. Cottonwood trunks were hollowed out to make water toughs. The local climate was moister then and mushrooms or *hungos* were gathered from trunks of the cottonwood. Mixed with red chili, the dish was a substitute for meat during the Lenten season.

Through time, each descendent of Juan Gonzales passed along his or her portion of the Alameda Land Grant to the children. Each time the parcels became narrower and narrower as the land was divided again and again. The land was divided into strips, measured north to south by *varas*. (A *vara* is equivalent to 32 inches, four inches less than a yard.) The *varas* extended from the Rio Grande on the east to the Ceja of the Rio Puerco on the west. In the late 1700s or the beginning of the following century, Andres Facundo Gonzales was given 1,000-plus additional *varas* of land from his mother, Maria Manuela Baca. Gonzales explains that each time those 4,000 to 5,000 (1.6–2 ha) acres was passed on to descendents, the "sliver would get thinner." In order, Juan Gonzales Bas gave part of his land to his son Juan Julian Gonzales, who passed some land on to his son Andres Facundo Gonzales. It was then divided again and Antonio Jose Gonzales received a parcel, then gave a portion to his son, Jose Faustin Gonzales. On June 18, 1820, Antonio Jose Gonzales was born. He is the grandfather of Hector Gonzales who in 2002 shares ownership of the land with his two brothers and six sisters. They are selling their 23 acres (9.2 ha). "The sliver can be divided no smaller," says Hector Gonzales, who has three grandchildren and three great-grandchildren.

The 23 acres are not even contiguous. There are three parcels—8.5 acres, 7.75 acres and 6.75 acres (3.4 ha, 3.1 ha, 2.7 ha)—separated by acequias, Old Church Road and the main canal. In the past some of the property was lost for failure to pay taxes when the Middle Rio Grande Conservancy District was formed.

The Gonzales family had to regain the land by paying the back taxes. Some land was purchased from the family for the riverside drain, the interior drain and for Corrales Road.

Gonzales's family has been leasing the property in recent years to Gus Wagner, who farms and sells produce in Corrales and Albuquerque's north valley. "He does it well," says Gonzales. "He grows sweet corn, green chili and black-eyed peas.

"When will we sell it? That's anybody's guess," continues Gonzales. "We would like to sell to a land trust for which the land will remain as open space and be farmed as it has been. Other options are to sell to developers or an individual. The best parcel is 'view land'."

For 290 years this has been the heritage of the Gonzales family.

*Simmons, Mark. 1982. Albuquerque: A Narrative History. University of New Mexico Press, Albuquerque. Page 103.

Procedure:

1. Introductory discussion: What are some of the ways that we use land? Ask students to think of different land uses in the Middle Rio Grande Valley. Make a list on the board. Then group these into the following categories: agriculture/range, commercial, residential, urban, riparian, river/open water, upland.
2. Explain to students that this is a two-part activity. First they will color maps; second they will make graphs. Then they will use their knowledge of both to interpret how the changes affect the users of the valley.

Part 1: Map Study

1. Ask the students how maps might be used to understand land-use changes. Introduce the concept of maps as a way of recording information about land use. If appropriate, cover the basic elements of a map, direction, scale, key, and title.
2. Have the students work individually or in pairs. Pass out the copies of the 1918 and 1992 maps of Corrales. Have the students color in the different land-use type areas and color the key to match. The 1992 map is more complex, and it will take good eyes to sort out the categories. Students could color only the riparian areas on both maps as a first comparison, then color

the agricultural areas, and finally the residential areas on the 1992 map—to make clear comparisons in stages.

1918. The original 1918 topographic map underlies the land-use symbols and terms. Students can ignore the topographic lines while coloring the categories. Look for the written categories of use in small print to determine the category of areas:

1918 key category	Term used on the map
Agriculture	*cultivated Class 1 or 2*
Commercial	two small squares saying *store* and *cemetery* (We know this is a stretch!)
Open water	trace the *Rio Grande* down the page
Riparian	*sand bars, alkali or timber* (the *timber* has a distinctive pattern like small shrubs) =bosque
Upland	topographic lines with the words *sand* and *sage brush*
Residential	(not represented in this 1918 survey)

• You only need to color the area within the dotted boundary of the current Village of Corrales.

• Color the land-use sections with distinctive colors and color the corresponding key box. Some areas, especially agriculture, have several boxes adjacent to each other; color them the same colors.

3. Have the students answer the worksheet questions:

Teacher key: 1918 map:

What is the largest land use (that is not upland)? Where is it located? *Riparian, along the river.*

What is the smallest land use? Where is it located? *Commercial, along the agricultural area.*

Why do you think it is the largest land use? or the smallest? *The river flooded regularly, and people did not use the riparian area next to the river where it was apt to flood.*

Is there a pattern to the land use? Are certain uses found in certain areas on the map? *Agriculture is found in the lowlands, riparian is immediately next to the river.*

1992: How is the 1992 map different from the 1918 map? *All of the area is divided into small pieces of agriculture, and residences, with much less riparian area. Commercial has grown.*

Has the size of the bosque riparian area changed? (Is it bigger or smaller, has it moved?) *It is much smaller.*

Has the upland area changed? *Many residences in the uplands.*

Part 2: Data Interpretation

The data are broken into four sections, so it may help to make teams of four or five students to work on this activity. If appropriate, cover the concepts of scale, how to construct a bar graph and how to read a bar graph.

1. Hand out the data sheet Land Use Changes in the Middle Rio Grande Valley and graph paper. If students use a computer program to create the graphs, orient students to that. The data are in hectares. One hectare (pronounced: "hec-tair") equals 2.47 acres.
2. Have the students graph the data with bar graphs. Have the class (or team) decide on an appropriate scale so the graphs can be compared.
3. Compare the graphs. Have the students answer the worksheet questions about the graphs:

   What is the largest land use in your stretch of river?

   Cochiti Reach. In 1935? *Range*. In 1989? *Range*.

   Albuquerque Reach. In 1935? *Agriculture*. In 1989? *Urban.*

   Belen Reach. In 1935? *Agriculture*. In 1989? *Agriculture.*

   Socorro Reach. In 1935? *Scrub-shrub.* In 1989? *Scrub-shrub.*

   What has changed between 1935 and 1989?

   Cochiti Reach. *River or man-made channel decreased; forest acres increased; scrub-shrub dropped dramatically; lake, wet meadow, marsh or pond decreased; urban increased; range and agriculture changed little.*

   Albuquerque Reach. *River or man-made channel decreased; forest acres increased a bit; scrub-shrub has dropped dramatically; lake, wet meadow, marsh or pond decreased to almost nothing; urban increased sky-high; range and agriculture decreased.*

   Belen Reach. *River or man-made channel decreased; forest acres increased; scrub-shrub dropped dramatically; lake, wet meadow, marsh or pond decreased; urban tripled; range dropped dramatically and agriculture increased.*

Socorro Reach. *River or man-made channel decreased by half; forest acres dropped by over half; scrub-shrub increased; lake, wet meadow, marsh or pond decreased; urban increased; range is little changed and agriculture increased.*

Why do you think there were changes?

Predict what your graph would look like 50 years in the future. State each category and how you think it will be different.

Summary interpretation from the maps and the graphs:

How would changes in the valley shown in the graphs and the maps affect these users of the Middle Rio Grande Valley?

Farmers. *There is still agriculture in the valley, but not in the urban areas.*

Residents, including you and your family. *Do you want to live in close proximity to other people or do you want to be in rural areas? Think about driving distances/commuting, gardens, animals, traffic, fresh air, open spaces for walking, local food, etc. The urban areas are growing and crowding out agriculture and natural areas.*

Wildlife. *There is less room for wildlife, fewer wetlands, a narrow forest, all in a long narrow line.*

Summarize the changes in land use over the 20th century.

The trend from the early 1900s to today is of increasing residential and urban areas and decreasing agricultural and riparian areas. Agricultural lands are being converted into residential areas. Both agricultural and riparian areas are being chopped into small pieces surrounded by residential or commercial uses. This is happening fastest near growing cities such as Albuquerque's metro area. What has changed in area is the amount of wetlands. There has been a decrease of over 70% of the wetland area over the 20th century.

Assessment: Ask the students to write an essay about why they think land use is different now from 1918. What has led to these changes over time? How has our change in land use affected the natural areas of the landscape? How would you predict land use in the Middle Rio Grande Valley landscape to change in the future?

There are two maps of Corrales, but how would other areas in the valley compare to those maps? Would they be the same or different? Is the area you live in similar to Corrales in the way it changed, or has little changed?

Extensions: Sum all of the cover type data to make one additional graph showing the land-use changes over the entire Middle Rio Grande Valley on one graph.

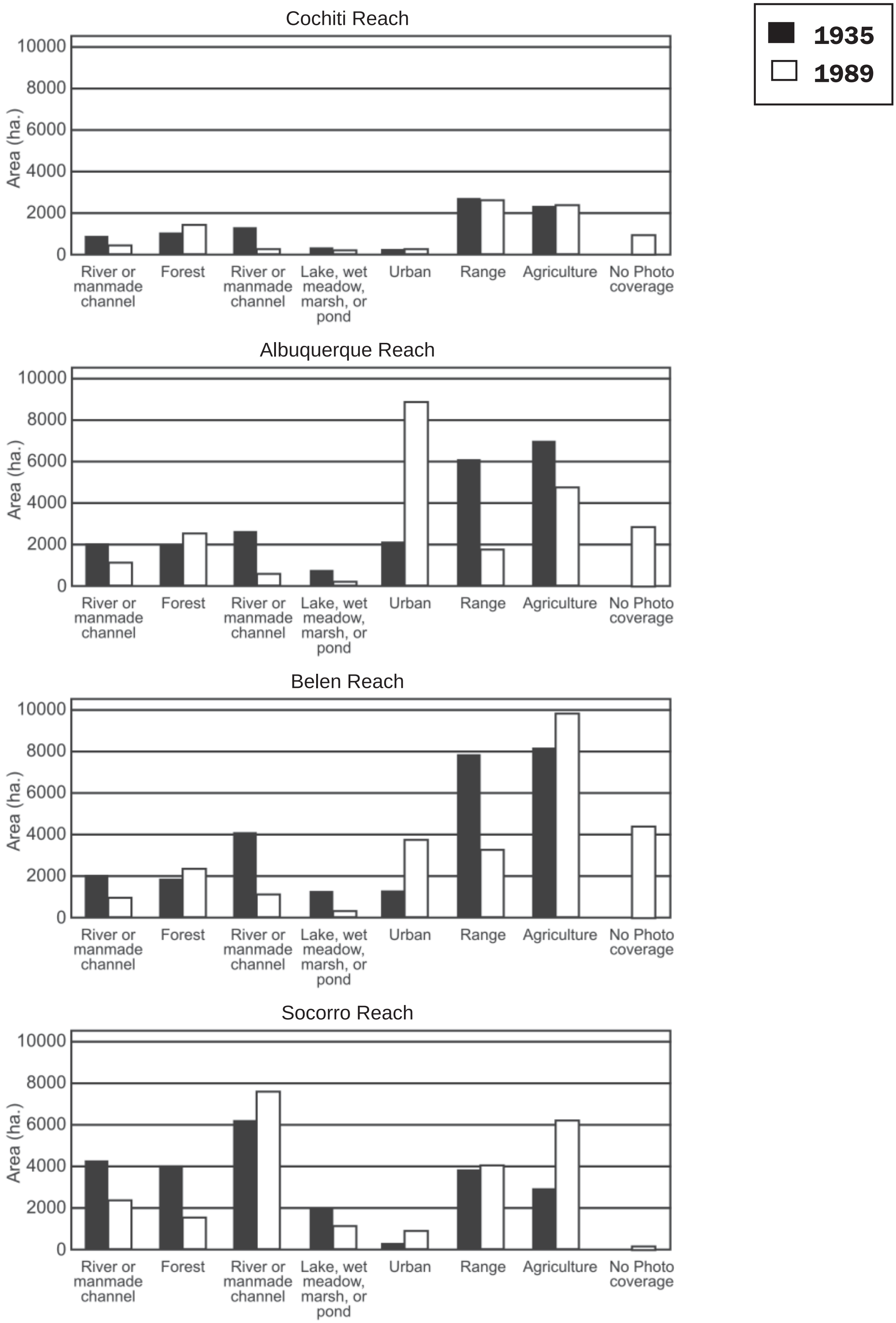
How might students' own neighborhood or town change over time? How would their town land-use map compare to the 1918 or 1992 Village of Corrales map? How would it be similar? How would it be different? Have the students research their own town or neighborhood to see how land use has changed. Have them write out an interview questionnaire related to land use (see "River Stories" activity in this guide). Encourage them to talk to relatives, neighbors, and business people to determine what sorts of changes have taken place.

Research how land is passed from generation to generation in different cultures. Hispanic families had property that went from the river for miles into the upland. They would divide their fields so that children would still have an edge on the river and acequia. This has resulted in fields today that are in long, narrow strips. Contrast this to the Pueblo fields that are in large squares. The fields are worked as a group and passed down as a whole field. This difference is clearly seen in the 1992 map, comparing the irrigated land in Corrales to that in Sandia Pueblo across the river.

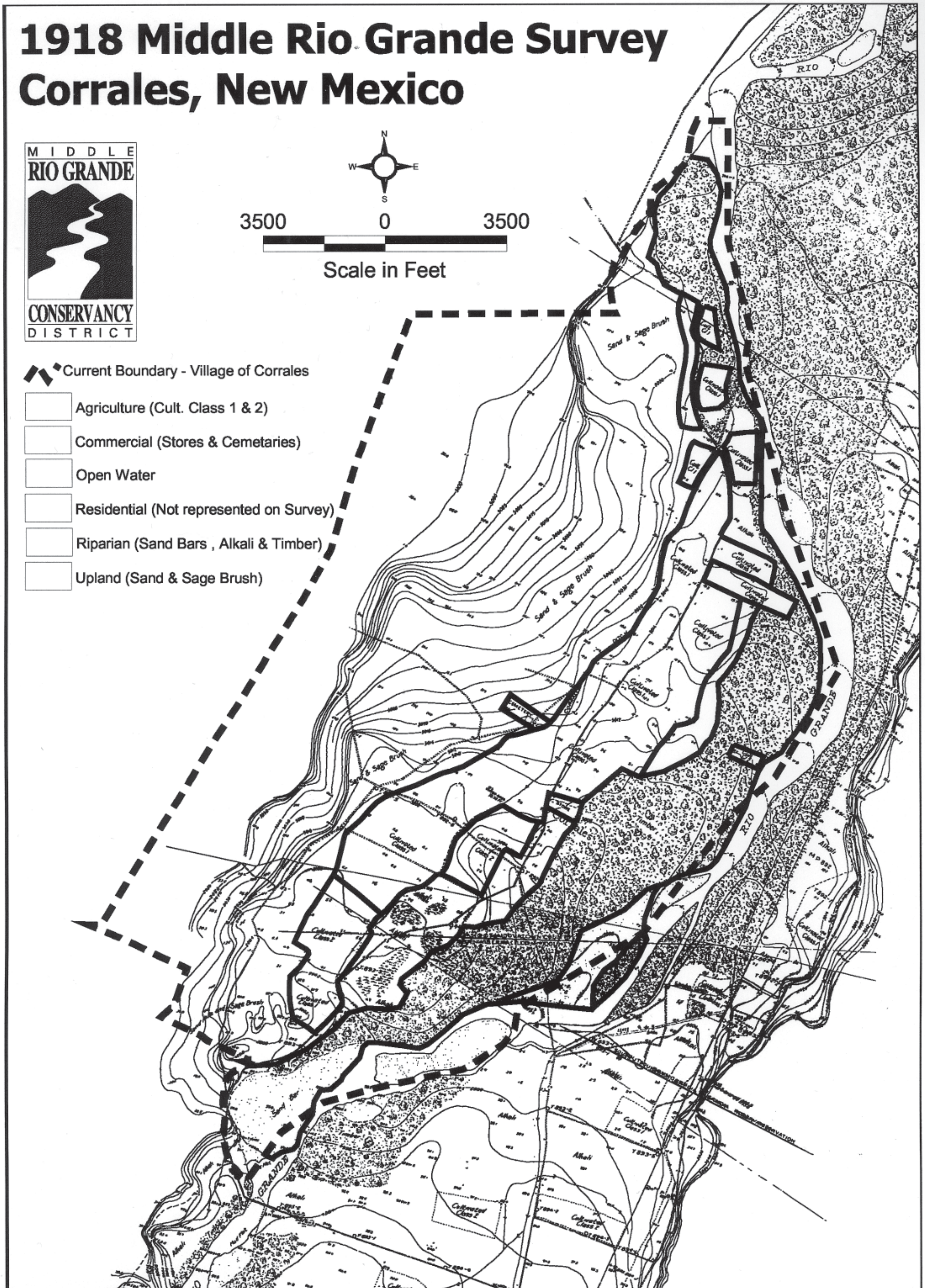
References:

Crawford, C.S., A.C. Cully, R. Leutheuser, M.S. Sifuentes, L.H. White and J.P. Wilber. 1993. Middle Rio Grande Ecosystem: Bosque Biological Management Plan. U.S. Fish and Wildlife Service, District 2, Albuquerque, New Mexico.

Teacher Key: Reach Cover Types



1918 Middle Rio Grande Survey
Corrales, New Mexico



Land-use Changes Part 1

1918. The original 1918 topographic map underlies the land-use symbols and terms. You can ignore the topographic lines while coloring the categories. Look for the written categories of use in small print to determine the category of areas:

1918 key category	Term used on the map
Agriculture	*cultivated Class 1 or 2*
Commercial	two small squares saying *store* and *cemetery*
Open water	trace the *Rio Grande* down the page
Riparian	*sand bars, alkali or 'timber* (the *timber* has a distinctive pattern like small shrubs) = bosque
Upland	topographic lines with the words *sand* and *sage brush*
Residential	(not represented in this survey)

- You only need to color the area within the dotted boundary of the current Village of Corrales.
- Color the land-use sections with distinctive colors and color the corresponding key box. Some areas, especially agriculture, have several boxes adjacent to each other; color them the same colors.

Questions about the 1918 map:

What is the largest land use (that is not upland)? Where is it located?

What is the smallest land use? Where is it located?

Why do you think it is the largest land use? or the smallest?

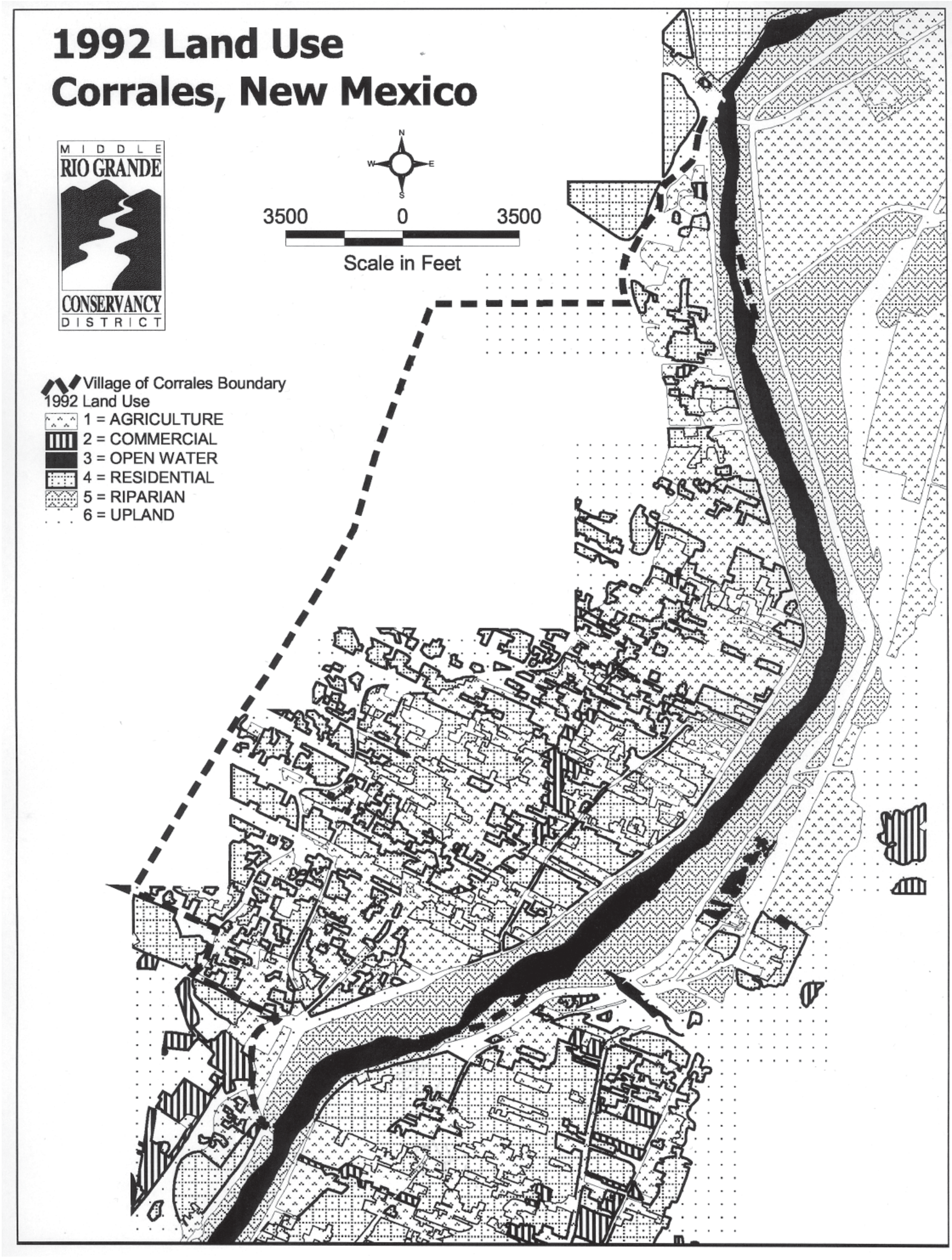
Is there a pattern to the land use? Are certain uses found in certain areas on the map?

Questions about the 1992 map:

How is the 1992 map different from the 1918 map?

Has the size of the bosque riparian area changed? (Is it bigger or smaller, has it moved?)

Has the upland area changed?


1992 Land Use
Corrales, New Mexico
MIDDLE
RIO GRANDE
CONSERVANCY
DISTRICT
N
W
E
S
3500
0
3500
Scale in Feet
Village of Corrales Boundary
1992 Land Use
1 = AGRICULTURE
2 = COMMERCIAL
3 = OPEN WATER
4 = RESIDENTIAL
5 = RIPARIAN
6 = UPLAND

Land-use Changes Part 2

The following charts give the cover type recorded in surveys in 1935 and 1992 of the Middle Rio Grande Valley. The data is divided into different stretches of the valley.

1 hectare = 2.47 acres

	Area in Hectares	
Cover type	1935	1989
Cochiti Reach		
River or man-made channel	767	417
Forest	888	1,441
Scrub-shrub	1,213	156
Lake, wet meadow, marsh, or pond	257	134
Urban	164	304
Range	2610	2,589
Agriculture	2,285	2,320
No photo coverage	0	824
Albuquerque Reach		
River or man-made channel	2,047	1,100
Forest	1,925	2,472
Scrub-shrub	2,649	600
Lake, wet meadow, marsh or pond	703	117
Urban	2,136	8,803
Range	5,974	1,763
Agriculture	6,974	4,772
No photo coverage	0	2,781
Belen Reach		
River or man-made channel	1,934	930
Forest	1,749	2,376
Scrub-shrub	4,076	1,097
Lake, wet meadow, marsh, or pond	1,161	229
Urban	1,184	3,856
Range	7,870	3,218
Agriculture	8,295	10,071
No photo coverage	0	4,493

1 hectare = 2.47 acres	Area in Hectares	
Cover type	1935	1989
Socorro Reach		
River or man-made channel	4,225	1,898
Forest	4,020	1,545
Scrub-shrub	6,107	7,447
Lake, wet meadow, marsh or pond	1,998	1,157
Urban	252	920
Range	3,785	4,015
Agriculture	2,887	6,164
No photo coverage	0	129

Questions about the graphs:

Which reach is the largest land use in your stretch of river in 1935?

In 1989?

What has changed between 1935 and 1989?

Why do you think there were changes?

Predict what your graph would look like 50 years in the future. State each category and how you think it will be different.

Look at the maps and the graphs: how would changes in the valley shown in the graphs and the maps affect these users of the Middle Rio Grande Valley?

Farmers:

Residents—including you and your family:

Wildlife:

Summarize the changes in land use over the 20th century.

37. *Aldo Leopold*

Writings on the Rio Grande Valley

Description: Students learn about Aldo Leopold, an early environmentalist who lived in and wrote about New Mexico. Students read an essay by Leopold and other overview essays and respond to the ideas in the essays.

Objective: Through an analysis of Leopold's writing, students will gain historical perspective on the Rio Grande Valley and the impacts humans and the river have had on each other.

Materials: "The Virgin Southwest," by Aldo Leopold

"Aldo Leopold and New Mexico" by Sterling Grogan

"Leopold's Land Ethic" by Cary Weiner

Procedure: Students read the Aldo Leopold essay and the background essays and answer the reading comprehension and/or discussion/essay questions below. For younger students, break the text down into "chunks" and have a student or group of students responsible for reading and summarizing for the class each "chunk."

Assessment: Discussion Questions—Teacher Key

"The Virgin Southwest" article

1. What time periods are covered in his essay?
   1824–1933.

37. *Aldo Leopold*

Grades: 9–12

Time: Two 50-minute class periods; one for reading and one for responding

Subjects: science, social studies, language arts

Terms: "The Virgin Southwest": *arid, seepage, silt, erosion, gradient, cobble bars, equilibrium, overgrazing, range management, leach, deltas, reclamation*; "Aldo Leopold and New Mexico": *levees, drains, watershed, succession*; "Leopold's Land Ethic": *integrity, biotic community*

2. According to Leopold, what is the major cause of erosion in the Rio Grande Valley? Use evidence from the essay to support your answer.
   Overgrazing.

3. Who was James Ohio Pattie? How does Leopold use Pattie's account to support his main idea?
   A trapper who kept a journal. Leopold compares the 1824 journal descriptions to the 1933/modern condition.

4. How was the Rio Grande valley different when Pattie wrote his account from when Leopold wrote his essay?
   There was heavy grass along the river and on the mesas. The main valley was used for grazing with agriculture in the side streams, such as the Rio Puerco. There is more silt in the valley today. Today's valley has "scant grass, much erosion and a river choked with silt."

5. What does Leopold state is the public's responsibility in this changed Southwest?
   The public needs to understand that there has been a change in the environment. There has been great erosion caused by human actions. People must learn from science about land use and develop a respect for "mother earth."

"Aldo Leopold and New Mexico" article

1. Who was Aldo Leopold?
   Forester, ecologist, hunter, pioneer, writer and conservationist.

2. What is the Middle Rio Grande Conservancy District?
   An agency designated in 1925 to prevent flooding, drain water-logged fields and improve irrigation in the Middle Rio Grande Valley.

3. What is environmental management?
   Management with all parts of the environment considered—including animals, trees, grass, soil, geology and humans.

4. What did Leopold study in college? What was his first job in New Mexico?
   Forestry. He worked for the U.S. Forest Service on the Carson National Forest as deputy supervisor.

5. What was the first wilderness area in the United States? How was Leopold involved in the designation of this wilderness area?
   The Gila Wilderness. He used his experience in the Gila as a forester and his interest in managing the land for wildlife to push the idea that blocs of unspoiled area should be set aside as "wild and scenic." Earlier views held that the forest was solely to use for human "progress" and did not consider that the loss of wildlife habitat widely affected organisms in the forest.

6. According to Leopold, how are human beings connected to nature?
Nature is a prerequisite of human well-being; without the natural world humans are somehow diminished, poorer and perhaps less human. Humans are a part of the interdependent community of nature that together make an organism.

7. What is *The Sand County Almanac*?
A collection of Aldo Leopold's essays about land conservation; sometimes called the "bible" of modern environmentalism.

"Leopold's Land Ethic" article

1. What does it mean to be a "plain member and citizen" of the land?
That humans were not superior to other life, that all plants and animals play a role in nature, including humans. The land should be managed for the ecosystem in which people belong, not managed solely for people.

2. In Leopold's anecdote, what did the "fierce green fire" represent?
The wildness of a predator in her own element; that the wilderness had a way of working that was not under human control and should not be.

3. Do you think that people are "ill-equipped" to understand nature? Why or why not?
Answers could include: we cannot know things from another species' perspective, we can use the best scientific methods to try to understand nature, but it is always from our perspective and there are many, many aspects of nature yet to be understood.

4. How do you think Leopold was perceived during his time?
He was ahead of his time in many ideas, so many people did not agree with him, but he used sound scientific evidence and persuasive writing to bring others to his view.

5. Write your own environmental ethic.
Answers will vary.

Possible Discussion/Essay Questions (answers will vary)

1. Do you think that Leopold was a visionary—ahead of his time? Why or why not?

2. What would Leopold think about the Rio Grande today?

3. Imagine you were Leopold in 1918, and you were lobbying the New Mexico Legislature to pass a law to protect the Rio Grande Valley. Write a law and give supporting evidence why this law should be passed.

4. Leopold made a persuasive case for "the importance of nature as a prerequisite of human well-being." What do you think that means? Use evidence from Leopold and also from your own thinking to support your ideas.
5. Write a paragraph or several paragraphs about Aldo Leopold. Use at least 10 of the following terms and concepts: *conservation, preservation, bosque, aquatic, adaptation, aquifer, ecosystem, endangered, erosion, ground water, habitat, irrigation, depletion, dams, reservoirs, riparian, runoff, watershed.*

Extensions: Stage a mock debate between Leopold and farmers/ranchers about the erosion problem.

Use a New Mexico map to locate all the places mentioned in these articles.

Have students draw the Rio Grande Valley that Leopold describes.

An additional activity about writers and the Rio Grande can be found in: The Watercourse. 2001. Discover a Watershed: The Rio Grande/Rio Bravo. Bozeman, Montana: The Watercourse. "One River, Many Voices," p. 266.

Resources/ References:

"The Virgin Southwest," by Aldo Leopold. 1933. From: Flader, Susan L. and J. Baird Callicott, eds. © 1991. The River of the Mother of God and Other Essays by Aldo Leopold. Reprinted by permission of the University of Wisconsin Press, Madison, WI.

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The Virgin Southwest

By Aldo Leopold, 1933

The major premise of civilization is that the attainments of one generation shall be available to the next. . . . .

It is only recently that the biological sciences have had new occasion to challenge [this premise], in their discovery of an abnormal erosion-rate in some of our best soils. The rate is rapid elsewhere, but in the Southwest and the adjoining semi-arid regions it is nothing short of alarming. At the mouth of one Utah canyon, for example, erosive deposits display seasonal color-layers, from which a chronology similar to that of tree-rings has been built. It shows more movement of soil since the introduction of livestock to the watershed fifty years ago than had previously occurred since the recession of the glacial epoch.

"Discovery" is a slow process. It is almost a generation since certain ecologists, range-managers, foresters, and engineers saw and described the present southwestern situation, but it is only a year or two since the social consequences of its continuance were given credence by the lay public. Even statesmen now show signs of being aware that the best soils are slipping, sliding, toward the sea, and that the basic cause of this abnormal movement is the devegetation of the range through overgrazing by domestic livestock.

I think, though, that the thoughtful citizen still entertains a mental reservation—he regards this thing as important, *if true*. This is only natural, since he is unable to weigh personally the technical evidence; he must take the ecologist's word for it. The fact of abnormal erosion, however, can be established on historical as well as ecological evidence. This paper aims to present such evidence as gathered from a single document: the journal of [James] Ohio Pattie, who trapped beaver in this region almost a generation before the Santa Fe Trail opened it to wholesale economic exploitation. Certain other material of miscellaneous origin, and certain personal observations, are interjected to give relief to the Pattie narrative.

Pattie was a young Missourian of the Boone and Kenton tradition, with an eye for game, grass, and timber. He traveled down the Rio Grande and the Gila, trapping beavers, in 1824. . . .

On the journey from Santa Fe to San Felipe, Pattie speaks of a "handsome plain, covered with herds of domestic animals."

Continuing down the Upper Rio Grande Valley to Socorro, he "traversed the same beautiful plain country," on which grazed "the same multitude of domestic animals." There must have been heavy grass, not only along the river but *on the mesas* adjoining the valley floor. There is little grass on these adjoining mesas today; many of them have become sand dunes.

Pattie remarks that the valley floor was not cultivated except at San Felipe and above Socorro. At these points the valley is narrow and the river has a steep gradient. They would be the easiest places to divert the irrigation water from an *unsilted river channel*, because the flatter the gradient of a stream, the more work is required to build intake ditches up its banks.

While the main valley was used for grazing, the farming, according to Pattie, was mostly conducted in side streams like the Puerco. Today the reverse is true. The main valley is all farmed, except where seepage (due to silting) makes it too wet, while the side streams are fit only for grazing, because erosion has gutted all the irrigable land.

Couzens says that in 1859 (?) the channel of the Puerco was only 12 to 15 feet deep where it crosses the road from Isleta to Acoma and Zuni. Abert says that in 1846 it was only 10 or 12 feet deep at a point a few miles higher up. Today, at these same spots, the channel of the Puerco is a miniature Grand Canyon carved in clay. I recollect it as over a hundred yards wide and thirty feet deep.

Pattie remarks that at Socorro the valley was thinly timbered, but covered with willow and cottonwood brush in which "great numbers of bear, deer, and turkey" found refuge. One infers there was little large timber anywhere along the upper river. Today the ancient cottonwoods that line its irrigation ditches are its principal ornament. Most of these cottonwoods *are rooted in the ridges of silt* that have resulted from the annual cleaning of the ditch channels; in fact the older ditches *have raised themselves from five to ten feet above the valley floor* by gradual siltage.

What do these seemingly disjointed facts tell us about the virgin Southwest?

They tell us that in Pattie's day the Rio Grande drained a stable watershed, devoid of abnormal erosion. Even the sand dunes adjoining the river carried a heavy growth of grass. By reason of this grass, prairie fires swept across the valley and kept it devoid of large timber. The river channel, now so filled with silt that it is actually higher than the valley floor, was then so far below the floor that irrigation was difficult, except at points where steep gradients facilitated the building of intakes. In short we now have scant grass, much erosion, and a river so choked with silt that it bogs its own bottoms with seepage and poisons their fertility with alkali. In Pattie's day there was grass everywhere, little erosion, a normal river, and bottomlands of sweet well-drained soil.

Pattie's testimony is really superfluous; there is hardly an acre that does not tell its own story to those who understand the speech of hills and rivers. The Galisteo which winds across Pattie's "handsome plain" has since been lived upon. We see the skeletons of ancient fruit trees, toppling one by one into the parched arroyo, which year by year gnaws away at the loam of what was once a farm.

That farm was irrigated once—one can trace the old ditches winding across the remnants of bottomland. If irrigated, there must have been a stream. There is no stream now, only a trickle in the sand.

The stream banks must have been shallow and gentle, else the water could not have been led upon the land. They are not shallow now. The channel is a flood-torn chasm.

If there were ditches, there must have been wide stretches of level, friendly soil to irrigate. That soil has been dumped as silt into the main river; one farm washed away to curse another in the making, somewhere below.

Pattie's handsome plain is still green, at times, but it is the kind of green which could deceive only a tourist. It is not the greenness of grass, it is the greenness of tumbleweeds and snakeweed and pinque—worthless substitutes which a denuded nature has invoked to cover her nakedness. On this same Galisteo, Doniphan, in 1846, found "grass and water abundant and of good quality. . . . ."

Nothing has changed in the watershed . . . except *grass*. Coronado and those who came after him brought sheep and goats and cattle to the Indians, and the subsequent overgrazing of the whole watershed is what upset its equilibrium. Throughout the Southwest the worst erosion is in the regions of the oldest settlements, because it is there that over-grazing has been most severe through the longest time. . . .

Let us now rejoin Pattie on his trip down the Rio Grande. He left the river near what is now San Marcial and crossed southwesterly to the copper mines at Santa Rita del Cobre. From Santa Rita he went to the head of the Gila River to trap beavers. He caught "trout" where the river emerges from the mountains, probably near the present settlement of Cliffs (sic). (If these were really trout, rather than 'bony-tails,' then the trout extended fifteen miles farther downstream than they do now.) The first night of trapping at this point yielded 30 beavers. But the important thing is not so much the abundance of beaver, as the fact that these hardy trappers "*were much fatigued by the difficulty of getting through the high grass which covered the heavily timbered bottom.*"

Today, at this spot, and for miles above and below, the river is flanked by naked bars of sand and cobblestones, and the bottoms, except where fenced, are as bare of grass, as naked of timber, as the top of a billiard table.

Ascending the box of the Gila, Pattie describes "*a thick tangle of grapevines and underbrush*" through which he crawled, sometimes on hands and knees. At the forks of the river (now the XSX ranch) the banks were still "very brushy, and frequented by numbers of bears." Here too, there is now little brush and many cobble bars.

Chop down the oldest of the young sycamores and alders that have found rootage on the cobble bars which have replaced Pattie's bottoms, and you will find that few are older than the cow-business, which invaded these hills in the early eighties. . . .

There was once a widespread impression that forest fires, as well as overgrazing, were an important cause of watershed damage. Recent evidence in other regions supports this belief, but not here. On the contrary, observations on their sequence and relative importance in the Arizona brushfields, indicates that when the cattle came the grass went, the fires diminished, and erosion began.

The foregoing comparisons of what Pattie saw and what we see today are merely random examples of what has happened, in some degree, to almost every watershed in the Southwest. On many of the National Forests and on a few well-managed private ranches the damage is partial and confined mainly to the loss of bottomlands. Near many old settlements the damage is complete, erosion having exposed enough rocks to substitute what might be called a mechanical equilibrium for the vegetative one which once existed. In most places the damage is still in process, and the process is cumulative.

It has been necessary to offer proof of these changes because most people do not know that any change has taken place, and some who do know deny that overgrazing is the primary cause. They persist in believing either that abnormal erosion was always there, or that it is somehow an act of God instead of an act of goats, sheep, and cows.

In trying to picture the meaning of the term overgrazing, it is important that the reader divest his mind of the assumption that overgrazing constitutes a uniformly distributed excess of consumption over growth. More often than not the excessive utilization of one plant or type of ground is accompanied by the underutilization of another. For this reason the very diversity of the country has contributed to its undoing. If a mountain cow on a cold winter day has the choice of basking in the warm sun of a hardwood bottom, or of climbing upon the wind-swept mesa, or scrambling among the rocky slopes between the two, she will choose the bottom. In fact, she may browse the last bottomland willow to death before the bunch grass on the slopes is even touched. It seems as if the greater the diversity of types, the less uniform their utilization and the quicker the inception of damage.

The reader must grasp the fact that overgrazing is more than mere lack of visible forage. It is rather a lack of vigorous roots of desirable forage plants. An area is overgrazed to the extent its palatable plants are thinned out or weakened in growing power. It takes more than a few good rains, or a temporary removal of livestock, to cure this thinning or weakening of palatable plants. In some cases it may take years of skillful range management to effect a cure; in others erosion has so drained and leached the soil that restoration is a matter of decades; again it has removed the soil entirely. In the latter event restoration involves geological periods of time, and thus for human purposes must be dismissed as impossible.

The rivers on which we have built storage reservoirs or power dams deposit their deltas not only in the sea, but behind the dams. We build these to store water, and mortgage our irrigated valleys and our industries to pay for them, but every year they store a little less water and a little more mud. Reclamation, which should be for all time, thus becomes in part the source of a merely temporary prosperity. . . .

How now shall we sum up the degree of doubt as to the future—the possible damage to the tempo of our time, which inheres in this question?

We are, of course, in the position of a biographer who cannot evaluate a contemporary because he knows too much and understands too little. The forces at work are still in operation; it is too early to foresee their final outcome.

But we can say this with assurance: If erosion proceeds unchecked the ranges, irrigation reservoirs, and wild life will be gone.

If we do check it, we will lose the mountain valleys, and eventually the reservoirs will be much impaired, but the ranges can come back.

We can say this: That what we call “development” is not a uni-directional process, especially in a semi-arid country. To develop this land we have used engines that we could not control, and have started actions and reactions far different from those intended. Some of these are proving beneficial; most of them harmful. This land is too complex for the simple processes of “the mass-mind” armed with modern tools. To live in real harmony with such a country seems to require either a degree of public regulation we will not tolerate, or a degree of private enlightenment we do not possess.

But of course we must continue to live with it according to our lights. Two things hold promise of improving those lights. One is to apply science to land-use. The other is to cultivate a love of country a little less spangled with stars, and a little more imbued with that respect for mother-earth—the lack of which is, to me, the outstanding attribute of the machine-age.

Excerpted from “The Virgin Southwest,” by Aldo Leopold, 1933. From: Flader, Susan L. and J. Baird Callicott, eds. *The River of the Mother of God and Other Essays by Aldo Leopold*.

Discussion Questions

1. What time periods are covered in his essay?
2. According to Leopold, what is the major cause of erosion in the Rio Grande Valley? Use evidence from the essay to support your answer.
3. Who was James Ohio Pattie? How does Leopold use Pattie’s account to support his main idea?
4. How was the Rio Grande valley different when Pattie wrote his account from when Leopold wrote his essay?
5. What does Leopold state is the public’s responsibility in this changed Southwest?

Discussion/Essay Questions

1. Do you think that Leopold was a visionary—ahead of his time? Why or why not?
2. What would Leopold think about the Rio Grande Valley today?
3. Imagine you were Leopold in 1918, and you were lobbying the New Mexico Legislature to pass a law to protect the Rio Grande Valley. Write a law and give supporting evidence why this law should be passed.

4. Leopold made a persuasive case for "the importance of nature as a prerequisite of human well-being." What do you think that means? Use evidence from Leopold and also from your own thinking to support your ideas.
5. Write a paragraph or several paragraphs about Aldo Leopold. Use at least 10 of the following terms and concepts: *conservation, preservation, bosque, aquatic, adaptation, aquifer, ecosystem, endangered, erosion, ground water, habitat, irrigation, depletion, dams, reservoirs, riparian, runoff, watershed.*

Estella and Aldo Leopold

This photo was taken at Tres Piedras, NM, in 1912. (Courtesy of New Mexico State Records and Archives, the Bergere Collection, negative no. 21354.)

Aldo Leopold and New Mexico

By Sterling Grogan
Middle Rio Grande Conservancy District

Aldo Leopold (born 1887, died 1948) was a forester, ecologist, hunter and pioneer who wrote about nature in ways that few Americans before him ever had. He studied forestry in college, created the field we now call "wildlife management," and wrote dozens of essays that combined ecology, aesthetics, and ethics to describe the connections between humans and the natural environment. *A Sand County Almanac*, a collection of his essays about land conservation published after his death in 1948, is sometimes called the "bible" of modern environmentalism.

Aldo Leopold came to New Mexico in 1911, just six years out of college, to be the deputy supervisor of the Carson National Forest. He lived first in Tres Piedras and later in Albuquerque with his wife Estella, a member of the prominent Luna-Otero family of Santa Fe. He explored much of New Mexico on horseback as part of his many jobs in the Forest Service. In 1918, Leopold left government service for 18 months to become the first secretary of the Albuquerque Chamber of Commerce.

In the first and second decades of the 20th century, flooding and water-logged land were among the biggest problems facing Albuquerque. Leopold advocated formation of a drainage district that could fund necessary improvements like flood control levees, drains, and improved irrigation ditches. He believed that Albuquerque would prosper by improving conditions for agriculture in the Middle Rio Grande Valley. His vision and leadership led to the establishment by the State Legislature in 1925 of the Middle Rio Grande Conservancy District. The Conservancy was given responsibility for preventing Rio Grande flooding, draining the water-logged farm fields, and improving the irrigation water delivery system, as Leopold had envisioned years before. Today the Conservancy looks a little different than it did in the 1920s, but its fundamental mission is much as Leopold imagined it could be. He also campaigned for an Albuquerque river park, and a little more than fifty years later the Legislature created the Rio Grande Valley State Park.

An avid duck hunter, Leopold paid close attention to the condition of rivers, including the Rio Grande, with observations of how erosion on the mesas that line the Rio Grande Valley lead to sediment filling the river channel. As Leopold's ideas of ecology evolved, he placed greater emphasis on the need to understand and improve the management of watersheds. He saw that the study of watersheds required the integration of ecology, forestry, geology, esthetics and ethics, an integration that he knew was essential to our understanding of the whole earth.

Leopold left New Mexico in 1924, and except for occasional family visits he did not return until the 1930s to work on erosion control with the Civilian Conservation Corps. Scholars think that New Mexico, and Estella's deeply-rooted New Mexican family, profoundly influenced Leopold's thinking about the environment. For example, the first wilderness area in the U.S., the Gila Wilderness in southern New Mexico, exists because Leopold used his experience as a forest ranger there, along with his growing interest in land management for wildlife, to push the idea of setting aside "wild and scenic" (i.e., wilderness) areas. Leopold also argued against the prevailing American attitude of "progress at any cost," pointing out that when wildlife (he called it "game") habitat is lost, the loss affects more than just a few animals.

Leopold was not alone in thinking of water, wild animals, trees, grass, and the land itself as intimately connected to every human being. However, he distinguished himself from other "nature philosophers" and conservationists of his day by making a persuasive case for the importance of nature as a prerequisite of human well-being. Leopold saw that without the values of open space, well cared-for land, and healthy wildlife, humans were somehow diminished, poorer, and perhaps less human.

Leopold's life is a testament to the importance of life-long learning. His persistent studies of the natural world led him to continually question and occasionally change his own views. He disowned and argued against ecological principles that in his early writing he had advocated. For example, his early career in the Forest Service was marked by essays supporting the suppression of all forest fires because they "set back succession." He also argued for the extermination of predators to protect and expand the herds of wild deer and elk. After he had spent decades observing nature and challenging the assumptions of experts, he wrote about the essential role of fire in the ecology of western pine forests, and he decried the extermination of wolves and other "varmints" because of the degradation their absence from the ecosystem would cause. Now, the value of fire is widely understood, and predators like wolves and coyotes are beginning to be seen as important components of the ecosystem.

Leopold was ahead of his time, and his thinking did not always find receptive audiences. He argued for the importance of grass as the main component of healthy watersheds, long before most foresters and ranchers conceded that overgrazing might be detrimental to watershed health. As early as 1923, Leopold wrote about the concept of the whole Earth as a living organism with some kind of soul or consciousness: "Plants, animals, men, and soil are a community of interdependent parts, an organism." That idea contrasted radically with the prevailing "mechanistic" view of nature, in which the natural environment is seen as a machine that can be manipulated by humans for our own purposes.

Today, Leopold's ideas are commonplace, forming the basis for what we call "environmental management." However, we need to remember that it took more than fifty years for those ideas to take root and blossom and for Leopold's vision of the natural world to be accepted.

Discussion Questions

1. Who was Aldo Leopold?
2. What is the Middle Rio Grande Conservancy District?
3. What is environmental management?
4. What did Leopold study in college? What was his first job in New Mexico?
5. What was the first wilderness area in the United States? How was Leopold involved in the designation of this wilderness area?
6. According to Leopold, how are human beings connected to nature?
7. What is *The Sand County Almanac*?

“The Binnacle Bat”

Aldo Leopold and his boat, “The Binnacle Bat,” on the Rio Grande, south of Albuquerque, in 1918. (X251729, courtesy of University of Wisconsin–Madison archives.)

Leopold's Land Ethic

By Cary Weiner
New Mexico Museum of Natural History & Science

In the early 1900s, while most people fought for their right to water, Aldo Leopold fought for the river's right to water. He created the Middle Rio Grande Conservancy District and promoted the establishment of what would become the Rio Grande Valley State Park. While most people fought for the right to mine the Wild West, Aldo Leopold fought for the West to remain Wild. He advocated for the establishment of America's first designated Wilderness, in the Gila National Forest. While most people attempted to conquer the land, Aldo Leopold realized he was a "plain member and citizen" of it. He developed an environmental ethic that challenges humanity's entire relationship to nature.

Many people feel no ethical obligation to the environment. They believe that wherever humans can exploit an ecosystem for their own benefit, they should. Politicians, economists, foresters, and special interest groups commonly clash over how people should use the environment. The first Chief of the National Forest Service, Gifford Pinchot, managed America's forests to provide "the greatest good for the greatest number [of people] over the long run."

Leopold himself even formed his early ideas of the environment based on his personal interests. As an avid hunter, he argued for the extermination of predators in order to protect and expand the herds of wild deer and elk for hunting purposes. Then one day, while eating lunch "on high rimrock," Leopold and his party were startled by the presence of an old wolf with her grown pups downhill:

> In those days we had never heard of passing up a chance to kill a wolf. In a second we were pumping lead into the pack, but with more excitement than accuracy: how to aim a steep downhill shot is always confusing. When our rifles were empty, the old wolf was down, and a pup was dragging its leg into impassable slide-rocks.
>
> We reached the old wolf in time to see a fierce green fire dying in her eyes. I realized then, and have known ever since, that there was something new to me in those eyes—something known only to her and to the mountain. I was young then, and full of trigger-itch; I thought that because fewer wolves meant more deer, that no wolves would mean hunters' paradise. But after seeing the green fire die, I sensed that neither the wolf nor the mountain agreed with such a view."
>
> —*A Sand County Almanac*

Here, Leopold writes eloquently about how he realized the ecological connections between wolves, deer, and mountains. After spending great lengths of time in wild New Mexico as an employee of the National Forest Service, Leopold realized his own intimate connections to ecosystems. He acknowledged the beauty of wild nature, the diversity of its inhabitants, and the complexities of its workings. He knew he depended on it, was privileged to experience it, and was ill-equipped to fully understand it. So he established an ethic to preserve it—the land ethic:

“A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.”

This environmental ethic is truly significant because it provides a clear and simple way of judging our actions toward the environment. Instead of managing the wild to benefit *people only*, Leopold insists that the wild should be managed to benefit the *ecosystem*, in which people are simply a “plain member and citizen.” To put it another way, Leopld saw that “we abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.”

Aldo Leopold questioned his own views and those of others as he studied nature throughout his life. This led to the preservation of thousands of acres of land in New Mexico and elsewhere. More importantly, it led to the establishment of the land ethic, which is a living, growing testament to the wild that can shape the attitudes of others for generations to come.

Discussion Questions

1. What does it mean to be a “plain member and citizen” of the land?
2. In Leopold’s anecdote, what did the “fierce green fire” represent?
3. Do you think that people are “ill-equipped” to understand nature? Why or why not?
4. How do you think Leopold was perceived during his time?
5. Write your own environmental ethic.

38. River Stories

Description: Students collect oral histories about the Rio Grande. The aim is to collect a wide range of experience and history that can then be used to shed light on the Rio Grande.

Objective: Students will learn:

- how to conduct oral history interviews; and
- about the importance of recording and learning about history through oral traditions, using the Rio Grande as a focus.

Materials: For each student:

time line, list of possible interview questions, ideas and guidelines
writing materials: paper and pencil

Optional: tape recorder; videocamera; camera; digital camera; film; envelopes; postage; book-making materials

Background: Oral history is a method of gathering and preserving historical information through recorded interviews with participants of past events and ways of life. It is both the oldest type of historical inquiry, predating the written word, and one of the most modern, initiated with tape recorders in the 1940s.

38. River Stories

Grades: 4–12

Time: Material preparation: 30–60 minutes

Doing the activity: ongoing and flexible depending on the extent of the project:
one class period for oral history, "river story" teller;
one class period for discussion and preparation of the interview;
outside class time for students to do the interview;
class time to share their stories and artwork and to compile the information;
class time for gathering/recognition of those who participated in the project.

Subjects: social studies, language arts

Terms: *oral history, oral tradition*

The student armed with nothing more than paper, pencil and a genuine historical curiosity can practice oral history. At the personal level of family history, a cassette of our grandparents relating their lives will be far more fascinating to our grandchildren and great-grandchildren than a name on a genealogical tree. Oral history is something students can do for themselves: an activity which is intellectually, socially and politically democratic and collective.

Oral history is a method of historical research, as well as a human challenge, because it involves direct and personal contact with other people. It asks us to assess other people's lives as well as our own ability to deal sympathetically but honestly and imaginatively with their memories and ourselves. It is based on documents that are spoken, and folklore and legend are only one kind of spoken document. Songs, speeches, interviews, and formal and informal conversation are all oral documents, useful for history. "Oral tradition" is the usual name for these verbal stories passed on from one generation to the next.

These interviews can collect a certain amount of information such as folk songs, tales, myths and specific interpretations of the river's past history. The accounts that the parents and grandparents of the students give them about their own experience can be instructive tools for learning about the Rio Grande. Such activities will undoubtedly be of immense value to historians in the future.

Procedures:

1. Guest storyteller: Arrange to have someone visit the class who can share a "river story" that will inspire the students for the oral history project they will be creating. This guest could be a storyteller who can share his or her stories using different mediums: music, artwork, or food…this brings a real-life dimension to the activity. It illustrates the idea of "river stories" that they will be collecting. It shows students a different side of an adult and that adult becomes a priceless source of information about the river. It gives students a flesh-and-blood subject with whom to study and interact.

   Prepare the students for the guest storyteller. Have the students prepare for this guest by thinking of questions they can ask the guest. Explain the usefulness of oral history.

2. Oral history project: Describe the project that the students will be doing: first-hand oral history research with people in their own communities and families.

3. Brainstorm, either as an entire class or in small groups, the possible sources of information, which could be used to find people in the community who have river stories. Examples

might include: their family members, friends, government offices, the telephone book, local newspapers and magazines, local television news directors, leaders of local groups or clubs. The class might place an advertisement in the paper, or enlist the aid of a reporter to write up a story on the class project.

4. Once a list of names has been compiled, students in groups of two or three will work together to prepare an oral history interview of the person they choose to interview.

   Each team should develop a plan. This should include the outline of the interview they will conduct with the person they have chosen to interview. (See Introduction to Interviewing)

   The basic format for the interview should include any personal history details of note but the major questions to be addressed should be memories about the Rio Grande. The list of questions could be modified to include personal interests of the students and to reflect particular circumstances. Each team's plan should be discussed with the class and suggestions for improvement considered. After the plans have been discussed and refined, the students should make contact with the people they want to interview.

5. Once the students have confirmed the willingness of the people to be interviewed, they should meet with them and conduct the interview.

6. After the interviews are complete, students should write up the oral history they have done. Ask each team to briefly tell the class about the story. Make copies of the oral history project with a letter of thanks to the people who were interviewed and others who assisted.

7. Optional: Create a book of all the completed stories, complete with photographs, pictures, stories, poems, or paintings. Invite the local people who were interviewed for a public recognition of their contribution. They could be given letters of thanks and copies of their oral histories at this time.

8. In the Native American culture, to interview an elder of a nation, the person conducting the interview must bring a gift in exchange for information. Permission should be asked before pictures are taken. When the oral history is complete, a copy should be given to the elder before it is released to the public.

Professor Enrique Lamadrid's Insight Into Collecting River Stories

The most effective way of preparing for a river interview is taking time to develop a comprehensive "question" set, a list of topics, concerns, and questions that is thoroughly internalized by the interviewers. Since you know beforehand what ground you hope to cover, you do not even need to shuffle paper or notes. You can give your consultant your full appreciative attention, and conversation can emerge with its own rhythms and directions. Unlike formal questionnaires, which can actually discourage or even cut off conversation, the question set is flexible and adaptable to each situation. Before you develop a question set, find a focus for your project. Are you collecting plant and animal stories? Are you documenting traditional agriculture? Are you doing an oral history of the survivors of San Marcial and the 1929 flood? Perhaps you are conducting an attitude survey of city water users. Be ready to shift your focus as the stories emerge. Rivers flow around obstacles.

Before the interview, identify your consultant and the kind of knowledge that he or she might have. Make a list of all the people you would like your group to interview. Then see how many of them you can actually find. There is a relationship between cultural diversity and biological diversity. Which are the "cultures of habitat" in your area? People who have lived along the river the longest are probably those who have developed the most knowledge about it.

Will the conversation be about irrigation, agriculture, floods, medicinal plants, animals, or river crossing experiences? Since the Rio Grande is an international boundary south of New Mexico, it takes on powerful meaning for people there. Make sure to ask about family stories, fishing stories, animal tales, songs, and legends such as La Llorona. Did you know that she was always associated with water? How did people think about the river and utilize the river's resources? Did they swim or play in it as children? Did they gather firewood or wild food there? Are there recipes for those foods? Make sure to leave the interview open-ended enough to gather information you were not expecting.

As you develop your own question set, it is useful to think about all the things you know and would like to know about the river.

Introduction to Interviewing

Procedure:

1. Discuss with the class the idea of interviewing.
2. Talk about the different types of interviews, such as interviewing for information on a topic vs. interviewing for information about that person.
3. Talk about possible questions that could be asked during an interview.
4. Have students come up with possible interview questions.
5. Discuss what is appropriate and what is not, as well as what kinds of information they should be looking for in the interview process.
6. Give students class time to come up with questions.
7. Divide the class into groups of two or three.
8. Have each group combine lists of questions and discuss again what is appropriate and what is not.
9. Discuss how the ordering of the questions facilitates the flow of the interview.
10. Each group should list questions in the way that they would like to ask them during an interview.
11. Have each group share its list of questions and get ideas and suggestions from other groups.
12. Each student should have a list of questions from his or her group. Shuffle groups and have students interview each other using their questions to make sure that they flow.
13. Once students have interviewed one another, have students reorganize questions as needed and discuss what worked and what did not work in their list of questions.

How to Conduct an Interview

Procedure:

1. Students will choose a person to interview. This may be a relative or family friend. If none is available, the teacher will need to help find someone.
2. After choosing a person, students will set up an interview time.
3. The students will begin the interview by explaining the project: We are compiling Rio Grande stories based on oral narratives about people's lives. "We are learning about interviewing and about writing narratives. A copy of the final project will be available to you after the project is finished."

4. Students will conduct the interviews based on the questions that they compiled during class.
5. Once the interview process is complete and the interviewer feels sufficient information has been gathered, he or she needs to thank the interviewee and then may leave.
6. After the interview, within three days, send thank-you notes.

Bringing the Stories Together to Be Shared

Find ways to share the stories that the students have gathered: Make a book of the collected stories and/or drawings. Have a sharing circle where the students retell the stories they have heard. The students could share the interview they conducted if they tape-recorded it or video-recorded it.

***Extensions*:** Have the students write about their experience, what they've learned from the oral history.

Have students create a storybook, art book/collection, or a video/audio presentation of what they've gathered.

Connect to other activities, e.g. ask family members for help with activities.

Have students create their own "river story" to share, inspired by what they've learned from their bosque experiences.

Have students ask each other their own interview questions.

Make lists of local plants and animals using local names.

Take picture cards of animals and plants home to get identified by elders using local names.

Research recipes for local plants and animals, and medicinal uses.

Create a cookbook: gather recipes related to the river or traditional family recipes.

Make place name books in class.

Share stories of plants and animals as told by elders of the community.

Explore ways the ecosystem can be protected for future generations.

Have a sharing circle where each student shares his or her own river story.

***Assessment*:** Evaluate the students' participation in the group process. Have them share stories they've heard.

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Resources in Albuquerque

Center for Southwest Research at University of New Mexico

Middle Rio Grande Conservancy District

The Albuquerque Museum

National Hispanic Cultural Center

Albuquerque Libraries: Special Collections Genealogy and Southwest History

River Stories

Time Line

Week 1: Guest storyteller comes to class and oral history is explained; develop questions

Week 2: Find someone to interview

Week 3: Complete the interview; send thank-you notes

Week 4: Collate the oral histories into a book

Week 5: Celebrate the oral history project with the contributors

Who You Can Interview

your mentor

grandparents

a Native elder, a Hispanic elder

a resident of Cochiti or Isleta Pueblo (a Rio Grande pueblo)

a flood survivor

a dam or bridge builder

a bosque fire fighter

a rancher or farmer

a duck hunter

someone who can see the river from where they live

an immigrant who crossed the river into the US

a fisherman

a ditch boss

a water engineer

a poet or artist

a gardener who uses the ditch

a river rafter

a swimmer

Developing Interview Questions

By Enrique Lamadrid

To Native people, the river is a living being. What is its shape and name? Which Pueblo always puts this creature on its pottery?

How many indigenous names are there for the Rio Grande? How many tribes and languages live along its banks?

Who are the River Men from Cochiti Pueblo, and why are kids so fascinated with them?

Why has La Llorona been heard in every community along the river?

The river has five names in Spanish. Which two are used today, and by whom?

The water of the river is “holy water” on one day of the year, June 24, the Feast of San Juan Bautista (St. John the Baptist). Many people bathe in it then for special blessings.

When the Spanish Mexican settlers first arrived in the 16^{th} century, the climate was colder and the river froze over every year. The ice made a good path for wheeled vehicles.

On which feast days is the river water blessed? The Matachines dancers in the Albuquerque area bless the acequias and water sources on two special days: San Isidro (the patron of agriculture) and San Antonio.

How is irrigation managed? What do the Pueblo prayers talk about before cleaning a ditch? What kind of music is sung while cleaning the ditches?

Each plant and each animal has its own stories to tell. People tell some of these stories. We can make up the other based on observation and science—this is called natural history.

Why are cranes (grullas) such good luck for people?

Why do daddy ducks have many wives and geese only one?

Which ducks have claws and why?

When did the grackles first arrive here?

Why do the seagulls follow the river? Why do they like the dump so much?

Why did the bears come to the bosque? Are they really lost?

Which fish used to be people in a previous world? Why don’t Navajos eat fish?

What were the fishing reports like in the 1600s?

Where are the eels and shovel-nosed sturgeons?

Why are trout considered so intelligent?

Why is the cottonwood tree sacred to traditional peoples? Why are native katsina images and Hispano santos both made of cottonwood root? Why are drums made from cottonwood?

Who brought the tamarisks, Russian olives, and Siberian elms and why?

That Elephant Butte dam was the biggest dam in the world in its day. What are the goals of the Army Corps of Engineers?

What happened to the town of San Marcial and where are its people?

What were the big flood years? Are there still flood stories around?

Why were female cottonwoods illegal in Albuquerque's city limits?

What happened to the Los Ranchos church when floodwater wouldn't drain?

How were all the wetlands in the North Valley drained?

Why are people building expensive houses south of Socorro where there is no levee? Who will pay if they are ever flooded out?

The questions are endless . . . See how many you can add to the list, both before and after your interviews.

39. Bosque Songs

Bosque Music: A Timeless Song

Natural sounds, celebrations, ceremonies, personal reflections, artistic expression: these are some of the ways music can connect people to the Middle Rio Grande bosque.

1. A Cultural Connection

As long as people have lived here, music has flowed throughout the Middle Rio Grande Valley. From ancient Pueblo harvest celebrations, to Spanish fiestas, to Las Posadas Christmas plays, to barn raisings, to Friday night dances at the local community center, music has always been a thread in the cultural fabric of the valley.

"…[W]hen they had a wedding or a dance the musicians would get on top of the wagon, and they would go all over the neighboring town playing. That was the announcement that there was going to be a dance. You could hear the musicians going from one street to the other playing. It was like a parade—what is going on: dance tonight."

"…When I was growing up and—let's say my cousin had a birthday—my dad would put all of us in a horse and wagon, and he had a guitar and my brothers played guitar, and we had to go sing "Happy Birthday" . . . before you knew it there was a big table set and it was all ready for everybody to eat. Then after that we would just start singing different songs in English or in Spanish . . . "

"…right on Christmas day they would bring boxes of clothes, gifts and candy. Your eyes would pop out. As a kid; I was raised in poverty. I remember one year I stood in line three times just so I could get a harmonica—that was what started me in music . . . "

Excerpts from *Shining River, Precious Land* by Kit Sargeant and Mary Davis

Studying the local music of the past can teach students about the culture and events that helped shape some of the human connections to the Middle Rio Grande bosque.

2. A Natural Symphony

Besides creating a setting for music of all kinds, the bosque creates its own music as well. By walking through the bosque or sitting on the river's bank, you can hear one of the greatest orchestras around. Crows chattering from the cottonwood canopies, frogs bellowing from shallow pools, coyotes howling from a distance and river water splashing around a piece of driftwood—the bosque performs its own natural concerts and admission is always free!

". . . and when the dawn wind stirs through the ancient cottonwoods, and the gray light steals down the hills over the old river sliding softly past its wide brown sand bars—what if there be no more goose music?"

Excerpt from Aldo Leopold's *A Sand County Almanac*

Studying, recording and creating natural sounds can greatly enhance a visit to the bosque, deepening observation skills.

3. Inspired by Nature

The natural world has always inspired musicians and composers, and water has especially found a place in many types of music. Composers like Maurice Ravel, Antonio Vivaldi and Claude Debussy made the sounds and feelings of water come alive through several of their compositions.

Other more modern songs use some form of "rivers" in their lyrics or title. "Moon River," "Bridge Over Troubled Water," "Take Me to the River" and "The Water is Wide" are just a few songs that use rivers as their theme or setting.

Songwriters may also use music to communicate their political or social views on the use or management of the river. This form of expression can be very effective in communicating a personal thought or opinion.

By exploring music about water, students may gain an appreciation for this form of creative expression and be inspired to write their own songs about the river.

Almost everyone enjoys listening to or playing some form of music. Even if you can't carry a tune in a bucket, you can help broaden students' views of the Rio Grande by using music as an engaging way to appreciate and study the cultural and natural history of the Middle Rio Grande bosque.

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Habitat Rap

By Gary M. Stolz

Oh, habitat is where it's at,
It's the home that all life needs,
It's food, water, shelter, space,
And it used to be all over the place,
But it's not the same, and it's not a game,
And we gotta do somethin' quick,
It's up to us, to make a fuss,
'Cause our world is growing sick.
Endangered species are a sign so strong,
That our ecosystem has something wrong,
It's biology's diversities. . .
Nature's universities,
That show us health of the world we share,
With every creature, common or rare.
Since dinosaurs we've never lost,
So many species at an unknown cost,
Cancer, AIDS and other disease,
Hidden cures in rainforest trees.
There's medicine and whole lot more,
To be discovered in nature's store,
But it's going fast and it won't last,
We must work quick with votes to cast,
Water flowing from the sink,
Is it really safe to drink?
To clean our air, everywhere,
Everybody's gotta care,
It's about our world, and the mess we're in,
What can we do? And where to begin?
Let's agree, just you and me,
To recycle more and plant a tree,
Conserve on fuel and share a ride,
Good stewardship will give us pride,
'Cause habitat is where it's at,
It's the home that all life needs,
It's food, water, shelter, space,
And it used to be all over the place,
But it's not the same, and it's not a game,
And we gotta do somethin' quick,
It's up to us, to make a fuss,
'Cause our world is growing sick.

Save the Rio Grande

To the tune of "Gilligan's Island"; new lyrics by Matt Schmader

Sit right back and you'll hear a tale
A tale of the Rio Grande
It starts up on the mountaintops
And flows across the land
The river was a mighty one
It flooded far and near
People farmed along its banks
For three thousand years
Three thousand years

The trees grew tall, proud and strong
The birds and fish were free
They were living on borrowed time
As you will come to see
For along came the engineers
Said the river must be tamed
It's now a shadow of its former self
And many are to blame,
Many are to blame

Dams, levees, and neighborhoods
Changed the way we live
The more people learned to take
The river had less to give
"Progress" now has finally come
With environmental cost
And if not for the courage of a fearless few
The minnow will be lost,
The minnow will be lost

The Rio dried and people fought
Over every precious mile
    With the Army Corps
    Fish and Wildlife too
    Big cities
    And their thirst
    The Conservancy
    The farmers and you and me,
Must save the Rio Grande
Must save the Rio Grande
Must save...the Rio...Grande!

Rio Grande Elementary School's Songs for the Bosque

One fun way to play with music and the bosque is to create lyrics to popular tunes. When Cindy Kuchera taught music at Rio Grande Elementary School in Belen, she worked with students who participated in the Bosque Ecosystem Monitoring Program (BEMP). They developed and performed these three songs at a BEMP Student Congress. Two of the songs are about BEMP sites: the Savannah Site at Bosque School in Albuquerque and the Belen Site at Willie Chavez Park in Belen. Can you make up some songs about the experiences you've had in the bosque?

The Bosque

(Sung to the tune "My Bonnie Lies Over the Ocean")

My bosque lies over the flood plain,
The Rio Grande runs right through it.
My bosque lies over the flood plain,
Oh, bring back the bosque to us.

Chorus: Bring back, bring back
Oh bring back the bosque to us, to us
Bring back, bring back
Oh bring back the bosque to us.

The pitfall collections are buggy,
With spiders, beetles and pillbugs.
Their numbers will help in our study
Of abundance of life in the bosque.

Chorus

Exotic and native forest foliage,
We count the woody stems,
To track the changes o'er the forest
Of trees, shrubs and vines.

Chorus

As students we must do our duty,
To help understand Mother Nature
As she controls the bosque,
This vital bosque eco-system

Chorus

Oh Savannah

(Sung to the tune "Oh Susanna")

We come to Bosque School
Just to see what can be seen
And found a whole new world
Where we can learn what's green

Chorus: Oh Savannah,
The mysteries you'll unfold
You are a new BEMP site
And your story will be told.

Out behind the school is the river
The Rio Grande, 'tis true
And in the maintained meadow
There's a lot of work to do.

Chorus

The flicker, coyote and rock squirrel
Are some of the wildlife that's here.
And in the forest we will find
Native plants, and exotics we fear.

Chorus

Along the river are the signs
Of abundant beaver life,
Tall cottonwoods are their target here
To what will end the strife?

Chorus

Belen

(Sung to the tune “This Land is Your Land”)

This land is your land,— this land is my land
From Willie Chavez—to the Rio Grande
From the ground below us—to the canopy high
This site belongs to you and me.
The Belen site is wild—the trail o’er grown,
The stakes were plotted—to help us find them.
And now exotics—have taken over,
This site was made for you and me.
Vegetation is plenty—as nature plans it
The kids come monthly—so they can find it
Pit fall and leaf litter—the tasks are taken
Rainfall and ground water are collected too.
The site floods often – along the river,
It breeds mosquitoes—and is home to beaver.
The trees are young here—they grow so wild.
This site is monitored by you and me.

(Repeat first verse)

El Río Grande

The song on the next page comes from *Musica del Rio Grande: Aguas Bravas,* an anthology of river music from the Upper Rio Grande compiled by University of New Mexico Spanish Professor Enrique R. Lamadrid.

The composer, a popular radio announcer on Spanish station KABQ in the 1970s, Juanito Lucero moved home to Torreon where he raised a family. He is a church deacon and has composed hundreds of sacred and secular songs, including “El Corrido del Rio Grande.” His daughter Lola Chavez documented his music for the John D. Robb Archive of Southwestern Music at the University of New Mexico.

El Río Grande

Por Juan S. Lucero

Este corrido, amigos míos,
es una fuente de puro amor,
como las aguas del Río Grande
que dan la vida y causan dolor.

Como en mi cuerpo corre mi sangre
por los veneros de mi corazón,
así es el agua del Río Grande
que va corriendo por la Nación.

El Río Bravo, río del Norte
en Colorado es donde nació,
sus aguas fluyen de las montañas
de Colorado hasta México.

En su corrida da nueva vida
a los paisanos de la región,
de Alamosa y Antonito
y el Norte de Nuevo México.

Por Española y Peña Blanca,
por Algodones sus aguas van,
por Bernalillo y Alameda
sigue corriendo sin descansar.

Va su corrida por Albuquerque
y por Atrisco pasa también,
de allí procede al sur su jornada
hasta Los Lunas, Tomé y Belén.

Cerca del Río corre un camino
que le llaman el Camino Real,
allí recuerdo como en un sueño
de aquel pueblito de San Marcial.

Allá en El Paso juntan sus aguas
las dos Naciones que quiero yo,
estas placitas son lagrimitas
que dejas en Nuevo México.

The Río Grande

By Juan S. Lucero

This corrido, my friends,
is a fountain of pure love,
like the waters of the Río Grande
which give life and cause pain.

Just as blood runs in my body
through the torrents of my heart,
thus is the water of the Río Grande
which flows through the Nation.

The Río Bravo, river of the North
in Colorado is where it was born,
its waters flow from the mountains
of Colorado to Mexico.

In its course it gives new life
to the inhabitants of the region,
of Alamosa and Antonito
and the North of Nuevo México.

Through Española and Peña Blanca,
through Algodones its waters flow,
through Bernalillo and Alameda
it keeps running without rest.

Its current goes through Albuquerque
and passes through Atrisco as well,
from there its journey flows south
until Los Lunas, Tomé, and Belén.

Along the River runs a road
that is called the Camino Real,
there I remember as in a dream
the village of San Marcial.

There in El Paso join the waters
the two Nations that I love,
these villages are tears
that you leave in New Mexico.

40. *If You Owned a Bosque Ecosystem*

Adapted from "If You Owned the Ecosystem," Ecosystem Matters Activity and Resource Guide for Environmental Educators, Rocky Mountain Region, U.S.D.A. Forest Service

Description: Through role playing various wildlife species or an individual profession, students make decisions about the use of natural resources within an ecosystem.

Objectives: Students will:

- describe food and habitat needs for certain species of wildlife and humans;
- discuss what makes up an ecosystem;
- discuss effects of different land use choices on the environment and other life forms;
- identify land uses that are considered compatible versus those that are considered less desirable or incompatible;
- demonstrate how land use conflicts can be resolved; and
- demonstrate cooperative problem-solving and decision- making skills.

Materials: writing materials, "The Ecosystem" drawing from Chapter 2 and role-play cards in this chapter

Optional: overhead projector, overhead transparencies, overhead markers

Background: Ecosystems are interacting systems of living things and their nonliving physical environments. The word ecosystem is also used to describe the place where these interactions (relationships) occur. Ecosystems can be as small as a tiny pond or as large as the Rio Grande, a forest, a desert, or a planet.

40. *If You Owned a Bosque Ecosystem*

Grades: 3–8

Time: One hour and 30 minutes

Subjects: science, social studies, language arts

Terms: *amphibian, aquatic, ecosystem, decompose, fresh water, habitat, mammal, natural resources, nymph, predator, reptile, terrestrial, wildlife, bosque, biodiversity*

We call the living parts of an ecosystem the biological component. The variety of the living species in an ecosystem is known as biological diversity or biodiversity. The non-living parts of the ecosystem are referred to as physical components and include such things as topography, moisture, soils, and climate.

The biological and physical components of an ecosystem interact naturally in give-and-take, interdependent ways. In a healthy ecosystem, native biodiversity is intact and the system operates in ways to maintain that diversity. Some ecosystems are very resilient, absorbing much change and impact. Some ecosystems are very fragile. For every change there is an effect. The loss of one species or the change in one physical factor can make a huge difference. It can even determine whether or not the entire ecosystem can function and survive.

In addition to the stresses put on ecosystems through forces of nature, today's growing human population continues to need and want more and different things. Most human needs (food, clothing, shelter, space, etc.) involve the use of natural resources. That means ecosystems are directly affected.

At times, human uses of natural resources are not destructive to the ecosystem. In some cases, human involvement is compatible with overall ecosystem health. At other times, human activities can harm and degrade ecosystem health. Some human caused changes may enhance some species and at the same time inhibit other species.

In this activity, students work in small groups to decide whether or not to make changes to a bosque ecosystem. The changes will be based on a specific wildlife, plant, human, or special-interest group they represent. Each group needs to consider what they eat, where they live, what materials they need to build homes or other structures, what they need for protection, how long the changes will last, or how the changes will affect the other groups. Students discover that different groups need many of the same natural resources. Some of the natural resource uses will be compatible and others will be conflicting. Each group has a right to present its members' needs. They must listen to the needs of others, and together make a decision as to the best use of the resources.

Procedure: Preparation:

1. Photocopy one ecosystem drawing for every two to three students and one class copy of role descriptions.

Option: Provide each group with an ecosystem drawing on an overhead transparency. They can use overhead markers to mark their changes. The transparency can also be used to make a presentation to the class.

2. Cut the role cards apart.

Doing the Activity:

1. Ask: What is an ecosystem?

    Students must understand that for every change in an ecosystem there is an effect. Everything in an ecosystem is connected at some level. Discuss "compatible use" with students. What examples can they think of, in their personal lives, of a common space that is run or managed with many different interests in mind? Have students briefly explain the area and how it is managed. The school building is an excellent example of compatible use. Others are a community center, park, gymnasium, or sports complex.

2. Divide students into small groups of two to three members. There should be at least eight groups, each of which represents a different viewpoint: farmers, students, citizens, ecosystem managers and, at least, insects, reptiles, fishes, trees, and birds. Additional groups can represent other species or viewpoints.
3. Give each group a copy of "The Ecosystem" and explain that this is the common space about which they will make decisions. Distribute a role card to each group.
4. Have students read the role description on the group's card. They should define or look up any vocabulary words that may be unfamiliar, and answer these questions in their groups.

    What do you eat?
    Where do you live?
    What are your habits or what do you like to do?
    What kinds of materials do you need to build a home or shelter?
    Where will you get the materials?
    What do you need protection from? (predators)

5. Each group talks about the kind of adjustments or changes they would like to make to the ecosystem. The changes are made from the point of view of the wildlife or human roles they represent. Changes can include planting, building, removing things, and other actions that will make their lives better or

sustainable. They should consider how long the changes will last, if they are permanent or temporary, and what effect the change will have on the other groups.

6. "The Ecosystem" can be used to make a rough copy of the changes.
7. Each group presents its recommendations for changes to the ecosystem, including who is being represented and pertinent information from the role card. They also define, for the group, any vocabulary words that come up in their group and may not be familiar to the class. (see ***Terms***, this activity, and Appendix A: Glossary).
8. After all presentations have been made, the class must work to reach a consensus on changes they will make to the bosque ecosystem. Begin by asking each group to identify:
   A. Who would be affected by your changes?
   B. How would the ecosystem be affected by your changes?
   C. Which changes are compatible, which are conflicting?
9. Summarize by asking:
   A. What was the most interesting part of this activity? Least interesting?
   B. What was the hardest part? Easiest part?
   C. Is there anything you learned in this activity that will help you in the future?

Assessment:

1. Evaluate students' participation in the group processes.
2. Have each group give reasons for the changes they make to the ecosystem.
3. If there is no consensus on change(s), have students identify reasons why consensus was not possible. What could have made consensus possible?

Extensions:

1. Have students do research to learn more about each of the birds, fish, and other wildlife and interest groups described on the cards. For example, find out how they protect themselves from predators (enemies), find an interesting fact (i.e., the importance of a squirrel's tail), etc.
2. Use this activity to lead into a discussion of the food web. (See "The Web" in this chapter.) Is anything missing from this ecosystem?
3. Have students add different animals to the ecosystem and prepare additional cards. Do the activity again with the new animals.

4. Have students create different land use scenarios. For example, the farmer has decided to sell her land to a developer to build a shopping mall.
5. Individually or in small groups, have students design ecosystems of their own. What animals, land uses, etc. would be included? Include any local land-use controversies near the school or within the community.
6. Explore and use different consensus-building techniques.
7. Explore ways the ecosystem could be protected for future generations.

Ecosystem Manager

I am interested in balancing human needs with the needs of animals and vegetation. My career requires that most of my time is spent working with a specific ecosystem. For example, I might be responsible for taking care of the natural resources (air, water, land, soil, plants, animals) at a national wildlife refuge, a park, forest, etc.

Citizen

I care about the environment, everything from the air we breathe to the water we drink. I believe we all can do something to help protect our environment, whether it is recycling or walking to school or work whenever possible. I believe it is important to balance human needs with the needs of animals and vegetation.
I am concerned with issues ranging from local government to the global (world) environment. I do things such as writing letters to Congress and cleaning up rivers.

Student

You can create your own role. Think about what you do at home, in school and outdoors. Prepare your self-description based on: what you eat, where you live, your habits and what you like to do, materials needed to build a home or shelter, where you will get the materials and what you need protection from.

Farmer

I grow alfalfa on about 1,000 acres of land in this community. I do not use fertilizers or pesticides. Irrigation water is needed from the river to make the plants grow. Alfalfa plants return nitrogen to the soil, which helps other plants grow. Alfalfa is used to feed my cows, providing people with beef to eat.

Red-tailed Hawk

(bird) I am usually found in open woodland areas. I build a nest in a tree or sometimes in a cliff or human-made building. My nest is usually large and made of sticks, lined with grass and green leaves. I generally hunt for live animals during the day, eating mice, rabbits, squirrels, beaver, prairie dogs and snakes. Coyotes, foxes, bobcats, other hawks, snakes, crows and ravens try to eat me.

Mallard

(bird) I live in marshes, shallow fresh-water ponds, rivers and coastal waters. I get my food by dipping my bill and head into the water looking for seeds, aquatic vegetation and small fish. I also eat grains and vegetation near the water's edge. Coyotes, foxes, bobcats, domestic cats and dogs, hawks, snakes, crows and ravens try to eat me and my eggs.

Frog

(amphibian) In the early stages of growth, my young are called tadpoles. Tadpoles have tails and live mostly in slow water such as ponds or marshes. They have gills so they can breathe like fish. They eat plant material. When I become an adult frog, I lose my tail. Some of my relatives (other frogs) live in the water, some live on land and some live in trees. I eat insects. Birds, mammals, reptiles (especially snakes) and humans (for frog legs) try to eat me.

Cottonwood Tree

(plant) I grow well only where my roots can reach into moisture provided by underground water. My seeds need to fall on bare, moist soil to germinate. They need a permanent water supply to survive and prosper. Many insects live in my branches, so many different kinds of birds come to eat these insects. My fallen leaves add nutrients to the soil when they decompose on the bosque floor.

Leaf-roller

(insect) As a caterpillar, I eat leaves of cottonwood trees. I also roll the leaves and tie them with silk. I hide inside and metamorphose into a small moth. It's easy to find the rolled-up leaves on the ground after they fall out of the trees. Birds often eat me when I'm young.

Mayfly

(insect) I have six legs and three tails. I spend most of my time under water in places where the sand moves around. I usually eat algae and detritus (small pieces of dead plants or animals in the water). As an adult, I live only for a day or two and I don't eat. I attach my eggs to stones or other objects in the water. Many fish eat me, both when I'm young and as an adult. I am named for the month when I can often be seen.

Garter Snake

(reptile) I am a reptile without any legs or arms. I have a long yellowish-white stripe down my back. I eat fish, frogs, toads, tadpoles, lizards and worms. I swim well, but usually I slide along the moist ground under the plants. Herons, roadrunners and some mammals try to catch me.

Silvery Minnow

(fish) I am a small, silvery fish with fins and scales. I have small eyes. I rarely get longer than 8 cm (3.5 inches) I hatched from a floating egg. I eat algae and tiny plant pieces I find floating in the water and on the gooey river bottom. Sometimes I eat old insect skins. I usually travel in large groups called schools. I prefer slow-moving waters where the river meanders and braids.

Meadow Jumping Mouse

(mammal) I jump like a frog with my long hind feet, but I have fur and a tail. I favor now-rare wet meadow habitats. My family lives around marshes. I mostly eat the flowers and seeds of grasses and other plants. I hibernate for half the year, living entirely on fat stored in my body. Coyotes, snakes, hawks and owls try to eat me.