13. Changing River

The Base Activity for the Middle Rio Grande Model

Description: In a directed class activity, students construct a paper and cloth model of a section of the Rio Grande Valley as it was before major human intervention, and then manipulate it to demonstrate the human-caused changes over the last century. In the context of today's river, the students contrast the differences between managing the river for only human benefits and managing the river with broader objectives of both ecosystem health and human needs. They then construct a model of the river of the future using those broader objectives.

Objectives: Students will:

- model the conditions of the old river (Rio Bravo);
- describe the way the river has been significantly altered by humans in the last century (Rio Manso); and
- predict the way the river can be managed to support a healthy ecosystem (Rio Nuevo).

13. Changing River

Grades: This model can be used with all ages, from kindergarten through adult, with discussion geared to the appropriate level. The discussion in this write-up is geared for Grades 3–8.

Time: Initial material preparation: about 30 minutes. Activity: a minimum of one hour to assemble the river, learn where the components are placed, and summarize how the river changes. This activity can be paired with others ("Who Lives Where," "Who Grows Where," "Cottonwood Creation," etc.) and can take many class periods.

Subjects: science, social studies, language arts

Terms: *acequia, biodiversity, bosque, decomposers, flood pulse, jetty jack, levee, meander, mosaic, nutrient cycling, oxbow, riparian, riverine, sandbar, sapling, seedling, snag*

New Mexico STEM Ready! / Next Generation Science Standards

NGSS DCIs and New Mexico State Performance Expectations

3.LS1.B Growth & Development of Organisms
3.LS2.C Ecosystem Dynamics, Functioning & Resilience
3.LS4.C Adaptation
3.LS4.D Biodiversity & Humans
3.ESS3.B Natural Hazards
4.ESS2.A Earth Materials & Systems
4.ESS3.B Natural Hazards
5.ESS3.C Human Impacts on Earth Systems
5.ETS2.A (5-SS-1 NM) Interdependence of Science, Engineering & Technology
MS.LS2.A Interdependent Relationships in Ecosystems
MS.LS2.C Ecosystem Dynamics, Functioning & Resilience
MS.LS4.D Biodiversity & Humans
MS.ESS2.C The Roles of Water in Earth's Surface Processes
MS.ESS3.A (MS-ESS3-3 NM) Natural Resources
MS.ESS3.C (MS-ESS3-3 NM) Human Impacts on Earth Systems
MS.ETS2.B (MS-ESS3-3 NM) Influence of Engineering, Technology & Science on Society & the Natural World

NGSS CCCs

Patterns; Cause & Effect: Mechanism & Explanation; Scale, Proportion & Quantity; Systems & System Models; Energy & Matter: Flows, Cycles & Conservation; Stability & Change

NGSS SEPs

Asking Questions & Defining Problems; Developing & Using Models; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence; Obtaining, Evaluating & Communicating Information

Materials:

For assembly:

- Scissors to cut the pieces
- Envelopes or plastic sandwich bags to hold the pieces and information cards
- Copy of information cards on pages 184-193 or kit materials from workshop
- Five copies of model components (pages 302–303) or kit materials

Your class can then make the following sets:

Before alteration pieces (Rio Bravo):

100	Cottonwood Seedlings
20	Cottonwood Saplings
10	Big Cottonwood Trees
100	Cattails
5	Sandbars
5	Grassy Meadows
15	Native Riparian Shrubs
15	Upland Shrubs

After alteration (Rio Manso):

20	Houses
20	Jetty Jacks
30	Exotic Riparian Trees
10	Snags / Downed Wood
2	(or more) Irrigation Ditches and Drains (see below)
2	Levees
10	Agricultural Fields
1	Dam
10	Additional Big Cottonwood Trees
5	Additional Upland Shrubs

Restoration pieces (Rio Nuevo):

6	Monitoring Plots

- Have students cut out the pieces. Place all of one kind into an envelope or sandwich bag and include the information card for that feature. Keep the *Rio Bravo*, *Rio Manso,* and *Rio Nuevo* pieces separate.

Additional model components (by color and/or instruction):

- One tan, white, or brown blanket, sheet, or large cloth at least 6 to 8 feet (2 to 2.4 meters) long for the Rio Grande Valley
- Strips of blue fabric about 6 to 12 inches (15 to 30 cm) wide for the river. Length should be about three times the length of the valley (blanket, etc., above). You can make long cuts lengthwise in the fabric for braids and meanders. Small separate pieces can be used to construct oxbows or ponds.
- Two brown ribbons or thin fabric strips for levees, 8 feet (2.4 meters) long each
- Blue ribbons for ditches or drains, two 8-foot (2.4-meter) ones and other shorter lengths to reach to fields from the river (The activity "Working Water" requires additional sizes and colors of ribbons for ditches, drains, etc.)
- Green and brown construction paper or felt for agricultural fields, various sizes (long, narrow for ditch-served fields, rectangular or square in some areas), varying from 2 to 5 inches (5 to 12.5 cm)

Note: A chart showing the number of model pieces needed for each river scenario follows below.

Note: Participants attending a *Bosque Education Guide* workshop receive color-coded, laminated model components. Kits can also be created using the model component pages in this activity.

Background:

In this activity students construct a model of a section of the Middle Rio Grande Valley. Models are tools that help us understand complex systems by simplifying their components. We use models to help demonstrate ideas that are not as easy to grasp when working with a real ecosystem.

One way to understand the relationship of the bosque to the Rio Grande is to think about the Rio Grande as "different rivers" depending on time. Long ago, the Rio Grande functioned much differently than it does today. Although people have used the river's water for irrigation for probably thousands of years, they did not start capturing the river water behind large dams or changing the river's natural hydrological functions until this past century. In the model we call this old river ***Rio Bravo***, which is the historic name for the Rio Grande meaning wild or brave—an untamed river.

In contrast, we call the river that has been highly altered by humans ***Rio Manso***. Manso is a Spanish word that means tamed, such as a horse that has been broken to riding. For many years, changes were made to the river system with the top priority being how the river was serving human society. Little attention was given to the ecosystem and the other animals and plants that depended on this important riparian corridor. In 1993, an important document, the *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*, brought a focus on the problems of prioritizing river management for human needs only.

Many projects before the *Plan* attempted to address biological issues on a small scale, and since its publication river managers have been more active in managing the river for both human needs and ecosystem health. In our model exercises, we call this third river ***Rio Nuevo***—a new river that meets human constraints but provides a healthy ecosystem with as many of the Rio Bravo features as can be allowed. This river will always be evolving. In actuality, there will always be places along the river that are more like Rio Manso and other places that are more like Rio Nuevo. When students ask what river we have today, we can tell them we have both, depending on the location.

Photograph courtesy of the Friends of the Rio Grande Nature Center.

"Changing River" Model Pieces

What to Have on the Model When

	Rio Bravo	Rio Manso	Rio Nuevo Summary	Habitat Restoration Projects (Rio Nuevo)								
				Overbank Flooding	Pole Planting	Wetland construction	Fuel-wood reduction	Secondary channels	Exotic species removal	Water conservation	Jetty jack removal	Monitoring along river
Cottonwood Seedlings	100	10	75	10		5		40		5	5	
Cottonwood Saplings	20	1	11		10							
Big Cottonwood Trees	10	20	20	1	1		-1	1	1		-3	
Cattails	100	5	73			50		10		5	3	
Sandbars	5	2	5					2			1	
Grassy Meadows	5	1	4				1		2			
Native Riparian Shrubs	15	7	13	2		1	1	2				
Upland Shrubs	15	20	17	-1		-1		-1				
Houses	–	20	19	-1								
Jetty Jacks	–	20	12					-3			-5	
Exotic Riparian Trees	–	30	11	-1		-1	-5	-1	-10		-1	
Snags/Downed Wood	–	10	5	-1			-4					
Irrigation Ditches/Drains	–	2	2									
Levees	–	2	2									
Agricultural Fields	–	10	10									
Dam	–	1	1									
Monitoring Plots	–	–	6									6

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Procedure:

Introduction to "Changing River" Model

- Have students make a KWL chart (see Appendix K**)**. Ask the question:

  *What do we **Know** about the bosque—the area near the river?*
  *What do we **Want** to know about the bosque?*

  After the lesson, revisit the chart and ask, *What have we **Learned** about the bosque?* Remember to come back to the KWL chart frequently to show what students have learned and to encourage new questions! **(Asking Questions & Defining Problems)**

- You can also use the lens of **Systems** to learn about the bosque ecosystem. For example, you can look at a cottonwood tree as a system itself, or as part of a larger bosque ecosystem. Brainstorm with students: Boundaries, components, interactions, inputs and outputs, properties.

  Here are more tips for using a Systems lens:

  1. Look for the bigger picture.
  2. Study systems from multiple perspectives.
  3. Consider the role of short and long time frames.
  4. Search for complex cause and effect relationships.
  5. Explore places where systems connect with other systems.

  --*WestEd/Making Sense of Science* **(Systems & System Models)**

Vocabulary for Introducing Rio Bravo

bosque: (BOH-skay) Spanish word for "woods"; in the Southwest it is used to describe the forest of trees along a river

riparian: (Latin root means "at a river") relating to or living or located on the bank of a natural fresh watercourse such as a river, stream or pond

oxbow

oxbow: U-shaped river channel that has been cut off from the main flow of a river causing a pond or lake to form

meander or bend in the river: the manner in which a river bends or curves

meander

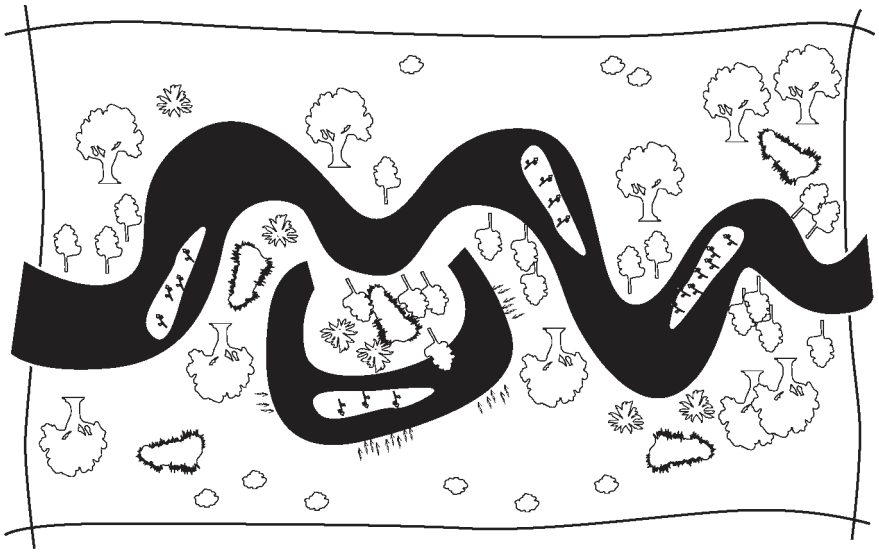
braid in the river: the manner in which a river splits into several channels forming islands between the waterways

seedling: a young plant grown from a seed. Often refers to a tree that has germinated or sprouted, but has not reached sapling size; ("baby trees")

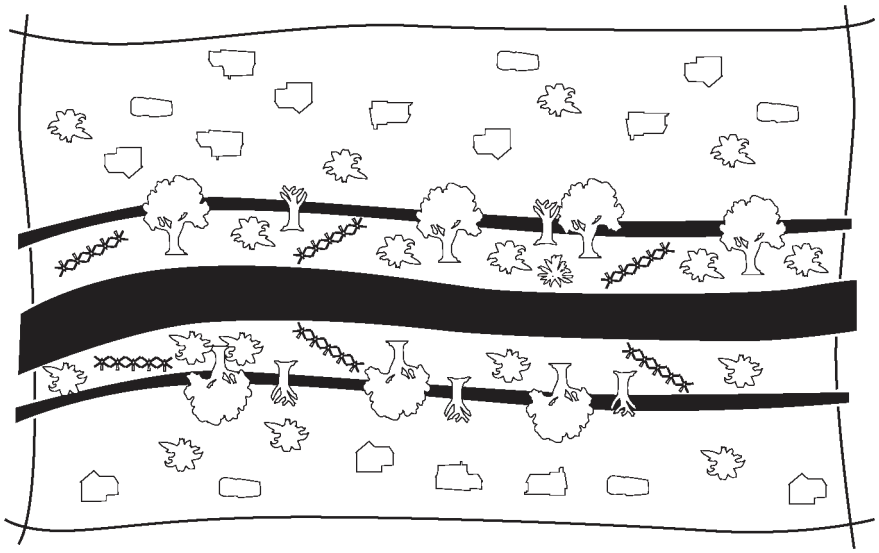
braid

sapling: a young tree, generally taller than 4.5 feet (1.5 meters) and less than 4 inches (10 centimeters) in diameter at breast height (dbh; "teenage trees")

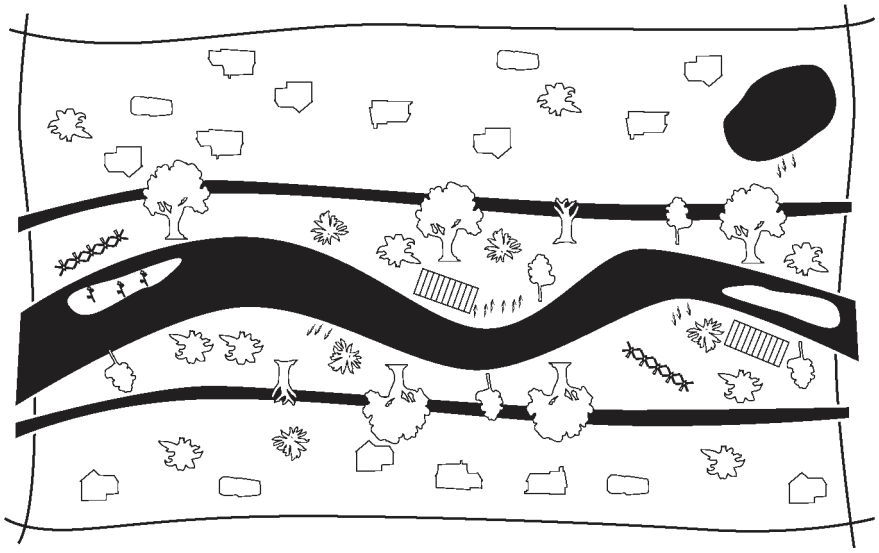
(See ***Terms*** for other words to introduce to your students.)



Rio Bravo



Rio Manso



Rio Nuevo

Pre-model Discussion Questions

*What is in a bosque? (*Water, trees, animals, bugs, soil . . .)

What animals have you seen in the bosque?

What is the main native tree in the Rio Grande bosque? (Cottonwood)

How does the bosque differ from the higher area surrounding the bosque? Are the same plants in the bosque and in the higher areas surrounding the bosque? (Keep in mind that cities will water yards and parks in the upland areas, but in natural areas there are very different plants and animals.)

What makes the bosque different? (The water! Get your students to think through this, it is a very important concept.) In addition to the river itself, the water table is near the surface and many riparian plants can reach down to get water. **(3.LS4.C)**

Cottonwood trees are very important to the bosque. *Can anyone tell me how they reproduce? What type of seeds do they have?* (The seeds are attached to fluffy cotton and they are carried by the wind up and down the river. They need special conditions in order to sprout: wet soil, an open area with lots of sunlight, and the roots must be wet as they grow—during the summer the groundwater drops, and if the roots of the sprouted seeds don't stay wet the seedlings will die). **(3.LS1.B)**

Floodplain showing different levels of sandbars along the Rio Grande
Photograph by Letitia Morris

Section A: Rio Bravo

Setting Up the Rio Bravo Model

- Initiate the activity by explaining to students that they will be building a model of the river and the bosque.
- Lay out the basin (blanket, sheet or other material) with raised edges along the two longest (opposite) sides. Since you may want the students walking on the model without shoes, suggest they place their shoes under the material to create the raised edges (valley); lunch boxes or books work, too. Students may raise all four sides of the basin at first. This is an excellent opportunity to discuss closed basins and explain that long ago, before the Rio Grande was a river, it was a series of lakes in closed basins. Then adjust the model so the two shortest sides are not upraised to emphasize that it is now a valley, with the river coming in one end and out the other end.
- Place the river down the center of the basin. Explain that since they are laying out Rio Bravo, the river should have:
  - large meanders or turns
  - oxbows—old abandoned channels separate from the river that are marsh areas (use small pieces of cloth)
  - braids—loop the fabric or make slits in the river material to represented the braided river
- Hand out only the Rio Bravo (pre-alteration) envelopes or baggies to the students. Teams can be given the larger number of items.
- Ask students to read the card and figure out where in the basin their pieces should be placed, and then place them. Pay close attention to the directions for each of the items in the bags.
- Go around the class with each student/group discussing why their item was placed where it was. Have students use their own words to explain their choices.
- Explain that this is what the river was like before humans made changes to the river.

Essential Rio Bravo Observations

Have the students describe the landscape they have created.

(The end result is a **mosaic** of mini habitats. A grove of old cottonwood trees here, a group of teenage trees (saplings) there, and baby trees (seedlings) in another spot. There was not a continuous forest of large cottonwoods along the river, but a patchwork of different-aged stands of trees. Each year the river might change course, taking out plants that had been there, but providing new open areas for seeds to get established. This mosaic created stability in habitats across the floodplain, and this spatial pattern was stable when considered over time.)

What role does spring runoff play in the ecosystem?

(Every three to five years the river would flood over its banks due to high runoff from snow in the mountains. This is called the **flood pulse**. During overbank flooding in spring, river water saturates the branches and leaves that have fallen on the ground in the bosque. This wet debris decomposes more quickly than dry leaves and sticks. Microscopic organisms such as bacteria and fungi feed on the downed material. The dead material is broken down into nutrients used by other plants. This is called **nutrient cycling**. Flooding promotes nutrient cycling. Flooding also structures floodplain habitats. For example, it creates wet areas for cottonwood seedlings, deposits nutrient-laden sediment into the forest, and may alter the channel of the river.) **(3.LS2.C; MS.LS2.C)**

Rio Bravo Discussion Questions *(after model has been laid out by students).*

Look for patterns. The Rio Grande once experienced temporal patterns in flooding that structured floodplain ecosystems and determined the species that survived there. Flooding also created spatial patterns in habitats.

What patterns can you see for Rio Bravo over time (what natural cycles were present temporally?)

Look for different plants living in different levels along the river, e.g., upland shrubs, wetlands, etc.

Are there patterns of where species can find the right conditions to survive?

(Patterns)

Consider specific plants and where they occur, such as cattails.

Where do cattails survive well? Where do they not survive?

Consider this for other plant species that have been placed on the model.

(3.LS4.C; MS.LS2.A)

The Rio Grande was once a dynamic system that changed greatly over time and space within the floodplain. Changes were much less predictable at a small spatial or temporal scale, but habitats were predictable when considered over a longer time or larger area. Look at the changes in habitats due to flooding and erosion, and consider how these affect organisms living in a given location.

What is the natural cycle of the river through time (within a year and across years)?

Did habitats change naturally? If so how? What caused these changes?
How is snowfall in the mountains related to flooding in the bosque?
How does the amount of mountain snow affect plants and animals living in the floodplain?
In what ways does flooding shape habitats in the floodplain along Rio Bravo?
How might flooding create stability over time and across space?
How does water restructure sediment within the floodplain, such as the distribution of sandbars?
How do the changes in the habitats affect the organisms living there?
(4.ESS2.A; MS.ESS2.C; Cause & Effect; Scale, Proportion & Quantity; Stability & Change)

The amount of water flowing in the river reflects the energy in the system; energy is the ability to bring about change. More water in the river means more potential to make changes to the system, such as moving sediment, rocks or logs.
Does the high volume of flow cause changes in the bosque ecosystem? If so, in what ways?
Consider both physical changes and changes in the composition of species that are present.
How did the floodplain change over time, particularly as relates to energy input?
(3.LS2.C; Scale, Proportion & Quantity; Energy & Matter)

At this point, you may want to proceed on to Section B, *Transitioning to Rio Manso*, or you may want to do the first parts of "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Bosque Chaos," and/or "Changing Fire".

Section B: Transitioning to Rio Manso

- Pass out the components for Rio Manso (the changed, tamed or altered river). Following the timeline below, have students restructure the river adding the new components and taking away older components as indicated by the timeline events. (See Appendix D: Human Chronology). Items with a ✓ give instructions for making changes to the model. This timeline addresses the valley between Cochiti Dam and Elephant Butte, so it may need to be adapted for other locations.

cottonwood catkins
(male, left, and female)
Photographs by Nolan Hester

Going from Rio Bravo to Rio Manso: Timeline for the Historical Rio Grande

Let us take a moment to recognize that we are on the land of the Indigenous People of the Tiwan Province—the Tiwa-speaking (TEE-wan/TEE-wa) people who live here today and who have lived here for many centuries.

2,000 years before present: The earliest horticulture was practiced here in the Rio Grande Valley. People mainly planted seeds along upper canyons and washes and relied on rain to provide moisture for plant growth.

✓ add one small agricultural field

AD 500-900: Semi-permanent small villages of pithouses were settled along the Rio Grande; the main agricultural crop was corn.

✓ add one pueblo-style house

AD 1275–1300: A major drought struck across the Southwest and many areas without permanent water were abandoned. Because of its reliable water, the Rio Grande became a focus for settlement. The population of the valley increased and pueblos made of adobe were built on both sides of the river. The people grew corn, beans, squash and cotton.

✓ add another pueblo-type house

✓ place a few agricultural fields

AD 1540-1598: First European explorers reached central New Mexico; Pueblo cultures were greatly impacted and had to change to meet these new cultural challenges.

1600s: The Pueblo people were consolidated into a few villages; the abandoned areas were readily colonized as ranchos by Spanish settlers.

✓ add four more houses along the river

1706: Albuquerque was founded as a villa real, or royally recognized town.

1874-1941: Large floods occurred in 1874, 1884, 1891, 1903, 1909, 1912, 1920, 1937 and 1941. There had been overgrazing in the hills; water sped off the land to the valley. There were few plants to hold the soil and slow the flow of water. Sediments filled the river channel. The water table of the valley was very high with standing water—fields were flooded and did not drain.

1885: A dike was built to protect "New Town," Albuquerque's downtown area where the new railroad had just been built. There was a lake in Los Ranchos for a month, but the soil was left enriched.

✓ add five more houses

✓ (option) use levee material doubled up to build "small dike"

1925: The Middle Rio Grande Conservancy District was formed to provide irrigation, drainage and flood control for the valley. Deep ditches called drains or clear ditches were built to remove standing water from farm fields. Levees were built for flood control and ditches to deliver water, called acequias (a-SAY-kee-uz), were improved.

✓ place levees along each side of the river on the model.

What happens to the river channel when levees are added? (The river was straightened and narrowed; see diagram earlier in activity.)

What happens to the marshes when the drains are installed? (Drains are used to lower the water table to decrease waterlogging of farm fields.)

✓ add the longest "drains" just outside of the levees

✓ remove about 95 cattails (leave 5) showing a decrease in marsh areas

✓ add more agricultural fields

1930s to 1990s: exotic saltcedar/tamarisk spreads through the valley. Saltcedar and Russian olive were introduced in the late 1800s as ornamental plants and to help drain water from marshy areas.

✓ add exotic riparian trees

1941: The levee was breached for the last time that century, and there were two months of standing water in town. If you walk between the levee and the river at the Rio Grande Nature Center State Park, many of the cottonwood trees you see sprouted during that 1941 flood year.

1957: There were major efforts to control the river after World War II. The levees were improved and many "Kellner" jetty jacks were installed to protect the levees.

✓ add jetty jacks to protect the levees and keep the river in its channel

✓ add the rest of the houses

✓ remove about 90 seedlings (leave 10), since lack of flooding means reduced natural regeneration; leave remaining seedlings on sandbars and immediately adjacent to river

1975: Cochiti Dam was completed and began filling. *What effect does a dam have on a river?* (This eliminated flooding, reduced sediment/sand and straightened the river channel.)

✓ add a dam at the up-river end of the model

✓ replace 19 cottonwood saplings with 10 additional mature cottonwood trees to show that no new tree recruitment is going on, but the trees in place are getting older

✓ remove three sandbars to show that Cochiti Dam traps sediment. The water flowing through is clear until it picks up sediment from the channel downstream. This sediment scours the channel and decreases sandbar formation.

Some of the gradual changes since 1975:

✓ add the burned snags: there are more fires with more people living in the valley

✓ add five more upland shrubs into the riparian area, because the water table is dropping and the bosque is losing its hydrological connection with the river allowing plants tolerant to drier conditions to become established.

Students should have made the following changes to the model:

- The number of cattails has decreased, since slow or standing water is harder to find (occasionally found near the sides of sandbars).
- The river is relatively straight. Curves are there, but no large meanders, oxbows, etc. Sandbars are still present, but braiding is greatly reduced.
- The river channel is narrower.
- There are levees on each side of the river channel. (There should be only a few inches between each levee and the riverbank.)
- There are jetty jacks between the river and levees.
- Irrigation ditches provide water to the valley.
- The majority of the mature cottonwood trees are between the riverbank and the levees. Some large trees can still be found elsewhere in the valley.
- The number of cottonwood seedlings and saplings has decreased. Seedlings can be on sandbars, but are frequently washed out, so rarely reach sapling size.
- There is a reduction in native shrubs and an increase in exotic shrubs; these are found primarily in the strip of land between the river and the levees.
- There are clumps of snags or burned trees within the bosque from human-caused wildfires (exotic shrubs are often underneath these snags).
- There should be a dam across the upper edge of the valley from upland to upland.

Rio Manso Discussion Questions

Consider how the floodplain environment/habitats change between Rio Bravo and Rio Manso (and Rio Nuevo after the next section). Humans have caused these changes by interrupting the annual flood cycle, installing drains, etc.

What has changed about each habitat, and how do those changes affect the species that survive there?

What kinds of habitats were available in Rio Bravo that are less available in Rio Manso?

Which plant species are able to survive well, less well, or not at all?

What will eventually happen to the cottonwood trees if there are not enough new seedlings to take their place?

How do changes favor saltcedar over cottonwoods?

Look for upland shrubs moving into the floodplain; why are they there?

Do you think the same animal species can live along both river systems? Which species might or might not survive?
(3.LS2.C; 3.LS4.C; 3.LS4.D; MS.LS2.A; MS.LS2.C)

Human settlement within the floodplain meant that the natural process of flooding became a natural hazard that affected human communities.

How were humans affected by natural hydrological processes along the Rio Grande?

How did humans reduce the impact of flooding? What have humans done to protect their towns and cities from floods? **(3.ESS3.B; 4.ESS3.B)**

What are the effects of these human activities on native plants and animals? **(5.ESS3.C; MS.LS4.D; MS.ESS3.C)**

Consider again the natural, dynamic nature of the river and floodplain, changing in time and space, and the impact of human alterations on this ever-changing system. Humans have not only reduced the peak spring flows but have increased the summer flows as water is apportioned throughout the irrigation season.

How have humans changed the dynamic cycle of the river?

Do these changes promote stability in the system overall?
(Patterns; Stability & Change)

Many of the changes that have occurred along the river are irreversible. For example, it will be impossible to eradicate all of the introduced plants, and some species are now extinct and can never come back, such as the Shovelnose sturgeon. We can't let the river run wild as it did before, because it would flood people in places such as Alameda, Corrales, Old Town and downtown Albuquerque.

Do you think anything can be done to make Rio Manso more like Rio Bravo?

Let students brainstorm. This is a lead into the next step: transforming the river to **Rio Nuevo**.

Consider the system from an engineering point of view:

How have we kept the river from destroying our communities in high water?

What aspects of the engineering solutions to flooding and to agricultural needs have had negative effects on the species in the ecosystem that were not known at the time of construction? **(Asking Questions & Defining Problems)**

At this point, you may want to proceed on to Section C, *Transitioning to Rio Nuevo*, or you may want to continue Rio Manso-related activities: "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Working Water," "Bosque Chaos," and/or "Changing Fire."

Section C: Transitioning to Rio Nuevo

Today's land managers know more about the potentially negative effects of the major projects installed along the Rio Grande in the 20th century than did earlier managers. They are now taking measures to ensure the maintenance of a variety of habitats that will provide appropriate places for the natural biodiversity of the valley and improve the situation for some endangered and threatened species.

- Let's think about ways to make Rio Manso more like Rio Bravo. Encourage students to come up with original ideas and make changes to the model. This is a good opportunity to focus on defining engineering problems related to restoration. For example, *Can we think of projects that will help to restore the river and bosque to the way it was in Rio Bravo?*

  How can we create more wetland habitat for bosque species?

  How might we help establish new cottonwood trees and other native plants?

  How might we decrease the risk of fire?

  Encourage students to come up with original ideas and make a list. They

may make those changes to the model or find similar projects on the cards to help them make changes.
(5.ESS3.C; MS.ESS3.C; Asking Questions & Defining Problems)

- Next, divide students into nine teams based on the Rio Nuevo Habitat Restoration Project cards (one per team). Look at the cards for ideas of additional projects they might implement and make those changes on the model. (Another option is to have the class work as a group on each project. This works particularly well with small class sizes.)
- Have each team tell the class what their project was and what changes they made on the model. Explain that we call this new river, in which humans are trying to restore characteristics of Rio Bravo within existing constraints, **Rio Nuevo**.
- You might share the story of an actual restoration project, "Bulldozers in the Bosque" (page 160), to discuss a real-world project, the Albuquerque Overbank Project, and its effects.

Rio Nuevo Discussion Questions

Ask the students to explain the differences between Rio Nuevo and Rio Manso. For example, Rio Nuevo has

- more natural river features, such as meanders, oxbows and braids
- more opportunity for the next generation of cottonwood trees to germinate
- fewer exotic species

Today's river has elements of both Rio Bravo and Rio Manso.

Ask students to give examples of aspects of each river that can be found in Rio Nuevo:

Rio Bravo: pole plantings (saplings), fewer exotics, constructed wetlands, etc.

Rio Manso: levees, jetty jacks, Russian olive trees, saltcedar stands, etc.

Look at the Changing River model to consider changes to the physical valley including sandbars and the river channel.

How has the physical landscape changed across Rio Bravo, Rio Manso and Rio Nuevo, and how do those physical changes affect the species living there? Compare the shape of the river channel in Rio Bravo, Rio Manso and Rio Nuevo. **(4.ESS2.A; Patterns)**

Drought is now more frequent in the Southwest due to climate change. Note that cottonwoods are susceptible to drought and the resulting lower water table. Mature cottonwoods will die if the water table drops below 3 meters / 10 feet. Trees combat climate change by taking in carbon dioxide (CO_2), a powerful greenhouse gas, during photosynthesis. So, human activity that affects cottonwoods in the bosque affects climate change.

How does drought affect cottonwoods?

What do cottonwoods need to survive?

What role do cottonwoods and other trees play in protecting us against climate change?
(3.LS2.C; 3.LS4.C; 5.ESS3.C; MS.LS2.C; MS.ESS3.A)

At this point you may want to continue with model activities "Cottonwood Creation," "Who Lives Where?," "Who Grows Where?," "Bosque Chaos," and/or "Changing Fire" that have Rio Nuevo sections.

Assessments:

- Revisit the KWL charts, focusing on what students have learned. *What have we **Learned** about the bosque?*
- Write a Claim, Evidence, Reasoning statement about:
  - The effect of flooding on the bosque.
  - The effect that human alterations have on natural flooding, and how this has affected the distribution of floodplain habitats along Rio Manso.
  - The effect of dams/levees/jettyjacks on the river, bosque or floodplain.
  - The role that land managers can play in restoring the health of floodplain ecosystems along Rio Nuevo.
  - How to improve conditions for endangered species.
  - The effect of climate change on drought and extreme precipitation events in the region and how those affect the bosque.
  - Changes in the habitats along the river affect the system's ability to withstand flooding. With current changes to the floodplain, could the system withstand flooding after an extreme rainfall event? **(MS.ETS2.B; Cause and Effect; Stability & Change; Constructing Explanations & Designing Solutions; Engaging in Argument from Evidence)**
- Devise a design solution about how to improve habitat in the bosque, the river or the floodplain. **(Constructing Explanations & Designing Solutions)**

Unit-Level Assessments

- **Build Models:** After building the class model of the bosque ecosystem, students can make their own model illustrating the three rivers over time, or some particular aspect of the river. This could be done at the end of each section (Rio Bravo, etc.) or after all three rivers have been completed. They can draw on paper or white board, make a 3-D model, video or photos, etc. **(Developing & Using Models)**
- To celebrate finishing the River of Change unit have students decorate three cakes for the three different river models they studied. Materials: three sheet cakes with plain icing; squeeze icing in different colors. Divide class into three teams, assign each team either Rio Bravo, Rio Manso, or Rio Nuevo. Have them decorate their cake appropriately. A spokesperson for each team then tells the rest of the class what they put on their river model. Then have a party and eat the cakes! **(Developing & Using Models)**
- **Writing:** Have students write about the differences between the rivers, what changes have occurred and what is being done to protect and restore the ecosystem today. Write letters, flyers, posters or books to show learning about human impact design problems, i.e., reducing the number of jetty jacks; cleaning water from/in the river. **(Obtaining, Evaluating & Communicating Information; ELA/Common Core standards)**

***Book Writing* (ELA Standards)**
After students have participated in the Changing River model, they have the experience and information to write a book. There are many Common Core English Language Arts Standards that will be addressed in this activity. Use a children's book to follow as a template. A wonderful example is *A River Ran Wild* by Lynne Cherry. This beautifully illustrated book describes the changes over centuries that occurred to the Nashua River in New Hampshire and Massachusetts. After reading the book several times, use the format to write a new book about the Rio Grande, incorporating the information from the Changing River activities. Write and rewrite the new book as a group, then print the text on multiple pages with room for the students to illustrate. The format used by Cherry includes very detailed illustrations and this could inspire all students to draw and label plants and animals of the Rio Grande.

Suggested adaptations

- Do a felt-board example of the basic items that are part of the bosque—a river, cottonwood trees, sandbar, etc. before working with the model of the river. Place a Velcro dot on some River Model pieces for use on the felt board.
- What animals live in the valley? Think of the needs of ducks and cranes they might see along the river—what do they find in the valley that they need?
- Discuss what trees need in order to live: sunlight, carbon dioxide, soil nutrients and **water**. We provide water for the trees at school and home. In the bosque tree roots must reach the water in the ground.
- Research: Have the students research the animals that live in the bosque. Put together a book or poster about the animals. Use these projects to teach younger students.

North American Porcupine
Illustration by Reese Bice

- Have older students learn the "Changing River" activity and then teach younger students using the model.
- Reduce the number of plant pieces by half to reduce visible clutter.
- Cut out and sort model pieces and label bags. Place pieces on the model in the proper locations.
- Teach the names associated with different model pieces: associate the symbol with living plants on a field trip activity
- Introduce the model cards before activity (what do students know before?) Review before resuming activity (what do students remember?) Review after activity (what did students learn?)
- Use repetition and repetitive patterns to support reading in this activity.
- Use cumulative patterns. For example: How many mature cottonwood trees do we have? How many do we need to play this activity? How many cottonwood saplings were burned?
- Create a chart of burned and removed plants (math component).
- Place a frame to isolate parts of the activity while in process. Ask groups to describe what is happening in that section.
- Have students think up alliterations about the activity such as, "How much wood would a woodchuck chuck, if a woodchuck could chuck wood?" Or something using rhythm such as a chant indicated by S-shaped movement using hands mimicking the directional flow of the water (change tenses to indicate time). "...and the Rio Bravo flowed on and on..." "...and the Rio Manso flows on and on..." "...and the Rio Nuevo will flow on and on..." Think of rhymes.
- Conduct oral or brief written assessment using Hansen's Comprehension Questions (from Freeman & Freeman, "Teaching Reading in a Multilingual Classrooms"):
  1) What do you remember?
  2) What else would you like to know?
  3) What does it remind you of?
  4) What other things have you read that it reminds you of?

Extensions:

- Until relatively recently, flooding in the Rio Grande Valley was a common and often devastating occurrence for human settlements. The math worksheet "How Long Ago?" (page 187) will help students realize that floods occurred in the Albuquerque region in the not too distant past. Make a copy of the worksheet for each student. Have students subtract the year for each event listed from the current year to determine how long ago these floods occurred.
- Have students pay attention to the news for items related to the bosque and the river. There are many issues that regularly appear in the news: endangered species, water planning/water sources, fires, clean-up activities, etc. Post newspaper items in the classroom; have students report on the news they have heard to the rest of the class.

- Look at different <u>time</u> windows on the river—Rio Bravo, Rio Manso and Rio Nuevo. *How has the volume and energy of the water in the river changed over these times? Where has the water gone? How has its flow changed? What effect does that have on the structure and functioning of the floodplain ecosystems?* **(Scale, Proportion & Quantity; Stability & Change)**
- There are numerous topics available for students to research further. For example, students can investigate how changes to the natural river system, such as the installation of dams and levees and the lowering of the water table, affect the distribution of habitats across the floodplain. Evaluate the importance of flooding in maintaining the diversity of habitats, and the impact of human changes on the system. Share these ideas orally, or by writing letters, flyers, posters or books. **(Obtaining, Evaluating & Communicating Information)**
- Student research: Consider conservation and restoration. *How can humans ensure the energy and matter needs of native species into the future? What is needed to understand the requirements of native species?* **(Energy & Matter)**

NGSS Connections to Changing River - Disciplinary Core Ideas

[Middle School details in Appendix K]

3.LS1.B Growth and Development of Organisms *Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.*

Cottonwood trees are very important to the bosque. In this activity we focus on three life stages of cottonwoods and the conditions they need in each.See also "Cottonwood Creation".
How do cottonwoods reproduce? What type of seeds do they have?
What conditions do cottonwoods need to get started growing (germinate)?
How do they manage to survive to old age?

3.LS2.C Ecosystem Dynamics, Functioning and Resilience *When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.*

Rio Bravo: In the prehistoric era, noticeable changes occur across the seasons. One example is the impact of high water on the ecosystem. Cottonwoods germinate on wet soil exposed as the floodwaters recede.
What is the role of the annual spring runoff/flood pulse in this ecosystem?
Does the high water cause changes in the bosque ecosystem? If so, in what ways? Consider both physical changes and changes in the composition of species that are present.

Think about what changes are tolerated and what are not.
An example is plants that tolerate flooding. Willows bend in high river flow and straighten/bounce back once the water recedes. Cottonwood bark can withstand logs running into it in high water.

Rio Manso and current conditions: Over the last century humans have made many changes to the river, such as building levees, dams and agricultural diversions, that have interrupted the annual flood cycle and resulted in changes to the bosque ecosystem.

Compare Rio Bravo to Rio Manso.
Look at introduced species such as saltcedar and the effect on native cottonwoods.
Look for upland shrubs moving into the floodplain—why are they there?

Rio Nuevo: Land managers today have the results of scientific research to help them refocus their work to keep as many aspects of Rio Bravo as possible in future river management projects.
Compare Rio Nuevo to Rio Manso and Rio Bravo, what aspects of each do you see?

There are future concerns such as more frequent drought in the Southwest due to climate change. Land managers and engineers have to be creative in providing conditions for long-term survival of cottonwoods. Cottonwoods are susceptible to drought and resulting lower water table (Mature cottonwoods will die if water table drops below 3 meters/10 feet.)
What do cottonwoods need to survive?

3.LS4.C Adaptation *For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.*

Compare species in different environments/habitats during each time period: Rio Bravo to Rio Manso to Rio Nuevo. Illustrate the conditions that are changing between environments—species may survive well, less well or not survive.

What species are in each category? Examples—cattails survive well in wetlands, not in the river itself—they are adapted to shallow water, and places that are wet most of the year. Saltcedar survives well under Rio Manso conditions.

Look at other categories of plant species on the model—native riparian shrubs, cottonwoods, upland shrubs, exotic riparian trees and what conditions they are adapted to do well in.

How does changing the habitat affect the species that live there?
What kinds of habitats were available in Rio Bravo that are less available in Rio Manso?
Which species are able to survive well, less well, or not at all as the habitat changes?
What do cottonwoods need to survive? Are these conditions available in Rio Manso?

3.LS4.D Biodiversity and Humans *Populations live in a variety of habitats, and change in those habitats affects the organisms living there.*

Start by looking at the changes in habitats in Rio Bravo due to flooding. Change was a normal part of this system: the river may change its channel and sweep away plants in one area, but leave its old channel as a wetland where other species will thrive.

Then contrast how humans cause changes to bosque habitats. Native organisms are less-well suited to these changes.

How do the human-caused changes to bosque habitats affect the organisms living there?

3.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Efforts to control flooding has allowed humans to settle in the floodplain, but has had negative impacts on natural ecosystems.

What type of natural hazard occurred along the river before humans made changes?
What effect does flooding have on the ecosystem and on the communities humans build along a river?
In what ways did humans reduce the impact of flooding on human settlements?

4.ESS2.A Earth Materials and Systems *Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.*

Water plays an important role in creating floodplain ecosystems. Under natural conditions, the floodplain is constantly changing from the forces of river water. For example, the active channel moves, sandbars are created or washed away and sediment is deposited in the forest. These changes affect the organisms living there.

Look at the Changing River model with a view to the river channel, the sandbars and the physical valley; list the changes that occur both within each time period and between Rio Bravo, Rio Manso, and Rio Nuevo.

Along Rio Bravo, in what ways does water change habitats in the floodplain?
How do physical characteristics and organisms in floodplain ecosystems change as a result of floods along the river?

4.ESS3.B Natural Hazards *A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.*

Flooding is a natural part of the Rio Grande and floodplain ecosystems. Efforts to control flooding have allowed humans to settle in the floodplain, but have had negative impacts on natural ecosystems.

What type of natural hazard occurred along the river before humans made changes?
What effect does flooding have on the ecosystem and on the communities humans build along a river?
In what ways did humans reduce the impact of flooding on human settlements?

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

Humans have made many changes to the river valley and the river channel, and these human alterations have changed the dynamic nature of the Rio Grande floodplain and altered many aspects of natural habitats (changing from Rio Bravo to Rio Manso). In Rio Nuevo, students learn how humans are able to make new changes that help restore some components of natural floodplain ecosystems.

What changes did humans make along the Rio Grande to promote agriculture and allow settlement along the floodplain?
How did those human alterations affect the bosque, and how could they be modified to allow a more natural, dynamic system?
What are the effects on native species from these human activities?
How can we decrease the number of species that are threatened or endangered?

New Mexico Specific Standards

Because these performance expectations are unique to New Mexico, we present the PEs as well as the supporting DCIs, CCCs and SEPs that can be addressed by the River of Change activities.

Performance Expectation

5-SS-1 NM. *Communicate information gathered from books, reliable media, or outside sources, that describes how a variety of scientists and engineers across New Mexico have improved existing technologies, developed new ones, or improved society through applications of science.*

DCI: 5.ETS2.A Interdependence of Science, Engineering, and Technology

-Advances in science offer new capabilities, new materials or new understanding of processes that can be applied through engineering to produce advances in technology.

-Advances in technology, in turn provide scientists with new capabilities to probe the natural world at larger or smaller scales; to record, manage and analyze data; and to model ever more complex systems with greater precision.

-In addition, engineers' efforts to develop or improve technologies often raise new questions for scientists' investigation.

After years of building structures in the Rio Grande and its floodplain with the goals of reducing flooding and delivering irrigation water, biologists began to see impacts on the bosque ecosystem that were not intended or expected. The cottonwood forest corridor of the river was getting old, with few seedlings growing to replace them. Fish species like the Rio Grande silvery minnow were not finding the shallow, muddy, backwater areas needed to lay their eggs and produce successful fry. Use any of the following ideas after completing the "Changing River" or "Who Lives Where?" activities to explore New Mexico scientists and engineers and how they are helping preserve the bosque into the future. Any of these assignments will address ELA standards.

- *What engineering efforts could help the Rio Grande silvery minnow?* For a case study, look at the Los Lunas Rio Grande Silvery Minnow Refugium, that has received awards for its engineering design.
- *What other science-based engineering efforts are being used for bosque restoration?* Read the "Bulldozers in the Bosque" essay in the River of Change chapter introduction for one example.
- Miles of jetty jacks were installed in the 1950s. *Are/were they working? What did they help? What drawbacks do they present?*
- "Drains" were built throughout the valley. Many people see drains and think they are the Rio Grande, but they are not. *What are they? Why were they built and what do they do?*
- There are different dams on the Rio Grande. They are built for different reasons and purposes. Research any of them, but two to consider are Cochiti and Angostura. *How are they the same? How are they different?*
- Bosque Ecosystem Monitoring Program (BEMP) has been researching the Rio Grande bosque for many years. Go to their website and look at the monthly data they collect. Some of their results have been published or posted. *How has this research, with data collected by school students, helped resource managers along the Rio Grande?*

CCC: Science is a Human Endeavor

Men and women from all cultures and backgrounds choose careers as scientists and engineers.

Most scientists and engineers work in teams.

Science affects everyday life.

Creativity and imagination are important to science.

CCC: Science is a Way of Knowing.

Science is both a body of knowledge and process that add new knowledge.

Science is a way of knowing that is used by many people.

SEPs: Obtaining, Evaluating & Communicating Information

New Mexico Gartersnake
observed in the Rio Grande bosque
Photograph by Brandon Bourassa

Rio Bravo Information Cards

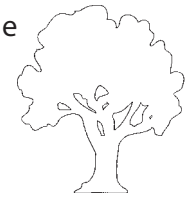
Cottonwood Seedlings — "baby" cottonwoods
(Populus deltoides ssp. wislizeni)
Small cottonwood trees which have just started growing. Generally, seedling stems are less than 1 inch (2.5 centimeters) in diameter at 4.5 feet (1.35 meters) from ground level.
Habitat needs:
• bare, wet soil to germinate
• open areas where there is a lot of sunlight
• roots must stay in water as the water table drops throughout the summer
• grows near water, on sandbars, near river's edge

RIO BRAVO

Cottonwood Saplings— "teenage" cottonwoods
(Populus deltoides ssp. wislizeni)
Small cottonwood trees. Larger than 1 inch (2.5 centimeters) in diameter and less than 4 inches (10 centimeters) in diameter at 4.5 feet (1.35 meters) above the ground level. Habitat needs:
• roots must reach to water as the water drops throughout the summer
• in former high water area—not far from riverbank
• not along the edge of river

RIO BRAVO

Big Cottonwood Trees— "mature" cottonwoods
(Populus deltoides ssp. wislizeni)
Mature Rio Grande cottonwood trees can be up to 80 feet (24 meters) tall with trunks up to 4 feet (1.2 meters) in diameter.
Habitat needs:
• usually not near current river channel (trees survived because the river changed location after the trees were established)
• in the flood plain, not on valley slopes
• roots must reach to permanent water table



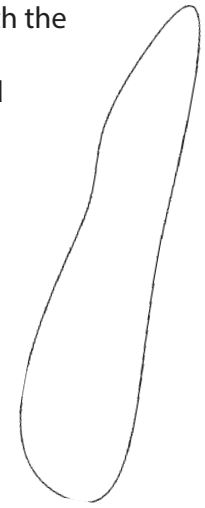
RIO BRAVO

Cattails (*Typha* sp.)
These wetland plants represent marshes and are important areas for wildlife nesting, protection and food. Habitat needs:
• there must be water at the surface for most if not all of the year
• often at an oxbow—an old channel of the river
• occasionally on the edges of sandbars or the inside curve of meanders

RIO BRAVO

Rio Bravo Information Cards

Sandbars
Sandbars form in areas of the river where the water slows. Sediments, such as sand, drop out of the slowly moving river. Place:
• in the river channel or along the edge of the river
• lengthwise, with the flow of water
• the narrow end points upstream

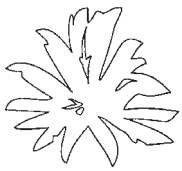


RIO BRAVO

Upland Shrubs
Upland shrubs grow in dry places where the water table does not come near the surface. Habitat needs:
• live in higher areas
• depend on rain for moisture
• can live on very little water each year
Examples: fourwing saltbush, fringed sage, broom dalea/false indigo

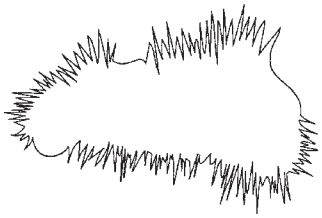
RIO BRAVO

Native Riparian Shrubs
Native shrubs have lived here for thousands of years.
Habitat needs:
• in the flood plain of the river—the lowland alongside the river
• in the shade under old/mature cottonwoods
• sandbars
Examples: New Mexico privet/ New Mexico olive, silverleaf buffaloberry, coyote willow



RIO BRAVO

Grassy Meadows
Grasses belong to one of the largest families of plants, providing food (seeds, leaves, and roots) and shelter for many insects, rodents and birds.
• Different species grow in many environments from dry uplands to wet marshes, in full sunlight or in forest shade.
Examples: saltgrass, blue grama

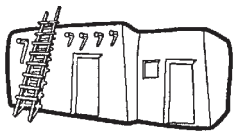


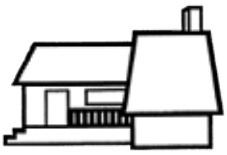
RIO BRAVO

Rio Manso Information Cards

Houses
People moved into the area.

• place houses where you would want to live





RIO MANSO

Agricultural Fields
Include gardens, orchards, cropland and pastures.

• place in the flood plain of the river

• you may need to clear land for your crops

• orient long, narrow fields with the short side next to a ditch

RIO MANSO

Irrigation Ditches and Drains
Irrigation ditches and drains move water to agricultural fields and back to the river.

• place drains outside of and parallel to the levees

• irrigation ditches should run from the river to the fields

• remember that water flows downhill

RIO MANSO

Levees
A levee is a raised embankment running parallel to the river. This high berm keeps the river confined in high water and protects areas beyond from flooding.

• place parallel along the entire length of the river

• place on both sides of the river

• narrow and straighten the river — confine it to a narrow channel

RIO MANSO

Rio Manso Information Cards

Jetty Jacks
These are giant metal frames the same shape as the pieces in the game of jacks—held together by thick cables. They were designed to protect the levees from being washed away by the river.
The river is narrowed and straightened by this process—confined to a narrower channel.
Place:

- some between the river and the levee, on both sides of the river
- some parallel to the river's edge
- some perpendicular to the levee, angling downstream

RIO MANSO

Exotic Riparian Trees
Non-native, exotic trees were brought here by people; most species were introduced in the last 100 years.

- place in the flood plain of the river—the lowland alongside the river
- may grow in the shade under big cottonwoods
- often grow in openings, such as after a fire

Examples: Russian olive, saltcedar or tamarisk, Siberian elm, tree of heaven

RIO MANSO

Snags / Downed Wood
Snags are standing dead trees. Many are created by fire. Most bosque fires are started by people, and fires have increased since humans settled in the area. Downed wood includes fallen branches and trees. Although they increase the risk of fire, snags and downed wood provide habitat for many animals.

- place in bosque between river and levee

RIO MANSO

Dam
Place a dam at the upper edge of the model

- it will cross from one edge of the flood plain to the other—from upland to upland across the river
- it will totally control the flow of the river—water will be released under specific conditions
- catastrophic flood will now be controlled—the spring runoff will be reduced and the summer flow will be increased as water held behind the dam in high flow will be released in times of lower flow

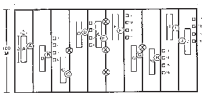
RIO MANSO

Rio Nuevo Information Card

Monitoring Plots

Resource managers need to monitor the results of their actions and monitor the bosque in general to understand what changes are happening:

- select sites where you want information about what is happening in the bosque
- select some sites that have not been disturbed
- select some sites where restoration projects are installed

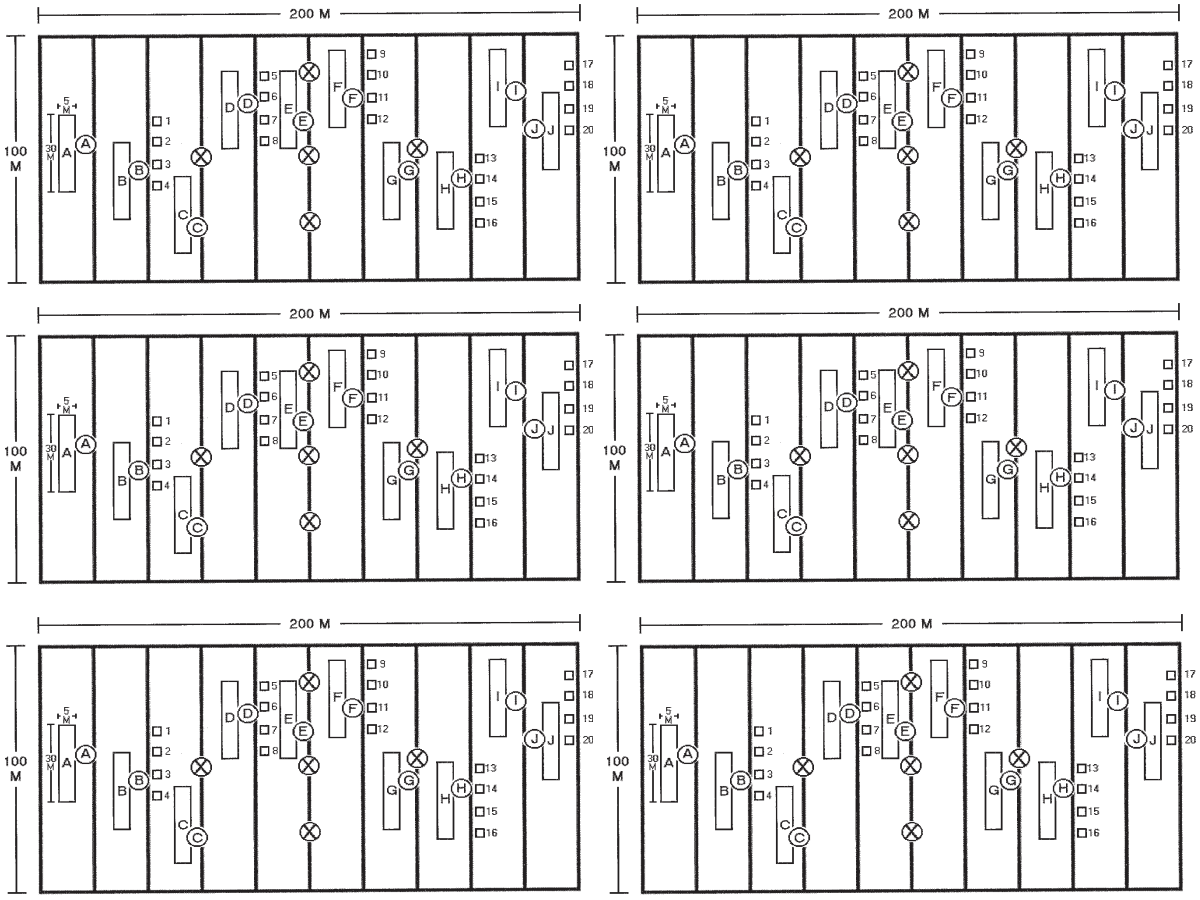


RIO NUEVO

About the monitoring icon:

The icon used to represent monitoring plots is a diagram of a study plot from the Bosque Ecosystem Monitoring Program (BEMP). BEMP is only one kind of monitoring study and other studies may have different designs. BEMP plots are 100 meters by 200 meters and are oriented lengthwise parallel to the river. Each plot contains 10 vegetation plots (the long rectangles), five groundwater wells (circle with an 'x'), 10 litterfall tubs (circle with letter), and 20 pitfall traps (small squares). The plots also have two rain gauges and three temperature data loggers, but these are not pictured on the icon.

Rio Nuevo Model Pieces **(make one copy and cut into six plots)**



Rio Nuevo Habitat Restoration Project Cards

Overbank Flooding

During years with a high winter snowpack there will be lots of water melting and flowing down the watershed in the spring. Much water will be held in reservoirs for irrigation through the summer, but in good years a large flow can be allowed downstream during the normal season for spring runoff. The water managers at the Army Corps of Engineers and Bureau of Reclamation can decide to allow for water amounts to pass through the dams that will spill over the banks of the river and flood some of the floodplain of the Rio Grande. This is called "overbank flooding." (The goal is to have standing water in wooded areas within the levees. This way the communities outside the levees are protected from flooding.) Overbank flooding creates habitat for cottonwood seedling establishment, increases the growth of mature cottonwoods and other native riparian plants as well as promoting the natural cycling of nutrients.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ place 10 more cottonwood seedlings on the model; seedlings can be added to sandbars or edges of the river or to places that have been cleared of other vegetation
- ✓ place 2 more native riparian shrubs on the edges of the Rio Grande; plants such as willows will grow well now
- ✓ remove 1 upland shrub; wetter areas are no longer attracting upland plants
- ✓ if any homes have been placed within the levees, remove these now; floodplains are a silly place to build anyway
- ✓ remove 1 snag; with overbank flooding fuels are reduced by faster decomposition and less likely to burn with wetter conditions
- ✓ remove 1 exotic tree as conditions are not as optimal for some of these plants

Pole Planting of Cottonwoods

The numbers of cottonwoods are decreasing along the Rio Grande, because for decades flooding has been prevented and natural places for cottonwood establishment are not being created. One way to counteract this is to plant cottonwoods. Cottonwoods have an adaptation that land managers can take advantage of: a long, young branch of a cottonwood tree (here called a "pole") can be cut and put in the ground where it will send out roots and grow. We can have tall trees quickly, without needing to grow them in a nursery from seed. This usually takes a lot of labor, a giant drill to drill a hole down to the water table (remember cottonwoods need to have their roots in the water to survive), and very long branches of cottonwood, 15 - 20 feet long (5 - 6 meters) (and even then, all but a few feet will be buried). The cottonwood pole is slipped in the newly drilled hole and dirt is packed in. This is a way to give some cottonwoods a good start, but it is expensive, especially if you are looking at miles of river needing more cottonwoods.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ add 10 more cottonwood saplings to the model, making sure you put them close to the river where the water table is not too deep
- ✓ add 1 more mature cottonwood tree to symbolize that this project will mean large trees in the future

Rio Nuevo Habitat Restoration Project Cards

Wetland Construction

The numbers of marshes and wetlands have been reduced over the last decades. Managers can create new ponds and wetlands. Some examples are the ponds at the Rio Grande Nature Center, at the Bosque del Apache National Wildlife Refuge, and southeast of the Alameda bridge over the Rio Grande in Albuquerque. A different type of wetland is a "constructed wetland" that takes wastewater and sends it through a series of small water pools. Each pool is filled with cattails and other plants that clean the water. Constructed wetlands can be found at Los Padillas Elementary School in Albuquerque, Sanchez Farm, Bernalillo County Open Space, and at Los Ranchos de Albuquerque village center.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ place 50 more cattails on the model in groups representing 10 new constructed wetlands
- ✓ add 5 cottonwood seedlings (although wetlands are not specifically designed to recruit new cottonwoods, they often provide a good site for cottonwoods to reestablish)
- ✓ add 1 native riparian shrub; conditions are better for native plants such as willows
- ✓ remove 1 upland shrub; wetter areas are no longer attracting upland plants
- ✓ remove 1 exotic tree; conditions are not as good for some of these plants

Fuel-wood Reduction

In earlier years, the overbank flooding that would occur every few years would saturate the branches and leaves that had fallen on the ground in the bosque. By being wet, they would decompose more quickly than they have in recent decades. Microscopic organisms such as bacteria and fungi break down plant material into nutrients that can be used by other plants; this is called nutrient cycling. Prior to the regulation of the river, the cottonwood forest did not burn as hot as it does today—sometimes it was so wet that fuel wood on the ground decomposed fairly quickly. Since the elimination of overbank flooding after large dams were constructed on the river, fuel wood has built up on the floor of the cottonwood forests and everything is much drier. Fires spread very quickly once they get started and generally burn hotter and longer in the same area. Most fires are caused by careless people, and there are many more people living in the valley today. The fires burn far and wide. One way to reduce the destructiveness of fire in the bosque is to clean the area of downed trees and branches—reducing the fuels that create destructive fires. Teams of volunteers can haul away branches and sticks. Some snags and downed wood are left for wildlife habitat.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 4 snags; as we control the fuel in the forest, fires will be smaller and less severe. Some snags will be left for wildlife habitat.
- ✓ remove 5 exotic trees; many of the excess trees removed in these projects are non-natives
- ✓ add 1 native riparian shrub; while removing exotic and upland plants we are making room for native riparian shrubs
- ✓ add 1 grassy meadow; fuel breaks create more grasslands
- ✓ remove 1 mature cottonwood; sometimes we do need to cut some cottonwoods down to make an effective fuel break

Rio Nuevo Habitat Restoration Project Cards

Creation of Secondary Channels

The river used to have many channels as it flowed down the valley. Some would only have water in them during the spring runoff, but this was enough for cottonwoods to get a good start. In some areas, the easiest way for cottonwoods to get established is for us to help out nature a little. In places where the banks are just too high, managers can take in a bulldozer, lower the bank, and create a small side channel where water will flow some times of the year. Cottonwoods and native shrubs such as willow can get established here. Sediment removed from the banks can be returned to the river, creating new sandbars and improving Rio Grande silvery minnow habitat. Examples of this are on the west bank of the river south of Bridge Street in Albuquerque (the Albuquerque Overbank Project) and the silvery minnow channel near Rio Grande Nature Center State Park.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 3 jetty jacks; removal clears a path for the channel
- ✓ remove 1 exotic riparian tree
- ✓ add 40 cottonwood seedlings; these projects are prime habitat for germinating cottonwoods
- ✓ add 1 mature cottonwood tree to represent the future forest
- ✓ add 10 cattails to show more wetlands being developed
- ✓ add 2 sandbars below the project site, created by sediment moved by the earth work
- ✓ add 2 native riparian shrubs: birds like Southwestern Willow Flycatchers need thickets of willows to nest; these thickets have been rare for many years, and now more are being created
- ✓ remove 1 upland shrub because the habitat no longer provides the dry conditions these plants need

Removal of Exotic Species

Many agencies and landowners are involved in reducing the number of introduced species such as saltcedar (also known as tamarisk, *Tamarix chinensis*), Russian olive (*Elaeagnus angustifolia*) and Siberian elm (*Ulmus pumila*) in the bosque. These exotic shrubs and trees have increased, in general, because human-caused changes in the river valley provide favorable conditions for them to grow. Saltcedar thrived, especially in the lower Middle Rio Grande Valley. Saltcedar trees flower and produce seeds throughout the growing season; their reproduction is not restricted to spring/early summer as are native cottonwoods. When bare ground is colonized late in summer by saltcedar, it will not be bare in the spring when cottonwoods are sending out seeds. Both Russian olive and Siberian elm can sprout in shaded areas, under the canopy of the cottonwoods and are becoming very common in the bosque. Entire food chains depend on the cottonwood trees of the bosque. As cottonwoods are crowded out by introduced species such as these, the entire ecosystem is affected and fewer native species thrive.

Large saltcedar removal efforts have been undertaken at the Bosque del Apache National Wildlife Refuge. They have experimented with different procedures to effectively keep the saltcedar from returning. Santa Ana Pueblo has also undertaken major projects to restore the bosque to its previous native-species-only state. The bosque near Tingley Beach in Albuquerque is a showplace contrasting a restored area to the invaded area. This work can range from volunteers cutting down and removing exotic trees to the use of large equipment for bulldozing and repeated rootplowing, sometimes using herbicides to reduce their reoccurrence. Now tamarisk beetles are also helping to reduce saltcedar numbers. In some areas, saltcedar is left as habitat for endangered Southwestern Willow Flycatchers.

What beneficial changes will there be as the result of this project?
What habitat components can we replace on the model now?

- ✓ remove 10 exotic riparian trees; 11 are left to provide habitat
- ✓ add 2 grassy meadows; removing exotic species provides space for more grasslands
- ✓ add 1 mature cottonwood; exotic species are removed and there is room for our native trees

Rio Nuevo Habitat Restoration Project Cards

Water Conservation

The amount of water that is used by people along the river has an impact on the health of the bosque and river life. Pumping more water than is replenished through infiltration each year causes the water table to drop; plants that depend on groundwater can no longer reach their roots to that depth and die. When the water table is lowered, more river water will soak down into the ground, leaving less flow on the surface — less water for all of the users who need water. Some New Mexico communities use river water for their household water supply. The more water taken from the river, the less is available for the plants and animals that have evolved to depend on that water. Though some water will be returned to the river after passing through a sewage treatment facility, much is used, evaporates, or returns to groundwater. The City of Albuquerque had used only groundwater for its water supply for many decades, though they owned the rights to Rio Grande water, referred to as surface water. As the population increased and water use increased, the City now removes and cleans Rio Grande water and includes it in its water supply. Water is returned, but the flow level in the Rio Grande is reduced, affecting life below the pull-out area. We can lessen the need to lower the flow of the Rio Grande by reducing the water we use: plant low-water use landscaping, install rain barrels and low-flow toilets, turn off the water while brushing your teeth, take shorter showers, etc. Now that Albuquerque is using river water, the aquifer below the City is actually recharging.

What changes will there be as a result of this water conservation project?
What habitat components can we replace on the model now?

- ✓ add 5 cottonwood seedlings; with more water in the river, more places can flood and start new trees, and seedlings can be added to sandbars or edges of the river
- ✓ add 5 cattails; more water in the river means more wetlands

Jetty Jack Removal

The Kellner jetty jacks were placed up and down the river, starting in the 1950s, to straighten the river and protect the levees. The jacks slow the flow of water so that sediment drops out and builds up and eventually plants can grow. This helps keep the bank of the river in one place. The straighter and narrower channel helps the water flow downstream more quickly. The jacks also help to protect the levees. Today, the riverbanks and levees are quite stable. Now the jacks are seen as a danger to emergency vehicles moving through during a fire, possibly blocking escape routes. Several management agencies are removing jacks from the bosque. Managers now realize that a stable riverbank does not benefit the bosque; the river and its banks need to be able to move again. In addition to removing the jacks, managers can lower the riverbank in certain places to promote flooding and to restore sediment to the river. All of these may improve habitat for silvery minnows and other species.

What beneficial changes will there be as a result of this project?
What habitat components can we replace on the model now?

- ✓ remove 5 jetty jacks from the model
- ✓ remove 3 mature cottonwood trees as trees sometimes are removed in the process
- ✓ add 5 cottonwood seedlings as the river can meander more and create new sites for cottonwood regeneration
- ✓ add 3 cattails as the river can be more braided and provide more wetlands
- ✓ add 2 sandbars below the jetty jack removal project
- ✓ remove 1 exotic tree; exotic trees like Russian olive often grow within the jetty jacks and are removed with them

Monitoring

An important part of managing the bosque is to understand what is happening to the plants, animals, water table and other ecological functions in the bosque. The process of collecting, compiling, and analyzing information is called "monitoring." Monitoring is an essential tool for land managers to understand if their actions are making any changes (good or bad) in the ecosystem. Many agencies responsible for caring for the river and the bosque collect data on a regular basis. Some schools also help collect important data. In addition to measuring the water table, weather factors, and soil factors, students also collect information about plants and animals.

Why is it important to collect information about the bosque over the long term?
How can this information be used to help manage the bosque?

- ✓ add 6 monitoring plots to the model. Carefully choose places you wish to monitor. You may want some sites that have not been disturbed by recent activities. You might also want some sites where you have done projects.

Note: The monitoring icon is an image of a Bosque Ecosystem Monitoring Program (BEMP) plot. These sites are scattered throughout the Middle Rio Grande Valley and are generally monitored by students from Grades 2–12.

BEMP students measuring depth to groundwater
Photograph by Lisa Ellis

How Long Ago?

Rio Manso Math Exercise

When	What	How long ago? This year minus:
1884	One of the worst floods in the history of the Rio Grande. Alameda Dike is started. Flood is kept out of Albuquerque's Old Town.	- 1884 =
1885	Alameda Dike is improved and flooding of New Town is prevented once again.	- 1885 =
1904	Water breaks through a dike. Los Ranchos area becomes a lake.	- 1904 =
1925	Standing water is drained and levees to control the river are being built.	- 1925 =
1941	Flood waters go over and through the levee. Last large crop of cottonwoods gets its start.	- 1941 =
1957	River is made to stay in one channel by levees, jetty jacks and natural boundaries.	- 1957 =
1975	Cochiti Dam is finished. No more serious floods are likely.	- 1975 =

Canada Geese on Rio Grande sandbars
Photograph by Mark Higgins