

Teaching Notes for Of Silt and Ancient Voices: Water and the Zuni Land & People

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ABSTRACT

This case explores the complex and multifaceted resource management issues that arose when traditional Zuni Indian land and water use practices were displaced by the construction of the Black Rock Irrigation Project by the U.S. government in the early 20th century. The case study is framed as a legal case brought by the Zuni tribe against the U.S. government in the mid-1980s, and relies on the extensive testimony provided by expert witnesses about traditional Zuni culture, resource management, and property rights. The case study combines the interrupted case method with the jigsaw approach. The jigsaw approach allows students first to examine resource management issues from a disciplinary perspective, with an emphasis on the fields of anthropology, soil science, and economics/policy, and then to combine those disciplinary elements to brainstorm potential resolutions that are informed by a multidisciplinary understanding of the issues.

Topical areas: Anthropology, Agriculture, Economics, Environmental Resource Management, Environmental Science, Geography, Law, Native American Studies, Socio-environmental Synthesis, Soil Science, and Water Policy.

Type/method: Interrupted case and jigsaw approach

SUGGESTED COURSES

The case study is appropriate for a variety of courses in the topical areas listed above. The titles of specific courses for which this case study is appropriate include:¹ Anthropological Ethnobotany; Crops, Soils, and Civilization; Environmental Science and Policy; Environmental Science and Technology; Ethnobotany: Plants and Peoples; Ethnoecology; Introduction to Environmental Policy; Geography of Environmental Systems; Introduction to Environmental Law; Introduction to Environmental Science; Natural Resource Economics; North American Indian Cultures; Science, Ethics, and Law of Water; Water Resources Policy and Economics.

EDUCATION LEVEL

Undergraduate – intermediate to upper level, Graduate (with modifications)

SOCIO-ENVIRONMENTAL SYNTHESIS LEARNING GOALS

This case study addresses the following Socio-Environmental Synthesis learning goals:

1. Ability to describe a socio-environmental system, including the environmental and social components and their interactions.

Related activity: Students are asked to describe how changes in resource management practices resulting from the construction of the Black Rock

¹ Specific course titles are drawn from course offerings at the University of Maryland – College Park, the University of South Carolina – Columbia, and Virginia Tech.

Irrigation Project impacted the Zuni culture and the environment. Doing so demonstrates the interconnectedness of natural and social systems and how a perturbation to one element of the system can generate far-reaching socio-environmental implications.

2. Ability to co-develop research questions and conceptual models in inter- or trans-disciplinary teams.
 - Ability to communicate across disciplinary boundaries.

Related activity: Students are asked first to take on the role of an expert witness, developing an understanding of the problem from the perspective of an anthropologist, soil scientist, or an economist/policy analyst. They are then broken into groups with representation from each field and asked to discuss and present potential resolutions to a complex problem based on information provided from each discipline.
 - Value different ways of knowing and understand the value of different knowledge sources.

Related activity: Students discuss how the Zuni traditionally understood their environment and managed natural resources, and contrast that with how the U.S. government understood and approached resource management problems in the arid U.S. West.

LEARNING OBJECTIVES

- Describe the advantages and disadvantages of multiple resource management practices, namely those of the Zuni tradition and those of the U.S. government.
- Understand the value of different kinds of knowledge (that of the Zuni vs. the U.S.).
- Recognize and characterize interactions between social and environmental systems.
- Understand a complex problem from multiple disciplinary perspectives.
- Synthesize knowledge from natural and social science disciplines to generate potential resolutions to a complex, “messy” problem, but also recognize that the nature of complex systems implies that no single resolution can solve such problems.

INTRODUCTION/BACKGROUND

The Zuni tribe of New Mexico and Arizona has brought suit against the United States for damage to their lands and economic wellbeing. Judith, an attorney representing the tribe, has adopted a strategy that employs a diverse range of expert witnesses from the natural and social sciences to unravel the complex relationships between the landscape and the Zuni culture.

The case study has been designed for use in introductory environmental studies/environmental science courses. Specialized terms from the key disciplines employed (anthropology, soil science, and economics) are explained, and no prerequisite knowledge is assumed. The case study would also have utility in anthropology, soil science, economics, and geography classes. In each classroom setting, we see its optimal placement in the middle to end of the course, when synthesis of earlier course concepts is possible.

An extensive literature exists on the Zuni, including anthropological studies that go back to the early 20th century and specialist studies stemming from the court case about the Zuni Irrigation Project. A number of books have been written about the Zuni. All of these resources supply a

rich body of data that may be incorporated into the case study by advanced students or by instructors who wish to redirect particular portions of the case study to better suit their interests or specialties. A small selection of those are listed under Selected Additional Resources.

CLASSROOM MANAGEMENT

Total Estimated Time: Approximately 2.75 hours total, including time for reading and drafting a report (and without modifications for upper-level courses).

Tips:

- We recommend spreading this exercise over several class periods, assigning some of the readings and the drafting of expert witness testimony as homework. In this plan, we present the total time required for each element of the case study and allow the instructor the flexibility to choose which elements to assign outside of class. We identify readings and writing assignments that are good candidates for homework in italicized text below.
- Handout 3B requires access to a computer and the internet to use a soil properties calculator. If this is not a classroom option, the reading and discussion questions may be assigned as homework, then the students may have time to discuss their answers as a group in a subsequent class.

PART 1. Survival in a Harsh Environment: Imagining Zuni Strategies for Resource Management

Total estimated time: 35 minutes

- Introduce the case study; students read Part 1 narrative (5 mins)
- *Students read Handout 1. Briefing Document: First Portion (10 mins)*
- Break students into small groups (3-4 students per group) to discuss Part 1 questions (10 mins)
- Instructor-led discussion of Part 1 questions; students report out from groups (10 mins)

PART 2. Zuni Resource Management Challenges through the Lens of an Expert Witness

Total time estimate: 80 minutes

- Students read Part 2 narrative (5 mins)
- *Students read Handout 2. Briefing Document: A Time of Change (10 mins)*
- Break students into expert witness groups (3-4 students each); assign 1/3 of class to be anthropologists, 1/3 to be soil scientists, and 1/3 to be economists (5 mins)
- *Students read expert witness handouts (15 mins):*
 - *Handout 3A. Expert Witness Materials: Anthropology for the anthropologists*
 - *Handout 3B. Expert Witness Materials: Soil Science for the soil scientists, and*
 - *Handout 3C. Expert Witness Materials: Economics and Policy for the economists*
- Students discuss directed questions in their expert witness group (15 mins)
- *Students draft a group expert witness report on the impacts of the Black Rock Irrigation Project (30 mins)*

PART 3. Understanding the Multiple Dimensions of the Zuni Case

Total time estimate: 50 minutes

- Re-organize students into mixed groups with one to two students from each expert witness group (5 mins)
- Students discuss Part 3 questions (15 mins)

- Instructor-led discussion of Part 3 questions; students report out from groups (15 mins)
- Debriefing: Students read Handout 4. A Resolution to the Zuni Case? (5 mins) and instructor leads a discussion of the Zuni case resolution and the case study activity (10 mins).

BLOCKS OF ANALYSIS

Part 1. Survival in a Harsh Environment: Imagining Zuni Strategies for Resource Management

Overview: Students are provided background information on the Zuni tribe and asked to discuss strategies for survival in an arid environment.

Total estimated time: 35 minutes including reading (25 minutes without reading)

Detailed Description:

Students begin by reading the narrative for Part 1, which introduces the case study through the eyes of Judith, a lawyer involved in a case being tried in the U.S. Court of Claims. The narrative alludes to the multidisciplinary nature of the case, which involves “depositions from anthropologists, engineers, economists, and soil scientists.”

Students then read Handout 1, part of a “briefing document” that presents background on the Zuni Indian tribe and the location of Zuni Pueblo in arid western New Mexico. After reading the handout, students discuss two questions in small groups (3-4 students per group). These questions are designed to spur the students’ imaginations by asking them to brainstorm ways that the Zuni may have survived in the arid U.S. West. After 10 minutes, interrupt the students’ discussions and ask them to share their thoughts on questions 1 and 2 with the class.

Part 2. Zuni Resource Management Challenges through the Lens of an Expert Witness

Overview: Students are provided information on the Black Rock Irrigation Project and are asked to develop a disciplinary understanding of the impact of the irrigation project on the Zuni from the perspective of an anthropologist, a soil scientist, or an economist.

Total estimated time: 80 minutes including reading and drafting a report (25 minutes without reading or report-writing)

Detailed Description:

PART 2(a):

Students begin by reading the narrative for Part 2, which again uses Judith’s internal monologue to allude to the impacts of western U.S. expansion on the Zuni tribe. Then allocate 15 minutes for students to read Handout 2, which provides background on the policies and resource management paradigms leading to the construction of the Black Rock Irrigation Project. This handout also provides a general overview of the impacts of the Irrigation Project on the Zuni.

PART 2(b):

After allocating 15 minutes for students to read Handout 2, take 5 minutes to split the class into expert witness groups. Each individual in the class should be assigned the role of anthropologist, soil scientist, or economist, so that 1/3 of each class is assigned to each discipline. Then groups of 3-4 students, *each in the same discipline*, should be assigned. After assigning groups, distribute Handout 3A to the groups of anthropologists; Handout 3B to the groups of soil scientists; and Handout 3C to the groups of economists.

Allow the students 15 minutes to read the handout relevant to their expert witness group. Each of these handouts discusses the impact of the Black Rock Irrigation Project on the Zuni, but from a different angle. The material presented on these three handouts deliberately overlaps, but the implications of the Irrigation Project are presented from different disciplinary perspectives. After 15 minutes, direct the students to discuss the questions provided on their handout. Allocate 15 minutes for this discussion.

After allowing 15 minutes for groups to discuss their questions, interrupt and instruct each group to begin drafting an expert witness report. The objective of the report is to document the impact of the Black Rock Irrigation Project on the Zuni. In so doing, the student will become familiar with the problem from the perspective of a single discipline. Students should be asked to document both positive and negative effects and to provide evidence to support their claims based on information received in the case study handouts. The instructor may choose the level of formality desired for this report. For example, it could range from a handwritten page of bullet points to a typed document describing the impacts in greater detail and using information from external sources. We allocate 30 minutes in the teaching plan for drafting a relatively informal report during class time. A detailed description of each handout is provided below.

Handout 3A. Expert Witness Materials: Anthropology

The goal of this exercise is to introduce students to a different worldview and culture, one in which people are not only part of nature, they are related to nature. It invites students to view nature and human-nature relationships differently by introducing them to a culture whose moral imperative states that only proper behavior and rituals on their part can help maintain a healthy balance of nature. It describes a number of ways in which the Zuni successfully and sustainably managed to live in a harsh, arid environment. In particular, it describes ways in which the Zuni managed water. The Zuni dams that are described are permeable, with the dual purpose of slowing water flow (to prevent erosion and spread out the water) and capturing valuable silt (to prevent erosion and add to field fertility).

The handout asks students to contrast their worldview with that presented for the Zuni, and then to imagine (from both explicit and implicit information) how a Zuni worldview versus their worldview would affect land, plant, and animal management. It specifically asks students to explain how Zuni dams differ from modern U.S. dams. Finally, it asks students to enumerate the strategies used by the Zuni for successfully living in this arid environment.

Handout 3B. Expert Witness Materials: Soil Science

The goal of this exercise is to provide students with a *compare and contrast* experience on soil classification and soil properties related to crop growth, looking at both the traditional Zuni and the contemporary, measurement-based classification systems used in Canada and the United

States. Our goal is to provide both disciplinary learning within soil science, and a multidisciplinary learning experience linking these principles to the cultural and economic factors operative in the Zuni case study.

The Soil Texture Triangle-Hydraulic Properties Calculator provides an excellent device for providing a working knowledge of soil-water relationships for even novice students (Pedosphere.ca 2011-2012). Some specific teaching notes are given below:

1. The Soil Texture Triangle-Hydraulic Properties Calculator gives the volumetric water content of the soil in units of $\text{cm}^3_{\text{water}}/\text{cm}^3_{\text{soil}}$. The cm^3 unit is explained in the student sheet for the benefit of those students uncomfortable with metric units and exponents. The volumetric water content can differ considerably from the more commonly used gravimetric water content ($\text{g}_{\text{water}}/\text{g}_{\text{soil}}$)— see for example ICRISAT (2013) ([http://www.icrisat.org/what-we-do/.../Soil Moisture Calculation.pdf](http://www.icrisat.org/what-we-do/.../Soil%20Moisture%20Calculation.pdf)). Differences between the two measures, and the use of bulk density (also calculated by the Soil Texture Triangle-Hydraulic Properties Calculator) in relating the two water content terms, can be explored with students in soil science, geology and geography classes using the case study.
2. The original research that forms the basis of the calculator covers most, but not all (e.g., all of the “heavy clay” area), of the area of the triangle. We have chosen to use the version of the Soil Texture Triangle-Hydraulic Properties Calculator available at <http://www.pedosphere.ca/resources/texture/triangle.cfm> due to its point-and-click feature. The version with the Canadian system triangle is easier for beginning students to follow than the U.S. version triangle (also available from pedosphere.ca at http://www.pedosphere.ca/resources/texture/triangle_us.cfm) with its third labeled axis and diagonal lines. Another advantage of the Canadian version is that it shows the shaded portion of the texture spectrum where the calculator is effective; students should be advised (or will soon discover) that clicking outside of this region does not yield water content data.

Handout 3C. Expert Witness Materials: Economics and Policy

The goal of this exercise is for students to compare and contrast traditional Zuni methods of resource management with those pursued by the U.S. government. The handout introduces traditional Zuni production methods, which tailor production methods to uncertain and variable surface water availability. The labor-intensity of these production methods is implicit and explicit in the text. These are contrasted with U.S. methods, which involve storing runoff for later use and conveying it to fields in irrigation canals. The handout also discusses traditional Zuni and U.S. property rights systems for land and water. Finally, problems arising from the Irrigation Project are described.

The handout further provides a description of potential market failures based on neoclassical economic theory. The level of presentation does not assume that students have had exposure to economic theory in the past. The students should use this material to understand how the U.S. may have justified the construction of the Black Rock Irrigation Project. They are asked to reflect about why intervention failed in this case and to debate whether this outcome is consistent with, or in opposition to, the predictions of neoclassical economic theory. Additional reading on

market failures that is appropriate for the level of the study can be found in Chapter 4 of Tietenberg and Lewis (2009).

Part 3. Understanding the Multiple Dimensions of the Zuni Case

Overview: Students are reorganized into mixed-discipline groups and asked to propose potential “solutions” for the cultural, environmental, and economic impacts of the Black Rock Irrigation Project. Students are then debriefed on the resolution of the actual Zuni legal suit and the instructor leads a discussion of the case study activity.

Total estimated time: 50 minutes

Detailed Description:

The jigsaw case approach is then implemented when the instructor reorganizes the students into groups of 3-6 with an equal representation of expert witnesses from the anthropology, soil science, and economics groups. Students are asked to combine the knowledge gained in Part 2 to discuss three questions

After reorganizing the groups, hand out the narrative for Part 3, which continues Judith’s internal monologue and emphasizes the complexity of finding a “solution” to a complex and multidisciplinary problem. Allow students 15 minutes to discuss the questions provided.

After the students discuss the questions in small groups, allocate 15 minutes for students to report out on their proposed solutions and to discuss the problem with the class as a whole. Afterward, allocate 5 minutes for students to read Handout 4, which describes the resolution of the Zuni suit against the U.S. government. Allocate 10 minutes for discussion of the resolution of the case. In particular, elicit student reactions about the actual “solutions” to the problem and allow them to discuss the advantages and disadvantages of the case outcome relative to their proposed solution(s).

In this section, the instructor may also introduce the definition of a socio-environmental system, an idea that is implicit to this point in the case study. A general definition of a socio-environmental system is one in which “tightly linked social and biophysical subsystems mutually influence one another” (SESYNC 2013). The class may discuss the following questions:

- Is the Zuni problem an example of a socio-environmental system? How so?
- How did their understanding of the Zuni problem and their proposed “solutions” differ when they included the input of multiple disciplines (Part 3) versus when they included only a single disciplinary perspective (Part 2)?
- Is there a simple “solution” to the Zuni problem? Do you think there are generally simple solutions to problems in socio-environmental systems?

ANSWER KEY

Part 1. Survival in a Harsh Environment: Imagining Zuni Strategies for Resource Management

The discussion questions (in italics) and suggested answers are as follows:

1. *Identify the elements of survival in this harsh environment: food, clothing, shelter.*

The students can glean a number of elements of survival from the text provided, focusing on the need to conserve and obtain water. Water is so valued that strong rituals and beliefs surround its use. Additionally, religious beliefs affected Zuni management of all the resources that allowed them to survive. A number of foods are listed, including traditional and introduced plant crops and livestock, as well as wild game. Although clothing is not specifically described, students may observe that both cotton and leather were available to the Zuni. No detail is supplied for housing, other than to mention that the Zuni began to build very large pueblos by the middle of the 13th century. Consultation with the Glossary (see Teaching Notes) can tell the students that such buildings are constructed of wooden frames covered in adobe. Students may reason that such construction supplies good insulation against hot and cold temperature extremes. They may also question where construction material was obtained, given that the area is described as having “low trees and shrubs.”

2. *Describe at least three methods you imagine the Zuni may have used for watering their fields.*

The students are not expected to anticipate how the Zuni watered their fields; they will be exposed to that information later. Rather, we anticipate that many students will provide answers based on Western production systems and paradigms concerning natural resource management. For example, students may argue that food production requires the delivery of water to fields via irrigation canals. The goal of allowing students to brainstorm before providing them with information on how the Zuni actually managed resources is to heighten the impact of that information, which introduces methods of production that the students may not have previously considered.

Part 2. Zuni Resource Management Challenges through the Lens of an Expert Witness

Handout 3A. Expert Witness Materials: Anthropology

The discussion questions (in italics) and suggested answers are as follows:

1. *Compare and contrast your worldview with that of the Zuni. What are the implications for how you versus the Zuni would approach land, plant, and animal management?*

To the Zuni, humans are not only part of nature, but related to nature and should respect it. To many Americans, humans are seen as separate from and “above” nature. Nature without humans is pristine: human actions “disturb” nature (to the Zuni, humans are not separate from nature, nor do they disturb nature). Whereas the Zuni consider themselves to have an obligation to and respect for nature, many Americans see nature as something to be “used”: their relationships to the natural world are often framed in terms of economics or recreation. According to the handout, the Zuni believe that proper ceremonies, rituals and behavior can positively influence the weather. Many Americans are in denial that human actions are causing climate change. The Zuni worldview places a moral obligation on Zuni individuals to be mindful of their interactions with nature: many Americans feel no such moral obligation towards nature.

The implications of these two differing worldviews on land, plant, and animal management are far-reaching. The Zuni feel a moral responsibility to maintain a balance and to interact sustainably with the environment. Many Americans feel no such responsibility; rather, they

attempt to “get” as much economic benefit out of nature as possible. They see little intrinsic value in nature for its own sake, and depend upon legislation to regulate human-nature interactions. The Zuni depend upon societal consensus to regulate human-nature interactions. Of the two, societal consensus is the stronger driver of human action. Conservation is not an issue or necessarily even a concept for a society like the Zuni: when humans treat nature like a relative, “conservation” is not needed.

2. *How do Zuni dams differ from the dams we usually see placed on U.S. rivers and streams? Do we use any dams similar to Zuni dams, and if so, where or for what?*

The Zuni dams, which are made of brush, sticks, and dirt, are relatively small and temporary. Their purpose is to slow and direct water in order to prevent erosion and spread the water out over a field. An additional purpose, which the students are less likely to grasp on their own, is to trap waterborne silt, sometimes to repair early erosion and build up a beginning gully or arroyo, and sometimes to help fertilize the fields or change the texture of the soil in a field. When constructing dams to direct and spread water across a field, they observed how well the system worked for a year before they began planting the field. The Zuni carefully studied each individual situation, changing techniques as needed through time or across an area. One take-away point that the instructor may make is that prior to U.S. intervention, the Zuni successfully kept arroyos (intermittent stream channels) shallow and were able to raise the riverbed level of arroyos that had down cut: essentially, they never allowed erosion to become a problem within their territory.

Today, in modern American construction projects that disturb the soil, one commonly sees small, permeable barriers such as lines of staked horticultural mesh or bales of straw staked into place. These presumably are meant to capture sediment and prevent pollution of nearby waterways, or prevent erosion.

3. *List the ways in which the Zuni traditionally managed to live successfully in a harsh environment. Note that not all of these are listed in the final paragraph*

The Zuni employed a number of strategies to conserve and use water. First, their religious beliefs required them to sustainably and equitably manage water, and not waste any. Thus, one of their driving forces for land and water management was not economics per se, but moral consensus. Additionally, their strategies were based on practical experience specific to their location – what academics call Traditional Ecological Knowledge (TEK) or Local Ecological Knowledge (LEK). The handout briefly describes four main techniques to water fields and gardens: run-off farming, flood-water farming, irrigation, and pot irrigation. Other strategies listed in the handout include (1) the development of local crop varieties that are adapted to conditions of little water and short growing seasons; (2) the use of weedy and wild plants and animals – useful weeds were left in the field or garden rather than pulled out; (3) moving their flocks of sheep to keep them from overgrazing any one area, thus avoiding erosion; (4) periodically reducing the size of their flocks, which helped avoid overgrazing leading to erosion; (5) burning to increase grass yields for their grazing animals; (6) building up soil in areas starting to erode; and (7) taking steps to protect plants from windblown sand or to keep surface soil from blowing away. Although many Americans might find the Zuni refusal to plant wild trees a contradiction in terms of conservation, the Zuni were not cutting down many wild trees (only those few needed for

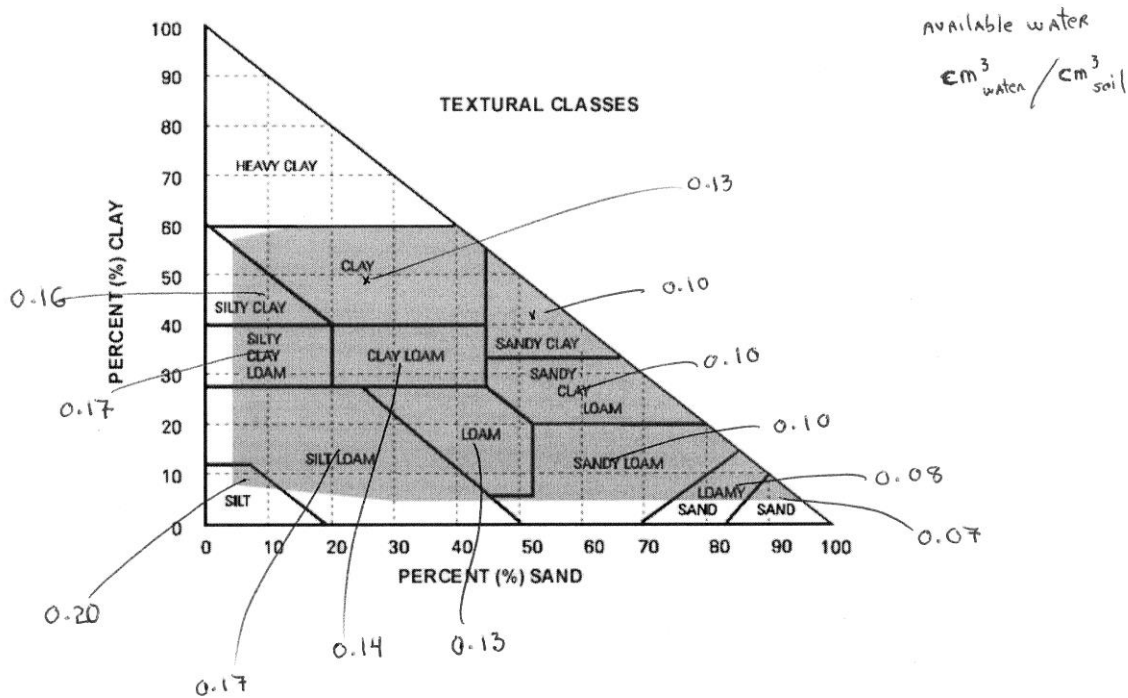
building houses) and instead relied on dead wood for fuel and other purposes. Thus, unlike America today, there was no need for reforestation.

The Zuni employed a number of risk management strategies. One was to plant many small fields in scattered locations, both to take advantage of pockets of good soil that best retained water, but also to mitigate the likelihood that any one large field of a crop might fail due to the unpredictable and spotty nature of the scant rainfall. Additionally, their goal was to store two years' worth of food, even if that goal could not always be met. The social and ceremonial structure of society also worked to help families in need of labor or food by helping out or redistributing food.

Handout 3B. Expert Witness Materials: Soil Science

The discussion questions (in italics) and suggested answers are as follows:

1. *Find a point near the center of the shaded portion of each textural class (such as “clay loam”). Annotate the soil triangle and space below by recording the value for available water at each such point. Do you see trends as you move in various directions from one portion of the triangle to another?*



The main point that the students will hopefully discern is that the highest available water content is seen in the silt/silt loam/silty clay loam/silty clay soils. Loam/clay loam/clay soils, with their higher sand contents, show intermediate values. Sandy soils (sandy clay/sandy clay loam/sandy loam/loamy sand/sand) show the lowest values.

Note: Available water is the difference between the water held at field capacity and at the wilting point (parameters also given by the calculator). Advanced students with an interest in this area may wish to further explore the triangle to examine questions such as: What is the influence of

clay content on the wilting point values? Independent study such as this is best done on the accompanying "[Go to Work Table](#)" link on the pedosphere.ca webpage.

2. *Soil scientists look not only at the soil at the surface, but also at the layers ("horizons") below. With knowledge of the entire soil "profile," they can learn how the soils formed from underlying earth materials, predict rates of water infiltration and retention, and assess the ability of roots to penetrate to various depths. Please look at the description of the "Typical Pedon" for the Aquima soil and answer the following:*

- *Is the texture uniform with depth?*

No, the designated horizons denote depth increments with changes in texture and other soil properties. See the excerpts on the next two pages of pp. 160-161 from USDA-NRCS (2005). Silt loam: 0-11, 17-33 inches. Sandy clay loam: 11-17, 45-49 inches. Silty clay loam: 33-45 inches. Gravelly clay loam: 49-65 inches.

percent gravel; 5 to 30 percent cobbles; 0 to 10 percent stones; 0 to 1 percent boulders. All fragments are cinders and basalt.

Bt horizon:

Hue: 2.5YR or 5YR

Value: 3 or 4 dry, 2.5 or 3 moist

Chroma: 3 or 4 dry or moist

Texture: loam, clay loam, or sandy clay loam

Rock fragments: 20 to 60 percent total; 15 to 60 percent gravel; 5 to 20 percent cobbles. All fragments are cinders and basalt.

Btk horizon:

Hue: 2.5YR or 5YR

Value: 3 or 4 dry, 2.5 or 3 moist

Chroma: 3 or 4 dry or moist

Texture: coarse sandy loam, loamy coarse sand, or sandy clay loam

Rock fragments: 50 to 90 percent total; 40 to 85 percent gravel; 5 to 10 percent cobbles; 0 to 5 percent stones. All fragments are cinders and basalt.

Bk horizon (when present):

Hue: 2.5YR or 5YR

Value: 3 or 4 dry, 2.5 or 3 moist

Chroma: 4 or 6 dry or moist

Texture: loamy coarse sand or sandy loam

Rock fragments: 80 to 95 percent total; 40 to 90 percent gravel; 0 to 20 percent cobbles; 0 to 20 percent stones. All fragments are cinders and basalt.

Aquima Series

Taxonomic class: Fine-loamy, mixed, superactive, mesic Ustic Haplocambids

Depth class: Very deep

Drainage class: Well drained

Permeability: Moderately slow

Geomorphic position: Valley sides and valley floors

Parent material: Fan and stream alluvium derived from siltstone, sandstone, and shale

Slope range: 1 to 5 percent

Elevation: 6,000 to 6,800 feet

Mean annual air temperature: 49 to 54 degrees F

Mean annual precipitation: 10 to 13 inches

Frost-free period: 120 to 140 days

Typical Pedon

Aquima silt loam, in an area of mapping unit 225, Aquima-Hawaikuh silt loams, 1 to 5 percent slopes; McKinley County, New Mexico; Ojo Caliente Reservoir Quadrangle; 2,800 feet east and 200 feet north of the

southwest corner of sec. 29, T. 9 N., R. 20 W.; latitude 34 degrees, 58 minutes, 27 seconds and longitude 108 degrees, 58 minutes, 09 seconds (fig. 14).

A—0 to 2 inches; reddish brown (2.5YR 5/4) silt loam, reddish brown (2.5YR 4/4) moist; weak thin platy parting to weak fine granular structure; soft, friable, slightly sticky and nonplastic; few very fine and fine roots; common very fine irregular pores; strongly effervescent; moderately alkaline (pH 8.0); abrupt smooth boundary.

Bk1—2 to 11 inches; reddish brown (2.5YR 5/4) silt loam, reddish brown (2.5YR 4/4) moist; moderate medium subangular blocky structure; soft, friable, slightly sticky and nonplastic; common very fine and fine roots; common fine tubular pores; 2 percent gravel; strongly effervescent; few fine irregular masses and weakly cemented concretions of calcium carbonate; 7 percent calcium carbonate equivalent; moderately alkaline (pH 8.3); abrupt smooth boundary.

Bk2—11 to 17 inches; red (2.5YR 4/6) sandy clay loam, red (2.5YR 4/6) moist; massive; soft, friable, slightly sticky and slightly plastic; common very fine and fine roots; common very fine irregular pores; 4 percent gravel; strongly effervescent; common fine and medium irregular masses and weakly cemented concretions of calcium carbonate; 8 percent calcium carbonate equivalent; moderately alkaline (pH 8.0); clear smooth boundary.

2Bk3—17 to 26 inches; red (2.5YR 5/6) silt loam, red (2.5YR 4/6) moist; massive; soft, friable, slightly sticky and nonplastic; common very fine and fine roots; common very fine irregular pores; slightly effervescent; 4 percent calcium carbonate equivalent; strongly alkaline (pH 8.8); clear smooth boundary.

2Bk4—26 to 30 inches; red (2.5YR 4/6) silt loam, dark red (2.5YR 3/6) moist; massive; soft, friable, slightly sticky and nonplastic; common very fine and fine roots; common fine irregular pores; slightly effervescent; few fine irregular masses and weakly cemented concretions of calcium carbonate; 5 percent calcium carbonate equivalent; strongly alkaline (pH 8.7); clear smooth boundary.

2Bk5—30 to 33 inches; red (2.5YR 4/6) silt loam, dark red (2.5YR 3/6) moist; massive; soft, friable, slightly sticky and nonplastic; common very fine and fine roots; common fine irregular pores; slightly effervescent; 4 percent calcium carbonate equivalent; strongly alkaline (pH 8.9); clear smooth boundary.

3Bk6—33 to 45 inches; red (2.5YR 4/6) silty clay loam, dark red (2.5YR 3/6) moist; massive; soft, friable,

slightly sticky and slightly plastic; common very fine and fine roots; common fine irregular pores; 1 percent gravel; slightly effervescent; few fine irregular masses and weakly cemented concretions of calcium carbonate; 5 percent calcium carbonate equivalent; strongly alkaline (pH 8.5); clear smooth boundary.

3Bk7—45 to 49 inches; red (2.5YR 4/6) sandy clay loam, dark red (2.5YR 3/6) moist; massive; soft, friable, slightly sticky and slightly plastic; common very fine and fine roots; common fine irregular pores; 5 percent gravel; strongly effervescent; common fine irregular masses and weakly cemented concretions of calcium carbonate; 9 percent calcium carbonate equivalent; moderately alkaline (pH 8.4); clear smooth boundary.

3Bk8—49 to 65 inches; red (2.5YR 4/6) gravelly clay loam, dark red (2.5YR 3/6) moist; massive; soft, friable, slightly sticky and slightly plastic; common very fine and fine roots; common fine irregular pores; 15 percent gravel; strongly effervescent; common fine irregular masses and weakly cemented concretions of calcium carbonate; 8 percent calcium carbonate equivalent; moderately alkaline (pH 8.4).

Range in Characteristics

Particle-size control section: 20 to 35 percent clay

Reaction: Slightly to moderately alkaline in the surface and moderately to strongly alkaline in the subsoil

A horizon:

Hue: 2.5YR or 5YR

Value: 4 or 5 dry, 3 or 4 moist

Chroma: 4 or 6 dry, 3 or 4 moist

Bw horizon:

Hue: 2.5YR or 5YR

Value: 4 or 5 dry, 3 or 4 moist

Chroma: 4 or 6 dry or moist

Texture: Silt loam, silty clay loam, and sandy clay loam

Rock fragments: 0 to 5 percent gravel. All fragments are sandstone.

Calcium carbonate equivalent: 2 to 10 percent

Bk horizons:

Hue: 10R, 2.5YR or 5YR

Value: 4 or 5 dry, 3 or 4 moist

Chroma: 4 or 6 dry, 4 through 8 moist

Texture: clay loam, sandy clay loam, or silty clay loam

Rock fragments: 0 to 20 percent gravel and 0 to 10 percent cobbles. All fragments are sandstone.

Calcium carbonate equivalent: 2 to 10 percent

Some pedons have a C horizon with textures of loamy sand and sand, below 50 inches.

Arabrab Series

Taxonomic class: Loamy, mixed, superactive, mesic Lithic Haplustalfs

Depth class: Shallow

Drainage class: Well drained

Permeability: Moderately slow

Geomorphic position: Mesas and cuestas

Parent material: Eolian material and slope alluvium over residuum derived from sandstone

Slope range: 2 to 6 percent

Elevation: 6,800 to 8,000 feet

Mean annual air temperature: 46 to 49 degrees F

Mean annual precipitation: 13 to 16 inches

Frost-free period: 100 to 135 days

Typical Pedon

Arabrab gravelly fine sandy loam, in an area of mapping unit 332, Evpark-Arabrab complex, 2 to 6 percent slopes; McKinley County, New Mexico; Thoreau Quadrangle; 2,100 feet west and 200 feet north of the southeast corner of sec. 35, T.15 N., R.13 W.; latitude 35 degrees, 28 minutes, 52 seconds N. and longitude 108 degrees, 10 minutes, 54 seconds W.

The surface is covered by about 20 percent gravel, 2 percent cobbles, and 1 percent stones.

A—0 to 2 inches; brown (7.5YR 5/4) gravelly fine sandy loam, dark brown (7.5YR 3/4) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; few very fine tubular pores; about 20 percent gravel, 2 percent cobbles, and 1 percent stones; slightly alkaline (pH 7.4); abrupt smooth boundary.

Bt1—2 to 7 inches; brown (7.5YR 4/4) sandy clay loam, dark brown (7.5YR 3/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine, fine, and medium roots; few very fine tubular pores; many distinct clay films on faces of peds and bridging sand grains; about 5 percent gravel; slightly alkaline (pH 7.6); clear smooth boundary.

Bt2—7 to 12 inches; strong brown (7.5YR 5/6) clay loam, strong brown (7.5YR 4/6) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; common very fine, fine, and few medium roots; few very fine tubular pores; many prominent clay films on faces of

- *Please show any variation by marking on the soil triangle below.*
- *If any textural classes are not contained on the triangle, please note that name and depth of occurrence.*
- *What textural class does it seem to be similar to?*
- *How do you think its difference from this similar soil will influence its plant-available water content?*

Variations noted above. Textural classes not contained on the triangle: Gravelly clay loam at 49-65 inches. The presence of gravel (larger than sand-sized particles) will likely decrease available water content. Note: For some crops, such as wine grapes, this is a desirable soil property.

3. *Under the description of clay (hepecha) is the statement: “A variety is lupopo:we, which is a crust of clay that forms on irrigated land. It must be broken in order for the plants to obtain water and to exchange gas at the shallow root level.” Answer the following:*

- *How may the clay layer affect plant growth?*

Fine particles such as clay can partially seal the soil surface, and thereby limit air and water permeability.

- *Where do you think the clay that forms the crust comes from?*

In the case of Zuni floodwater irrigation, the clay-sized particles might come from the stream or arroyo from which the water was drawn; or it might come from the erosion of up-slope soil, the clay being picked up as the water is released from the ditch and flows overland towards the irrigated field.

- *Once that crust is broken up, how might the presence of these clay materials be a good thing for crop production on these soils?*

These fine particles can carry nutrients that stimulate crop production. Note: Think of the story of the annual flooding of the Nile.

4. *In the description of clay (hepecha) is the statement: “Clay is found in patches in the farming villages, irrigated land, and in greatest abundance in the Zuni Irrigation Project.” What are the implications of this distribution for the Zuni farmers?*

High clay content soils can be sticky when wet, and thus difficult to farm. Thus the abundance of such soils in the Zuni Irrigation Project, the area within which the Office of Indian Affairs granted Zuni males 10 acres of irrigable land, would be problematic for the recipients.

Additionally, the special maize varieties specifically developed by the Zuni, which are preferred by the Zuni and required for ceremonies, are not well-suited for cultivation in these soils.

5. *How would the Zuni farmers likely classify the Aquima soil? Be prepared to explain your answer.*

See the excerpt from the soil survey report above. The Aquima is a silt loam soil. Therefore, the closest soil type in the Zuni classification scheme would be loam (*helyalo:we*).

Handout 3C. Expert Witness Materials: Economics and Policy

The discussion questions (in italics) and suggested answers are as follows:

1. *Compare and contrast the Zuni method of land and water management with that of the U.S. government. Describe the economic advantages and disadvantages of each.*

Zuni methods minimize the production of environmental externalities (incorporate the social cost of agricultural production decisions) and provide risk diversification by cultivating a mix of fields, crops, and production methods. The primary disadvantage is that Zuni methods are labor-intensive. U.S. methods have the advantage of saving labor and of providing risk diversification by smoothing the availability of water throughout and between growing seasons.

2. *What economic argument(s) might the U.S. government have used to justify the construction of the Zuni Irrigation Project? Is there a market failure (or multiple market failures) that might result in an inefficient allocation of water across individual irrigators had the U.S. not constructed the Project? Did the Zuni Irrigation Project effectively correct those market failures?*

With respect to water, the quotation from John Wesley Powell (1879) points to natural monopoly as a justification for government intervention to provide irrigation infrastructure. Because of the high fixed costs of constructing dams and canals, it is in no one farmer's private interest to provide that infrastructure. A perverse outcome of the Irrigation Project is that it resulted in a movement away from a system that minimized the production of environmental externalities towards one that produced substantial negative externalities in the form of increased soil erosion.

3. *Neoclassical economic theory holds that well-defined and complete property rights are necessary to achieve an efficient outcome in a free market. What were the effects on the Zuni culture of enforcing private property rights for land and water? How do you reconcile this outcome with neoclassical economic theory?*

Zuni management relied on communally regulated private property as well as communal property rights, while U.S. management relies on private property rights for resources. Neoclassical economic theory holds that well-specified property rights are required for an efficient allocation of resources. The common property rights applied to land and water by the Zuni would therefore be problematic because they do not establish exclusivity, and they would present some problems similar to public goods (though they are not public goods because they are to some extent excludable and they are certainly rival). The instructor may refer to additional readings by Elinor Ostrom (e.g. Ostrom 1990; Dietz et al. 2003) to discuss cases in which communal property rights systems are successful.

Part 3. Understanding the Multiple Dimensions of the Zuni Case

The discussion questions (in italics) and suggested answers are as follows:

1. *List physical changes to the land and water on the Zuni Reservation, comparing post-U.S. government intervention to pre-U.S. government intervention.*
2. *List social and economic changes (and non-changes) to the Zuni people, including both those enumerated in the documents, and those changes you reason may have occurred.*
3. *What "solutions" can you propose for remedying the agricultural and water problems the modern Zuni now face that stemmed from U.S. government intervention in Zuni traditional land and water management?*

The objective of this part of the case study is for students to combine their disciplinary knowledge of the issues to arrive at a more comprehensive, mixed-discipline understanding of the case. At a minimum, discussion of the physical changes to the land and water on the Zuni

Reservation should include the siltation problem caused by overgrazing and timber harvesting. Other changes mentioned in the class handouts include (1) overgrazing and crowding due to the implementation of private property rights on lands formerly used for open range; (2) the loss of tributaries once sustainably managed for agricultural production as the Zuni moved into the lands serviced by the Irrigation Project; (3) massive erosion and creation of deep arroyos resulting from historic overgrazing, dam breaks, and cessation of traditional sustainable management; and (4) problems with windblown sand covering fields. From a social and economic perspective, the discussion should include a shift from labor-intensive crop production in a non-cash economy to participation in a cash economy based on livestock production and jewelry making, and the loss of traditional communal resource management regimes.

There are no defined “solutions” to the resource management problems faced by the Zuni in the wake of U.S. government intervention. Rather, the goal is for students to come to an answer that is informed by a mixed-discipline discussion. Any solutions proposed should therefore differ from solutions that would be advanced based on a disciplinary understanding of the problem.

This was an actual court case, and the “solution” reached is outlined in Handout 4.

ASSESSMENT

Upon completion of the case study, the following assessment questions may be asked of the students to determine whether the case study exercise achieved its Socio-Environmental Synthesis learning goals.

1. A socio-environmental system is one in which “tightly linked social and biophysical subsystems mutually influence one another” (SESYNC 2013). Does the Zuni example illustrate a socio-environmental system? Explain why or why not. You may use a diagram to illustrate your answer if it helps.
 - This question assesses whether students understand how social and environmental system interact in the context of this example. A secondary goal of this question is to assess whether students can reduce the complexity of the problem to clearly define interactions between the systems.
2. How does the Zuni understanding of their environment differ from your own, prior to this exercise? Has learning about the Zuni changed your perspective on resource management at all? Explain why or why not.
 - This question assesses whether the case study successfully introduced to the students different cultural “ways of knowing” the environment.
3. Describe one of the “solutions” that your mixed-expert group proposed to the Zuni land and water management problems that resulted from the Black Rock Irrigation Project. Then answer the following questions:
 - a. What discipline did you represent as an expert witness? How did your understanding of the problem from a disciplinary perspective shape the solution that your group proposed?
 - b. What did you learn about the Zuni problem from discussing it with expert witnesses from other disciplines?
 - c. How did your final “solution” differ from one that you might have proposed based on your expert witness materials alone?

- This question assesses how a multidisciplinary understanding of the problem resulted in a different outcome than would a disciplinary understanding.

SUPPLEMENTARY TOPICS

A number of topics may be covered in greater depth in the case study, depending on the level of the audience. For example, the following text elaborates on the cutting of arroyos and on the use of permeable barriers to prevent erosion.

Arroyos

The cutting of arroyos—the channels of ephemeral streams, usually with vertical banks—can increase sediment loss, change plant communities, and decrease overland flow of water for traditional irrigation. Much of the legal debate during the 1980s about damage to Zuni lands by activities of the U.S. government focused on arroyos and evidence of an enhanced rate of their formation associated with human activities, particularly dam building and changes in grazing and logging policies. Indeed, the very definition of “arroyo” in historical context from documents examined by the litigating parties dating from the 1500s to 1900s came under intense scrutiny by the attorneys and their expert witnesses (Monson 1995). The Zuni litigation offers an ideal case study in which students can explore how we can assess alleged environmental impacts when these are superimposed upon a non-zero background. Arroyos are a natural erosional feature on the landscape, and most geomorphologists agree that their formation increased in the American southwest during the period from approximately 1865-1915. While not denying the possible impacts of overgrazing and tree removal, some have argued that the enhanced rates of arroyo formation during this period were also associated with a naturally occurring period of higher rainfall (Cooke and Reeves 1976). Such climate effects, rather than just policies and action of the government, could be explored with advanced students in geography and earth science courses.

Modern Permeable Barriers: Some Examples

The U.S. Environmental Protection Agency (EPA) regulates pollution due to windblown sediments as well as stormwater runoff resulting from construction (EPA 2013a). The agency supplies contractors and the public with information on how to apply various techniques to limit wind-blown sediment as well as runoff of silt and other pollutants from a construction site, and many of these mimic Zuni methods of water control and silt retention. The EPA supplies fact sheets on methods for controlling stormwater runoff: see especially the fact sheets on brush barriers, check dams, compost filter berms, filter berms, silt fences, and wind/sand fences. All of these are temporary structures that are removed once construction has ended and the area has been stabilized.

Brush barriers are “constructed of material such as small tree branches, root mats, stone, or other debris left over from site clearing and grubbing. Brush barriers can be covered with a filter cloth to stabilize the structure and improve barrier efficiency” (EPA 2013a). The barriers should be at least three feet high and five feet wide at the base. The use of brush barriers is recommended for low-velocity flow areas. A **check dam** is a relatively small (less than three feet high), temporary structure built across a channel that drains from two to 10 acres. It may be made of a variety of materials, including gravel, rock, sandbags, logs, or straw bales. Its purpose is to slow the velocity of water and trap silt, but check dams are not to be used in active stream channels without prior EPA approval. The EPA notes that a series of check dams may be needed,

and that it is important that the pores of the dam not become clogged with material such as leaves. **Compost filter berms**, which are trapezoidal in cross-section, are placed perpendicular to sheet flow runoff that does not exceed one cubic foot per second of flow. A berm is made of compost and may be vegetated (in which case it is left in place permanently) or unvegetated (in which case it is removed following stabilization). A **filter berm** slows, diverts, and filters water. It may be a temporary ridge made of gravel, stone, or crushed rock, or it may be geosynthetic fabric such as the silt fencing shown in the accompanying photographs. They work best in areas with 10% or less slope, but they clog quickly without maintenance. A **silt fence** is “a temporary sediment barrier made of [heavy] porous fabric. It’s held up by wooden or metal posts driven into the ground” (EPA 2013b:1). It may help filter sediment from an area of a quarter acre or less in size and should be placed to help pond the water. Although it should not be used in a flowing channel, it may be placed parallel to the channel banks to filter runoff entering the channel. A **wind or sand fence**, which is made of small, evenly-spaced wooden slats or fabric, acts to reduce wind velocity, which in turns helps to trap wind-blown sand or sediments. The fence should be two to four feet high and placed perpendicular to the prevailing wind direction. Efficiency in increased when multiple fences 20-40 feet apart are installed.



Permeable Silt Fences Used Today at Construction Sites

Notes: Permeable silt fences are designed to retain sediment, while allowing the passage of storm water, thereby protecting receiving water bodies from excessive inputs of disturbed soil. They function in a manner similar to the stone dams that the Zuni built across arroyos (Ford 1985:37-38) or hillslopes (Homburg and Sandor 2011:147) to slow water and trap sediment. Photos reproduced with permission of Gail Wagner, Department of Anthropology, University of South Carolina, Columbia.

USING THIS CASE STUDY WITH ADVANCED STUDENTS

Instructors using this case study with advanced students may wish to assign original articles in addition to or instead of the text supplied here. We supply a range of selected additional references and have made some suggestions under Supplementary Resources. For example, the instructor may assign students to read the original expert witness documents. For a concise but comprehensive overview, we especially recommend Cleveland et al. (1995).

SUPPLEMENTARY RESOURCES

For more information on the Colorado Plateau, see: Grahame and Sisk (2002): *Canyons, cultures and environmental change: An introduction to the land-use history of the Colorado Plateau*. Available at <http://www.cpluhna.nau.edu/>.

For instructors wishing their students to delve more fully into the legal record, the book *Zuni and the Courts: A Struggle for Sovereign Land Rights* (Hart 1995) has a supplementary CD-ROM

that contains approximately 50 expert reports and more than 30 Zuni depositions, including 6,000 pages and 200 historical photographs. An excellent, lyrical educational movie *The Hopi: Corn is Life* explicitly ties maize to all stages in Hopi life and demonstrates the deep spiritual connections the Hopi and Zuni hold with maize (Coughlan 1997). The instructor should be careful in selecting movies: some movies available online on venues such as YouTube include photographs of Zuni dances and ceremonies. Such photographs are forbidden by the Zuni and to be culturally sensitive, the instructor should respect their laws. Note that in the recommended movie, footage is never shown of actual dances, but instead artistic renderings give the flavor of the ceremonies. For an excellent overview of the differences between a generalized indigenous worldview and the generalized Western worldview, see Schelbert (2003).

For more information on the installation of fusegates to resolve the accumulation of silt behind Black Rock Dam, see Gannett Fleming (2002). Afshar and Takbiri (2009) and Falvey and Treille (1995) discuss the benefits of fusegates and present the engineering details on fusegate design and operation.

GLOSSARY

adobe	Clayey soil, or a form of construction in which a wooden structure is coated with such soil.
arroyo	A channel with intermittent water.
geomorphologist	A geologist who studies landforms and how they developed.
matrilineal	A society that traces descent through the mother's lineage.
matrilocal	A society in which a newly married couple sets up their household with the wife's family.
pinyon	A type of pine tree with edible nuts called pine nuts.
pueblo	Apartment-like adobe structures where people live. A large pueblo may encompass the entire town.
worldview	A culture's hidden viewpoint that structures that society's perception and understanding of life and the world around them. It is often taken for granted rather than explicitly taught or discussed.

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