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Water resources assessment of the Mora River

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WATER RESOURCES ASSESSMENT OF THE MORA RIVER

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PREFACE

Water Resources 573, Field Problems, is one of three core class taught in the Water Resources Program at the University of New Mexico (http://www.unm.edu/~wrp). WR573 is taught each summer with the purpose of introducing students to methods used in water resources investigations. Included in the instruction are: the use of field equipment to measure hydrologic parameters, field and laboratory analysis of water samples to determine water quality characteristics, and methods of collecting and interpreting information on water resources management and policy in a particular watershed.

The class of 2009 studied the Mora River watershed in Mora County in northern New Mexico. The class was taught by Dr. Bruce Thomson (Director, Water Resources Program) and Dr. Abdul-Mehdi Ali (Senior Research Scientist, Analytical Chemistry Laboratory Manager for the Department of Earth & Planetary Sciences). Questions regarding this report should be directed to Dr. Thomson (bthomson@unm.edu).

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ABSTRACT

During the second week of June 2009, the UNM Masters of Water Resources students, staff, and collaborators studied the Mora River watershed by measuring flows and water quality characteristics at over 20 surface water sites in the watershed. The main objective of the study was to conduct a river assessment of the Mora River and its corresponding acequia systems. It is expected that this report will serve as a baseline for future research on the hydrology, water quality, and to a lesser extent, the socioeconomic characteristics of the river and its watershed.

The Mora River watershed drains 1,476 square miles and is located on the eastern slopes of the Sangre de Cristo Mountains in northeastern New Mexico, originating in mountains with elevations over 12,000 feet above sea level. The Mora River then flows eastward onto the eastern plains of New Mexico, draining into the successively larger Canadian and Arkansas Rivers, which ultimately makes its confluence with the Mississippi. Approximately 47 acequias, or irrigation ditches, intersect the Mora River and its tributaries throughout the watershed.

The principal source of water supply in the watershed is surface water, and most is used for agricultural activities consisting of irrigation and livestock watering. Drinking water is supplied almost entirely by ground water although there are reports of a few homesteads that use water from acequias or adjacent streams for domestic use.

Measurements and site descriptions were recorded either on New Mexico Environment Department Surface Water Quality Bureau data sheets or in notebooks, following the EPA's Environmental Monitoring Assessment Program (EMAP) protocol. Data was collected and analyzed concerning the hydrology, geomorphology, riparian vegetation, human impacts, benthic macroinvertebrates, and water quality at five segments of the Mora River, and 19 tributaries and acequias.

This assessment found that generally high quality conditions of the river and riparian environment. This conclusion was supported by the type and diversity of benthic macroinvertebrates, by channel geomorphic criteria, and by water quality measurements. However, it is recognized that this assessment was done near the peak of spring runoff; it is likely that low flow conditions later in the summer will present environmental stresses to the system. In this regard, the nearly complete diversion of the Mora River for agricultural use as it passes through the Mora Valley was noted. Much of this water is returned to the river at the eastern end of the valley and has measurably increased concentrations of plant nutrients including nitrogen and phosphorous species that may result in eutrophic impacts.

Recommendations are included for further studies to quantify stream flows and diversions in the watershed to gain a better understanding of water use. Information is also needed on the seasonal concentrations of chemical constituents in the river and its tributaries to understand the impact of development, especially that associated with non-residential vacation homes and potential development of coal bed methane.

INTRODUCTION

The principal objective of the study was to conduct an assessment of the Mora River, its main tributaries and its corresponding acequia systems. The study was performed in the expectation that this report will serve as a baseline for future research on the hydrology, water quality, and to a lesser extent the socioeconomic characteristics of the river and its watershed.

The main stem of the Mora River is more than 100 miles long and drains a watershed of 1,476 square miles (Figure 1). The river originates in the Sangre de Cristo Mountains with the highest point of the watershed above 12,000 ft. It flows east onto the high plains of New Mexico. The majority of the Mora River lies within Mora County, NM, but also flows through and drains parts of Colfax and San Miguel counties. The watershed contains federal, state and privately owned lands. The Mora River is a tributary to the Canadian River and joins it above Conchas Dam. The Canadian River subsequently flows into the Arkansas River. The focus of this report is the main stem of the Mora River between the community of Watrous located on Interstate 25 in eastern Mora County and the headwaters in the Sangre de Cristo Mountains. This report summarizes the results of a field investigation on the river that was conducted from June 8, 2009 through June 12, 2009.

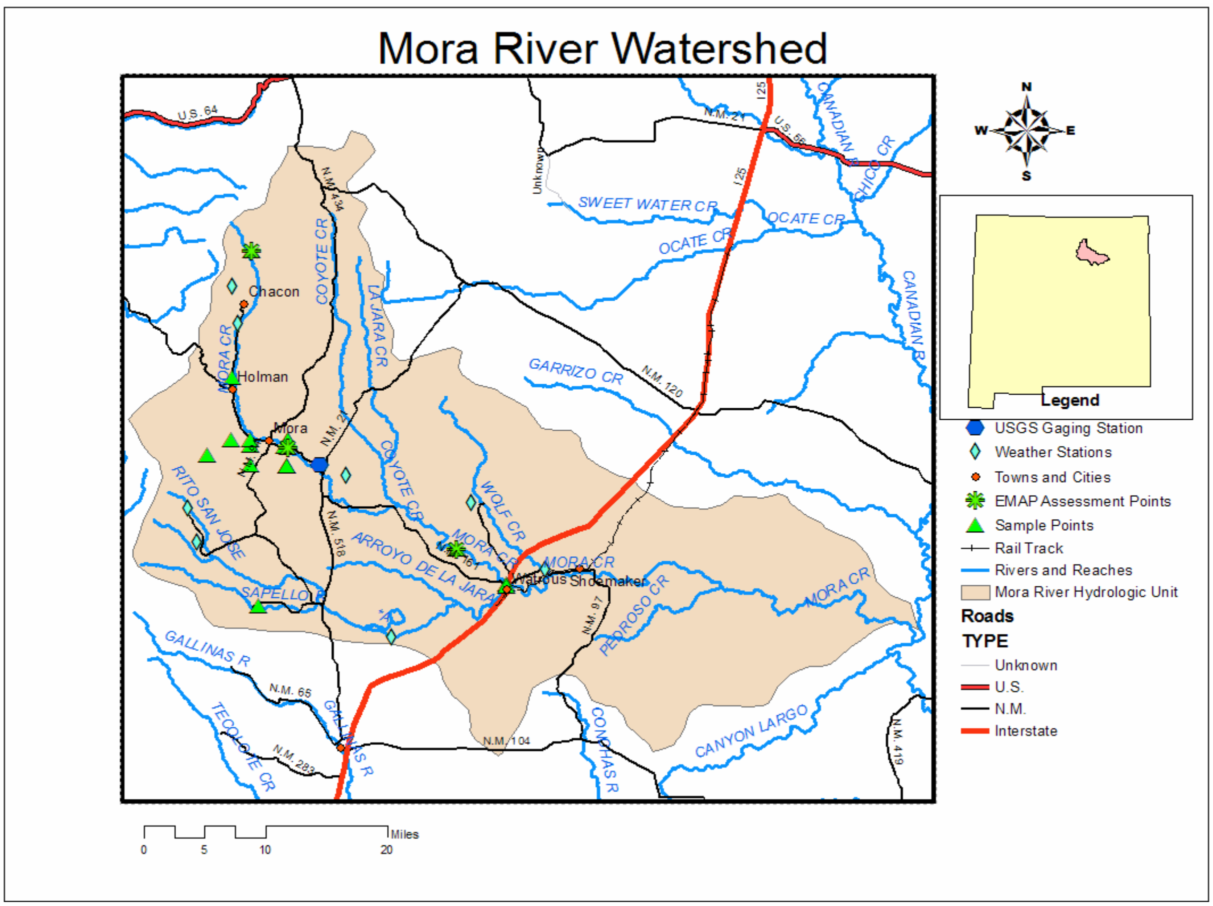


Figure 1. The Mora River watershed in northeastern New Mexico, USA.

The only known endangered fish in the Mora River or its tributaries is the Southern redbelly dace (Phoxinus erythrogaster). Although it is not a federally listed species (USFWS, 2009) this species has been protected in New Mexico as an endangered species (19 New Mexico Administrative Code (NMAC) 33.1) since 1975 (Platania, 2007). The fish is found in Coyote Creek and the headwaters of the Mora River (Sublette et al., 1990; Platania, 2007). In addition, "a small population may persist in Jarosa Creek (a tributary of Coyote Creek)" (Platania, 2007). The southern redbelly dace inhabits permanent streams with cool water and gravel substrates (Sublette et al, 1990).

Interstate Compacts are an important part of water in New Mexico including the Mora River. The Canadian Compact states that "New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of Canadian river above Conchas Dam" (Canadian River Compact, 1951). The New Mexico Office of the State Engineer (NMOSE) had no plans as of June 2009 to adjudicate water rights in the Mora River watershed (Farmer, 2009). Furthermore, there is no current community support for appointment of a Water Master to assist in management of the river (Farmer, 2009).

Previous Work

There has been limited previous research conducted on the water resources of the Mora River watershed. Mercer and Lappala (1972) evaluated the ground water resources within Mora County. The New Mexico Surface Water Quality Board (SWQB) conducted an assessment of the Canadian River and its tributaries in 2002. This study found that the water quality in some reaches of the river and its tributaries did not support the designated uses identified in the New Mexico Stream Standards (Table 1). In order to address these problems, the New Mexico Environment Department (NMED) established Total Maximum Daily Loads (TMDL) for the impaired reaches of the river (SWQB, 2007). A TMDL "documents the amount of a pollutant a water body can assimilate without violating a state's water quality standards" (SWQB, 2007). As the Mora River is a major tributary of the Canadian River, it was included in the study. A professional project done by UNM student Andrew Erdmann considered the impact of forest management forest fuel reduction program on the watershed in the vicinity of the Rio La Casa (Erdmann, 2008). In addition, the University of New Mexico's Water Resources Program conducted a study similar to that described in this document on the Sapello River which is tributary to the Mora River located in a watershed approximately 20 miles south of the Mora Valley(Thomson & Ali, 2008). Appendix D contains more information about previous work done on the watershed.

Table 1 Impaired waters of the Mora River watershed.

	Probable Causes of Impairment						
Reach Name	Dissolved Oxygen	Low flow alterations	Nutrient/Eutrophication Biological Indicators	pH	Sedimentation/Siltation	Specific Conductance	Water Temperature
Coyote Creek (Mora River to Black Lake)						X	X
Little Coyote Creek (Black Lake to headwaters)			X	X			
Mora River (HWY 434 to Luna Creek)					X	X	
Mora River (USGS gage east of Shoemaker to HWY 434)	X		X				
Morphy (Murphy) Lake	X		X	X			
Rito San Jose(Manuelitas Creek to headwaters)		X					
Sapello River (Mora River to Manuelitas Creek)					X		
Wolf Creek (Mora River to headwaters)		X					

Source: (SWQB, Aug. 2008).

WATERSHED DESCRIPTION

Physical Characteristics

The Mora River flows eastward onto the high plains of New Mexico as it drains into the successively larger Canadian and Arkansas Rivers, the latter of which ultimately feeds into the Mississippi River. Tributaries to the Mora River include Coyote Creek and Wolf Creek to the north, and the Sapello River and Pedroso Creek to the south (Figure 1). Kammer (1992) identified 47 acequias, or irrigation ditches, in the Mora River watershed upstream of Shoemaker near the community of Watrous. Figure 2 shows the topography of the watershed. Of special relevance is the transition from a steep, mountainous, high altitude alpine terrain on the west to a relatively flat topography towards the east.

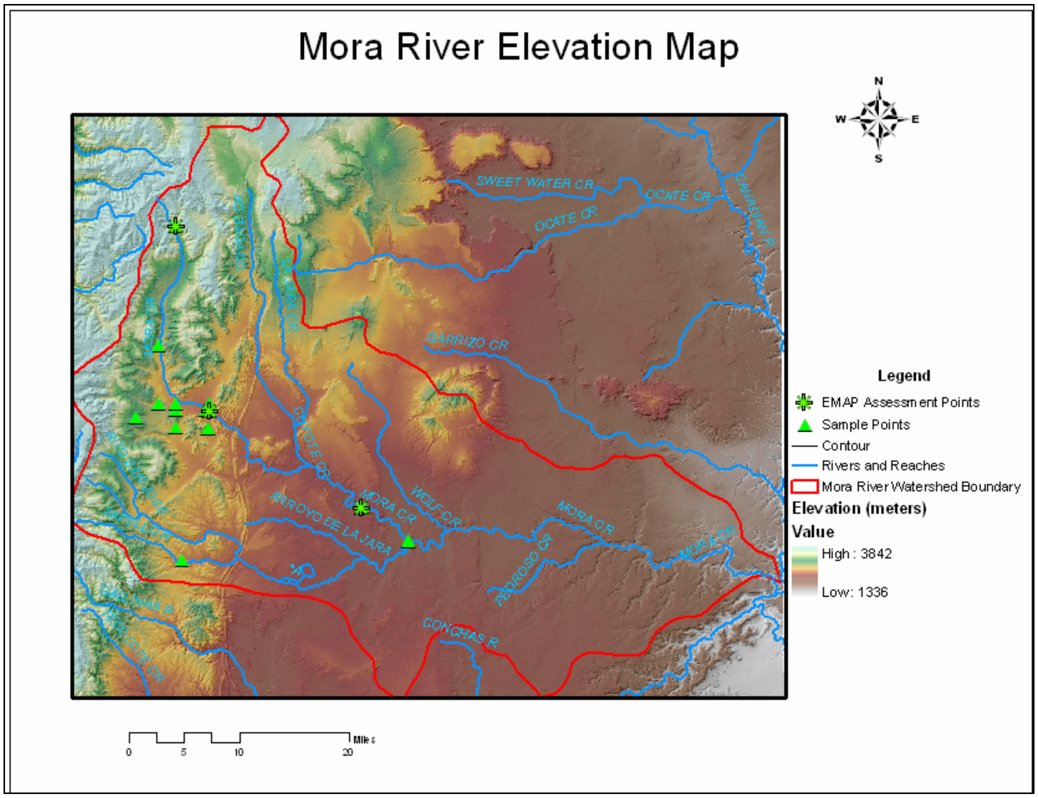


Figure 2 Topography of the Mora River watershed

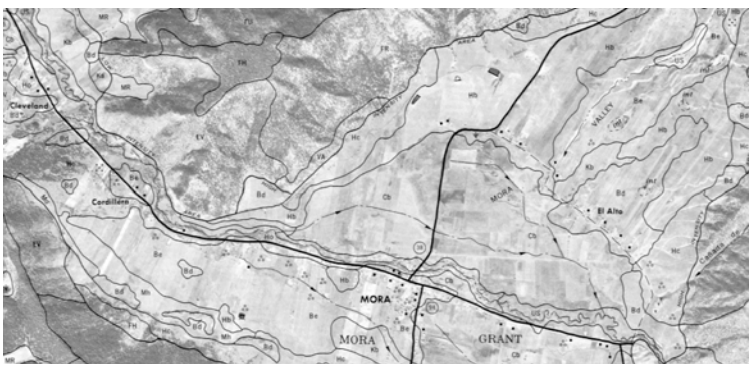
Soils

The USDA (1981) describes the soils in the Mora region as originating from parent material of metamorphic, igneous and sedimentary rocks. They vary in age from Precambrian to Holocene. Principal soil formation occurred during the Quaternary Period. Broad alluvial deposits occur on the eastern plains. The valleys consist mostly of Mollisols (highly erodible) and are dark colored due to warmer conditions and vegetation, while the higher mountain regions have higher organic matter with non-decomposed leaf litter due to higher precipitation and cooler climates. Soils here tend to have thicker layers and higher occurrence of leached profiles. In the western region, rocks consist of gray and red shale, thin strata of gray limestone and sandstone beds. The Sangre de Cristo Mountains consist of various colored shales, siltstone, arkosic sandstone and clay shale. Climate is the major factor affecting vegetation, parent material, drainage, soil temperatures and precipitation. Figure 3 presents a soil survey of the Mora County region.

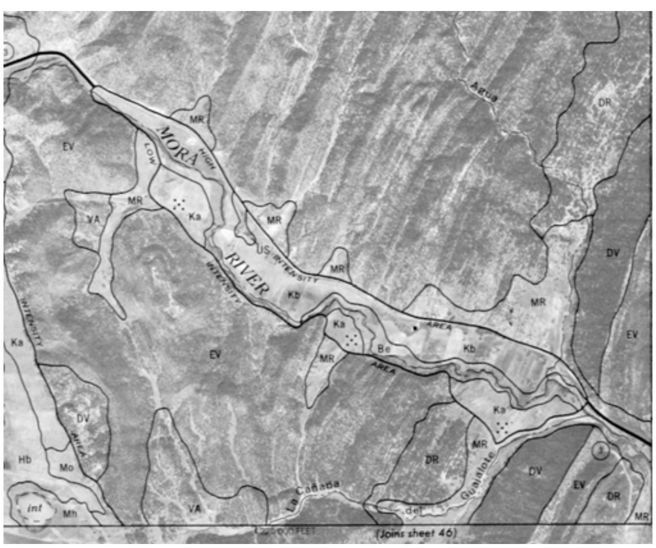
Soils map 10

Soil legend

Bd Breece Variant sandy loam 3-8% slope
Be Brycan loam, 1-3 percent slopes
DR Dargol-Rocio-Vamer assoc., hilly
DV Dargol-Rocio-Vamer assoc., very steep
EV Eutroboralts-Rock outcropVamer complex, extremely steep
FH Firo-Hesperus assoc., hilly
Hb Hesperus sandy loam 1-3% slopes
Hc Hesperus sandy loam 3-8% slopes
Ho Holman complex, 3-5% slopes
Ka Kinesava sandy loam 3-8% slopes
Kb Kinesava loam 1-3% slopes
KR Krakon-Rock outcrop complex, hilly
MR Moreno-Brycan assoc, sloping
VA Varner-Rock outcrop- EV complex, hilly



Soil map 28



Soil map 28

Figure 3 Soil Survey of Mora County (United States Dept. of Ag., Soil Conservation Service, 1981)

Climate

The climate of the Mora River watershed is dominated by the high altitude alpine climate of the Sangre de Cristo Mountains on the west and the semiarid climate of the high plains to the east. The high altitudes force the traveling air masses to lift (orographic lifting) which in turn causes super-saturation of the atmosphere (precipitation). Daytime heating also causes lifting, especially during summer (convective lifting). Annual precipitation is strongly influenced by summer monsoons that bring in moisture from the Gulf of Mexico. Figure 4 shows temperatures at three weather station locations: Gascon (COOP ID 293488) is located on the upper reach of the Rito San Jose; Ocate (COOP ID 296275) is located near the intersection of NM State Highways 21 and 120; and Valmora (COOP ID 299330) is located near the confluence of Wolf Creek and the Mora River (Figure 1). Evapotranspiration (ET) is greatest at the lower altitudes of the eastern end of the Mora River watershed. Conversely, ET is lowest in the forest of the Sangre de Cristo Mountains.

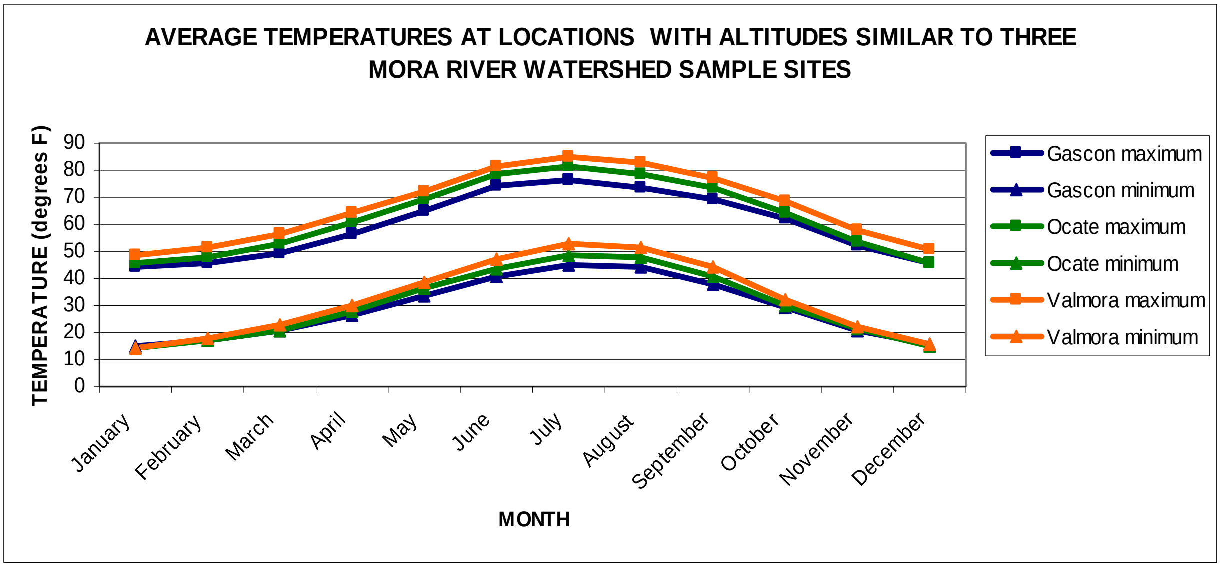


Figure 4 Average temperature at three locations in the Mora River watershed (WRCC, accessed June 2009).

Average monthly precipitation data from the three NOAA weather stations is plotted in Figure 5 and is consistent with the double peaks for stream runoff shown in Figure 8. Differences in rainfall during the historical periods and the years 1998-2007 for the Gascon and Ocate stations are slight and variable. Valmora received less rainfall in the more recent ten year period when compared to the long-term average. It appears that rainfall has decreased recently, however due to the short period of record it is not known whether this is due to normal variability of rainfall, drought, or climate change.

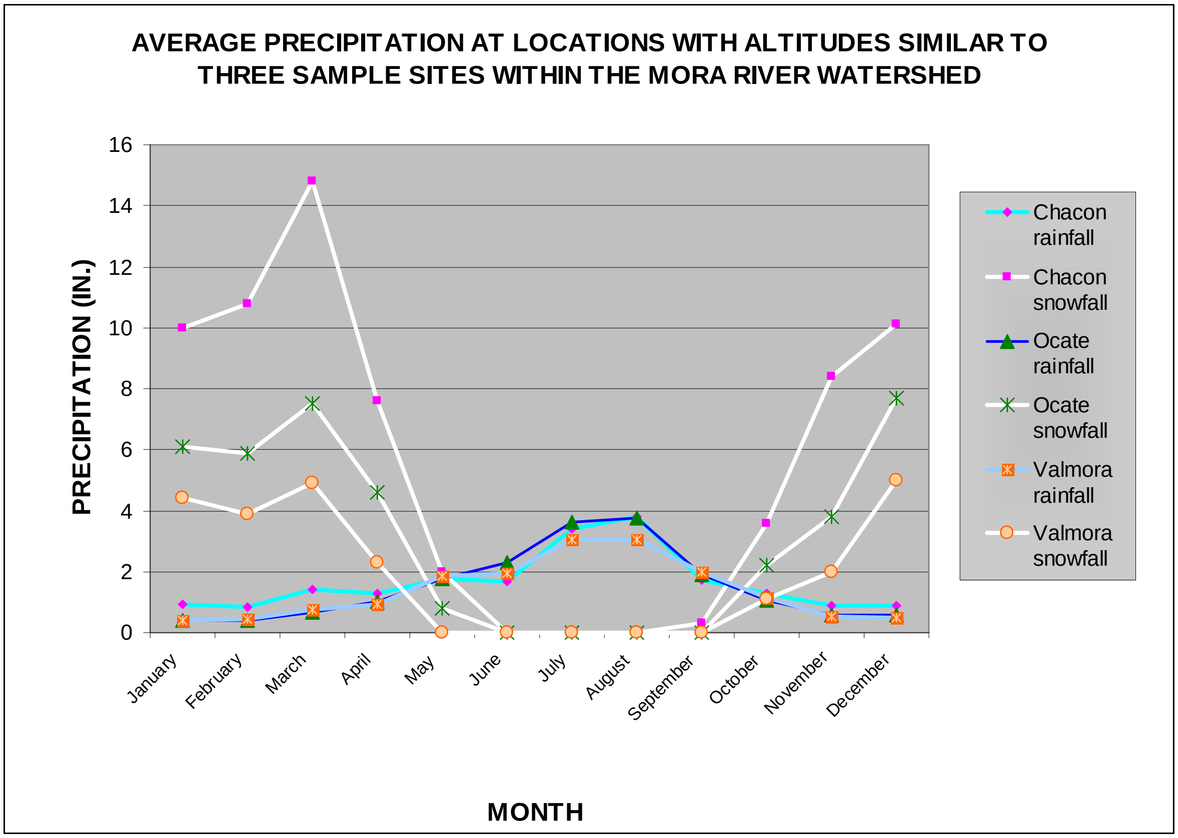


Figure 5. Monthly average precipitation in the Mora River watershed (WRCC, accessed June 2009).

Vegetation

The western region of the Mora River watershed consists of subalpine forest with gradations to short dry season grasses in the east (Figure 6). Douglas fir (*Pseudotsuga menziesii*), White fir (*Abies concolor*), Subalpine fir (*Abies lasiocarpa*), Colorado blue spruce (*Picea pungens*), Engelman spruce (*Picea engelmani*), Quaking aspen (*Populus tremuloides*) and Gambel oak (*Quercus gambelii*) comprise the majority of the canopy trees characteristic of the higher altitudes of the Sangre de Cristo Mountains (www.cabq.gov/resources/waterconservation). Moving eastward, altitude decreases as does precipitation, while temperature and evapotranspiration increase. Below an elevation of about 8,200 feet above sea level the fir and spruce trees give way to ponderosa pine (*Pinus ponderosa*). At lower elevations, below about 7,000 ft, piñon (*Pinus edulis*), Rocky Mountain juniper (*Juniperus scopulorum*), and One Seed juniper (*Juniperus monosperma*) are found which are adapted to the warmer and drier climate. Watershed canopy trees are sparse. At lower elevations of the valley, riparian areas are populated by willows (Salix sp.), cottonwoods (*Populus sp.*) and alders (*Alnus sp.*) (Thomson & Ali, 2008). The grasslands are dominated by warm season grasses and shrubs such as snakeweed (*Gutierrezia sarothrae*), four-wing saltbush (*Atriplex canescens*), wolfberry *(Symphoricarpos occidentalis)*, chamisa (*Chrysothamnus nauseosus*), and sages (*Artemisia sp.*)

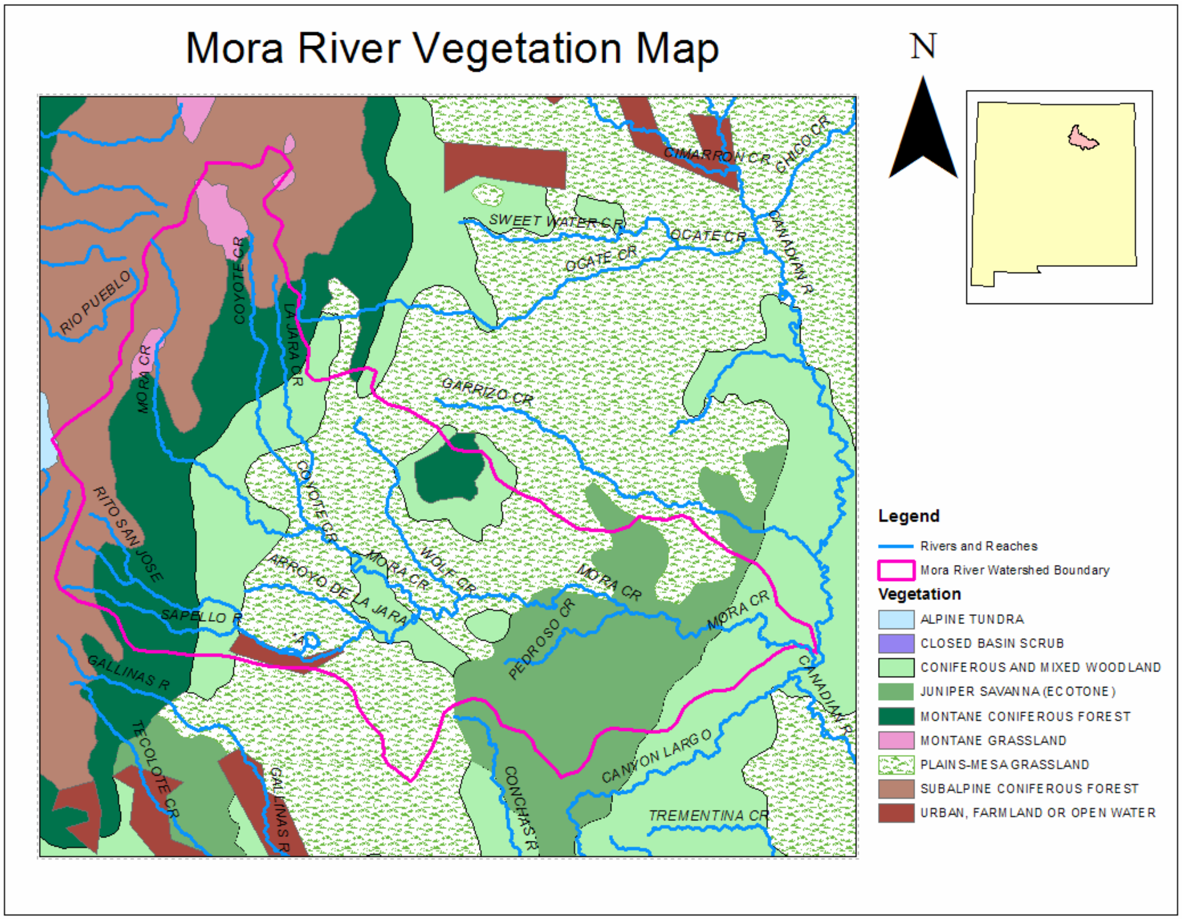


Figure 6 Vegetation on the Mora River watershed

HYDROLOGY

The major source of water supply in the watershed is surface water, with less significant quantities coming from ground water for livestock watering and domestic supply. Drinking water is supplied almost entirely by ground water, though there are reported to be a few residences that use water from their acequias for domestic use (Rupert, 2009). Table 2 shows a summary of non-agricultural water use by source in Mora County for the year 2000.

Table 2 Summary of non-agricultural water use (acre-feet/year) in Mora County, 2000 (NMOSE, 2000).

Use	Surface water withdrawal	Ground water withdrawal	Surface water depletion	Ground water depletion	Surface water return flow	Ground water return flow
Commercial (self-supplied)	0.00	6.41	0.00	6.41	0.00	0.00
Domestic (self-supplied)	0.00	343.12	0.00	343.12	0.00	0.00
Public water supply	0.00	305.27	0.00	176.58	0.00	128.69

Ground Water

Mercer and Lappala (1972) studied ground water resources in the Mora River watershed above Shoemaker for the New Mexico State Engineer (now New Mexico Office of the State Engineer (NMOSE)). They estimated alluvial groundwater storage in the "upper tributary valleys of the Mora River, the Cebolla Creek, and Coyote Creek to sum to 12,700 acre-feet" (Mercer and Lappala, 1972). Based on seismic investigations the Mora Valley was estimated to have an average alluvial aquifer thickness of 200 feet that contains approximately 12,000 acre-feet of ground water. Further downstream the alluvial deposits store another 4,000 acre feet of ground water near Watrous (Mercer and Lappala, 1972) and 7,000 acre-ft from Valmora to Shoemaker (Figure 7).

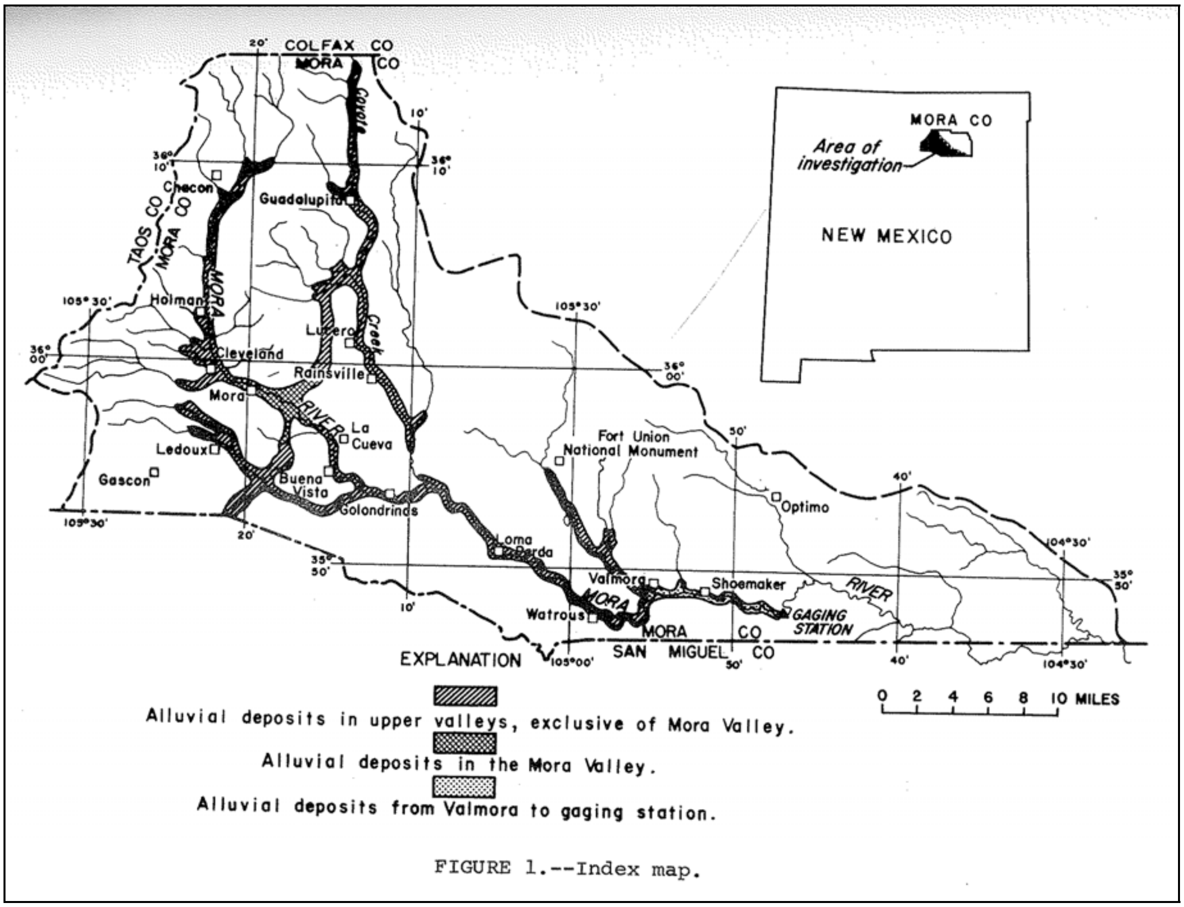


Figure 7 Alluvial ground water resources on the mainstem Mora River (Mercer and Lappala, 1972)

Surface Water

Surface water in the Mora River watershed consists of the Mora River and its tributaries. Four small lakes are in the watershed including Morphy Lake, Red Lake, Lake Isabel, and Lake David. 47 acequias were identified in the watershed upstream from Shoemaker (Kammer, 1992). The USGS currently operates four gaging stations in the Mora River watershed. However,

stream flow records exist for 18 gages that have been in use at one time or another over the past 100 years as summarized in Table 3.

Table 3. Summary of USGS gaging stations in the Mora River watershed.

Station Number	Station Name	Period of Record
07214470	Sierra Ditch Near Chacon, NM	2003-2009
07214600	Vigil Canyon near Holman, NM	1957-1963
07214680	La Sierra Ditch Near Holman, NM	2003-2009
07214700	Agua Fria Creek near Holman, NM	1957-1963
07214800	Rio La Casa near Cleveland, NM	1956-1970
07215100	La Cueva Canal below La Cueva, NM	1906-1972
07215500	Mora River at La Cueva, NM	1906-2009
07215600	Rito Cebolla near Golondrinas, NM	1957-1963
07216500	Mora River near Golondrinas, NM	1915-2009
07217000	Coyote Creek below Black Lake, NM	1953-1963
07217100	Coyote Creek above Guadalupita, NM	1956-1974
07218000	Coyote Creek near Golondrinas, NM	1929-2009
07218100	Mora River near Watrous, NM	1930-2008
07218700	Manuelitas Creek near Rociada, NM	1957-1963
07220000	Sapello River at Sapello, NM	1917-1974
07220100	Lake Isabel Canyon near Sapello, NM	1965-1975
07220600	Sapello River near Watrous, NM	1957-1963
07221000	Mora River at Shoemaker	1920-1996

Figure 8 compares average stream flow between the ten most recent available years with the complete records from three USGS gaging stations on the Mora River watershed: the Mora River near Golondrinas for the time periods of 1916-2007 and 1998-2007, the Mora River at La Cueva for the time periods 1906-2007 and 1998-2007, and Coyote Creek (Mora tributary) for the time periods 1930-2007 and 1998-2007. Peak runoff due to snowmelt occurs in late spring and early summer, and a second peak occurs during late summer due to monsoon activity. The plots illustrate decreases in stream flow from 1998-2007 when compared to the historical averages for all three stations. The difference may be greater than two-hundred percent (e.g., June at the Mora River near Golondrinas). This may be the result of drought, increased water diversions for irrigation, or both. Several gaging stations in the watershed are no longer in operation or are located on acequias and operate only on a seasonal basis.

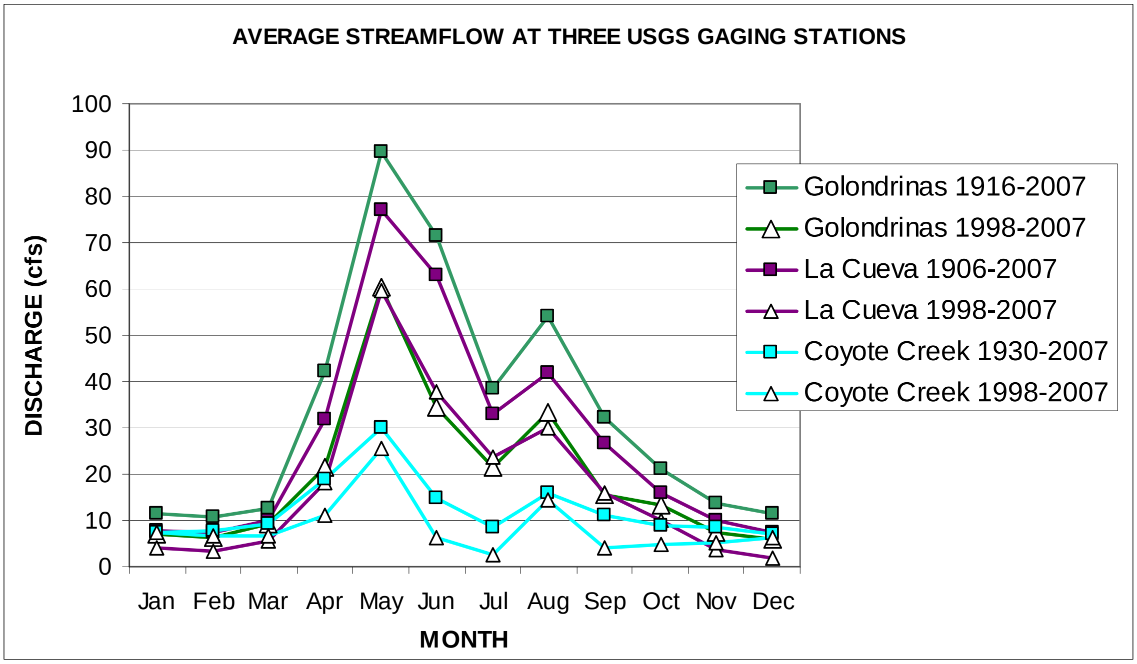


Figure 8. Average stream flow of the Mora River at Golondrinas and La Cueva, and of Coyote Creek (USGS, 2008).

WATER QUALITY ISSUES

The designated uses of various reaches of the Mora River are summarized in Table 4.

Table 4 Designated uses of the Mora River (Section 20.6.4, New Mexico Administrative Code)

Site	Description	Designated Use
20.6.4.307 Canadian River Basin	Perennial reaches of the Mora River from the USGS gaging station near Shoemaker upstream to the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora river downstream from the USGS gaging station at La Cueva in San Miguel and Mora counties, perennial reaches of Ocate creek and its tributaries downstream of Ocate, and perennial reaches of Rayado creek downstream of Miami lake diversion in Colfax county.	Marginal coldwater aquatic life Warm water aquatic life Secondary contact Irrigation Livestock watering Wildlife habitat
20.6.4.309 Canadian River Basin	The Mora River and perennial reaches of its tributaries upstream from the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora River upstream from the USGS gaging station at La Cueva, perennial reaches of Coyote Creek and its tributaries, the Cimarron river and its perennial tributaries above state highway 21 in Cimarron, all perennial reaches of tributaries to the Cimarron river north and northwest of highway 64, perennial reaches of Rayado creek and its tributaries above Miami lake diversion, Ocate Creek and perennial reaches of its tributaries upstream of Ocate, perennial reaches of the Vermejo River upstream from Rail Canyon and all other perennial reaches of tributaries to the Canadian River northwest and north of U.S. highway 64 in Colfax county unless included in other segments	Domestic water supply Irrigation High quality coldwater aquatic life Livestock watering Wildlife habitat Municipal and industrial water supply Secondary contact

(Source: Commission of Public Records, 2009).

Point Sources of Pollution

In early 2004 the Surface Water Quality Bureau (SWQB) of the NMED completed an evaluation of the upper reaches of the Canadian River and its tributaries including the Mora River (SWQB, 2008 and SWQB, 2004). They found that some reaches of the Mora River and several of its tributaries did not meet the criteria identified in the NM State Stream Standards to support the designated uses, in particular its ability to support coldwater aquatic life. The probable causes of impairment were listed as elevated sedimentation/siltation (above Highway 434) and high

nutrient concentrations and low concentrations of dissolved oxygen (Shoemaker to Highway 434). There are two permitted point source discharges on the Mora River; the Mora Municipal Water and Sewer Association's wastewater treatment plant (WWTP) discharge at the eastern end of the Mora Valley, and the Mora National Fish Hatchery and Technology Center which discharges treated effluent to an acequia (see fish hatchery discharge shed data and analysis below. Outflow from the WWTP enters the Mora River immediately upstream from the sampled site of this assessment at the middle reach of the assessed portion of the river. The probable sources of impairment for the reach of river from Shoemaker to Highway 434 were listed as flow alterations from water diversions, municipal point source discharge, and non-point introduction of contaminants from on-site wastewater treatment and disposal systems.

Non-point Sources of Pollution

Non-point sources of pollution in the Mora River watershed include seepage from on-site wastewater treatment and disposal systems, surface runoff from roads, and agricultural runoff. Throughout the watershed there are numerous examples of heavily grazed pastures which drain directly into the Mora River, its tributaries, or acequias. A further concern is that large numbers of animals in pastures with restricted access to rivers and streams may damage stream banks and riparian vegetation.

Watershed Restoration Projects

Two watershed restoration projects are in progress in the Mora River watershed. The Quivira Coalition has received a grant from the state of New Mexico to do restoration on the Mora River as well as Comanche Creek and Gold Creek which are located in Vermejo Park and are not part of the Mora watershed (NMED, 2009). $90,000 of the $157,000 provided by the state of New Mexico is allocated for restoration of the Mora River on the Wind River Ranch (NMED, 2009) and (Miller, 2009).

VEGETATION & LAND USE

Vegetation in the Mora River watershed consists mainly of deciduous forest in the upper reaches and grasslands in the middle and lower reaches. Figure 6 displays the vegetative cover in the Mora River watershed. A small amount of land is used for pasture/hay purposes adjacent to stretches of the river and its tributaries. There are also some areas of open water in the watershed, including Morphy Lake. These and other land use features are shown in Figure 9.

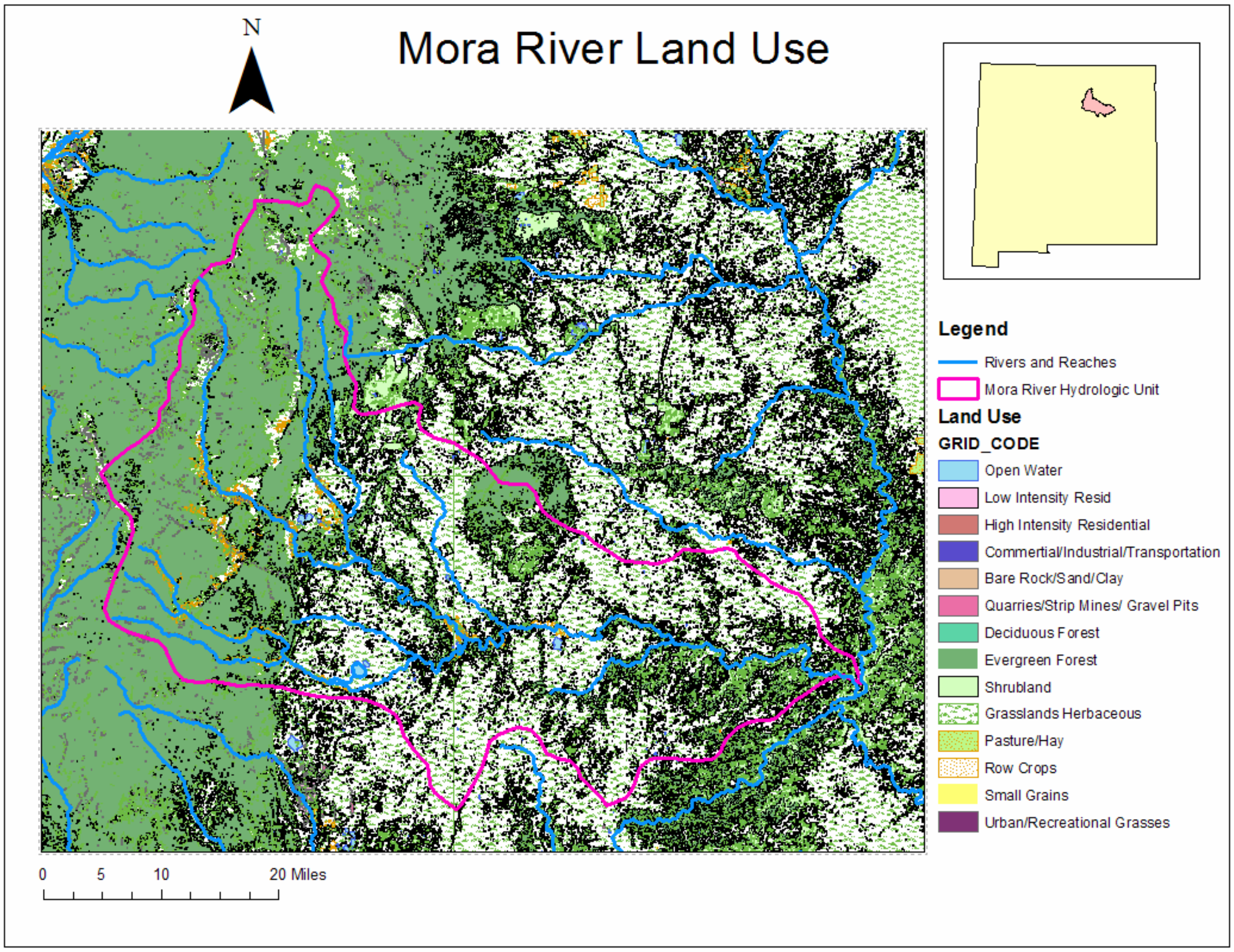


Figure 9 Land use map of the Mora River watershed

Figure 10 shows land ownership on the watershed. A majority of the land is privately owned. There are tracts of state-owned land in the lower reaches on the southeastern portion of the watershed. There are also tracts of U.S. Forest Service land on the western portion of the watershed near the upper reaches of the Mora River and its tributaries. Other small patches of federally-owned land managed by the National Park Service and Bureau of Land Management are scattered throughout the watershed.

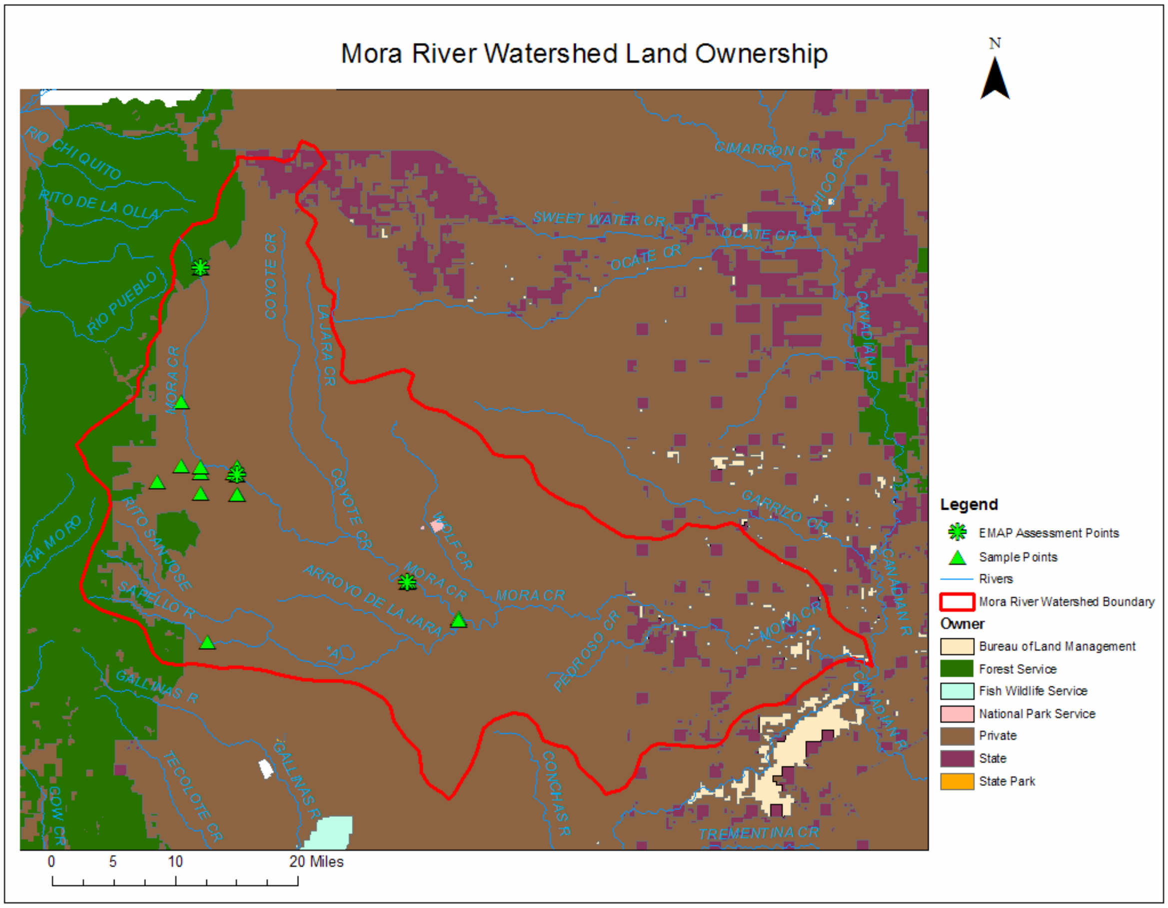


Figure 10 Land ownership in the Mora River watershed.

ACEQUIAS

Acequias, or communal irrigation ditches, have played an important historic role in the region and they continue to do so today. A defining attribute of acequia associations is that water distribution and management stays in the hands of the users of the water. Each community ditch is managed by a Mayordomo who is responsible for keeping the ditch in workable condition and delivering water to the users of the ditch. These water sharing customs and traditions have been in place for centuries in northern New Mexico.

Because acequias seldom utilize water pumps which are costly to purchase and operate, the location of diversion points are selected so that adequate elevation is available to provide gravity flow to fields to be irrigated. Therefore the construction of acequias was instrumental in creating the landscape mosaic of long, rectangular lots, each abutting the acequia that is seen in the watershed today.

An integral part of the acequia system is the network of footpaths used by the Mayordomo, ditch riders, and farmers to manage the ditch. These paths are also often used by livestock as a means to access the water in the ditches. Kammer (1992) identified 47 acequias in the upper Mora River watershed, all of which list priority dates prior to 1900, and at least 16 of the 47 acequias list priority dates of 1852 or earlier. These acequias vary in size throughout the valley. The longest

extend some 10 miles over the mountains and the shortest are about a half mile in length (Kammer, 1992).

Initially the acequias were constructed to support subsistence agriculture in the Mora River valley. With the construction and development of the U.S. Army's Fort Union on the Santa Fe Trail north of Watrous, economic conditions changed as local farmers focused their efforts on growing crops to supply the military. This activity caused a change in crop selection from a variety of vegetable, fruits, grasses, straw and grains for livestock to primarily grains (Kammer, 1992). Along with producing crops for the army, families maintained small herds of animals. The trend toward farming a single cash crop has continued with farmers combining small scale operations with outside jobs. There have been a few recent, notable endeavors at crop specialization such as the raspberry farm at Salman Ranch east of the community of Mora. In addition to providing water for agriculture, at least one acequia was used to provide water to power a grain mill in Cleveland, NM, just upstream from the community of Mora.

New Mexico recognizes acequias as political subdivisions of the state with the acequia associations having the power of eminent domain and authority to borrow money and enter into contracts for maintenance and ditch improvements. Acequia associations do not have the power to impose taxes so the cost of maintenance and improvements are generally borne by the individuals served by the system.

The NM Acequia Commission (www.nmacequiacommission.state.nm.us) maintains a list of the acequias currently along the upper reach of the Mora River. It should be noted that numerous ditches are unnamed and no map could be located that documents the locations of the acequias and points of diversion from the river.

SOCIO-ECONOMIC AND CULTURAL DESCRIPTION

Economic activity in the Mora River watershed centers on its natural resources, including ranching, farming and logging, along with tourism in the form of hunting, fishing and other recreational activities. The village of Mora is home to the Mora National Fish Hatchery and Technology Center which is dedicated to the restoration and recovery of the threatened Gila trout and the New Mexico State University Mora Research Center which focuses on woody plant physiology and restoration ecology. Two other entities of special relevance to water resource protection in the basin are the Pritzlaff Ranch, owned by the Biophilia Foundation, which focuses on protecting biodiversity, and the Wind River Ranch which serves as an educational center to conserve wild landscapes through restoration and research.

Demographics

The population of Mora County declined throughout the 20^{th} century (Figure 11) but appears to have stabilized in about 1990 and is slightly growing at present (UNM, 2008). The population in Mora County in 2000 was 5,810 with 81% of the population being of Hispanic origin. Population projections for 2035 estimate the County's population will increase to 6,134 (UNM, 2008).

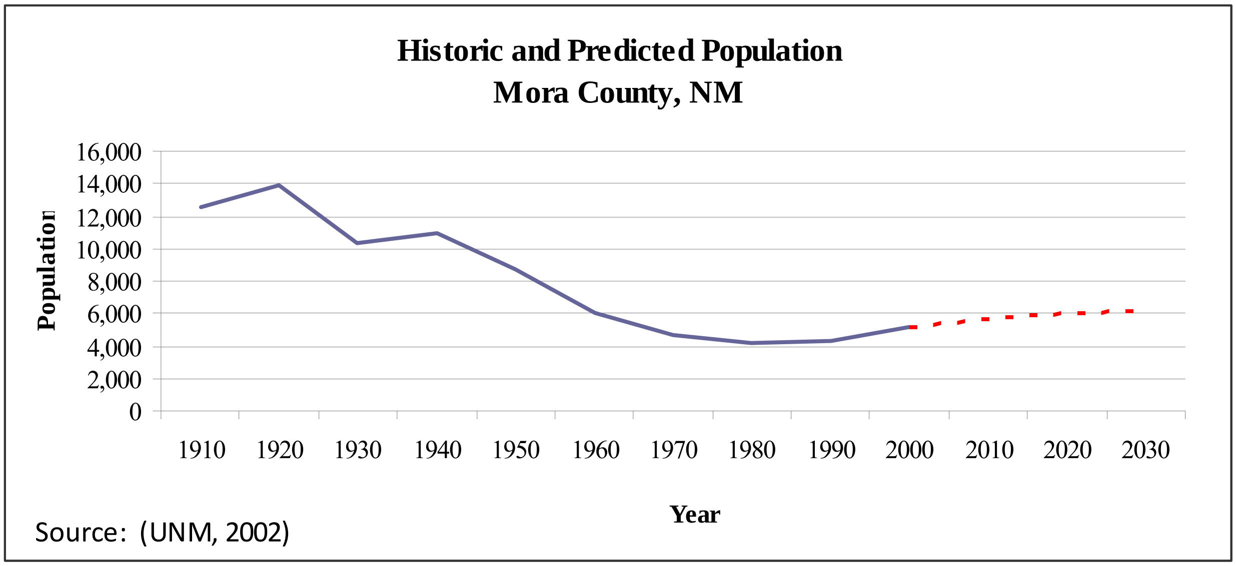


Figure 11 Population of Mora County

In 2000 per capita income of Mora County was $12,340 (1999 dollars) which places the county among the poorest in the U.S. (U.S. Census Bureau). In April 2009, the unemployment rate for the county was 9.4% (New Mexico Dept of Workforce Solutions). Figure 12 depicts employment by sector in the county for the year 2000.

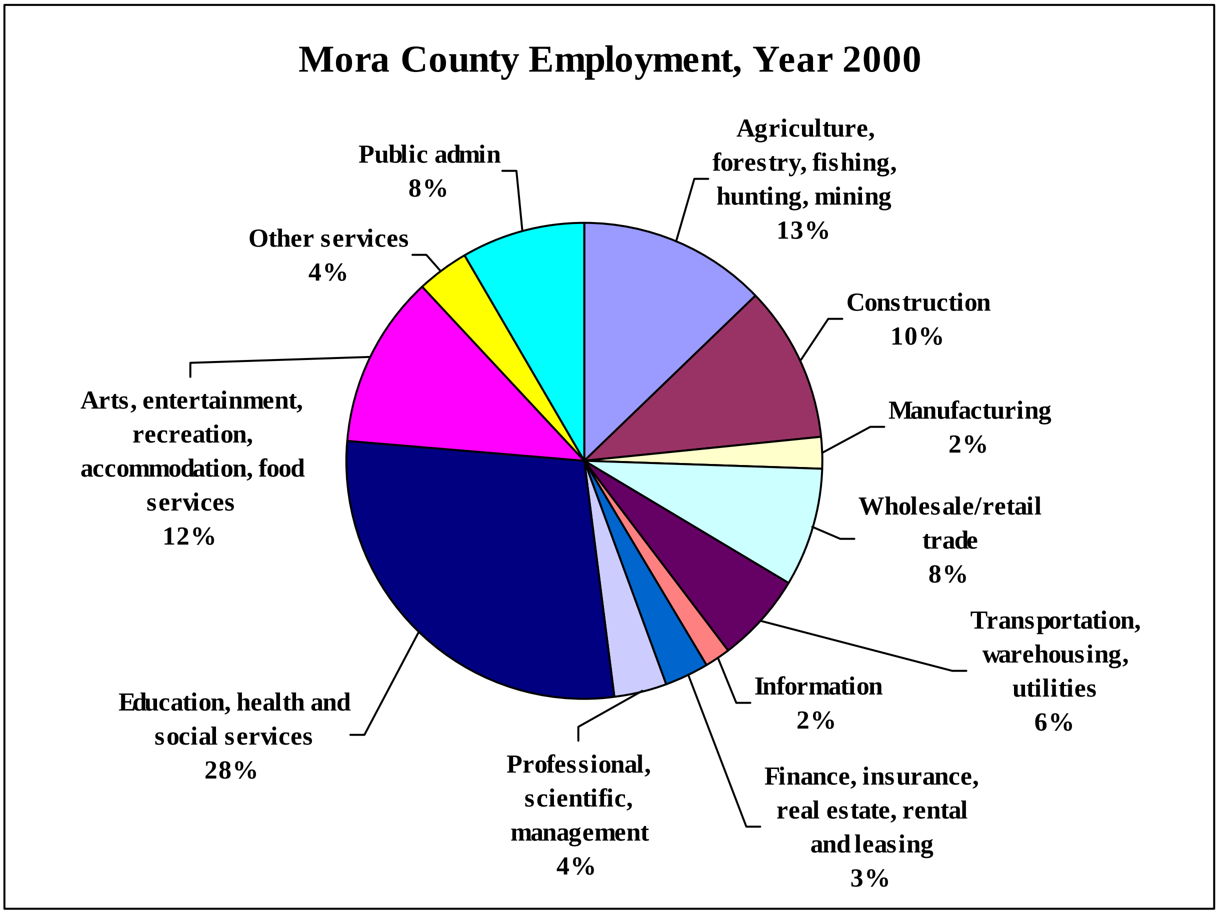


Figure 12. Mora County employment (U.S. Census Bureau, 2000).

Oil and Gas Development

Coal bed methane (CBM) is a natural gas created by chemical or biological processes within coal seams and held in place by hydrostatic pressure causing the gas to adsorb to the coal surfaces. Extraction of CBM entails drilling a well into a coal seam and pumping out the water holding the gas in place, allowing the gas to desorb from the coal's surface and be captured for productive use. Initially, pumping produces large volumes of water, but as gas production increases the volume of wastewater pumped (referred to as produced water) typically decreases.

This pumping of ground water from coal deposits causes several issues related to ground- and surface water resources. First, the withdrawal of groundwater can lower aquifer levels, affecting water levels in nearby wells. Second, the pumped water can be low in quality and is often brackish and can contaminate surface waters if not managed properly. Third, the method chosen to dispose of the so-called "produced water" can adversely affect the receiving ecosystem if it is discharged to the surface, and drinking water supplies can be contaminated if the pumped water is re-injected underground. Supporters of CBM development often argue that in the arid west, produced water can be put to beneficial use in times of drought or to recharge depleted aquifers.

According to the U.S. Department of Energy, the handling and disposal of this produced water "is the single greatest environmental impediment to domestic oil production" (NETL, 2005).

There are several options available for CBM producers to dispose of produced water. These include surface discharge, releasing water to agricultural areas for irrigation, storing the water in reservoirs to allow it to infiltrate or evaporate, using misters to atomize the water to promote faster evaporation from holding reservoirs, or injecting/re-injecting to recharge aquifers or dispose of highly saline water (Bryner, 2004). Surface discharge with no treatment yields the highest level of economically producible CBM (Bank & Kuuskraa, 2006). Due to this economic incentive to discharge directly to the surface, the water quality of surface freshwater systems is at risk in CBM producing regions.

In Mora County there has been recent interest in exploration for deposits of oil and gas. A search of the Bureau of Land Management's Land and Mineral Use Records indicates that oil and gas deposits have not been mapped in Mora County (BLM, 2009). Despite this, in 2008, the State Land Office leased 12,900 acres of school trust lands in the county to KHL, Inc, an oil and gas field exploration services company, for oil and gas exploration. Additionally, in the far west region of Mora County there are small tracts of Federal land available to be leased for exploration with a very small parcel of leased Federal land that has produced oil and gas since 1982 (Environmental Working Group, 2004). In fiscal year 2009, the county received $1.58 million in capital outlay money, mostly from oil and gas revenue, to pay for 60 community improvement projects including improvements to six acequias (New Mexico State Land Office, 2008). On private lands, KHL has offered to lease acreage for amounts ranging from $1/acre to $2.50/acre for a 10 year lease (Dudley, 2009).

Agriculture

Although the growing season in the Mora valley is short at approximately 90 days, there is significant agricultural activity in the valley. The market value of agricultural production was $7.6 million, with an average production value per farm of $12,843, totaling $1.8 million (24%) from crop sales and $5.8 million (76%) from livestock sales (USDA, 2007). Agricultural and farming water use in the county primarily consists of irrigation of alfalfa and mixed hay (6,528 acres in 2002), and livestock watering. More than 99% of irrigation water comes from surface water sources (Daniel B. Stephens & Associates, Inc., 2005).

Data in Table 5 shows that the total irrigated acreage in the County has remained relatively stable over the past 25 years.

Table 5 Total irrigated acreage in Mora County

Year	Total Acres Irrigated	Total Withdrawal (ac-ft)	Total Depletion (ac-ft)
1975	14,420	44,700	20,140
1980	13,760	42,660	19,550
1985	13,150	41,342	15,338
1990	13,990	38,174	17,715
1995	14,610	36,485	16,976
2000	14,880	32,671	15,234

(Source: Daniel B. Stephens & Associates, Inc., 2005)

Livestock raised in the watershed includes horses, cattle, alpacas and llamas. The estimated number of livestock in 2000 was 24,000 cattle and 400 sheep with an estimated water use of 10.2

gallons/day/head with 40% of this water using coming from surface water sources (Daniel B. Stephens & Associates, Inc., 2005).

Figure 13 shows agricultural water use in the county for the year 2000. Surface water (SW) and ground water (GW) withdrawals, depletions and return flows are shown.

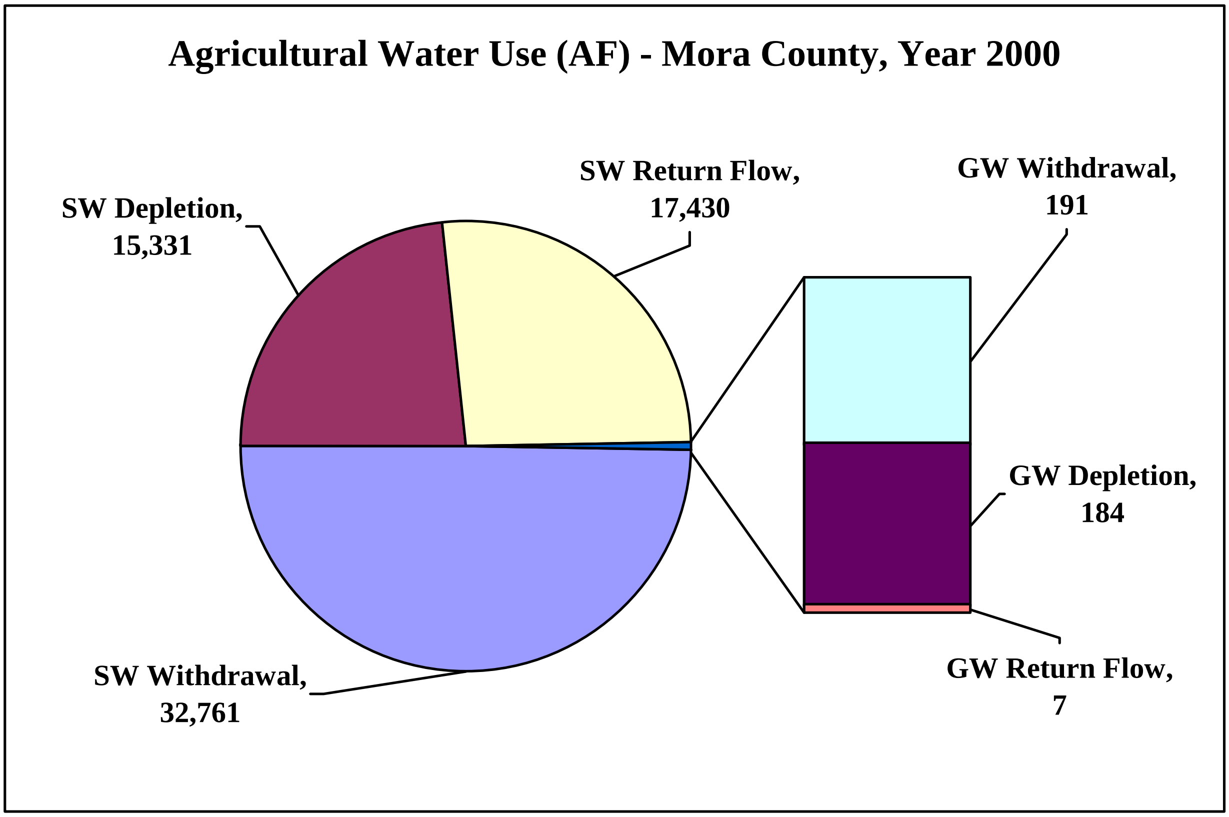


Figure 13. Agricultural water use in Mora County (NMOSE, 2000).

STUDY METHODOLOGY

The methodology used in the UNM Mora River study was adapted from the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) (EPA, 2003) as modified by the NMED SWQB (SWQB, 2007a). The EMAP protocol was abbreviated somewhat for this study due to time and, in some cases, limitations associated with availability of equipment and time. Deviations from EMAP procedures are noted below. By using standard protocols, current study results can be added to the limited data available about the Mora River system.

Three primary sites on the Mora River were selected by the project team leaders for EMAP evaluation. The three sites represent the upper reach of the Mora River as near to the headwaters as practicable, a middle reach just below the community of Mora, and a lower reach in a more open, flat terrain at the Wind River Ranch. Other locations within the watershed were chosen for flow and in some cases, water quality characterization and included other sites on the Mora River, its tributaries and several acequias. A particular interest of the team was to obtain

measurements of the flows of the river and the major acequias flowing east through the Mora valley (legal access being the primary constraint). Evaluation of these other sites was limited to flow measurement and in some cases measurement of water quality. In the discussion that follows all distances are referred to as the distance from EMAP site number 1, the site upstream from the community of Chacon.

Each site in the study was considered a “wadeable stream” using the EPA criteria: “the stream can be sampled with wadeable stream protocols, continuous water flow and greater than 50% of the sample reach is wadeable” (EPA, 2003). GPS coordinates and weather conditions, were recorded at each site to provide site description and document site conditions, and photographs were taken to document site characteristics. Measurements and site descriptions were recorded either on NMED SWQB data sheets or in field notebooks. Specific sites were chosen per EMAP protocol to be as much like a canal as possible using the following criteria (EMAP, 2003):

- segment of the river up/downstream is generally straight
- depths mostly greater than 15 centimeters and velocities mostly less than 0.15 meters per second
- flow is generally uniform with no obstructions, eddies, backwater or excessive turbulence
- a cross-section of the river bottom is U-shaped with a uniform streambed free of large debris (according the EMAP protocol, large rocks and debris may be removed *before* measurements, however, minor site adjustment up/down stream obviated the need to do this).

EMAP protocol for a full evaluation of a reach recommends selecting a baseline river transect and at five upstream and downstream locations for a total of 11 transect evaluations. However, in this study only five transects were evaluated at each of the three EMAP sites consisting of a central location, two transects upstream and two downstream. The stations were 100 feet apart so a total of 400 feet of stream was evaluated at each site. Due to time constraints flow measurements were only taken at four transect stations at the upper and middle Mora River locations, and three transect measurements were performed at the downstream at the Wind River Ranch location (EMAP site number 3).

At each of the EMAP sites, the study team divided into smaller teams to perform site evaluation tasks. These tasks were rotated at each primary site to ensure that each team member performed each task at least once. The primary team consisted of the seven UNM Water Resources Program graduate students and the three NM Tech undergraduate students. At the lower (Wind River Ranch) site, the UNM team was assisted by Las Vegas high school students attending an environmental workshop at the ranch.

Hydrology

River discharge in all cases was measured using the EMAP velocity-area procedure. This involves measuring the cross-section of a stream and the flow of the stream to obtain the amount of discharge in the stream at any point in time. However, because the flow is not uniform across a channel, multiple measurements of depth and flow must be taken to provide a better estimate of total discharge. To accomplish this, a measuring tape was staked across each transect near the

water surface perpendicular to the stream flow. The channel was divided into 10 to 20 equal segments with no interval less than 10 centimeters. Beginning at the left bank when facing downstream, the depth and flow at each interval was recorded. Depth was measured using a surveyor's rod and velocity was measured using a Marsh-McBirney Flo-Mate electromagnetic flow meter suspended at 40% of stream depth. Data were entered into a spreadsheet which was used to calculate flows and plot channel profiles at each transect.

Geomorphology

Geomorphologic characteristics at each of the three EMAP sites were recorded as described below.

- The thalweg depth (the deepest point in the stream's cross section) was measured every ten feet for 400 feet centered on the baseline transect using a surveyor's rod (Figure 14).

- At each transect, bank-full height and bank-full width (i.e., river height and width at a nominal two-year maximum flow) were identified and measured, as was the wetted-width (i.e., current width of river). Bank angle was recorded. An undercut bank was noted as having a negative bank angle.

- River bottom composition was characterized by selecting locations at each bank and at 25%, 50% and 75% across each transect. The surveyor's rod was placed at each location and the underlying substrate was estimated by determining the size of the particle(s) directly beneath the rod and the fractional embeddedness of the particle using EMAP criteria.

Figure 14. Measurement of thalweg depth at EMAP site number 2 downstream from the community of Mora.

Riparian Vegetation Cover and Human Influence

Specific measurements of the riparian vegetation density per EMAP procedures were not completed. However, visual inspection of the vegetation at each primary site was performed and recorded using the EMAP criteria for canopy, understory, and ground cover plants. Evidence of human influence on the river, beaver activity, presence of filamentous algae and other

indications of river health were also recorded on the appropriate NMED SWQB assessment forms. Photographs were taken looking upstream and downstream at each site.

Benthic Macroinvertebrates

At the baseline transect for each primary site a two-foot wide net was stretched across a representative riffle section of the river and firmly seated to the bottom. Immediately upstream of the net, a team member(s) kicked about the river bottom and disturbed/lifted rocks on the bottom to dislodge organisms clinging to the substrate. The net was quickly and cleanly lifted into the upstream flow and the contents deposited onto two collection trays. The net was rinsed with water from a bucket to dislodge organisms onto the trays. Organisms were then identified using the Taxonomic Key to Benthic Macroinvertebrates from the Hoosier Riverwatch website, sponsored by the Indiana Department of Resources Division of Fish and Wildlife. Organisms were then totaled by type and sorted as one of four Pollution Tolerant (PT) Index Groups as identified by Hoosier Riverwatch to create a Pollution Tolerance Index Rating (PTIR) (Hoosier Riverwatch). Two slight deviations from the Hoosier Riverwatch forms were used. In some cases similar organisms were lumped together when the Hoosier Riverwatch sheet did not accommodate all organisms identified in the sample. A more significant modification was in the case of red water mites found in the upper reach of the Mora River. From the Sapello River assessment (Thomson & Ali, 2008), it was noted that water mites are "one of the best indicators of the quality of the stream environment". From this information the water mite was added to the Hoosier Riverwatch PT Group 1 list (most intolerant organisms) to reflect its value as an indicator of high quality aquatic conditions in the PTIR.

Water Chemistry

At the central transect for each EMAP site and at selected other sites, the pH, temperature, electro-conductivity (EC), and dissolved oxygen (DO) were measured, and water samples were collected for determination of alkalinity, metals and non-metal constituents as described below.

An Oakton multi-probe meter was used to measure pH, temperature, and EC of river water samples. The probe was calibrated with a buffer solution of pH 7. A Yellow Springs Instruments (YSI) DO meter was used to measure DO in the river. The DO meter was calibrated at each site to correct for site elevation prior to measuring DO. Elevation at each site was determined using handheld GPS receivers.

Prior to any disturbance of a site a one liter sample of river water was collected in a clean plastic bottle which had been acid-washed and rinsed with 18MΩ (de-ionized) water. The sample bottles were rinsed with river water prior to collecting a sample. The bottles were completely filled to achieve zero headspace. Each evening the water samples collected that day were prepared for analysis for preservation. Two 125 ml portions of each sample were filtered through Whatman Qualitative Paper filter to remove suspended material and placed in plastic bottles. Approximately 10 drops of HNO_3 were placed in one of the bottles to lower the pH to less than 2. Both bottles were then placed on ice for preservation. The acidified and filtered water was analyzed for the concentration of metals while the filtered water was analyzed for anions.

A third aliquot of each filtered sample collected during the day was used to measure alkalinity by acid titration using dilute, standardized sulfuric acid (0.02 N H_2SO_4). Two indicators, phenol

phthalein and bromocrysol methylred (BC-MR), were used to test for carbonate and bicarbonate alkalinity respectively.

After completing the field work, all of the water samples were analyzed for metal and non-metal constituents in the Environmental Analysis Laboratory of the Department of Earth and Planetary Sciences at UNM. Metal concentrations were measured using an Optima 5300 Dual View (DV) inductively coupled plasma optical emission spectrophotometer (ICP OES). Anion concentrations were measured using a Dionex Ion Chromatograph (IC). All samples were analyzed using procedures listed in Standard Methods (APHA et al., 2005).

RESULTS

Hydrology

Table 6 provides a summary of field measurements collected at each of the 23 sites sampled during this study. Field instruments were used to measure DO, EC, pH, air and water temperature, elevation, latitude and longitude, flow volume, depth, and width. Sample numbers 3, 12, 13, 17, and 19 are on the Mora River and thus were included in the Mora River averages. All other sites were acequias or tributaries. Note that all distances are reported as distance from site number 1 (sample number 1 in Table 6, the upper EMAP site located on the Mora River above the community of Chacon, the site closest to the headwaters of the river.

The locations corresponding to sample numbers 3, 13, and 17 were subjected to the full EMAP analysis procedures as described in the Study Methodology section of this report. The EMAP protocol includes a Rapid Assessment evaluation which evaluates ten characteristics of the stream including the substrate, sediment deposition, channel alteration and sinuosity, bank stability, and vegetation. Field measurements taken at the other 19 sites included determination of cross sectional area, flow, temperature, DO, pH, and/or EC. Water samples for chemical analysis were collected at most of these sites and are discussed below.

The upper Mora EMAP site number 1 is located near the headwaters approximately three miles above the community of Chacon at an elevation of nearly 8800 ft and is located in a sub-alpine forest. A few residential summer fishing camps are present and a gravel road follows the river near its left bank. This site was well above any land with agricultural activity and there were no acequias diverting water from the river. The river bottom substrate was a mixture of silt, cobbles, coarse sand, bedrock, and boulders. The left bank angle was 20 degrees from horizontal while the right bank angle was -60 degrees. The negative bank angle indicates an undercut bank which provides valuable habitat for fish. This site received a rapid assessment score of 134 out of 200, which is 67%.

Site #13, middle Mora River EMAP site number 2, is located downstream from the wastewater treatment plant discharge point at an elevation of 7100 ft and is adjacent to Highway 518, a high-traffic paved two-lane road. Cattle grazing occurs in a pasture adjacent to the river at this location, man-made debris that is thrown onto the highway finds its way into the river channel. The discharge point from the Mora community wastewater treatment plant is located at this site. The channel was straightened to construct the highway and bridge. The river bottom substrate is embedded between 25 - 50%, with a composition of silt/clay/muck and coarse gravel (16-

64mm). The left bank angle is 0 degrees, while the right bank angle is 80 degrees. This site received a rapid assessment score of 116 out of 200, which is 58%.

Site #17 on the lower Mora River, is located at the Wind River Ranch at an elevation of 6600 ft. The river in this section was previously straightened to maximize the area of an adjacent hay meadow, approximately 100 years ago (Wind River Ranch Foundation, 2008), although visual assessments show that the riparian vegetation has grown back, and the river is surrounded by small rocky cliffs and open grassland. The substrate is embedded between 30 - 90%, with a composition of small boulders, fine gravel, and mud/clay. This site was not analyzed by the rapid assessment protocol.

Table 6 Summary of field measurements

Name of Site	Sample #	pH	DO (mg/L)	EC (µS)	Temp (air) (°C)	Temp (H_20) (°C)	Elev (ft)	Dist from #3	Flow (cfs)	Rapid Assessment	Avg.Depth (ft)	Width (ft)
Santiago Creek	1	6.41	6.92	60.9		11.8	8131	17.8	6.38	(0-200)	0.97	7.6
Acequia at Chacon turnoff	2						7641	11.1	0.8		0.32	3.5
Upper reach of Mora River-EMAP site 1	3	8.95	8.5	247	8.4	7.8	8788	0	4.87	134	0.8	9.4
Mora research station - lower acequia	4	8.28	13	476	8.89	10.7	7287	16.3	11.53		1.05	4.42
Mora research station - upper acequia	5	7.82	13.6	172.2		9.7	7318	16.8	5.92		1.18	4.08
A002 acequia	6						7597	18.4	n/a		0.24	1.67
Fish hatchery outflow tank	7								1.38			
Fish hatchery inflow tank	8								n/a			
Fish hatchery discharge @ shed	9	7.23	14.9			13.7			1.38		0.54	2.83
Trambley acequia	11	7.84		516		15.9	7150	16.4	14.44		0.98	10
Mora River @ Allsups	12	8.12	9.6	402		14.8	7228	16.4	3.49		0.43	16.75
Middle reach of Mora River (Below WWTP discharge) – EMAP site 2	13	7.21	11.23	490		15.3	7098	17	38.78	116	0.85	27.5
La Cueva acequia culverts @ Hwy 518	14	7.3	10	491		10.9	7037	18.7	1.60		1.9	5.5
Lower reach of Mora River (Wind River Ranch) – EMAP site 3	17	8.01	13.15	561	19.6	16.4	6605	30.5	33.1	n/a	0.69	21

Name of Site	Sample #	pH	DO (mg/L)	EC (µS)	Temp (air) (°C)	Temp (H_20) (°C)	Elev (ft)	Dist from #3	Flow (cfs)	Rapid Assessment	Avg.Depth (ft)	Width (ft)
Wind River acequia	18						6573	30.5				
Mora River above confluence with Sapello	19	7.87	10.6	682		19.3	6401	35.4	5.44		1.53	32.5
Sapello River above confluence with Mora	20	7.84	11.7	630		20.8	6419	35.6	n/a			
El Carmel acequia	21						7124	16.9	5.59		0.52	8
Sapello River at Pritzlaff Ranch	22	7.55	13.5	262	20.3	14.4	8193	30.5	2.57		0.49	17

Yellow indicates EMAP sites, center transect included in table

Green indicates other sites on Mora River

One of the most intriguing issues regarding the Mora River is the impact of surface diversions in the Mora Valley. It is reported that nearly every summer a seven mile reach of the river from near Holman to the Highway 518 bridge downstream from the community of Mora becomes completely dry. Though this reach of the river was not completely dry during this study, the flow measured immediately upstream from the community of Mora (site number 12) was less than 10% of that at the 518 bridge (site number 13), 3.49 cfs versus 38.8 cfs. The main sources of flow to the river immediately upstream from the 518 bridge were the Trambley ditch (14.44 cfs), the unnamed acequia at the fish hatchery discharge shed (1.38 cfs), and the El Carmel acequia (5.59 cfs). These flows added to the flow in river upstream from the community total 24.9 cfs, or 64% of the flow in the river at the 518 bridge. It is likely that much and perhaps all of the difference of 13.9 cfs is runoff from drainage ditches in the community of Mora, most of which were flowing completely full during the week of this study.

The highly variable flow in the main stem of the Mora River is illustrated in Figure 15. It is recommended that future studies measure flow in the river between the head waters (mile 0 on this chart) and the community of Mora at the Allsups gasoline station (mile 16) to better understand the nature of flow in the river and the effects of acequia diversions.

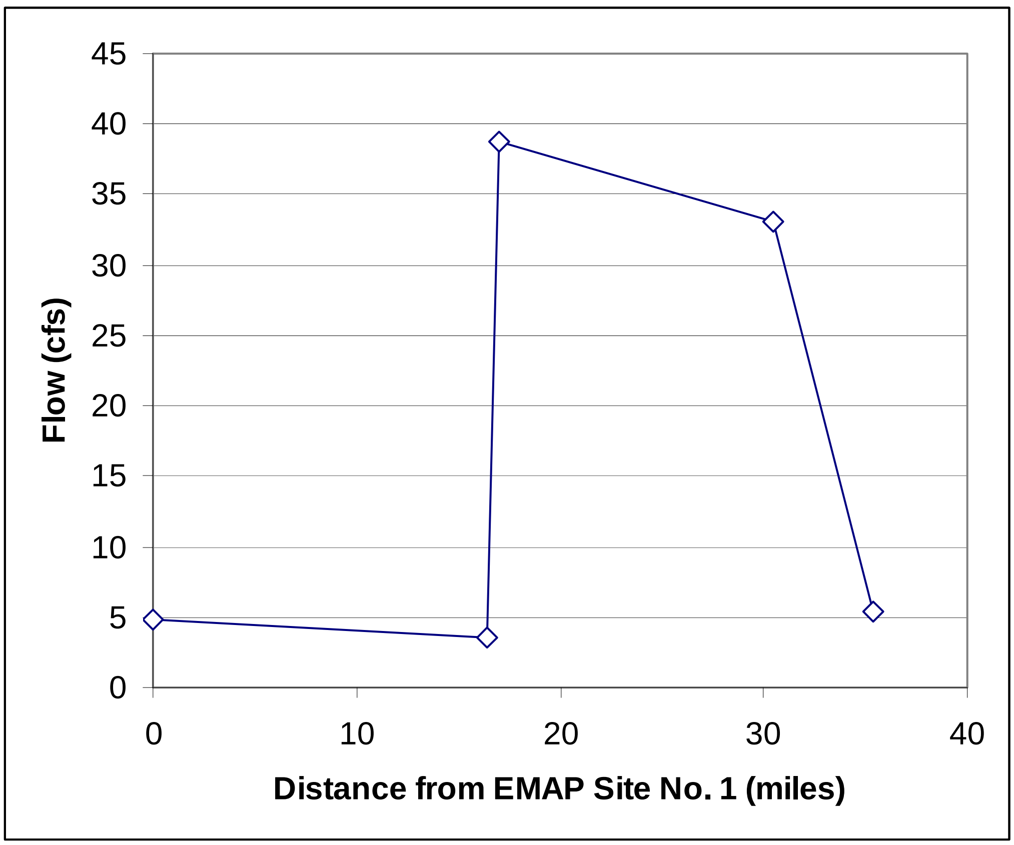


Figure 15. Flow in the main stem of the Mora River as a function of distance downstream from EMAP Site No. 1 near the headwaters.

The significance of this measurement is that the lack of water in the river in the Mora Valley is almost certainly due principally to the diversion of surface water for agricultural use. Further,

reestablishment of flow in the river downstream from the community of Mora is due almost entirely to water agricultural return flows, surface runoff in the community of Mora, and water in acequias not used for irrigation. This observation has important consequences when considering water quality impacts on the river downstream from the highway 518 bridge as it means that virtually all of this water has been subjected to direct human influence.

There is little change in pH and DO along the length of the main stem of the Mora River, although there is some variability in the acequias and tributaries (Figure 16 and Figure 17). The ideal pH for trout is less than 8, therefore since nearly all the sampled reaches are below this level all sampled reaches have a safe pH for trout (Seals, 2009). Dissolved oxygen (DO) levels should be greater than 5-6 mg/L to support a healthy cold water fish population (North Carolina State University, 1998) and it is clear that water in the Mora River meets this criteria.

Note that at several locations in the lower part of the watershed the DO concentrations were substantially greater than the saturation value. The saturation concentration is that which occurs when the solution is in equilibrium with the atmosphere. The DO saturation levels in the Mora River watershed ranged from about 8 mg/L to near 10 mg/L, depending on elevation and water temperature, yet several of the sampling sites had DO concentrations much higher than this, particularly in the Mora Valley and below (Figure 17). It is believed that these high levels are the result of photosynthetic oxygen production by aquatic plants, particularly algae, which are stimulated by elevated nutrient concentrations. This observation is consistent with the finding of impairment of the Mora River by the NMED SWQB (SWQB, 2007a).

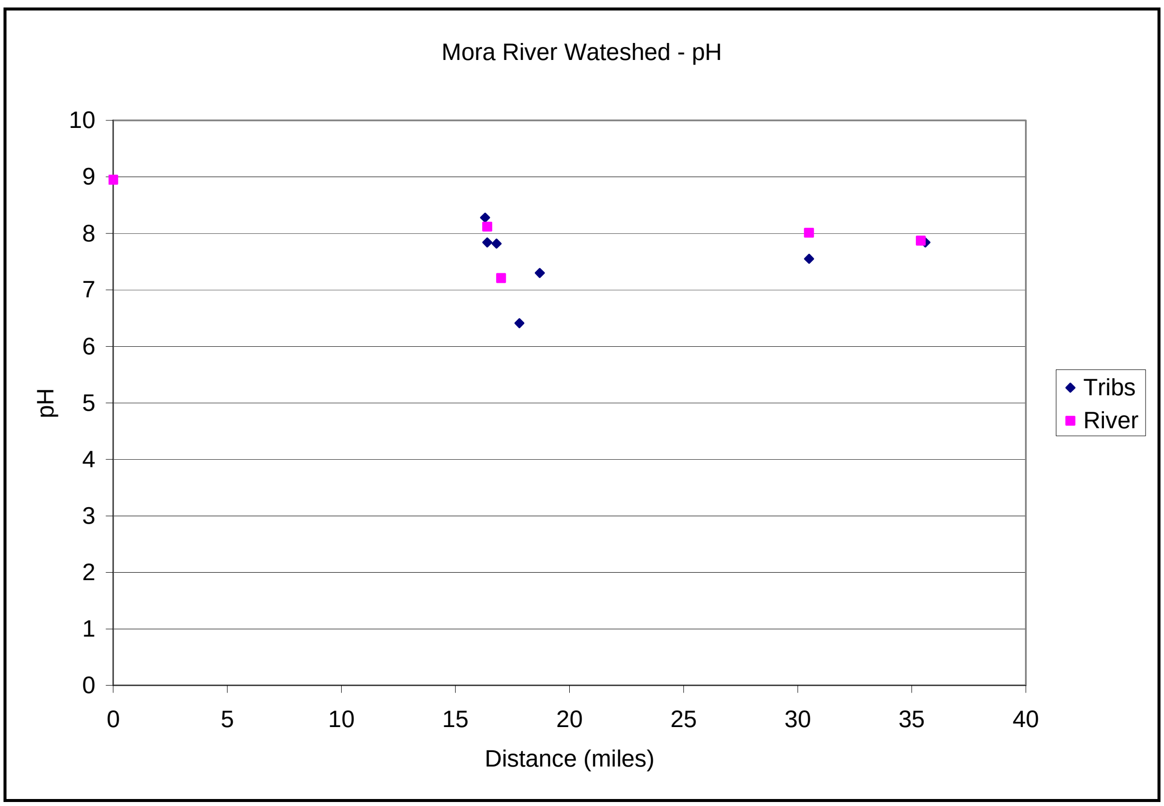


Figure 16. pH measurements in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1.

Field measurements of EC along the length of the Mora River are shown in Figure 18. These show a very clear increase in the ionic content of the water as one proceeds downstream. This increase is principally due to evaporation, especially in lower and warmer parts of the watershed, which increases the concentration of dissolved constituents. This is especially important for irrigation return flows. An example is the EC in the Trambley acequia (516 µS) which drains several square miles of pasture and is much higher than the EC in the river above the community of Mora (402 µS). The surface water standard for EC upstream from Highway 434 is 500 µS (20.6.4.309 NMAC).

Electrical conductivity is often used to estimate the total dissolved solids (TDS) in water. The correlation between TDS and EC depends on the nature of the ionic constituents in the solution. An approximate relationship for this watershed is (data comparing TDS and EC) is presented by the relation

$$\text{TDS (mg/L)} = 0.7 \text{ EC } (\mu\text{S})$$

Data comparing TDS and EC in water samples in the Mora River watershed have been measured by the SWQB (2007b). Thus, the approximate TDS of the river immediately above the confluence with the Sapello River is 480 mg/L. There are no surface water quality criteria for EC in the reach of the Mora between Shoemaker and Highway 434.

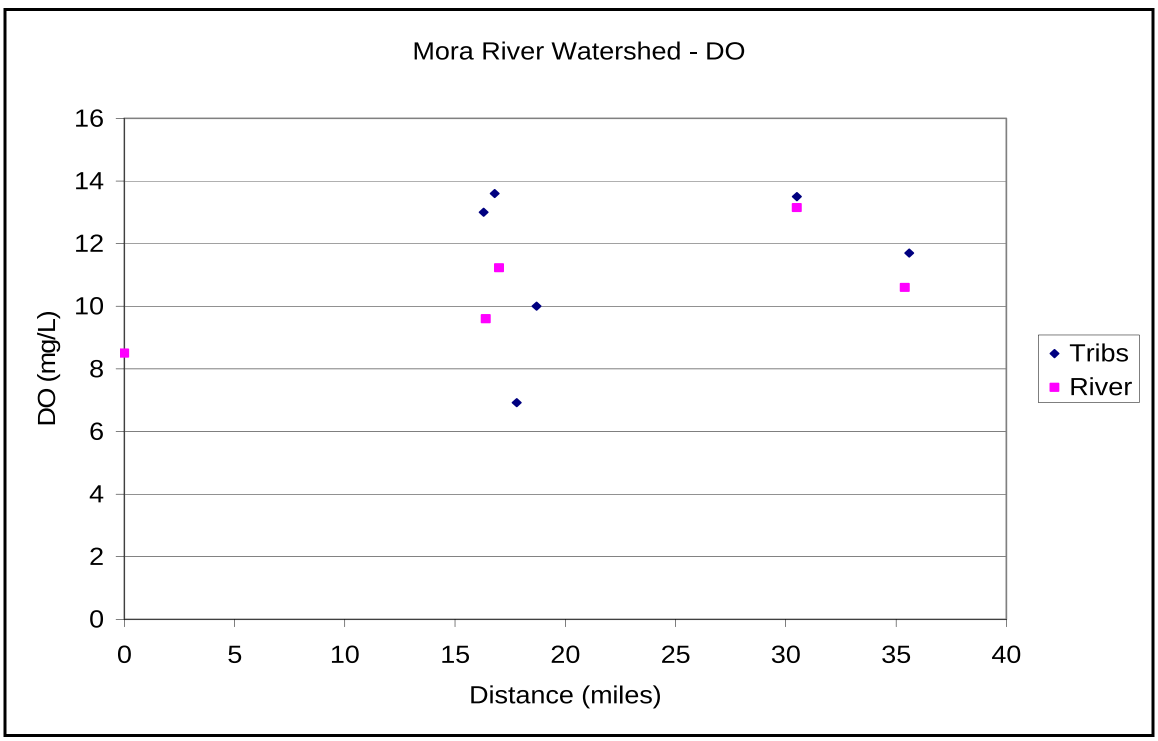


Figure 17. DO measurements in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1

Temperature measurements in the Mora River, its tributaries and acequias are plotted in Figure 19. The maximum water temperature for trout habitat is 60° F, or 15.5° C (Seals, Appendix D). The New Mexico stream standards for the river upstream from highway 434 is 68 °F (20 °C) (20.6.4.309 NMAC) and below highway 434 it is 77 °F (25 °C) (20.6.4.307 NMAC). Temperature standards were not violated during this study, but it should be remembered that this study was conducted early in the summer near the peak of spring runoff. Furthermore, the weather throughout the duration of the study was unseasonably cool which likely affected water temperatures measured during this study.

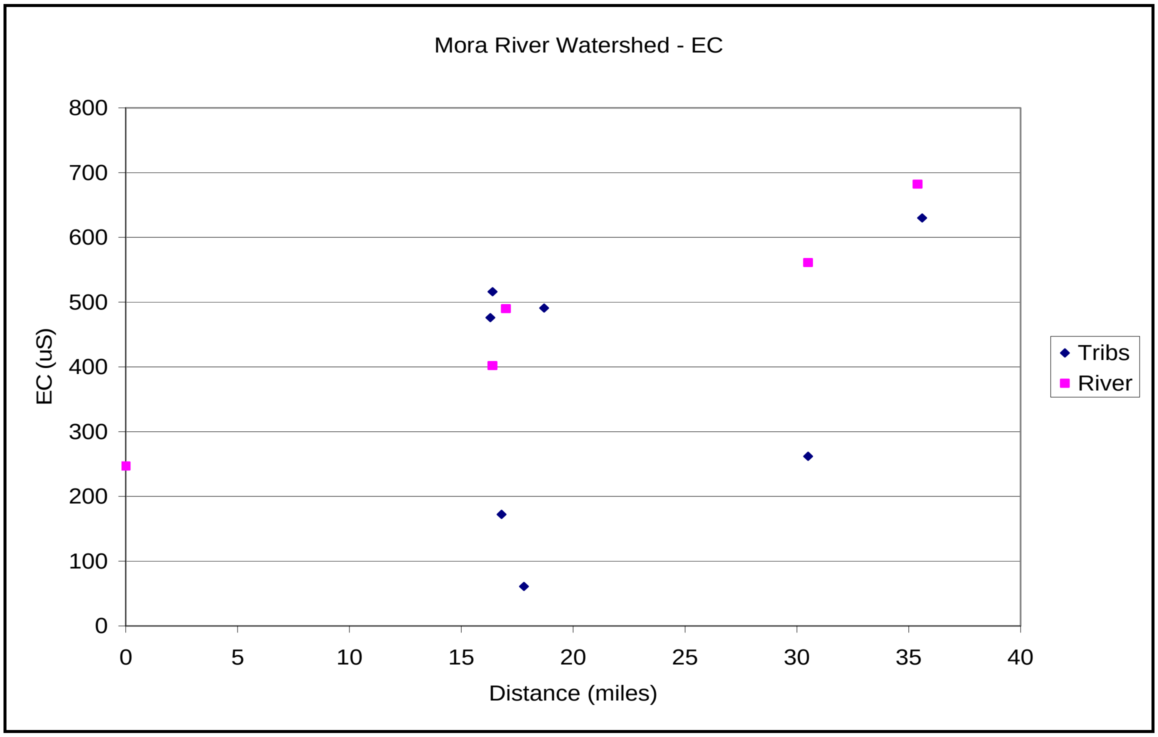


Figure 18 Electrical conductivity measurements in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1

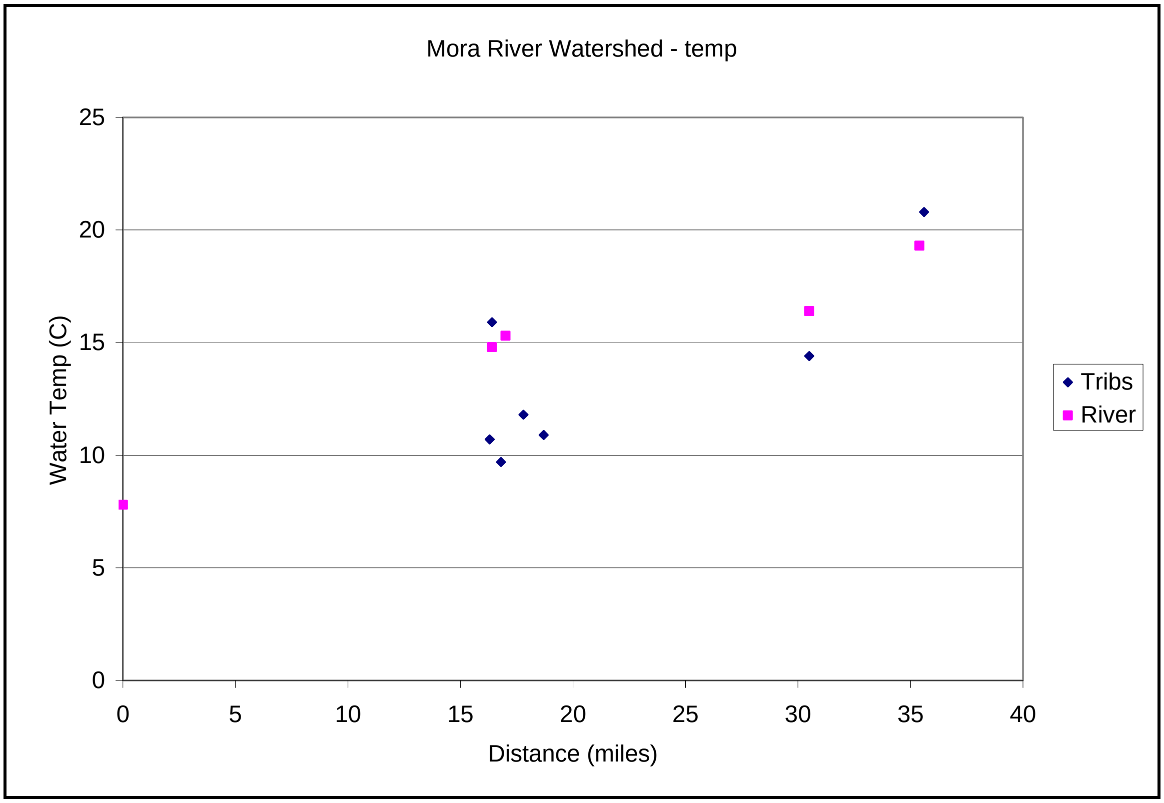


Figure 19 Temperature measurements in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1

Flow Measurements & Channel Characteristics

The EMAP procedures involve measurements of flow and geomorphic characteristics of multiple transects at each site. The flows measured at the transects at each of the EMAP sites are shown in Table 7. They give an estimate of the precision of flow measurements taken using state of the art flow meters and careful attention to procedures. The standard deviations of the measurements are reported and range from a minimum of 2% of the average flow to 14% of the average flow. The greatest variation was measured at the uppermost EMAP site and is due to the highly irregular channel bottom consisting of large gravel and small boulders, high water velocities with much turbulence, and relatively small stream channel. The least variability was at the lowest site which consisted of a straight, very uniform channel.

Table 7 Flow measurements at the three EMAP sites

Location on Mora River	Flow (cfs)	Width (ft)	Distance from Upper EMAP site
Upper EMAP Site			
Transect 1- 200 ft upstream	4.71	9.4	0
Transect 2 - 100 ft upstream	6.12	7	0
Transect 3 - Middle	4.87	9.4	0
Transect 4 - 100 ft downstream	4.52	9.5	0
Average (std. dev.)	**5.06 (0.72)**	**8.83 (1.22)**	
Middle EMAP Site			
Transect 1 - 100 ft upstream	38.19	21	17
Transect 2 - Middle	38.78	27.5	17
Transect 3 - 100 ft downstream	33.1	21	17
Average Flow (std. dev.)	**36.69 (3.12)**	**23.17 (3.75)**	
Lower EMAP Site			
Transect 1 - 200 ft upstream	32.55	30.8	30.5
Transect 2 - 100 ft upstream	31.97	24	30.5
Transect 3 - Middle	33.1	21	30.5
Average Flow (std. dev.)	**32.54 (0.56)**	**25.27 (5.02)**	

The flow data shows that the flow increases from the upper reach to the middle reach, and then decreases downstream to the lower reach. This decrease is believed to be due to acequia diversions, evaporation, and perhaps ground water infiltration. The channel width gradually increases as the river flows eastward reflecting increased peak flows and a flatter gradient.

Figure 20 shows plots of the thalweg depths at each of the three EMAP sites on the Mora River. As shown on the graphs, the thalweg depth at the upper reach is nearly 1.2 ft deep, at the middle reach is nearly 4.5 ft deep, and at the lower reach is nearly 2.5 ft deep. Within each site the thalweg varies greatly, which is an indicator of a healthy stream system as variations in channel depth provides habitat for aquatic organisms, while shallow riffle areas produce turbulence which aerates the water.

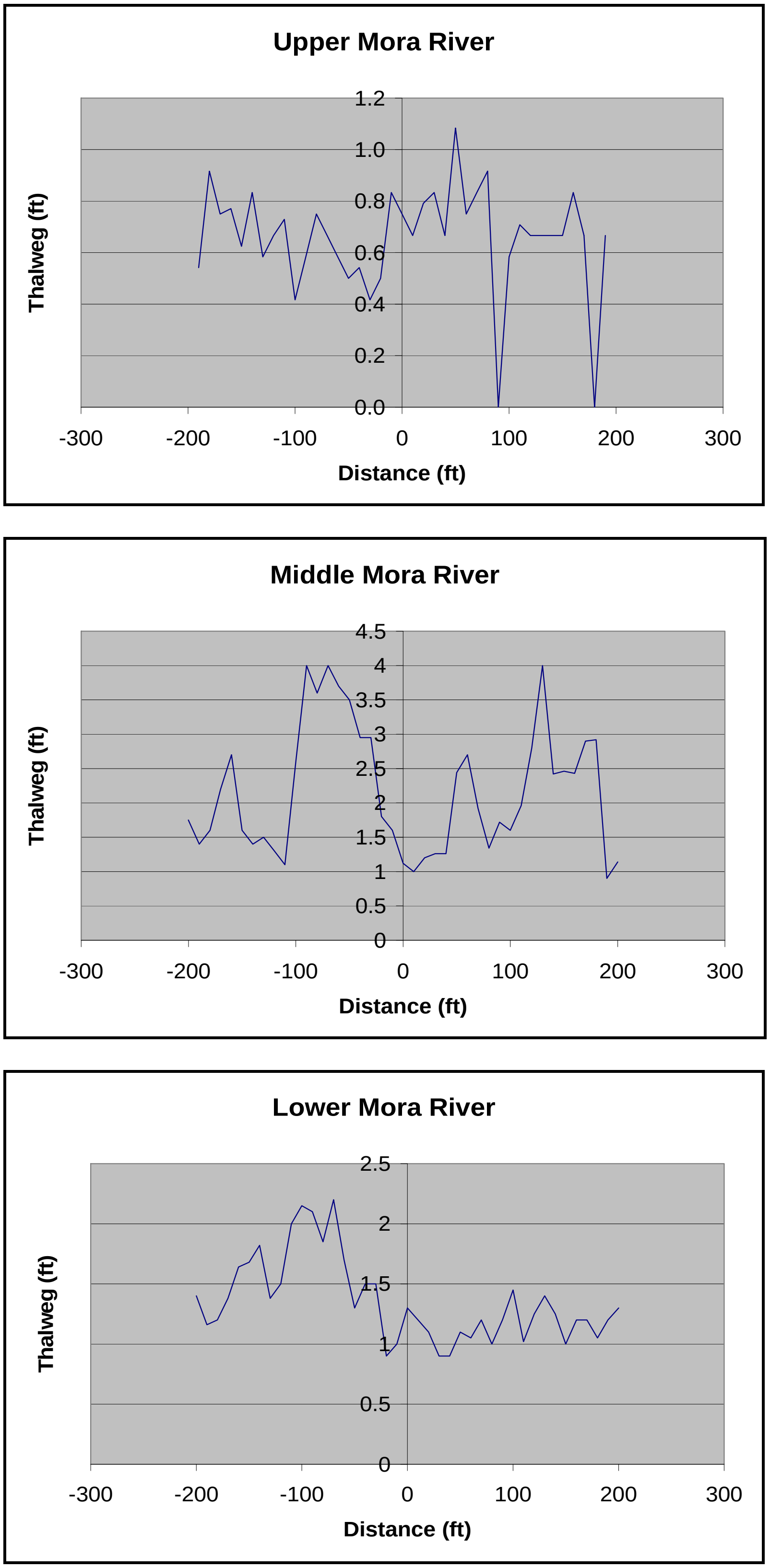


Figure 20 Plots of thalweg depths at the three EMAP sites

Water Quality Characteristics

In this study 23 water samples were collected and analyzed for major cations, anions and transition metals. Five samples were taken from the Mora River, two samples from water wells, and the remaining samples were collected from tributaries, acequias, or the discharge from the National Fish Hatchery at Mora. The five Mora River samples (sample IDs #3, 12, 13, 17 and 19) included those at the three EMAP sites, (upper reach of the Mora River above Chacon (sample ID #3) and ended at the lower segment of the river at Wind River Ranch (site #17)) as well as samples collected in the village of Mora and in the community of Watrous near the Mora River confluence with the Sapello River. The two ground water samples were taken at Ms. Rupert's home (site #23) and the inflow tank at the National Fish Hatchery (sample ID #8). Outflow from the fish hatchery were taken immediately after wastewater treatment at the hatchery (sample ID collected from tributaries or acequias of the Mora River.

The parameters that were analyzed for in the water samples are listed in Table 8. No detectable concentrations were found of nitrite (NO_2^-), chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), or lead (Pb). The water quality results were compared to New Mexico stream standards established by the New Mexico Water Quality Control Commission (20.6.4 NMAC).

Table 8. List of chemical constituents analyzed for in water samples.

Major Cations	Major Anions	Transition Metals	Nutrients
Ca	HCO_3^-/CO_3^{2-}	B	NO_3^-
Mg	Cl^-	Si	NO_2^-
Na	SO_4^{2-}	Al	NH_4^+/NH_3
K		Cr	PO_4^{3-}
Ba		Mn	
		Fe	
		Co	
		Ni	
		Cu	
		Zn	
		As	
		Se	
		Pb	

Alkalinity titrations were completed in the field within 12 hours while all other chemical analyses were performed at the University of New Mexico Environmental Analysis Laboratory in the Department of Earth and Planetary Sciences. Cations were analyzed using a Perkin Elmer Optima 5300DV Inductively Coupled Plasma Optical Emission Spectrometer (ICP OES) with filtered and acidified sample water. The anion analysis was completed using a Dionex EX500 ion chromatograph with filtered sample water. Results of all chemical analyses are shown in Table 9 for anions and Table 10 for metals and cations.

Aluminum analyses gave concentrations greater than stream standards for aquatic life in five river water samples (#3, 12, 13, 17, and 19). Chronic aquatic life standards are 87 μg/L. It was suspected that this might be due to the presence of colloidal aluminum particles passing through the qualitative filter paper. Accordingly, a second set of Al analyses were conducted on water samples filtered through 0.2 μm membrane filters and acidified. This procedure was used for water samples from the three EMAP study sites along with samples from the Mora River and Sapello River sites just above their confluence (sample numbers 3, 13, 17, 19 and 20). None of these analyses detected aluminum above the MDL of 25 μg/L. The difference between the first analyses of samples filtered with qualitative filter paper and the second samples filtered using 0.2 μm membrane filters provides strong evidence that aluminum is present in the water samples as colloidal suspensions. This may have implications for future water quality assessments as previous stream assessments by the SWQB of the NMED have found reaches of other streams in the Canadian River watershed and elsewhere that did not meet their designated use due to elevated aluminum concentrations.

Concerns about high plant nutrient concentrations in the water due to livestock impact, agriculture activities, and on-site wastewater treatment and disposal were considered in this study. Nitrate (NO_3^-) concentrations were low but present at sufficiently high levels to contribute to eutrophication. Average nitrate concentration for the reach analyzed was .094 mg/L reported as nitrogen. In comparison the analysis of the Sapello River nitrate concentration at Watrous (Thomson & Ali, 2008) was not detectable above the MDL. The NMED SWQB (2007) report found a 0.03 mg/L concentration of total nitrogen within the same reach. Figure 21 shows nitrate concentrations in the Mora River and other water samples versus distance from the upper Mora EMAP site.

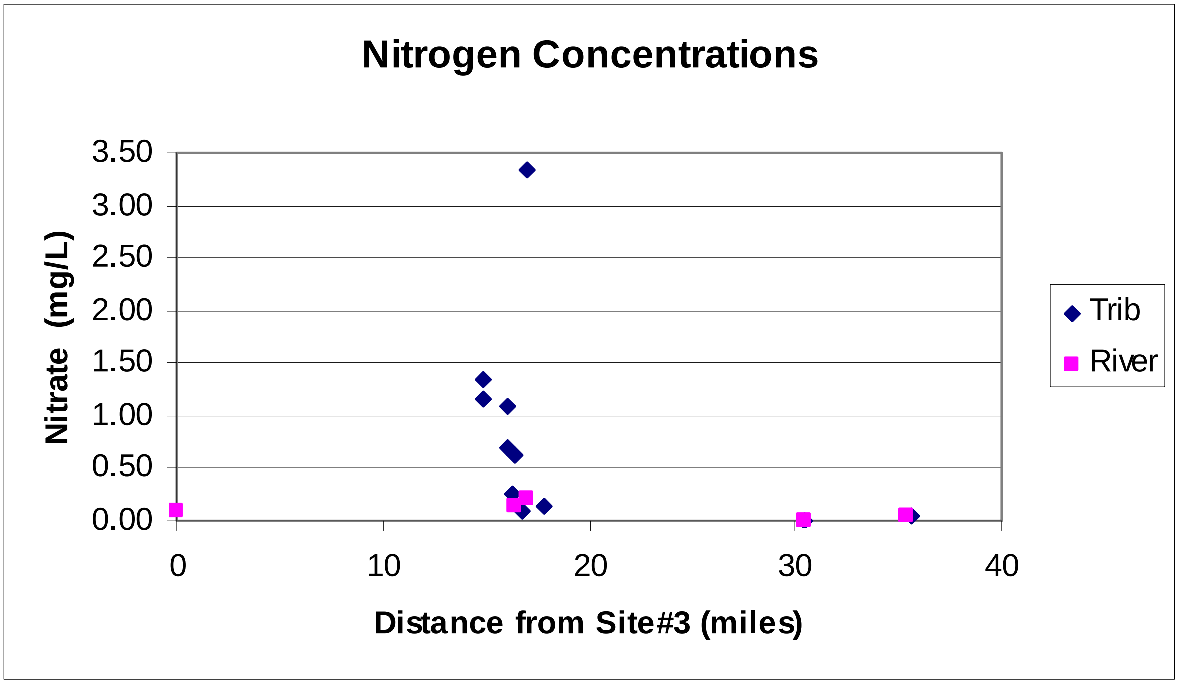


Figure 21 Nitrate nitrogen concentrations in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1 (mg NO_3^-/L reported as N).

The filtered ammonium concentrations (NH_4-N mg/L) in the water samples are shown in Figure 22. The ammonium concentrations in the Mora River range from 0.25 to 0.11 mg/L while the concentrations in the other samples range from .05 to .45 mg/L. Results are shown in Table 9 and Figure 22.

The NMED has established a goal of 0.38 mg/L for total nitrogen in the TMDL for the Canadian River and its tributaries (SWQB, 2007b). Although this study did not measure organic nitrogen (ammonium and organic nitrogen are measured together as total kjeldahl nitrogen or TKN), the sum of nitrate and ammonium concentrations in the river ranged from 0.34 mg/L at the upper EMAP site and decreased to 0.16 mg/L above the confluence with the Sapello River at Watrous. Recognize that these measurements were taken near peak flow conditions when dilution would be expected to reduce the nitrogen concentrations. It is possible that later in the summer or fall when dilution effects are less significant that the total nitrogen concentrations may exceed the TMDL goal (see historic flow data in Figure 8).

The TMDL also established a goal for total phosphorous in the river of 0.03 mg/L. Concentrations near or slightly above this value were measured at several locations along the river (Table 9). However, this concentration is close to the method detection limit (MDL) for the procedures used, and therefore definitive interpretation of these results cannot be made. The fact that detectable phosphorous concentrations were found suggests that further investigation of this parameter and its impact on water quality is warranted.

Although the river samples collected during this study met the water quality goals established by the TMDL it is important to note that the quality of some of the tributaries and ditches that flow to the Mora do not. This is consistent with the finding that non-point sources are important contributors to contaminants in the watershed (Table 9 and Table 10).

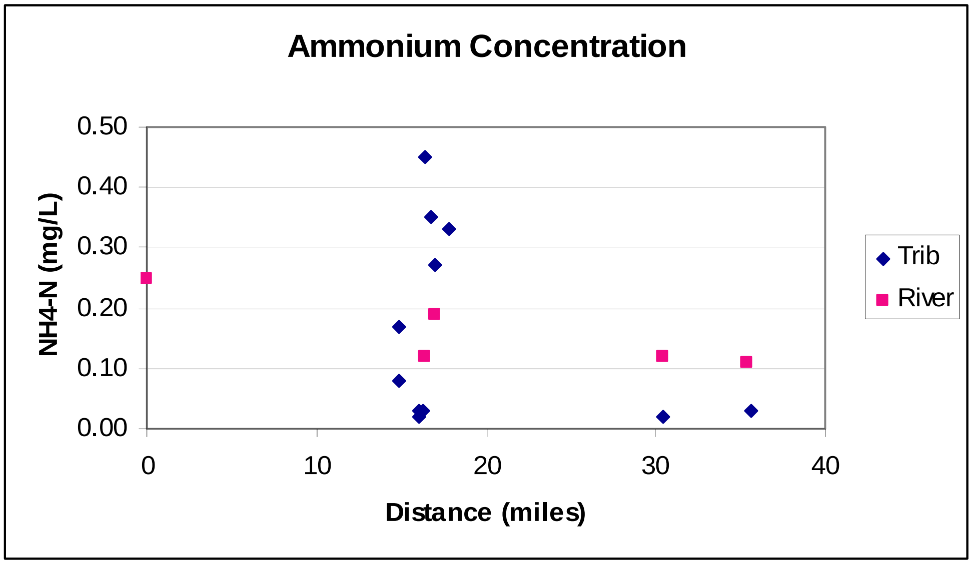


Figure 22 Ammonium nitrogen concentrations in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1 (mg NH_4^+/L reported as N)

Calcium concentrations in ground water samples were roughly twice as high as those in the upper reaches of the Mora River. It is believed that they are due to the soil characteristics in the Mora watershed, many of which have high fractions of calcareous minerals such as limestone ($CaCO_3{}^{2-}$). Calcium concentrations in the river and acequias increase as the river flows eastward, presumably due to the influence of weathering of basin soils and concentration increases due to evaporative water losses. Figure 23 shows calcium concentrations in the Mora River and other waters versus distance from the upper Mora EMAP site.

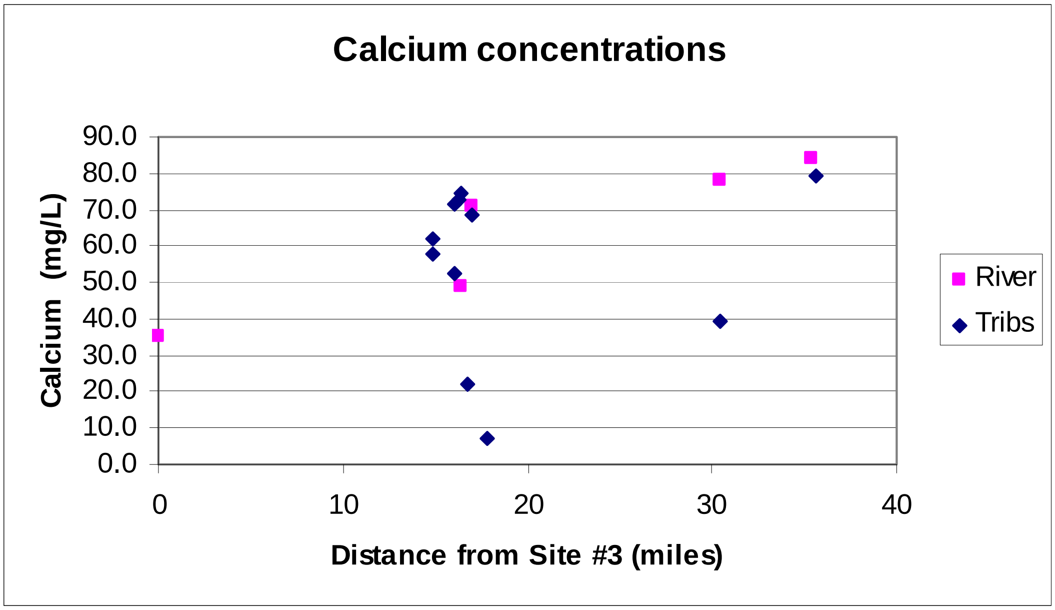


Figure 23 Calcium concentrations in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1

Alkalinity was measured at each water quality sampling site. It varied within the sample region from 23 mg $CaCO_3$/L to 244 mg $CaCO_3$/L. Concentrations increased further down the river likely due to dissolution of soil minerals in the basin and concentration by evaporation. Figure 24 depicts alkalinity along the sampled reaches of the river and other waters.

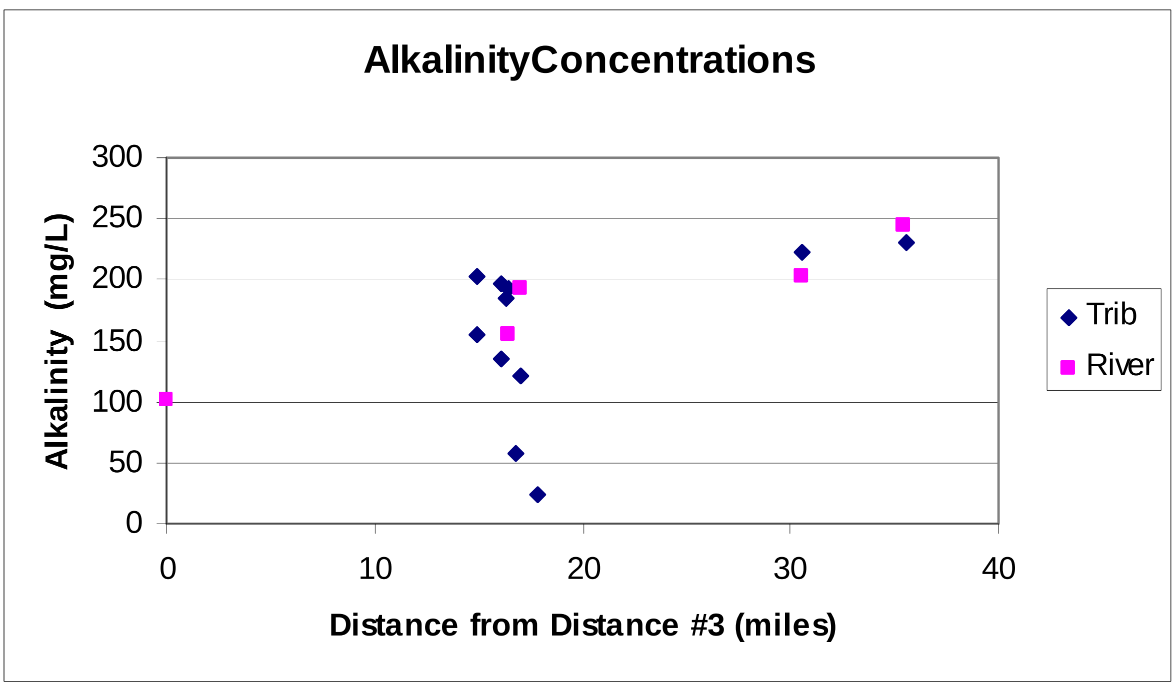


Figure 24 Alkalinity in the Mora River, its tributaries and acequias plotted versus distance from EMAP site number 1 (mg $CaCO_3$/L)

Table 9 Summary of chemical analysis for anions and ammonium/ammonia

Sample No.	Location	Distance from #3	Fluoride	Chloride	Bromide	Nitrate	Ammoniua	Phosphate	Sulfate	Alkalinity
		(miles)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	(mg/L)	(mg/L)
3	Upper Reach of Mora River	0	0.06	0.88	0	0.09	0.25	0	17.96	102
7	Fish Hatchery Outflow Tank	14.9	0.36	5.49	0	1.34	0.08	0	52.34	154
8	Fish Hatchery Inflow Tank (gw)	14.9	0.29	3.84	0	1.17	0.17	0	53.61	202
10	Fish Hatchery Acequia Downstream	16.1	3.88	6.15	0.06	0.69	0.02	0	73.17	197
9	Fish Hatchery Discharge Shed	16.1	0.44	6.37	0.01	1.08	0.03	0.04	48.95	136
4	Mora Research Station Lower Acequia	16.3	0.12	2.79	0.01	0.25	0.03	0.04	65.39	184
11	Trambley Acequia	16.4	0.15	4.59	0	0.63	0.45	0.06	76.7	192
12	Mora River at Allsups	16.4	0.08	3	0.03	0.13	0.12	0.02	54.26	155
5	Mora Research Station Upper Acequia	16.8	0.21	1.58	0	0.1	0.35	0.03	13.82	57
13	Middle Reach Mora River	17	0.19	5.26	0.04	0.2	0.19	0	64.57	193
23	Ms. Rupert's Tap Water (gw)	17	0.24	7.18	0	3.33	0.27	0	10.16	122
1	Santiago Creek	17.8	0.02	1.1	0	0.15	0.33	3.51	0	23
17	Lower Reach Mora River	30.5	0.13	6.58	0	0	0.12	0	103.18	203
22	Rio Sapello at Pritzlaff ranch	30.5	0.07	1.11	0	0	0.02	0.03	8.32	223
19	Mora River above confluence with Sapello	35.4	0.22	10.92	0	0.05	0.11	0	133.93	244
20	Sapello River above confluence with Mora	35.6	0.17	9.42	0.04	0.05	0.03	0	112.66	230

Table 10 Summary of chemical analysis for metals

No.	Location	Dist. From #3	Aluminum	Aluminum (after .2 um filter)	Boron	Barium	Calcium	Iron	Potassium	Magnesium	Sodium	Silicon	Strontium
#		(miles)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
3	Upper Reach of Mora River	0	0.14	-0.08	0.44		35.00		0.66	5.65	3.58	3.51	0.25
7	Fish Hatchery Outflow Tank	14.9	0.13		0.42	0.03	57.66		1.19	8.43	10.81	8.00	0.33
8	Fish Hatchery Inflow Tank (gw)	14.9	0.14		0.44	0.04	61.88		1.09	8.81	9.64	7.23	0.36
10	Fish Hatchery Acequia Downstream	16.1	0.19		0.38	0.00	71.54	0.01	1.26	13.84	10.16	4.87	0.66
9	Fish Hatchery Discharge Shed	16.1	0.14		0.43	0.02	52.42		1.11	8.05	11.45	8.80	0.29
4	Mora Research Station Lower Acequia	16.3	0.20		0.46	0.08	72.46	0.29	1.07	14.04	8.00	4.25	0.74
11	Trembley Acequia	16.4	0.19		0.39	0.00	74.49	0.02	1.10	13.86	9.00	4.52	0.64
12	Mora River at Allsups	16.4	0.19		0.39		48.63	0.02	0.98	10.48	5.94	3.83	0.49
5	Mora Research Station Upper Acequia	16.8	0.21		0.43		22.14	0.02	0.49	3.06	1.89	2.34	0.11
13	Middle Reach Mora River	17	0.21	-0.09	0.49	0.01	70.90	0.02	1.14	12.50	9.51	4.36	0.56
23	Ms. Rupert's Tap Water (gw)	17	0.13		0.40		68.57		0.83	12.44	10.07	6.51	0.87
1	Santiago Creek	17.8	0.22		0.44		6.96	0.10	0.63	1.15	2.13	3.27	0.01
17	Lower Reach Mora River	30.5	0.21	-0.09	0.50	0.01	78.02	0.04	2.01	17.66	15.63	4.74	0.67

No.	Location	Dist. From #3	Aluminum	Aluminum (after .2 um filter)	Boron	Barium	Calcium	Iron	Potassium	Magnesium	Sodium	Silicon	Strontium
22	Rio Sapello at Pritzlaff ranch	30.5	0.18		0.37		39.50	0.19	1.30	5.13	4.10	5.40	0.15
19	Mora River Watrous	35.4	0.14	-0.09	0.44	0.02	83.89	0.01	1.86	21.30	27.84	7.31	0.72
20	Sapello River Confluence	35.6	0.18	-0.09	0.40	0.00	79.34	0.14	1.40	15.87	27.12	5.81	0.56

Riparian Vegetation/Human Influence

The team's recorded observations of riparian vegetation and evidence of human influence on the river channel at the upper and middle Mora River sites are included in Appendix B. In general, the left bank at the upper site had limited riparian vegetation and biodiversity as the river flows through a meadow. There may be some historical straightening of the channel resulting from construction of the dirt road on the left bank. The left bank lacked canopy trees and understory but had a lush cover of meadow grasses. The right bank at the upper site had mixed species of canopy, understory and groundcover. There were no obvious human influences except the gravel road. Both the left bank and the right bank at the middle Mora River site (EMAP site number 2) had good growth of mixed riparian species. However, human influence on the river was prominent due to proximity to the highway, the bridge over the river, the wastewater discharge, and cattle grazing in the area. The riparian vegetation at the Wind River Ranch (EMAP site number 3) was in excellent condition with a good mixture of grass, understory and canopy vegetation (Figure 27). There were no signs of human influence, although the ranch manager reported that the river had been straightened approximately 100 years ago to expand a meadow used for crop production and grazing.

Benthic Macroinvertebrates

Benthic macroinvertebrates inhabit channels, clinging to the substrate or the bottom of water courses. Certain classes of these organisms have proven more intolerant of pollution or other stressors (e.g., heat, direct sunlight, stream disturbance, less oxygen) than others. Several methods of measuring stream health by using a combination of the diversity of organisms within the stream and the relative abundance of the stress tolerant vs. the stress intolerant organisms have been formulated (EPA, 2003). This study uses a Pollution Tolerance Index (PTI) rating adopted from the Hoosier Riverwatch website (Hoosier Riverwatch). The system separates the organisms by taxa into four groups of varying pollution tolerance or PTI Groups where PTI Group 1 contains taxa which are pollution intolerant, PTI Group 2 organisms which are moderately intolerant, PTI Group 3 organisms are fairly tolerant, and PTI Group 4 organisms are very tolerant. The PTI Groups are then weighted and totaled to provide a Pollution Tolerance Index Rating (PTIR). According to this system all three primary study reaches of the Mora River rated excellent with the upper, middle, and lower reaches achieving scores of 24, 37, and 36 respectively. An excellent rating is defined as any score over 22, good is 17-22, fair is 11-16, and poor is 10 or less. Figure 25 shows the total number of taxa per PTI Group and Figure 26 shows both the weighted scores for the PTI Groups and the final Pollution Tolerance Index Rating (PTIR) for the three study sites. The data sheets tabulated by organism and showing the weighted ratings calculations are located in Appendix A: Biological Monitoring Data Sheets.

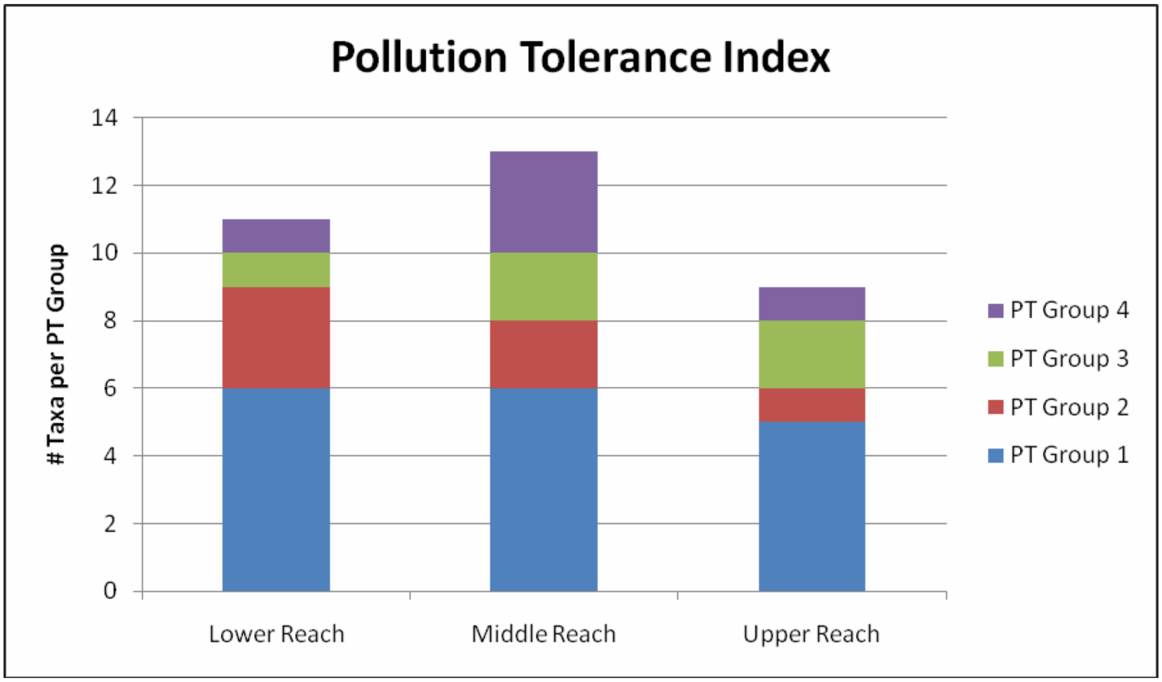


Figure 25. Pollution Tolerance Index rating at each of the EMAP sites.

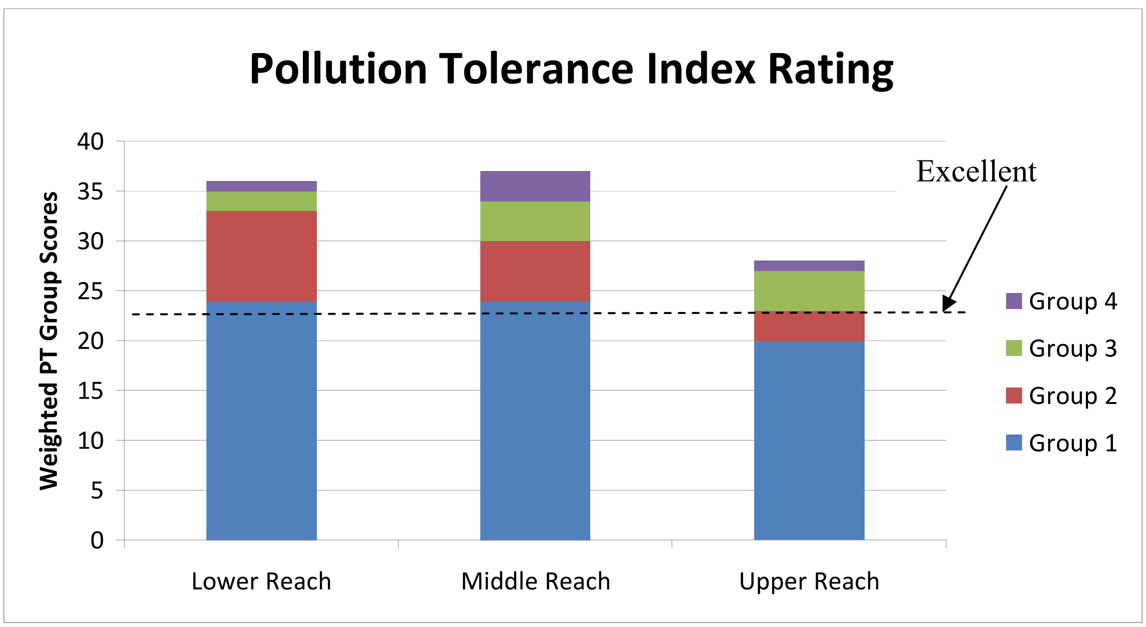


Figure 26 Weighted Pollution Tolerance Index Rating at each of the EMAP sites

As shown in Figure 25, the PTI at the upper reach is somewhat lower than that at the middle and lower reach EMAP sites. Possible explanations for this unexpected result include: 1) the reach was evaluated at the peak of spring runoff and soon enough after the winter thaw that a fully

diverse population of organisms had not developed; 2) inconsistent collection and/or identification procedures as a result of this reach being the first site visited by the research team. Regardless of this potential inconsistency, it can be said that, based on this benthic macroinvertebrate rating scale, the Mora River shows scores reflecting excellent aquatic conditions at all sites investigated.

Figure 27. Photograph of the Mora River at the Wind River Ranch (EMAP site number 3).

INFORMATION GAPS AND FUTURE DATA NEEDS

The UNM Water Resources Program study team received multiple reports from Mora Valley residents that there is a seven-mile segment of the Mora River between the communities of Holman and Mora that is dry for much of the summer. Though this was not directly observed during this study, the flow in the river immediately upstream from the community of Mora was only 10% of its flow two miles farther downstream where two large acequias and agricultural drains discharge to the river (Figure 15). It is assumed that diversions to the acequias remove all of the water from the river. However, because no maps are available showing acequia diversion points and access to many ditches was limited, flows in most acequias in the watershed were not measured. Therefore, determining a water balance for the Mora River during this study was not possible. Locating and mapping the acequias and determining the flows through them is important to understanding the Mora River system. Additionally, acquiring knowledge from community members and especially Mayordomos would increase the understanding of stream diversions in the watershed, and is vitally important for retaining cultural and historical significance that is related to the acequias.

There are numerous tributary creeks in the watershed, some of which were sampled and reported on by the NMED (SWQB, 2007a); however there are many which have not been investigated. An extended future study to collect and analyze more flow and water quality data on the Mora and its tributaries is required for a thorough understanding of the watershed as a whole.

This study sampled only two ground water locations, therefore a more thorough analyses from numerous ground water source locations in the watershed is needed in order to understand the ground water quality and quantity.

The impact of potential climate change on water resources and stream characteristics needs further investigation. Well placed and increased numbers of weather and stream gaging stations in the Mora River watershed would enhance data collection. This information could then be integrated with ground water data, diversions, and other usage and inputs to create a water budget. A water budget would improve management of the watershed.

Perhaps the most important shortcoming of this study was that it only documents conditions during the second week of June, 2009. This time period reflects conditions near the peak of spring runoff. It is clear that the characteristics of the river and its tributaries, especially flow, vary seasonally. A more comprehensive study would include assessment of the river throughout the course of the year, particularly during late July and late fall, periods of reduced flow when the benefits to water quality of dilution are minimized. An assessment in late July would be especially informative because the impacts of wastewater discharges, agriculture and other non-point sources of pollution (i.e. summer residences) on the river would be expected to be most significant.

CONCLUSIONS

The objective of this study was to assess the Mora River, its tributaries and acequias upstream from Watrous, NM by evaluating their hydrologic, biologic, chemical, and geomorphic characteristics. The results will serve as a baseline for future studies on the river. The benthic macroinvertebrate analyses indicated that the Mora River is in excellent condition. The hydrologic and geomorphic analyses are consistent with a high quality stream. Visual observations of vegetation at sample and EMAP assessment locations suggest the riparian conditions along the river are good. Finally, water quality analyses of the river showed that during the week of this study the water quality in the Mora River met surface water quality criteria for its designated uses established by NM surface water quality standards. However, the concentrations of nitrogen and phosphorous are both close to goals established in a TMDL for the Canadian River and its tributaries (SWQB, 2007b). Further, there was visual evidence of plant and algal growth in the river, possibly due to stimulation from aquatic nutrients. Because these conditions were found during the peak of spring runoff it is possible that water quality will deteriorate later in the summer and fall as flows decrease.

Elevated aluminum concentrations in filtered water samples led to additional filtration through 0.2 μm membrane filters. The absence of detectable aluminum following this filtration step showed that elevated aluminum concentrations were due to the presence of colloidal particles. This finding may have consequences in light of previous findings that some reaches of the river and its tributaries, as well as other streams in northern NM do no meet their designated use due to elevated aluminum concentrations.

Although the river had a continuous flow throughout its length during this study, a seven-mile stretch through the Mora valley is reported to run dry each summer. Flows measured on the river,

acequias, and tributaries confirm that most of the water in the reach of the river flowing through the valley is diverted. This has important implications both to aquatic life and riparian vegetation in the river and to the water quality in the river downstream from the community of Mora. Measurements of water quality parameters show that the quality in return flows is substantially poorer than that in the river. In particular, non-point runoff from agricultural activities and on-site wastewater treatment and disposal systems may be important sources of nutrients (nitrogen and phosphorous) in the river.

Integrated management of the agricultural diversions from the Mora River and its tributaries was not apparent to members of this study team. Reports from residents and OSE employees have suggested that there is strong community resistance to State involvement in management of water resources in the watershed. It is likely that conflict over water resources will occur as development within the watershed continues. Residents within the watershed need to work with State water managers to develop procedures for resolving these issues as they arise.

Oil and gas development is being considered in the region and could impact the river through discharge of poor quality water. In the event that this does occur, studies such as this and that by the NMED (SWQB, 2004; SWQB, 2008) will be especially important in establishing base line conditions to detect the impacts of development on the river.

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APPENDIX A: BIOLOGICAL MONITORING DATA SHEETS

BIOLOGICAL MONITORING DATA SHEET

Date 6 / 9 / 09 (MM DD YY) Begin Time ____:____ (am/pm) # Adults ________

End Time ____:____ (am/pm) # Students ________

Certified Monitors' Names Beth Jordan Volunteer ID________

Organization Name ________________

Watershed Name Mora River Watershed # __ __ __ __ __ __ __ __

Stream/River Name Mora River Upper Reach Site ID ________

(Please do not abbreviate.) (Above ID numbers are required.)

Check Methods Used

- [x] Kick Seine Net (~~3 times~~)
- [ ] D-Net (20 jabs or scoops)

Check Habitats Sampled

- [x] Riffles
- [ ] Leaf Packs
- [ ] Undercut Banks
- [ ] Snags/Vegetation
- [ ] Sediment
- [ ] Other

POLLUTION TOLERANCE INDEX (PTI)

PT GROUP 1 *Intolerant*		PT GROUP 2 *Moderately Intolerant*		PT GROUP 3 *Fairly Tolerant*		PT GROUP 4 *Very Tolerant*	
Stonefly Nymph	28	Damselfly Nymph		Midges	2	Left-Handed Snail	
Mayfly Nymph	138	Dragonfly Nymph		Black Fly Larvae		Aquatic Worms	16
Caddis Fly Larvae	48	Sowbug		Planaria	9	Blood Midge	
Dobsonfly Larvae		Scud		Leech		Rat-tailed Maggot	
Riffle Beetle	12	Crane Fly Larvae	1				
Water Penny		Clams/Mussels					
Right-Handed Snail		Crayfish					
Red water mite	9						
# Of TAXA	5	# Of TAXA	1	# Of TAXA	2	# Of TAXA	1
Weighting Factors: (x 4)	20	(x 3)	3	(x 2)	4	(x 1)	1

23 or More	Excellent
17 - 22	Good
11 - 16	Fair
10 or Less	Poor

POLLUTION TOLERANCE INDEX RATING 28

(Add the final index values for each group.)

Other Biological Indicators

- [ ] Native Mussels
- [ ] Zebra Mussels
- [ ] Rusty Crayfish
- [ ] Aquatic Plants

______ % Algae Cover ______ Diversity Index

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BIOLOGICAL MONITORING DATA SHEET

Date 6 / 10 / 09 (MM DD YY) Begin Time ____:____ (am/pm) # Adults ________

End Time ____:____ (am/pm) # Students ________

Certified Monitors' Names Lani Tsinnajinnie Volunteer ID ________

Organization Name ________

Watershed Name Mora River Watershed # ________

Stream/River Name Mora River Middle Reach Site ID ________

(Please do not abbreviate.) (Above ID numbers are required.)

Check Methods Used

- [X] Kick Seine Net ~~(3 times)~~ 2
- [ ] D-Net (20 jabs or scoops)

Check Habitats Sampled

- [X] Riffles
- [ ] Leaf Packs
- [ ] Undercut Banks
- [ ] Snags/Vegetation
- [ ] Sediment
- [ ] Other

Pollution Tolerance Index (PTI)

PT GROUP 1 *Intolerant*		PT GROUP 2 *Moderately Intolerant*		PT GROUP 3 *Fairly Tolerant*		PT GROUP 4 *Very Tolerant*	
Stonefly Nymph	128	Damselfly Nymph		Midges		Left-Handed Snail	2
Mayfly Nymph	349+1	Dragonfly Nymph		Black Fly Larvae		Aquatic Worms	27
Caddis Fly Larvae	4	Sowbug		Planaria	5	Blood Midge	5
Dobsonfly Larvae		Scud		Leech	1	Rat-tailed Maggot	
Riffle Beetle	7+4	Crane Fly Larvae	4				
Water Penny	4	Clams/Mussels	3				
Right-Handed Snail	7	Crayfish					
# Of TAXA	6	# Of TAXA	2	# Of TAXA	2	# Of TAXA	3
Weighting Factors: (x 4)	24	(x 3)	6	(x 2)	4	(x 1)	3

23 or More	Excellent
17 - 22	Good
11 - 16	Fair
10 or Less	Poor

POLLUTION TOLERANCE INDEX RATING 37

(Add the final index values for each group.)

Other Biological Indicators

- [ ] Native Mussels
- [ ] Zebra Mussels
- [ ] Rusty Crayfish
- [ ] Aquatic Plants

______ % Algae Cover ______ Diversity Index

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BIOLOGICAL MONITORING DATA SHEET

Date 6 / 11 / 09 (MM DD YY)   Begin Time ____:____ (am/pm)   # Adults ________

End Time ____:____ (am/pm)   # Students ________

Certified Monitors' Names Ralph Monfort   Volunteer ID ________

Organization Name ________

Watershed Name Muru River   Watershed # __ __ __ __ __ __ __

Stream/River Name Muru River Lower Reach   Site ID ________

(Please do not abbreviate.)   (Above ID numbers are required.)

Check Methods Used

- [X] Kick Seine Net (~~3 times~~) 2
- [ ] D-Net (20 jabs or scoops)

Check Habitats Sampled

- [X] Riffles
- [ ] Undercut Banks
- [ ] Sediment
- [ ] Leaf Packs
- [ ] Snags/Vegetation
- [ ] Other

POLLUTION TOLERANCE INDEX (PTI)

PT GROUP 1 *Intolerant*		PT GROUP 2 *Moderately Intolerant*		PT GROUP 3 *Fairly Tolerant*		PT GROUP 4 *Very Tolerant*	
Stonefly Nymph	10	Damselfly Nymph		Midges		Left-Handed Snail	
Mayfly Nymph	80+1	Dragonfly Nymph	3	Black Fly Larvae		Aquatic Worms	5+3
Caddis Fly Larvae	3	Sowbug		Planaria	1	Blood Midge	
Dobsonfly Larvae		Scud	11	Leech		Rat-tailed Maggot	
Riffle Beetle	3+3	Crane Fly Larvae					
Water Penny	1	Clams/Mussels					
Right-Handed Snail	1	Crayfish	1				
# Of TAXA	6	# Of TAXA	3	# Of TAXA	1	# Of TAXA	1
Weighting Factors: (x 4)	24	(x 3)	9	(x 2)	2	(x 1)	1

23 or More	Excellent
17 - 22	Good
11 - 16	Fair
10 or Less	Poor

POLLUTION TOLERANCE INDEX RATING 36

(Add the final index values for each group.)

Other Biological Indicators

- [ ] Native Mussels
- [ ] Zebra Mussels
- [ ] Rusty Crayfish
- [ ] Aquatic Plants

______ % Algae Cover   ______ Diversity Index

www.HoosierRiverwatch.com   91

APPENDIX B: RAPID ASSESSMENT DATA SHEETS

Upper Mora River Above Chacon 06/09/2009

Visual Riparian Estimates

Riparian Vegetation cover	Left Bank	Right Bank
Canopy (>5 m high)		
Vegetation Type		Mixed
>0.3 m DBH		
<0.3 m DBH		40-75%
Understory (0.5 to 5 m high)		
Vegetation Type		Mixed
Woody Shrubs & Saplings		>75%
Non-Woody Herbs, Grasses & Forbs		40-75%
Groundcover (<0.5 m high)		
Woody Shrubs & Saplings		
Non-Woody Herbs, Grasses & Forbs	>75%	>75%
Barren, Bare Soil or Duff		

Human Influence

	Left Bank	Right Bank
Wall/Dike/Revetment/Riprap/Dam	Not Present	Not Present
Buildings	Not Present	Not Present
Pavement/Cleared Lot	Not Present	Not Present
Road/Railroad	Not Present	Not Present
Pipes (Inlet/Outlet)	Not Present	Not Present
Landfill/Trash	Not Present	Not Present
Park/Lawn	Not Present	Not Present
Row Crops	Not Present	Not Present
Pasture/Range/Hay Field	Not Present	Not Present
Logging Operations	Not Present	Not Present
Mining Activity	Not Present	Not Present

Middle Mora River 06/10/2009

Visual Riparian Estimates

Riparian Vegetation cover	Left Bank	Right Bank
Canopy (>5 m high)		
Vegetation Type		
>0.3 m DBH	0%	0%
<0.3 m DBH	10-40%	<10%
Understory (0.5 to 5 m high)		
Vegetation Type	Deciduous	Deciduous
Woody Shrubs & Saplings	10-40%	<10%
Non-Woody Herbs, Grasses & Forbs	40-75%	40-75%
Groundcover (<0.5 m high)		
Woody Shrubs & Saplings	0%	0%
Non-Woody Herbs, Grasses & Forbs	>75%	>75%
Barren, Bare Soil or Duff	<10%	<10%

Human Influence

	Left Bank	Right Bank
Wall/Dike/Revetment/Riprap/Dam	Not Present	Not Present
Buildings	Not Present	Not Present
Pavement/Cleared Lot	>10 cm	Not Present
Road/Railroad	>10cm	Not Present
Pipes (Inlet/Outlet)	Within 10 m	Not Present
Landfill/Trash	On Bank	On Bank
Park/Lawn	Not Present	Not Present
Row Crops	Not Present	Not Present
Pasture/Range/Hay Field	Not Present	Within 10 m
Logging Operations	Not Present	Not Present
Mining Activity	Not Present	Not Present

APPENDIX C: MEETING SUMMARIES

During the course of this investigation, the study group had discussions with a Ph.D. student/resident of the community, manager/operator of the Mora water authority, the center director of the Water Research Fish Hatchery at Mora, and the ranch manager of the Pritzlaff Ranch on the Sapello River, a tributary of the Mora River. This appendix summarizes the salient points from those discussions.

Discussion with Shannon Rupert, Ph.D. Student, UNM Department of Biology and Resident of Monte Aplanado 2 June 2009.

The Mora Valley was settled in the 1840s, but people had lived in the high country long before. Ms. Rupert stated that essentially all northern New Mexico has been exploited; even the high country vegetation we see today is not natural. When Ft Union was established to the south, the Army needed food and drove the residents of the Mora Valley to plant cash crops. For many years intensive agriculture continued even after the fort was abandoned. She described this period as exploitation of the land as agriculture slowly changed from farming to grazing. Current land use is not overly intensive with the main use alfalfa production and grazing. Today the community relies heavily on the acequia system. Ms. Rupert reported 46 main acequia trunks currently on the books and four trans-mountain acequias to the west. She reported that during the summer, a seven mile stretch of the Mora River actually dries up due to acequia use. At one time the Mora valley had 17,000 people, but that has now dropped to about 5,000. She noted that the town of Mora is one of the five poorest towns in the United States and that the natural gas industry is currently looking at moving in which has created a major issue for the community.

Ms. Rupert emphasized that the standard River Continuity Concept (RCC) ignores the horizontal connections which are particularly rich in the Mora Valley. Her study of the valley focuses on the social ecology, particularly of the acequia community, connectivity both lateral and horizontal, watershed modeling with respect to the acequias, and place-based education using traditional ecological knowledge and non-formal educational exchange with the community. A particular question she is considering is whether acequias encourage or inhibit biodiversity; she has gotten indications that local lore which favors the former position might prove to be the correct position.

Ms. Rupert played an important role in this investigation by hosting the research team at her residence, assisting with all of the field work, and providing the technical assistance of three undergraduate students in the NSF supported Research Experience for Undergraduates (REU) studying at NM Tech during the summer of 2009.

Discussion with Clarence Aragon, Manager and Operator of the Mora Mutual Water and Sewer Association, 9 June 2009.

The town of Mora is 100% dependent on groundwater which it gets from two primary wells from 240-250 feet deep with a new well planned to reach about 500 feet. The current wells can pump 100-150 gallons per minute and the Town has 500,000 gallon storage capacity. Mora has water rights to 200 acre-feet which Mr. Aragon stated would be difficult to defend if the Canadian River watershed (of which the Mora River is a tributary) is adjudicated by the state. He believes adjudication would be strongly opposed by residents of the watershed and is not planned at this time. Currently, although essentially part of Mora, the small communities of El Alto and Del Rio have their own Mutual Domestic water organizations, but some merging of the duties and responsibilities is beginning to take place which should provide opportunities for better service. Mr. Aragon stated that Mora does chlorinate its water.

Mr. Aragon stated that the association is very family oriented with no meters which makes it sometimes difficult to initiate changes to association procedures. The association is perennially short of funds for operations, maintenance, and utility replacement expenses. Currently the focus is not on expansion but on improving current infrastructure and current customer services. Most of the steel pipe has been eliminated from the old system, but the distribution network is underdeveloped leading to sustainability issues. Mr. Aragon mentioned that even the Mora school does not have the required infrastructure for fire suppression capability. Not only does this put current structures at risk, but new businesses and other development are discouraged because compliance and insurance costs are high. The system has massive pressure difference problems which, although Mora has plenty of water, make it very expensive to pay the pumping costs. Mr. Aragon plans to begin remedying this situation by upgrading Mora's water protection plan when the new well comes in.

Mora is unusual for small northern New Mexico towns in that it operates its own waste water treatment system. Mr. Aragon said it was installed in 1950 and speculated it was put in because of the high water table. He said a current hydrologic survey showed that the area had once been a lake. In addition, the waste water is too near the town's water source. For these reasons, source water protection is a big issue in Mora, one Mr. Aragon hopes the deeper well will help rectify. The state has placed a compliance limit on Mora's waste water discharge of 0.029 mg/L for total nitrogen, a concentration below that achievable by any current wastewater treatment technology. Mr. Aragon opined that the drinking water standard for total nitrogen was 10 and that technology does not exist to drive nitrogen this low. This requirement will have a large impact on the Mora community. Mr. Aragon stated that the only other point source on the Mora River besides his water system is the National Fish Hatchery, but other contributors of nitrogen are agriculture, overgrown forests and domestic septic tanks which are essentially unregulated. The low temperature in the higher elevation of Mora also inhibits the lowering of nitrogen.

Mr. Aragon said that the solution to this dilemma might be to eliminate the wastewater discharge from the river as a point source. In his words, "dilution is the solution to pollution." With so much land available to it, Mora might be able to use their treated wastewater for irrigation. However, he countered this almost immediately by saying that moving the problem isn't a good solution. He feels the state, by forcing Mora off the river (his words), is missing the big picture and that to solve the total problem, the state must deal with all the non-point sources noted above.

Discussion with John Seals, Center Director for the Mora National Fish Hatchery and Technology Center, U.S. Fish and Wildlife Agency, 10 June 2009.

The hatchery is the other permitted discharge on the Mora River, in addition to the Mora Mutual Water and Sewer Association. Since 2000 the hatchery has been dedicated to maintaining root stock and raising two strains of the threatened Gila trout (Spruce Creek and both the main and south Diamond lineages) for reintroduction to the Gila River. It is one of seven fish research hatcheries in the country and the only one raising these Gila Trout strains. Currently the hatchery has 10,000 trout on station managing the trout on a yearly cycle from spawning to stock out. They use no antibiotics and try to maintain the fish in a wild state. Currently, the hatchery has a 20-30% mortality rate. Mr. Seals noted that the relatively recent downgrading of the Gila trout from endangered to threatened (which allows catch and release stocking) was a big boost to his effort as it provides very good public relations for the hatchery program among the fishing community.

Because there is not enough surface water in the watershed, the hatchery pumps groundwater from 200-foot deep wells. Current static head is approximately 60-70 feet. Their water right is 988 Acre-Feet per year though they normally pump between 240-250 Acre-feet per year. This is because the hatchery treats and recycles their water, one of the few hatcheries in the country to do so. Mr. Seals mentioned that it is easier to raise healthy fish by using water only once, but that a limited supply and power costs to pump water to the hatchery justify implementation of the recycle project. Nevertheless, the hatchery is already the second largest power consumer in the county.

At an annual budget of $650,000 per year, the hatchery employs a staff of five. They measure the water coming out of the ground and the water returning to the acequia. They regularly monitor the levels of phosphorous and total nitrogen and yearly check for whole effluent toxicity. Their wastewater treatment consists of a physical filter to remove excess food and fecal material, a bio filter and tower to remove ammonia and to aerate the water. Though the system was built to use ozone, Mr. Seals is currently replacing this filter with ultraviolet as safer and less expensive. The optimum water quality within the hatchery is dissolved oxygen near saturation, a pH < 8, and temperature < 60ºF which is lowered to ~40ºF to simulate winter in readiness for spawning (nevertheless, hormones are injected to get the trout spawning at the same time). Mr. Seals is currently very happy with the quality of water he is releasing to the Acequia.

Discussion with Sterling Grogan, Ranch Manager for the Pritzlaff Ranch, 12 June 2009.

The Pritzlaff Ranch was the staging area for the 2008 Sapello River assessment performed by UNM's Water Resource Field Methods class. The project's final report has a good summary of the history of the ranch (Thomson and Ali, 2008). Basically the ranch was a cattle, then horse ranch until 1997 when it was willed to the Nature Conservancy. After placing a sixty-page conservation easement on the property, the Nature Conservancy sold it two years later to the Biophilia Foundation, its current owner. The Foundation's plan is to develop and repair the natural riparian and forest biosystems. The latter effort has been focused on forest thinning in order to minimize the threat of devastating crown fires. Mr. Grogan showed us an example of the progress they have made to date.

The Foundation also maintains two acequias with a combined water right of 11.5 acre-feet per year and a small fish pond containing about five acre-feet of water.

APPENDIX D: PREVIOUS STUDIES RELEVANT TO THE CURRENT PROJECT

This appendix summarizes previous work in the Mora river watershed. For easy reference, the three collection sites that were subject to the EPA's Environmental Monitoring and Assessment Protocol (EMAP) during this project are referred to as the Upper Reach Mora River (above Chacon), Middle Reach Mora River (immediately downstream from the community of Mora), and the Lower Reach Mora River (the Wind River Ranch).

The New Mexico Surface Water Quality Bureau (SWQB) conducted an extensive assessment of the water quality of the Canadian River and its tributaries in 2002 with the aim of determining whether they were in compliance with state surface water quality criteria. (SWQB, Sep 2007). As the Mora River is a main tributary of the Canadian River, it was included in the study.

The findings pertinent to this project were fourfold. Non-attainment of state water quality criteria were found for: 1) specific conductance at Coyote Creek from Mora River to Black Lake and on the reach of the Mora River from Hwy 434 (at the town of Mora) to its headwaters. Coyote Creek empties into the Mora River about midway between the Mora and Watrous and could therefore impact readings at the Lower Reach Mora River collection site. 2) Impairment of the narrative plant nutrients criterion was determined on the Mora River between the USGS gage east of Shoemaker to Hwy 434 which could impact readings at both the Middle and Lower Reach Mora River collection sites. 3) Temperature limits were exceeded on Coyote Creek from Mora River to Black Lake which could impact readings at the Lower Reach Mora River collection site. Impairment due to sedimentation/siltation was documented for the Mora River between Hwy 434 and the Mora headwaters which could impact both the Upper and Middle Reach Mora River collection sites, and for the Sapello River from Manuelitas Creek to where it enters the Mora River at Watrous. This confluence is downstream of the three collection sites, but could impact the Mora River downstream of Watrous (SWQB, Sep 2007).

In addition to the four major findings above, the report noted that both the Mora and the Sapello Rivers exceeded fecal coliform criteria. The report further explained that some of the exceedences found in the study might be due to the 2002 drought conditions. While flow in the Mora River generally ranges from 10-40 cubic feet per second (cfs), the river had flows as low as 2 cfs during the 2002 study period (SWQB, Sep 2007).

The study summary states that some assessments could not be made due to insufficient data. Not expressly stated is that some standards are not yet clearly delineated which seems to be a major goal of the data collection. A SWQB document published in 2004 (SWQB, 2004) notes that data collected on the Mora River in 1999, 2002 and 2004 led to a change to the state's integrated TDML list for the middle reach of the Mora River (USGS gage east of Shoemaker to Hwy 434) for Nutrient/Eutrophication Biological Indicators changing the original determination to one of not supporting (as noted above) and the TDML assessment unit to Category 5C indicating more data is needed and being collected. An updated "Guidance for Nutrient Assessments of Streams" is attached to the SWQB report (SWQB, 2004). Possibly data from this current study will be beneficial to the state as they continue to evolve water quality standards for streams. The TMDL

established target concentrations of .03 mg/L and 0.38 mg/L for total phosphorous and total nitrogen respectively in the Mora River east of the USGS gage at Shoemaker (SWQB, 2007)

In 2008, the SWQB published another water quality survey report based on the TDML study mentioned above but updated with some new information (SWQB, May 2008). However, the Mora River specific information noted above remained unchanged in this later report.

The New Mexico Clean Water Act Integrated Report, Appendix A: List of Assessed Surface Waters provides additional information on the Mora River and its tributaries pertinent to this report (SWQB, Aug 2008). The May 2008 SWQB report discussed above defers to this integrated list if there are any inconsistencies in the data since it uses the most recent state-developed assessment protocols and the most recent USEPA-approved water quality standards (SWQB, May 2008). For all of the following information, the cycle last assessed was 2004. The findings are listed below:

1) For the reach of the Mora River from Hwy 434 to Luna Creek (which could impact readings at both the Upper and Middle Reach Mora River collection sites), the assessment showed the river to be fully supporting its designated uses of domestic water supply, industrial water supply, irrigation, livestock watering, municipal water supply, secondary contact, and wildlife habitat, but was not supporting high quality coldwater aquatic life. The probable causes of the impairment are listed as sedimentation/siltation and specific conductance (see WQS §20.6.4.309 in the appendix) with probable sources of the impairment listed as natural sources, rangeland grazing and silviculture harvesting. It is noted on the form that there is a mineral spring in the area and inflow from wetlands which might contribute to the high specific conductance (SWQB, Aug 2008).

2) For the reach of the Mora River from the USGS gage east of Shoemaker to Hwy 34 (which could impact readings at both the Middle and Lower Reach Mora River collection sites), the assessment showed the river to be fully supporting the designated uses of irrigation, livestock watering, secondary contact, warm-water aquatic life and wildlife habitat, but was not supporting marginal coldwater aquatic life. The probable causes of the impairment are listed as nutrient/eutrophication biological indicators and dissolved oxygen (see WQS §20.6.4.307 in the appendix) with probable sources of the impairment listed as flow alterations from water diversions, municipal point source discharges and on-site treatment systems (SWQB, Aug 2008). It should be noted that several small communities are located on the river along this stretch including Mora, La Cueva, Buena Vista, Golondrinas, and Watrous.

3) Four sections of Mora River tributaries upstream from their confluence with the Mora River were included in the study and are worth mentioning: a) Coyote Creek from Black Lake to its headwaters is fully supporting for all designated uses except two which were not assessed (SWQB, Aug 2008). However, Coyote Creek from Black Lake to the Mora River was not supporting for high-quality coldwater aquatic life (SWQB, Aug 2008). b) The Little Coyote Creek from Black Lake to its headwaters was fully supporting for all designated uses except high-quality coldwater aquatic life for which it was not supporting (SWQB, Aug 2008). c) Morphy (Murphy) Lake at the headwaters of Rio Cebolla which flows into the Mora River upstream of Watrous was not supporting for both marginal coldwater aquatic life and warmwater aquatic life which, although almost twenty miles upstream from the confluence with the Mora

river, should not impact any of the three primary sites, but could impact the Mora River downstream. (SWQB, Aug 2008). d) In addition, Wolf Creek was found be not supporting for its designated use of marginal coldwater aquatic life (SWQB, Aug 2008). Wolf Creek flows into the Mora River near Watrous.

A water quality assessment of the Sapello River which flows into the Mora River at Waltrous was conducted by a University of New Mexico Water Resources graduate class in June 2008 (Thomson & Ali, 2008). They concluded that the upper reaches of the Sapello River were relatively healthy with slightly elevated nitrate levels possibly due to on-site wastewater systems from adjacent residential development. The lower reaches to the Mora River are "slightly impacted by agricultural activities" with increased total dissolved solids (TDS), alkalinity, dissolved aluminum, calcium, iron, potassium, magnesium, sodium and silica (Thomson & Ali, 2008). In addition, there was a decrease in nitrates as the river proceeds downstream (Thomson & Ali, 2008). Although the Sapello River flows into the Mora River downstream of the three primary collection sites, water samples of the Sapello River were taken in the current study to compare to last year's results.

Mercer and Lappala (1972) studied ground water resources in the Mora Valley watershed that was located within Mora County. The purpose of the report was that "the upper part of the Mora River drainage basin has a history of shortages of surface water for irrigation … one possibility … use of wells to supplement surface-water supplies (Mercer and Lappala, 1972). The field work for the study was conducted in the fall of 1968 and past summer of 1969 (Mercer and Lappala, 1972). The authors' findings were that "In general, the possibility for additional ground-water development to supplement present surface-water supplies for irrigation is limited" (Mercer and Lappala, 1972). In addition, "The quality of both ground-water and surface-water supplies throughout the project area meets established criteria for irrigation use" (Mercer and Lappala, 1972). Another important point in the study was that "river water is uniform in chemical character throughout the study area … dissolved-solids concentrations ranging from 244 to 296 mg/l" (Mercer and Lappala, 1972).

Erdmann (2009) considered the impact of forest fuel reduction on a sub-watershed with the Mora River watershed. The area studied by Erdmann was called Walker Flats. "Walker Flats is a grazing allotment located in the Santa Fe National Forest … and is part of the Rio La Casa Watershed" (Erdmann, 2008). The Rio La Casa is a tributary to the Mora River. The town of Cleveland uses the Rio La Casa for its acequias (Erdmann, 2008). "Water quality testing revealed clean water with low levels of all tested nutrients. One anomaly … two samples … have substantially greater levels of sulfates" (Erdmann, 2008).

APPENDIX E: NEW MEXICO WATER QUALITY STANDARDS FOR MORA WATERSHED

Below are the two state water standards from the New Mexico Administrative Code that pertain to the reaches of the Mora River investigated in this project. The full listing of Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC) may be found at http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf

20.6.4.307 CANADIAN RIVER BASIN - Perennial reaches of the Mora river from the USGS gaging station near Shoemaker upstream to the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora river downstream from the USGS gaging station at La Cueva in San Miguel and Mora counties, perennial reaches of Ocate creek and its tributaries downstream of Ocate, and perennial reaches of Rayado creek downstream of Miami lake diversion in Colfax county.

A. Designated Uses: marginal coldwater aquatic life, warmwater aquatic life, secondary contact, irrigation, livestock watering and wildlife habitat.

B. Criteria:

(1) In any single sample: temperature 25°C (77°F) or less and pH within the range of 6.6 to 9.0. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.307 NMAC - Rp 20 NMAC 6.1.2305.3, 10-12-00; A, 05-23-05] (NMAC).

20.6.4.309 CANADIAN RIVER BASIN - The Mora river and perennial reaches of its tributariesupstream from the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora river upstream from the USGS gaging station at La Cueva, perennial reaches of Coyote creek and its tributaries, the Cimarron river and its perennial tributaries above state highway 21 in Cimarron, all perennial reaches of tributaries to the Cimarron river north and northwest of highway 64, perennial reaches of Rayado creek and its tributaries above Miami lake diversion, Ocate creek and perennial reaches of its tributaries upstream of Ocate, perennial reaches of the Vermejo river upstream from Rail canyon and all other perennial reaches of tributaries to the Canadian river northwest and north of U.S. highway 64 in Colfax county unless included in other segments.

A. Designated Uses: domestic water supply, irrigation, high quality coldwater aquatic life, livestock watering, wildlife habitat, municipal and industrial water supply and secondary contact.

B. Criteria:

(1) In any single sample: specific conductance 500 µmhos/cm or less, pH within the range of 6.6 to 8.8 and temperature 20°C (68°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 235 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.309 NMAC - Rp 20 NMAC 6.1.2306, 10-12-00; A, 7-19-01; A, 05-23-05]

[**NOTE: The segment covered by this section was divided effective 05-23-05. The standards for the additional segment are under 20.6.4.310 NMAC**.] (NMAC).

For the purposes of this project, §20.6.4.307 covers the water quality at both the middle and the downstream sites and §20.6.4.305 covers the water quality at the upstream site.