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An Ecological Characterization and Landscape Assessment of the Muddy-Virgin River Project Area

RESEARCH AND DEVELOPMENT

An Ecological Characterization and Landscape Assessment of the Muddy-Virgin River Project Area

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Acronyms and Abbreviations

A Value	Gross Soil Erosion Rate
AML	Arc Macro Language
ATtILA	Analytical Tools Interface for Landscape Assessment
ARS	Agricultural Research Service
AUM	Animal-Unit-Months
BLM	Bureau of Land Management
BOR	U.S. Bureau of Reclamation
C Factor	Surface Cover Effect
DEM	Digital Elevation Model
EMAP	Environmental Monitoring and Assessment Program
ESRI	Environmental Systems Research Institute
GIS	Geographical Information System
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
K Factor	Surface Erodibility
LS Factor	Slope Length/Steepness
MRLC	Multi-Resolution Land Characteristics Consortium
MV PA	Muddy-Virgin Project Area
NAC	Nevada Administrative Code
NASA	National Aeronautics and Space Administration
NDA	Nevada Department of Agriculture
NLC	Nevada Legislative Counsel
NLCD	National Land Cover Database
NNHP	Nevada National Heritage Program
NRCS	Natural Resources Conservation Service
NPS	National Park Service
NDWP	Nevada Division of Water Planning
P Factor	Conservation Practices
pH	Hydrogen Ion Concentration
QAPP	Quality Assurance Project Plan
R Factor	Rainfall Erosivity

Acronyms and Abbreviations (cont.)

RF3	River Reach File Version 3
RUSLE 2	Revised Universal Soil Loss Equation
SEDMOD	Spatially Explicit Delivery Model
STATSGO	State Soil Geographic Database
SNWA	Southern Nevada Water Authority
TM	Thematic Mapping
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USDA	U.S. Department of Agriculture

Acknowledgements

The authors would like to recognize the good people that helped us with this report; Sherman Swanson, Tad Harris, Pam Grossmann, May Fong, Maria Gregorio, Angela Hammond, Richard Snell and Heather Powell. We feel that this ecological landscape analysis will be of value as a starting point to assess the condition of the Muddy-Virgin River Project Area. We strongly believe that reporting this analysis will greatly aid in the understanding of this unique river system. We want to fully acknowledge the late Dr. Gary Vinyard for his vision and leadership and we wish to dedicate this report to his memory. We are also grateful to those who help us review this report in their time and effort including, Richard E. Lizotte, and Donald Ebert.

Notice

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Executive Summary

The Muddy-Virgin River Project Area covers a large part of southern Nevada. Very little is known about the water quality of the entire Basin. The Muddy and Virgin Rivers drain into Lake Mead which provides drinking water for communities located in the Las Vegas Valley. The area covers some of the most densely populated and fastest growing communities in the United States and yet this area also covers some of the most remote lands in Nevada. The people living in this area depend on clean water. Not knowing about water quality or ecological condition is a concern because people will need to manage the negative impacts of mining, agriculture, livestock grazing, land development, water use (dewatering) and recreation. These activities may adversely affect water quality for human use and for any unique aquatic biota found in the rivers and streams. Having more ecological knowledge of this Project Area will help community leaders and decisions makers balance water quality protection with economic growth and social concerns. This will require a great deal of thought, coordination and cooperation. Landscape characterization and analysis are cost-effective tools which can be used to characterize the quality and condition of ecological resources. This information can be used by local resource managers and local stakeholders to make decisions that will help sustain the economic growth, ecological health and social benefits. This study will provide a data set and demonstration of analyses that can serve as a basis for a landscape ecological assessment. It can substantially increase our knowledge of conditions in this area using data collected from an earlier water quality study (Hare et al., 2013).

Three water quality parameters were chosen to analyze the association between water quality parameters and landscape and soil metrics. Total nitrogen (TN), total phosphorus (TP), and benthic macroinvertebrate structure index of biological integrity (IBI). High levels of TN and TP can indicate excess nutrient input from agriculture and manure deposition from cattle which can lead to increased algal growth and disturb the ecological balance of streams. The IBI combines metrics sensitive to stressors representing diverse aspects of the biota. Benthic macroinvertebrate structure can be effected through many land use practices which change channel shape and form, thus decreasing stream bank stability, leading to erosion and change in vegetation and habitat.

Multiple regressions were used to associate land cover/use metrics and sediment delivery metrics to stream water quality parameters in watershed support areas in the Muddy-Virgin River Project Area. Seven landscape metrics were used, road length, stream density, soil erodibility, gross soil erosion, percent natural grassland, percent urban and percent forest all had relationships to the water quality parameters. Percent forest and soil erodibility are important factors for the Index of Biotic Integrity (IBI). The final regression models were used to predict the water quality parameters (TN, TP, and IBI) in areas were measurements do not exist. The predicted water quality values were ranked in group classes and mapped to examine their magnitude with that of land use activities like mining and cattle grazing.

1.0 Introduction

1.1 Objectives

This study is presented to give the results of an ecological assessment using landscape ecology and water quality methods in the Muddy-Virgin River Project Area located in Environmental Protection Agency (USEPA) Region 9. Landscape ecology focuses on the relationships of spatial arrangements and the ecological processes of the landscape. To ecologists and environmental scientists, a landscape is more than a vista, but comprises the features of the physical environment and their influence on environmental resources. Landscape ecology integrates biophysical approaches with human perspectives and activities to study spatial patterns at the landscape level, as well as the functioning of the region. There are many applications of this approach. (Heggem et al., 1999 Mehaffey et al., 2001). For example, areas most disturbed by anthropogenic sources can be identified by combining information on population density, roads and land cover. Vulnerability of areas can also be identified by looking at the surrounding conditions. Potential erosion control issues can be evaluated as well by considering variables such as precipitation and the steepness of slopes. Ecological processes connect the physical features of the landscape linking seemingly separate watersheds.

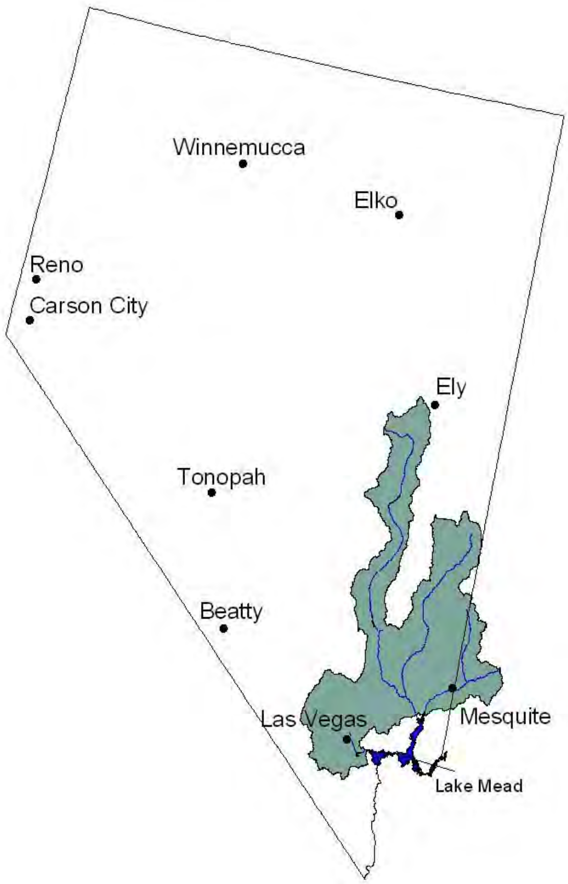

Figure 1. Location of the Muddy-Virgin River Project Area.

The Muddy-Virgin River Project Area (Figure 1) drainage is of interest to water quality managers due to potential human impacts including livestock grazing, agriculture, mining practices, commercial and industrial waste and urban runoff (Clark County Nevada, 2000). This report presents an environmental assessment of the project area, studying the relationships between water quality and landscape, considering the potential human impacts. This assessment can be used as a tool to estimate the impact of human land use practices that are being implemented to improve environmental quality. Currently, large areas of southern Nevada are undergoing intensive land management changes ridding the landscape of the exotic, invasive species tamarisk (Tamaricaceae: *Tamarix ramosissima* Deneb). Tamarisk is a brushy, woody shrub that out competes native vegetation for large quantities of water while excreting salt through shed leaves and can overtake the riparian corridor. A concentration of tamarisks can result in changes in stream flow, increase dissolved solids in nearby streams, increase wildfire hazards while decreasing wildlife habitat (Washington County Water Conservation District, 2006). Landcover analysis could be used to assess the changes in water quality before and after restoration.

This assessment can also be used for ecosystem targeting and help people make decisions on the best locations for restoration sites. The information presented in the following pages provides a visualization of the conditions across the basin and within each delineated sub-watershed.

1.2 Broad-Scale Environmental Condition

Taking a broader view, the landscape perspective changes allows an easier understanding of land cover interactions and helps to make predictions of future anthropogenic problems. At a small-scale level, perspectives and concerns are based locally. Looking at the national setting can help place the basin in context and interpret individual conditions, as well as help determine land cover similarities elsewhere in the country which is important because local environmental issues can have regional impacts. As seen in Figure 2**,** the southwest is unique in that shrublands and barren land dominate the landscape, whereas forests are prominent in the east and agriculture in the mid-west. In the south western United States, rivers are the flowing arteries in the midst of huge, arid, and often desolate western landscape (Homer et al., 2007). There are also significantly fewer roads in the west compared to the east, thus greater amounts of open areas (Figure 3).

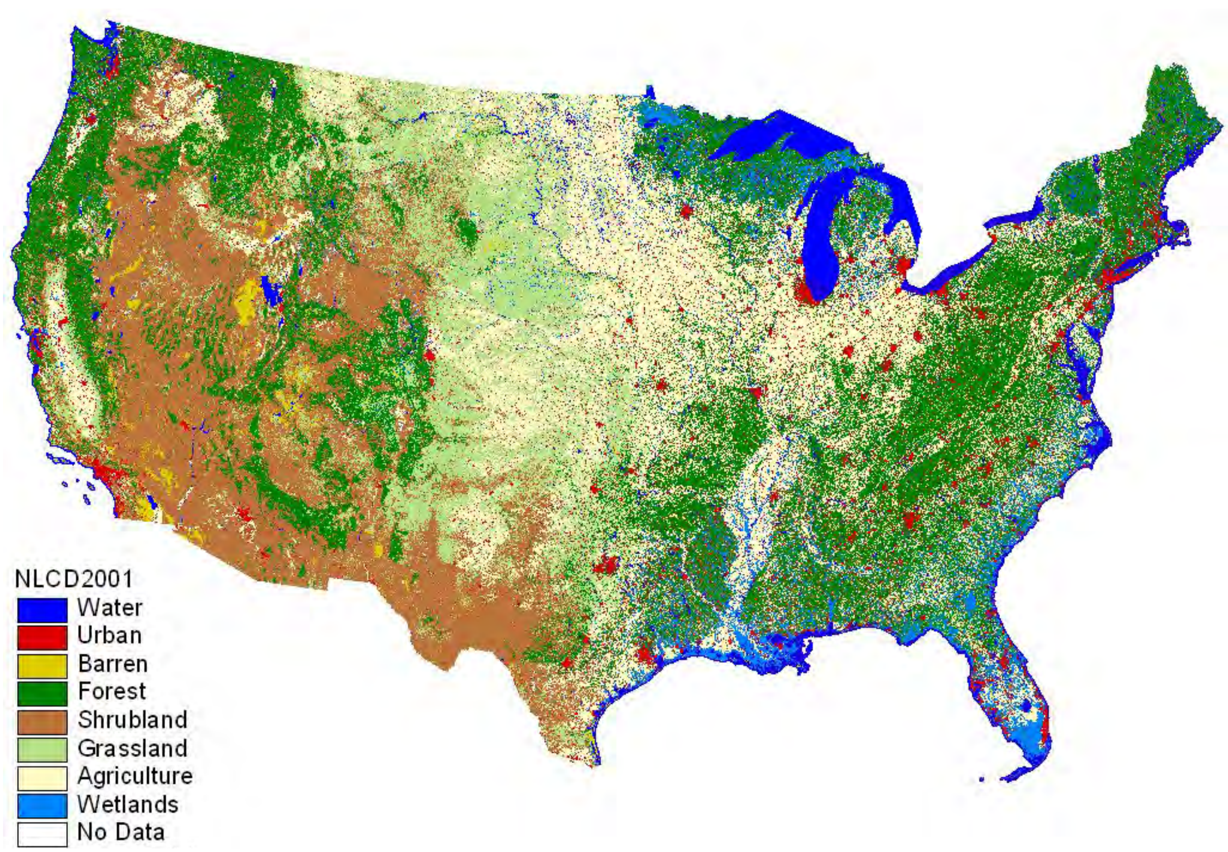

Figure 2. 2001 NLCD (MRLC, 2008).

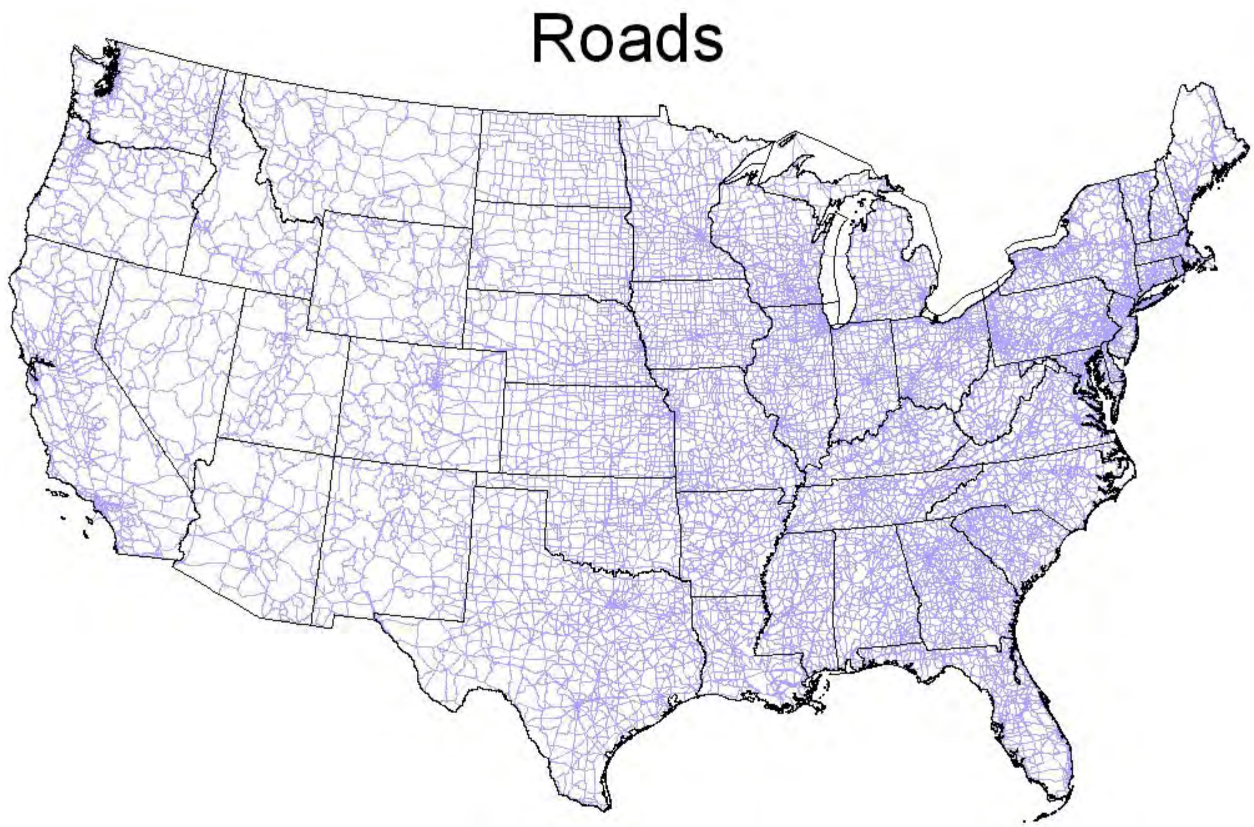

Figure 3. National Map of Roads (USGS, 1995).

1.3 Overview

The Muddy-Virgin River Project Area, located in Nevada, with portions of southwest Utah and northwest Arizona included to incorporate the lower Virgin River Basin, holds rivers which are resources for both humans and wildlife, and are of primary importance in both the economy and ecology of the region. The Las Vegas area originally was a stopover on the Spanish Trail because of its natural springs. With the discovery of minerals in the 1850s, a community arose to mine the mineral commodities. The upper half of the project area had its history as a stop on the Mormon Trail alternate route until silver and gold ore was discovered. Natural springs abound throughout the project area feeding the streams (Clark County Nevada, 2000). These streams provide water for agricultural irrigation and ranching, as well as feeding into the Colorado River, proving additional water for urban areas downstream. Today, much of Nevada State is managed by the Bureau of Land Management (BLM), originally known as the Grazing Service, due to excessive habitat degradation from overgrazing (Figure 4)**.**

Another prospective anthropologenic impact is the effects of mining. Nevada State is the third largest gold producer globally. Although today, mining in the project area consists mostly of nonmetallic minerals such as gypsum, limestone and gravel, potential anthropologenic effects can occur such as increasing instream sediment load and dissolved minerals in nearby washes and floodplains. In this study, relationships between landscape and water quality indicators in the watersheds are investigated using a snapshot in time to establish the influence of the landscape.

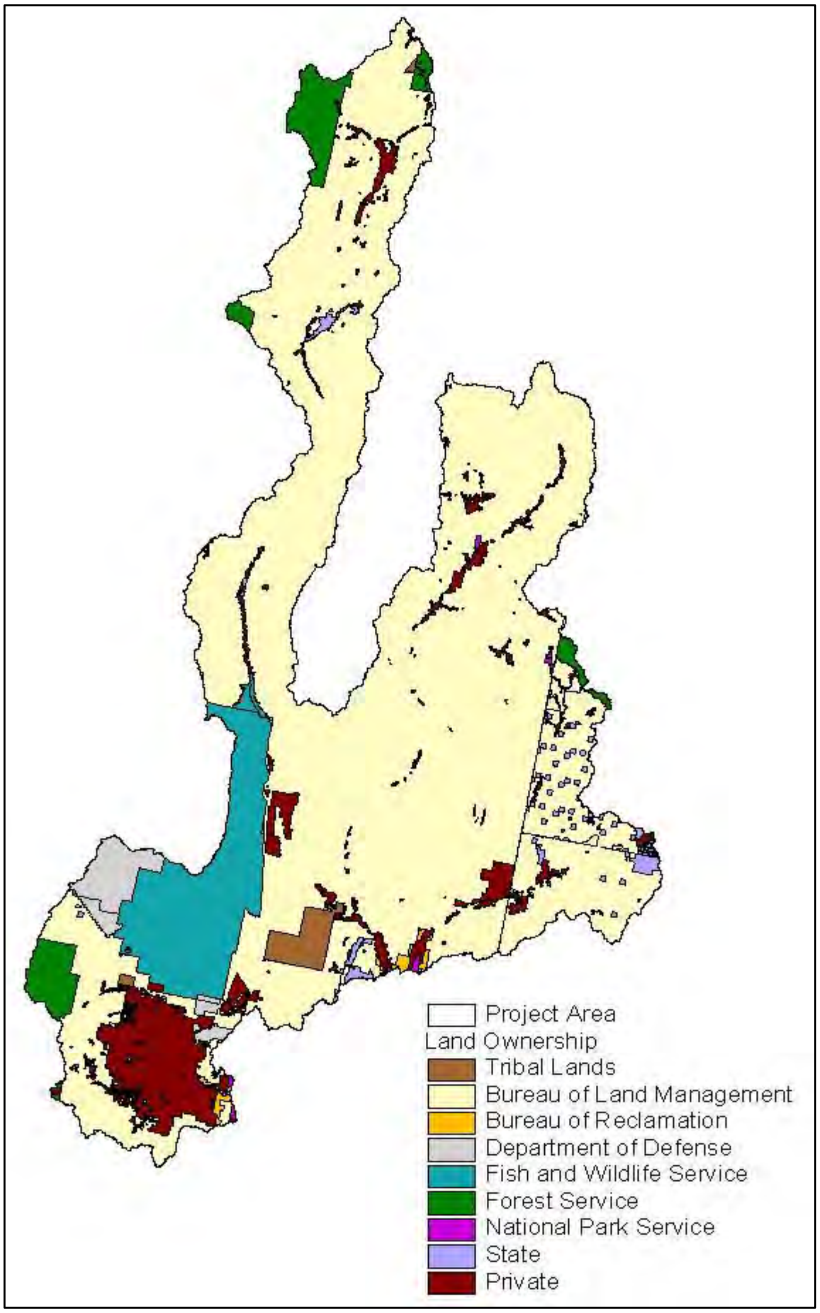

Figure 4. Jurisdictional Boundaries for the Muddy-Virgin Project Area.

2.0 The Biophysical Setting

2.1 Land Cover and Topography

The Muddy-Virgin River Project Area covers 85,100 square kilometers (32,850 square miles) in Nevada, 14,000 square kilometers (5,400 square miles) in Arizona and 6200 square kilometers (2,400 square miles) in Utah. Located in the semi-arid Great Basin and Mojave Desert, precipitation is low. In the Mojave Desert, precipitation is less than 15 cm (6 in) per year, and around 30 cm (11.8 in) per year in the Great Basin. The low annual precipitation for this subecoregion is both a function of distance from the Pacific Ocean and the rain-shadow effects of the Sierra Nevada mountain range. Elevation ranges from 367 m (1204 ft) in the valley floors, located in the central areas to the south, up to 3626 m (11900 ft) in the surrounding mountain ranges. Butte, Egan, White Pine and Egan Ranges border the area to the north, while the Spring and Sheep Ranges rise to the south (Figure 5). The mountains are steep and deeply incised with alluvial/colluvial deposits in the canyons with fine sediments becoming the dominant substrate in the broad valleys. Fan deposits in the south are predominantly composed of debris flows.

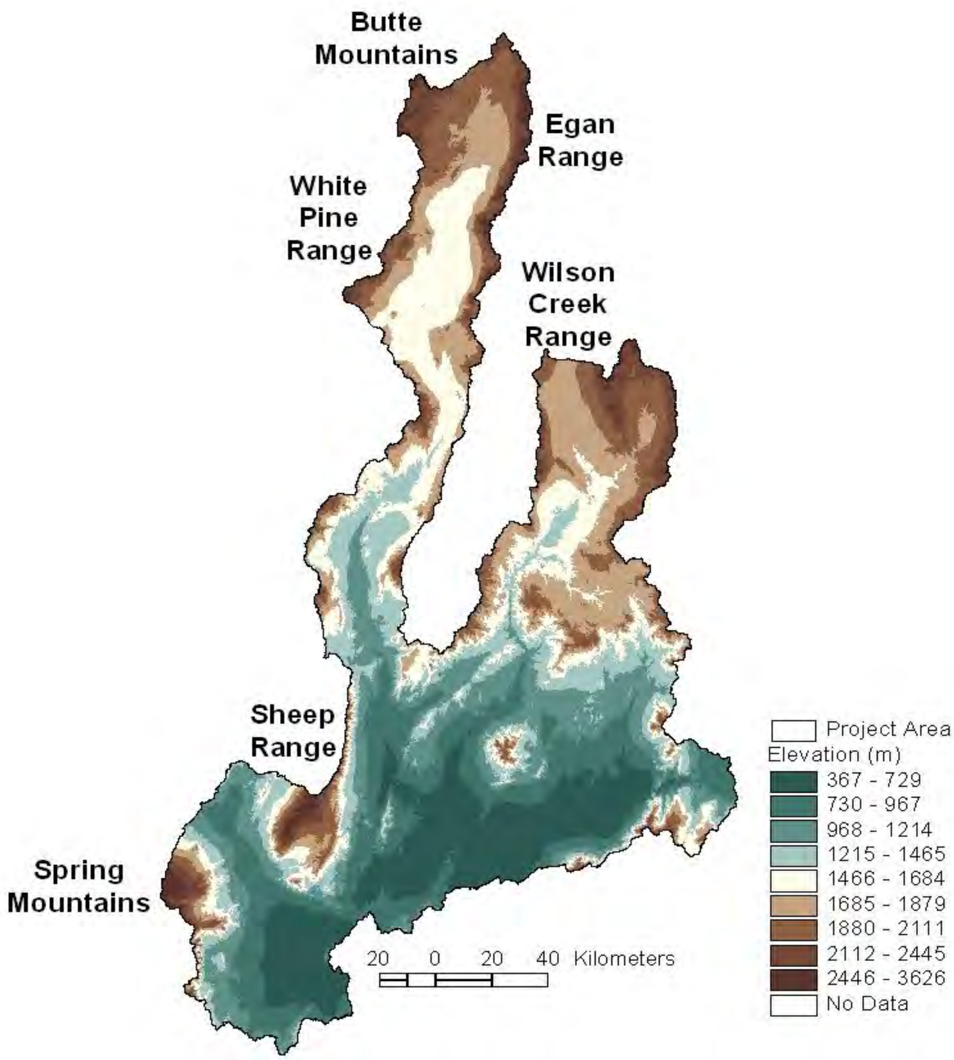

Figure 5. National Elevation Data for the Muddy-Virgin Project Area.

Surface water resources in the drainage basin are primarily spring fed, generally draining north to south, with the Virgin River receiving drainage from seasonal snowmelt in central and eastern Utah. Hydrology within the Great Basin is internal, depositing in underground aquifers. Most high elevation streams are dry throughout most of the year, with flow alternating between the surface and the hyporheic zone, and returning to valley streams.

The project area is split between subecoregions 13 (Central Basin and Range) and 14 (Mojave Basin and Range) with a small portion of Arizona and Nevada in subecoregion 22 (Arizona/New Mexico Plateau). The portion of the lower Central Basin and Range and upper Mojave Basin is comprised of north-south trending fault-bounded horst and graben geomorphology. The Mojave Basin and Range physiography is a creosote bush-dominated shrub community (Figure 6) which is distinct from the saltbush-greasewood and sagebrush-grass associations that occur to the north in the Central Basin and Range. Major vegetation communities include montane, pinyon-juniper, western juniper, sagebrush/grassland, shadscale, and Mojavean (Mac et al., 1998).

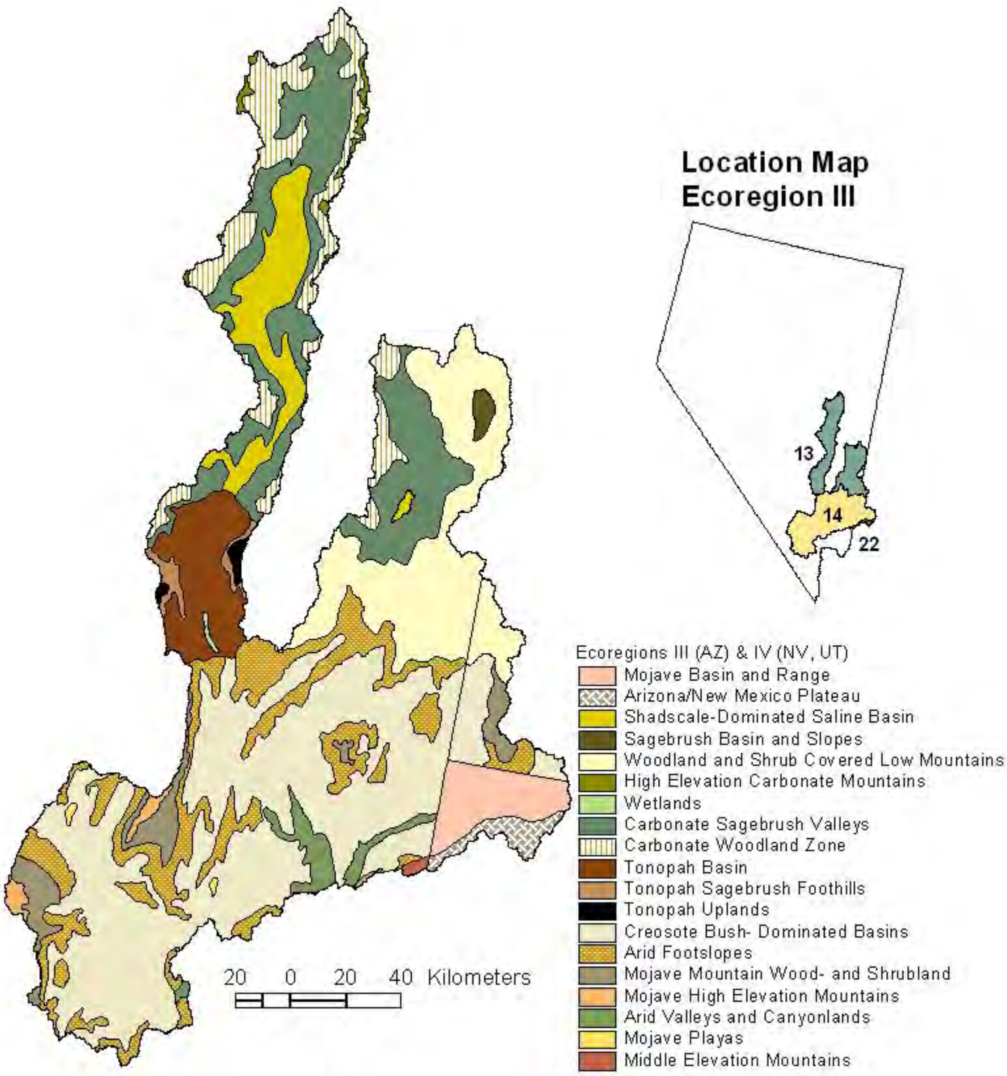

Figure 6. Ecoregions in the Muddy-Virgin River Project Area.

The land cover in the basin is made up primarily of shrub/scrublands, predominantly big sagebrush (*Artemisia tridentata Nutt.*), black sagebrush (*Artemisia nova*), rabbitbrush ((*Chrysothamnus* spp. and *Ericameria* spp.), and shadscale (*Atriplex confertifolia*) (Figure 7). Grasslands consist of Indian rice grass (*Achnatherum hymenoides*) and the invasive cheatgrass (*Bromus tectorum*). Forests are generally dominated by single-needle pinyon pine (*Pinus monophylla*) and juniper (*Juniperus sp*). In higher altitudes, bristlecone (*Pinus aristata*), and white firs (*Abies concolor*) can be found (USEPA, 2007; Benke and Cushing, 2005). Riparian vegetation along rivers mainly includes rushes, cattails, inland salt grass, stands of mesquite (*Prosopis L.*) and willows *(Salix sp.)* with the invasive tamarisk (*Tamarix sp.*) (*Tamarix ramosissima* Deneb) becoming more common. Creosote bush (*Larrea tridentata)*, cacti, and yuccas exist in the lower Mojave Basin.

Urban areas are minimal throughout the Project Area, with the largest population, Las Vegas, located in the southwest corner with a large military instillation bordering to the northwest. Other sizable populations are Mesquite, located on the border of Arizona, and Hiko, located in the center of the project area, north of Pahranagat Valley. A substantial percentage of the basin's agricultural crops provide alfalfa hay for the cattle and sheep farms that graze throughout. Agricultural areas are prevalent around the main rivers.

2.2 Streams

Streams and rivers not only direct the flow of water, but also provide necessary resources, such as essential habitat for plants and animals, the filtering of pollutants, processing of litter and debris, distribution of nutrients, and recreation. The landscape surrounding a stream provides a diverse and productive system for plants and animals while designated a primary resource for human use. The stream network used for this assessment is the USEPA River Reach File (RF3), derived from the U.S. Geological Survey (USGS) Digital Line Graph (Figure 8).

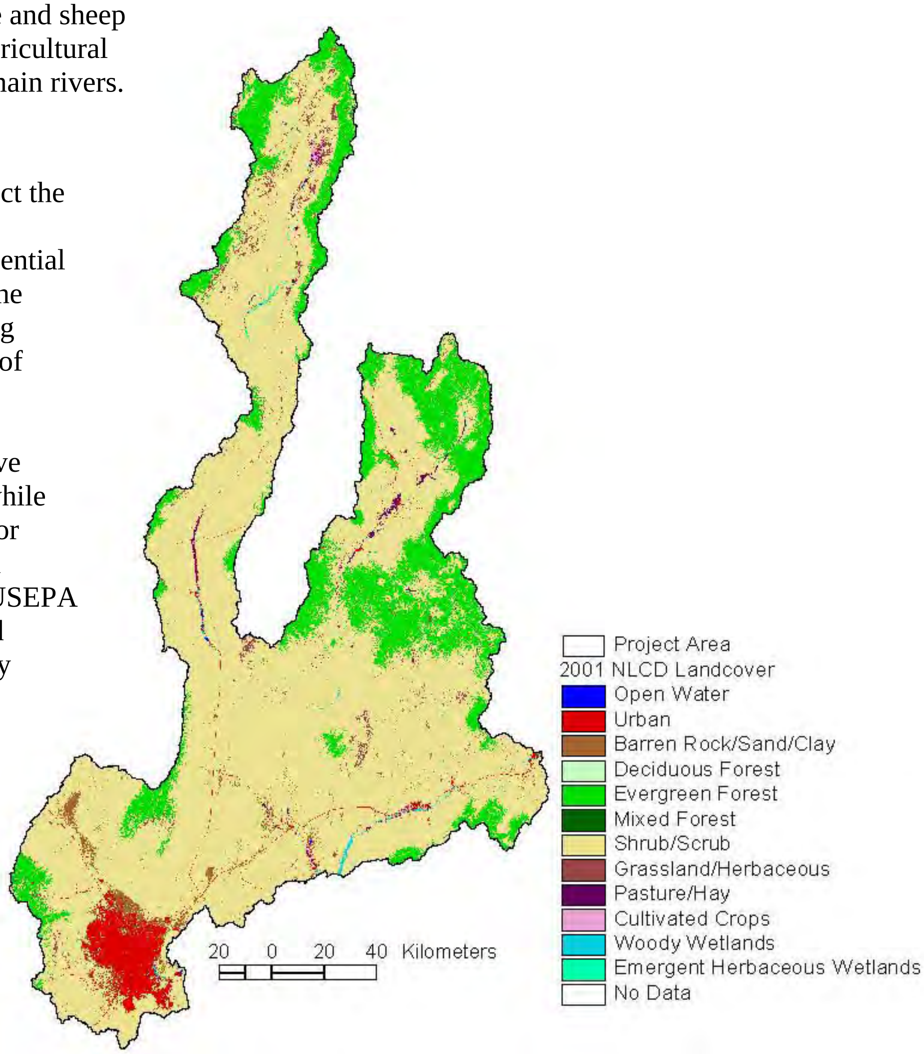

Figure 7. Land Cover/use in the Muddy-Virgin River Project Area.

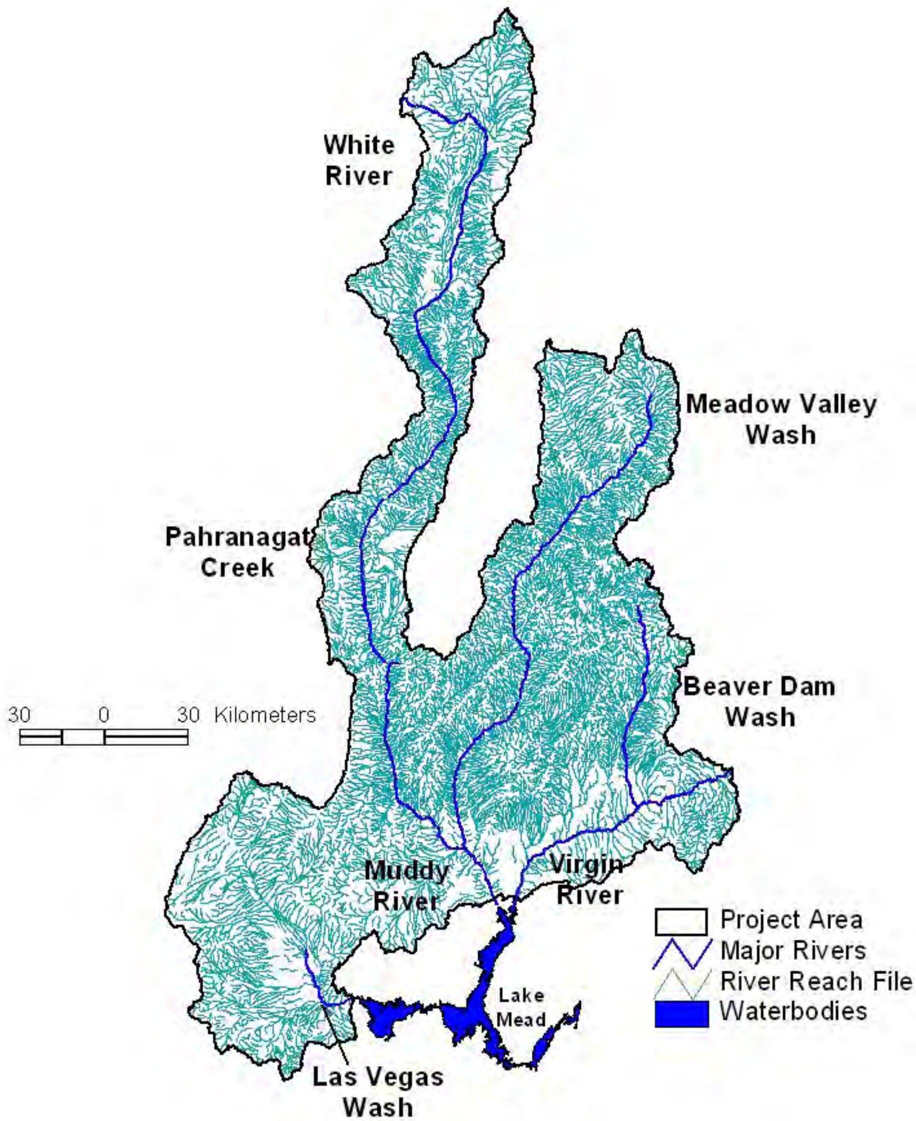

Figure 8. Streams and Water Bodies in the Muddy-Virgin River Project Area.

The Virgin River originates east of Rockville, UT where the confluence of the East and North Forks converge in Washington County. It then disappears into the riverbed through the Beaver Dam mountains and resurfaces above Littlefield, AZ, flowing northeast to southwest. During low-flow periods, most of the flow in the Virgin River originates from a highly saline, major spring system in Littlefield, Arizona, located approx 16 km (10 miles) upstream of Mesquite (ADWR, 2009). The Virgin River also drains numerous springs and washes as well; the Beaver Dam Wash being its largest tributary. It is the largest contributor to the Colorado River in Nevada accounting for 1.4% of water resources in Lake Mead, a reservoir created by the Hoover Dam (Las Vegas Wash Coordination Committee, 2010). The Meadow Valley Wash, an intermittent stream system flowing from its northern headwaters in the Wilson Creek Range emptying into the Muddy River, is the principal drainage channel in the range with flow originating from precipitation in the mountains (Resource Concepts, 2001). The Muddy River originates from thermal springs in the Moapa Valley and flows 51.5 km (32 miles) into Lake Mead. Currently an urban drainage system with few naturally flowing springs, the Las Vegas Valley Wash contains urban runoff and treated waste water flowing through the local wetlands and into Lake Mead and receives spring or autumnal monsoon rainfall. To the north, the Pahranagat and White Rivers are highly manipulated waterways with large portions in straight ditches rather than natural channels. About 90% of Pahranagat Creek is in irrigation ditches or are dewatered during the irrigation season. Only during the winter months do the four water impoundments in the Pahranagat Valley (North Marsh, Middle Marsh and Upper and Lower Pahranagat Lakes) receive water from the Hiko, Crystal and Ash Spring sources (USFWS, 1998).

2.3 Watersheds

A watershed is an area of land into which all forms of precipitation permeate into the ground or drain into streams. Watersheds can provide a way of evaluating landscape and water relations based on the water flow through the system. A hydrologic unit code (HUC) is an area which represents all or part of a surface drainage area, a combination of drainage areas, or a distinct hydrological feature (USGS, 2009). The United States is divided into different levels of hydrological units: regions (2-Digit areas), sub-regions, accounting units, and cataloging units (Figure 9).

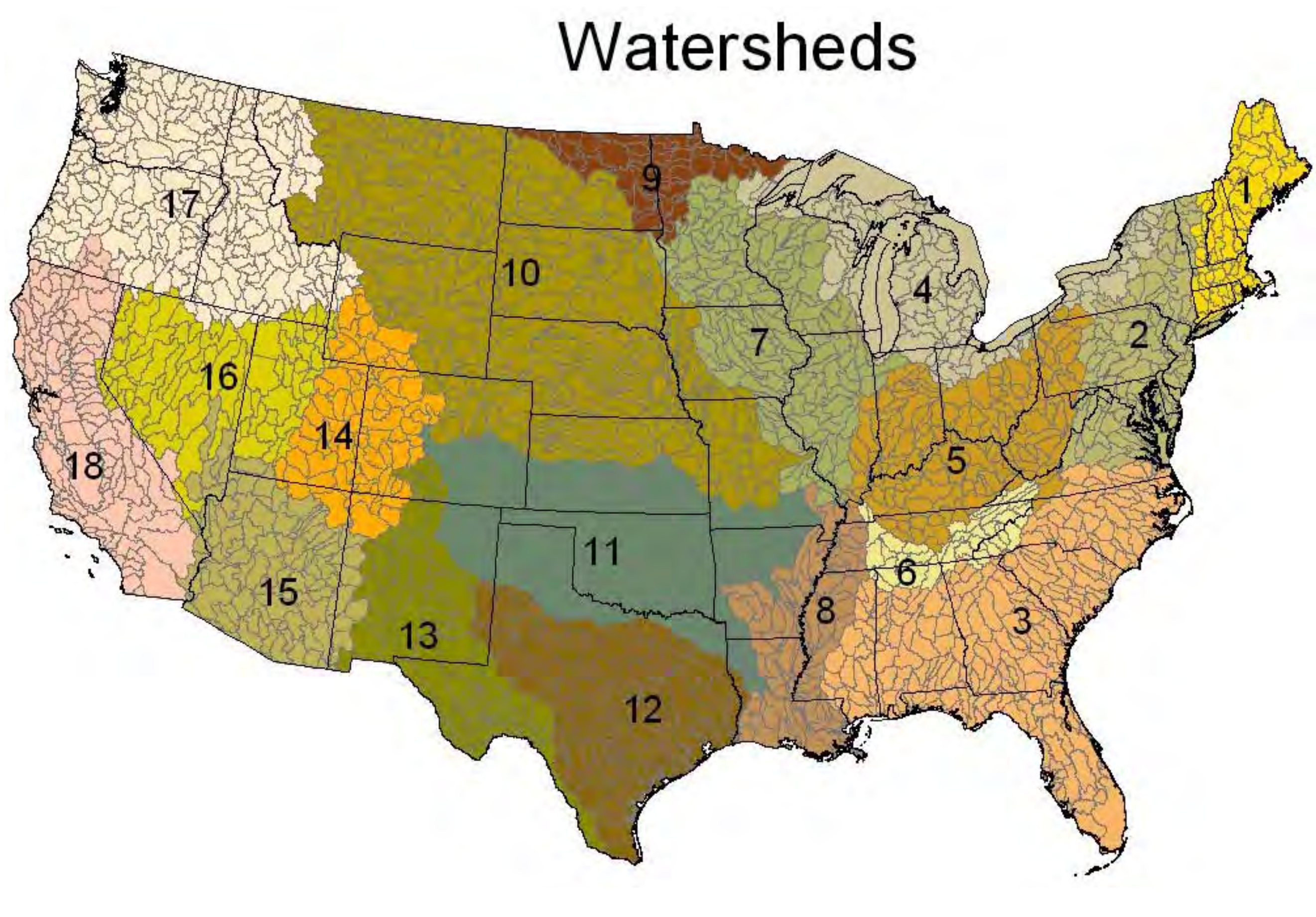

Figure 9. National Map of 8-Digit HUCs. 2-Digit HUCs are Illustrated in Color.

The Muddy-Virgin River Project Area is located within region 15, which represents the Lower Colorado Basin. The USGS's national 12-Digit hydrologic unit code is used in this report to summarize landscape metrics. Figure 10 displays all 12-Digit HUCs in the project area within the larger 8-Digit cataloging units, illustrated in color. For 8-Digit HUC numbers and total area, see Table 1.

Table 1. Regional HUC Numbers and Corresponding Names.

8-Digit HUC	Name	Area Square Kilometers	Area Square Miles
15010010	Lower Virgin, Arizona, Nevada, Utah	5361	2070
15010011	White, Nevada	7356	2840
15010012	Muddy, Nevada	4533	1750
15010013	Meadow Valley Wash, Nevada, Utah	6579	2540
15010015	Las Vegas Wash, Nevada	4817	1860

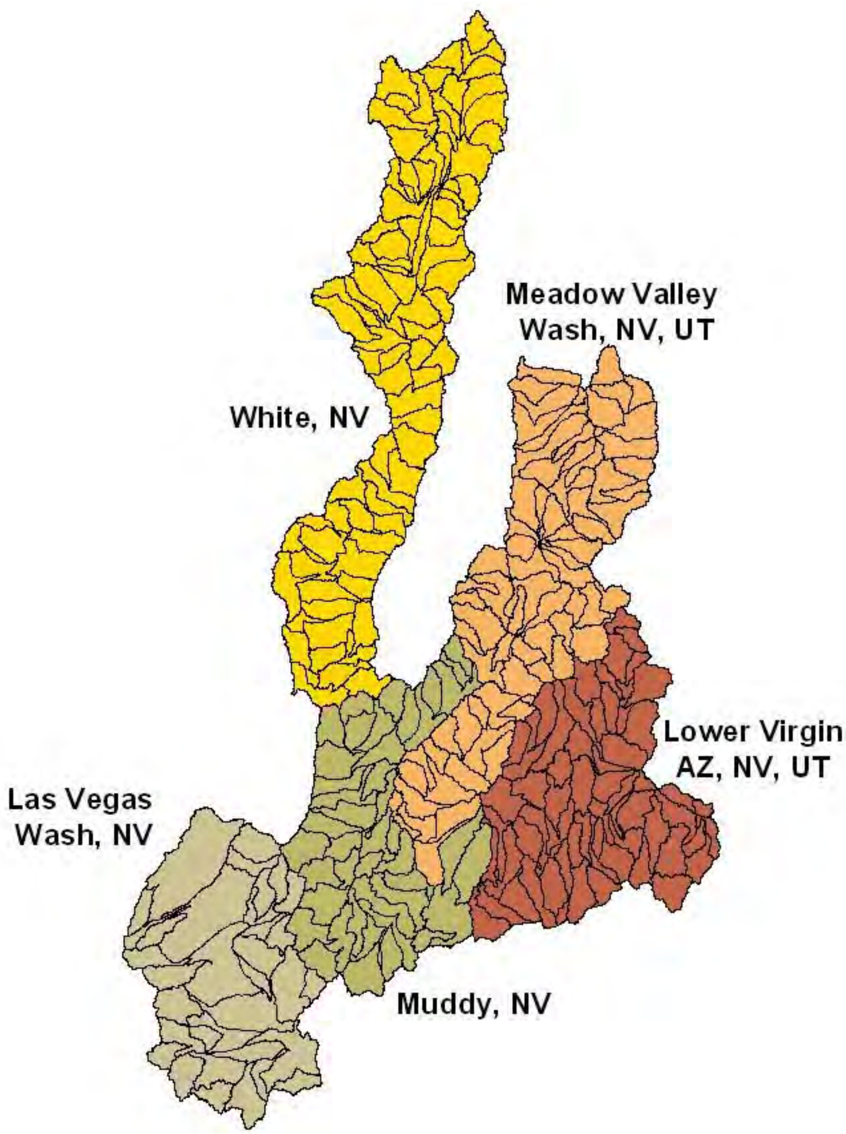

Figure 10. Watershed Boundaries for the Muddy-Virgin River Project Area.

3.0 Methodology

3.1 Regional Classification

The land cover used in this report is from the 2001 National Land Cover Database (NLCD) completed by the Multi-Resolution Land Characteristics Consortium (MRLC)(Homer et al., 2007). The 2001 land cover was used due to availability of datasets and the proximity to the sampling period. The MRLC is a federal consortium created to use Landsat 5 and Landsat 7 thematic mapping$^{(TM)}$ imagery, as seen in Figure 11, to provide consistent land cover for the entire United States. By analyzing the different wavelengths reflected by different surface types, land cover is able to be classified from reflected light. NLCD 2001 data uses 30 m Digital Elevation Model (DEM) to distinguish 29 land cover classes. In the Muddy-Virgin River Project Area, there are fifteen individual NLCD classifications which, for this study, have been assembled into eight dominant categories (Table 2).

Table 2. 2001 National Land Cover Data Regional Land Cover Classes.

NLCD class	Regional class
Open Water	Water
Developed, Open Space Developed, Low Intensity Developed, Medium Intensity Developed, High Intensity	Urban
Barren Land	Barren
Deciduous Forest Evergreen Forest Mixed Forest	Forest
Shrub/Scrubland	Shrubland
Grassland/Herbaceous	Grasslands
Pasture/Hay Cultivated Crops	Agriculture
Woody Wetlands Emergent Herbaceous Wetlands	Wetlands

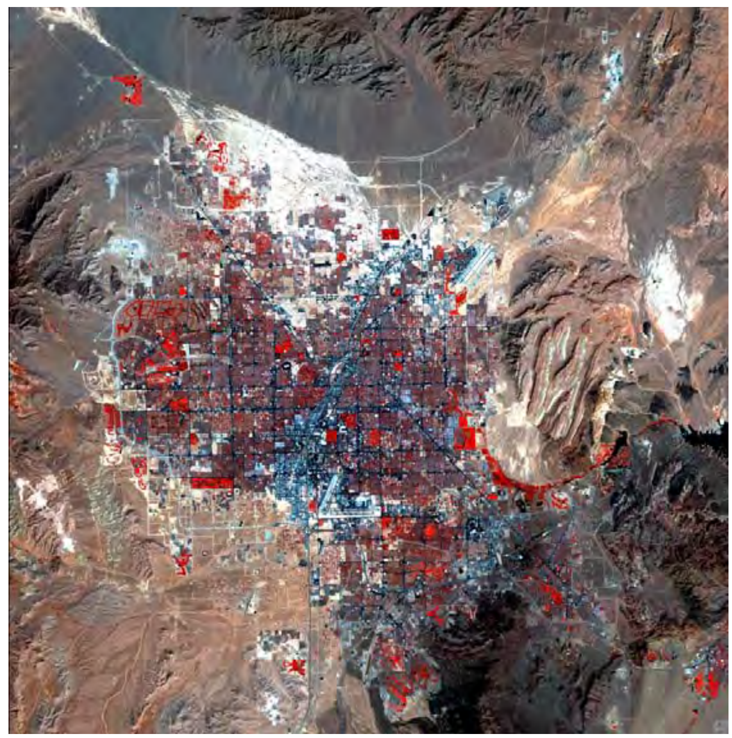

Figure 11. Las Vegas Valley. Vegetation Shown in Red.

3.2 USEPA- Delineated Sub-Watersheds

The sample locations were determined by using a spatially distributed, randomized site selection process (Herlihy et al., 1998, Herlihy et al., 2000). This sampling design may not be appropriate in an area with so little water. In this arid basin the design called out 35,000 stream kilometers but only 706 km were usable wet streams. Nested sites, which are sampling site sub-watersheds within a larger sampling watershed, were unavoidable, thus all sites were kept for analysis, although they may skew results. A separate set of GIS-delineated sub-watersheds (Jones et al., 2001) was used for the assessing relationships between landscape and water quality in the Muddy-Virgin Project Area based on 37 sampling points

(Figure 12). These watersheds were delineated using DEM data to calculate flow direction and flow accumulation. This process determines boundaries and ridge tops that divide water flow to drainage or outlet points. These delineated sub-watersheds ranged in size from less than 7 square kilometers (2.7 square miles) to over 18,000 square kilometers (6950 square miles). Corresponding site names are listed in **Appendix 1**.

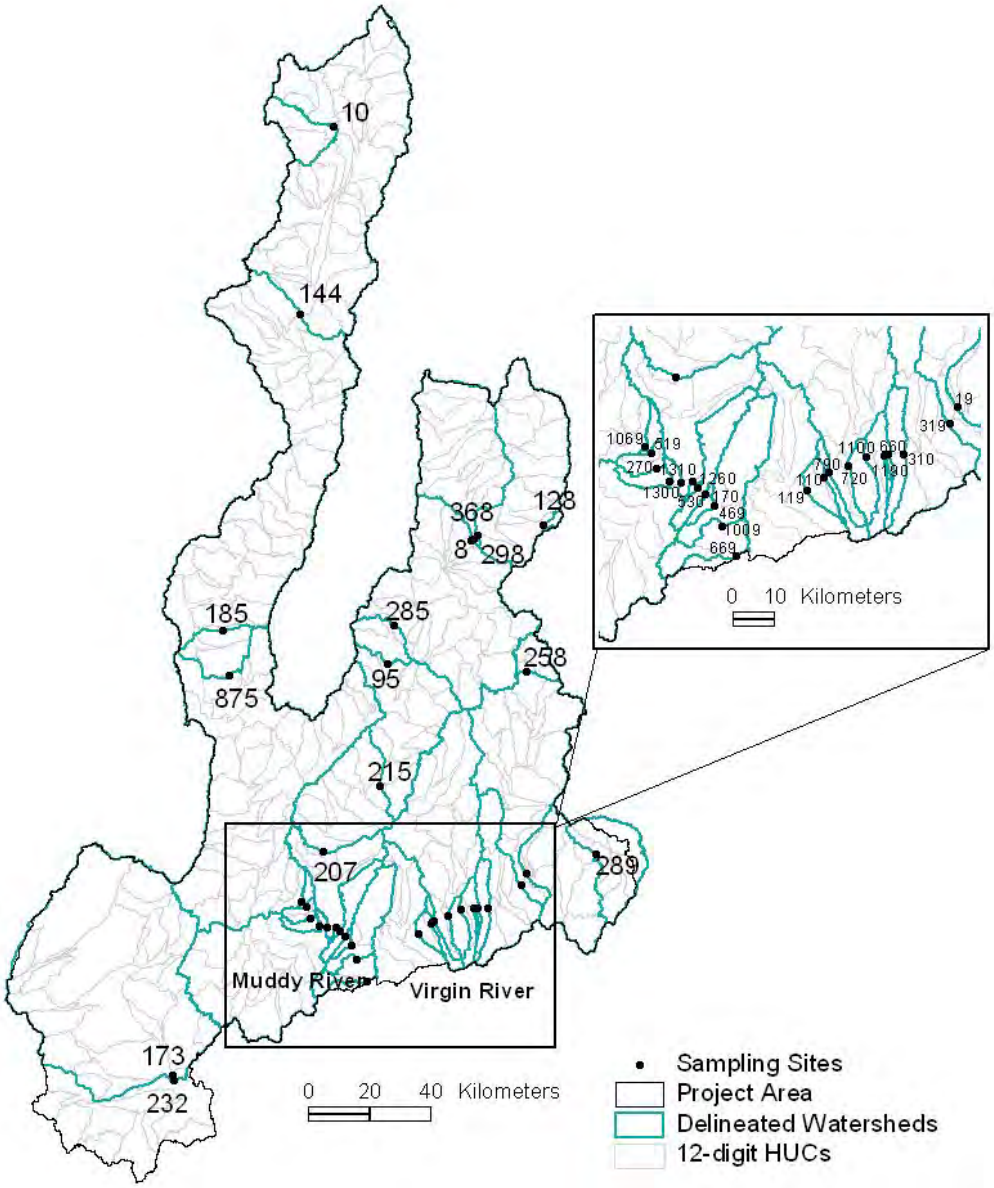

Figure 12. Muddy-Virgin River Project Area HUCs and GIS-Delineated Sub-Watersheds.

3.3 Landscape Metrics

Understanding watershed characteristics will help in the identification and interpretation of biogeographical patterns in biological communities. To characterize a watershed or a stream, it is necessary to identify the geologic, geomorphologic, hydrologic, land cover vegetation and distribution and land use. The first step is to identify a set of landscape indicators with which to conduct a comparative landscape assessment on the sub-regional study areas. The landscape monitoring and assessment approach involves the analysis of spatially explicit patterns of, and associations between, ecological characteristics such as soils, topography, climate, vegetation, land use, and drainage pathways, and interprets the resulting information relative to ecological conditions on areas ranging in size from small watersheds (a few hundred hectares) to entire basins (several million hectares).

A combination of the NLCD and a reporting unit, either HUCs or delineated sub-watersheds, were used to generate a new dataset (e.g., the amount of forest cover in each HUC). Both the HUCs and delineated watersheds, used as reporting units, were overlaid on the NLCD 2001 image. Using Analytical Tools Interface for Landscape Assessments (ATtILA), four different categories of metrics are calculated: landscape characteristics, riparian characteristics, human stressors and physical characteristics.

Landscape characteristics include basic summary calculations such, as the percent of natural land use, forests, or shrublands. Riparian characteristics calculate the percentage of stream length adjacent to a specified component. Human stressors compute population density (and/or change), phosphorous and nitrogen loading and stream/road density. Physical characteristics are calculations of general statistics such as elevation, slope and stream density.

Maps showing the relative ranking of each metric in the reporting unit were also produced. Figure 13 uses the 12-Digit HUCs as reporting units in calculating the percent forest in the basin. The map is color-coded to show relative conditions among watersheds. The dark green areas have the most amount of forest, while the brown areas have the least. The natural breaks classification method was used which displays results by finding groups and patterns using a statistical formula to minimize variance within each class.

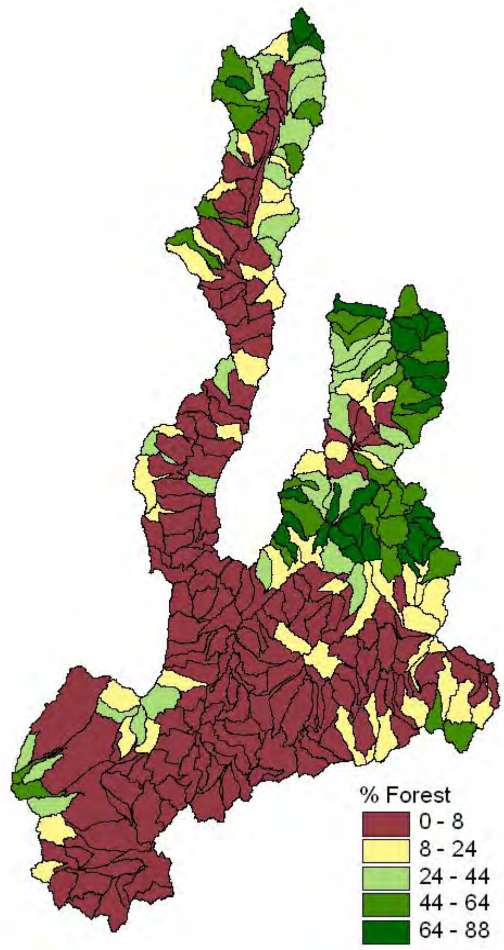

Figure 13. Example of the Maps that Appear in this Report. The Maps are Color Coded to Show Land Cover/use

3.4 Soil and Landform Metrics

Soil erosion metrics were calculated using the watershed analysis tool for RUSLE 2/SEDMOD soil erosion and sedimentation modeling. The Revised Universal Soil Loss Equation (RUSLE 2) model and the spatially explicit delivery model (SEDMOD) were the primary framework for this tool. The soil and landform metrics use GIS ArcInfo as the platform for the four arc macro language (AML) scripts and two ANSI C++ executable programs. State Soil Geographic (STATSGO) database soil data, NLCD 2001, boundary area, delineated sub-watersheds, ArcHydro generated filled DEM, flow direction, flow accumulation and stream network grid were used to run the model. The RUSLE 2/SEDMOD model generates master soil and landform geodatasets that are used to calculate the LS (slope length/steepness), R (rainfall erosivity), K (surface erodibility), C (surface cover effect), and P (conservation practices) factors, as well as, STATSGO derived soil parameters. These factors are used together to achieve the gross soil erosion rate (A value).

3.5 EMAP Measurements

Through the Environmental Monitoring and Assessment Program EMAP, planktonic and benthic macroinvertebrate data were collected between May and June, 2000. Peck et al., 2006, describes field procedures that were used during the EMAP Western Pilot Study, conducted from 1999 through 2004 which were the same methods use for this study. Sites were selected using a probability-based or random design to represent the wadeable streams within the Muddy-Virgin area using the USEPA RF3.

In general terms, a water quality standard defines the goals for a body of water by designating the use or uses to be made of the water, setting criteria necessary to protect those uses, and preventing degradation of water quality through anti-degradation provisions. Water quality standards apply to surface water of the United States, including rivers, streams, lakes, oceans, estuaries and wetlands. Under the Clean Water Act, each state establishes water quality standards which are approved by the USEPA.

Benthic macroinvertebrate assemblages reflect overall biological integrity of the stream, and monitoring these assemblages is useful in assessing the current status of the water body, as well as monitoring long-term changes. In this report, an Index of Biotic Integrity (IBI) is used to represent the overall health of the assemblages. This method evaluates biological variables using a number of criteria, and a subset of the five best performing metrics is then combined into a single, unitless index. These final variables, or metrics, should be sensitive to stressors, represent diverse aspects of the biota and be able to discriminate between reference and stressed conditions. Values range from 1 to 100 with higher numbers corresponding to healthier biotic assemblages.

3.6 Data Sources

Data sources include (1) USEPA delineated sub-watersheds, RF3 files, and EMAP data; (2) Natural Resource Conservation Service (NRCS) State Soil Geographic Data Base (STATSGO) soil data; (3) United States Geologic Survey (USGS) digital elevation model (DEM) and hydrologic unit code (HUC); (4) Multi-Resolution Land Characteristics Consortium (MRLC) 2001 national land cover data (NLCD); and (5) NASA satellite thematic mapping (TM) imagery. Using this data, statistical analyses were conducted.

3.7 Data Analysis

To study the relationship between landscape and water quality, stepwise multiple regression was used to associate stream indicators with ATtILA landscape and RUSLE 2 sediment transport metrics in each delineated sub-watershed. Prior to regression, pairwise correlations were examined between predictors (landscape and RUSLE 2 metrics). When two predictors were found to be highly autocorrelated ($R > 0.75$), one was arbitrarily excluded from further analysis to prevent the presence of collinearity. Soil variables were standardized to achieve comparable data. A natural log transformation was performed, if necessary, to linearize relationships. Outliers were also tested for, and removed to achieve normal distribution for residuals. The amount of variability explained by the regression model was assessed using the regression coefficient of determination R^2. The multiple regression model is:

$$y=\beta_0+ \beta_1 x_1+ \beta_2 x_{2\ldots}+\beta_n x_n + \varepsilon$$

where y is the response predicted value, β_0 is the constant, $\beta_{1\ldots}\beta_n$ are the coefficients of the predictors (x's), and ε are the residuals. Residuals were all tested for normality, using a Shapiro-Wilk's test ($p > 0.30$). Table 8 presents the final regression models. We used R version 2.13.1 (2011-07-08) software for our statistical analyses.

3.8 Quality Assurance Summary

A Quality Assurance Project Plan (QAPP) was prepared for this work entitled, Northeastern Nevada Landscape and Aquatic Resource Characterization on Federal Lands: A Landscape Assessment of the Humboldt River Basin, which was approved on April 29, 2009. A Technical Systems Audit was performed on all landscape ecology projects in the Environmental Sciences Division from February to March of 2011 and this project was given three minor revisions. Laboratory Notebooks were reviewed by the Environmental Sciences Division Director and Quality Assurance Manager annually. There were no findings requiring corrective actions. The audit and review conclusions did not impact the quality of the environmental data. The QAPP title caused a deviation in that the title stated the study was done in the Humboldt River Basin and not the Muddy-Virgin Project Area. The QAPP does state in the Abstract and Research Work Plan Summary that, "future research areas will coincide with the State of Nevada Total Maximum Daily Load (TMDL) priority watersheds", which is the case for sections of both Rivers and the Las Vegas Bay area of Lake Mead. This deviation did not have any impact on the environmental data quality. Environmental measurement data included locational data (e.g. National Land Cover Data, Satellite Data, and Geographic Information System Data) which all met performance and acceptance criteria stated in the QAPP. There were no deviations to methods or general or specific limitation on the use of the results.

4.0 Land Cover/Use

Humans are seen as a force behind environmental changes. Humans have been altering land cover throughout history through fire, clearance of forests for agriculture and livestock grazing through animal domestication. Human activities have only increased with the passing of time. Thus, today's land cover can be seen as the product of past land uses. Yet, land use and land cover are linked. Humans structure the landscape, but the landscape determines the activity. For example, soil type, geology and topography decide the feasibility of agriculture in an area. The relationship between humans and the landscape is important in understanding changes and quantifying linkages. For example, changes in land cover affect climate which in turn alters vegetation transpiration and surface hydrology.

4.1 Forests

Trees are an important element for humans and wildlife alike, playing numerous significant roles in a watershed. Clearly, forests are an economical, natural resource. Yet, forest ecosystems are also of great importance to water quality and quantity, habitat and climate. Trees regulate hydrologic flow by capturing rainfall and reducing the intensity of rainfall that reaches the ground. This can increase absorption and water storage capacity and decreases surface flow and erosion. Trees are essential for erosion control by stabilizing soil with roots systems, thus decreasing sedimentation, and improving water quality. Trees also provide habitat through food supply and shelter, and through forest litter, large woody debris present in stream beds which is a natural habitat for aquatic species. Air and water temperatures are also regulated by shade proved by a forest canopy (Center for Watershed Protection & USFS, 2008). In the Great Basin, forests within mountain ranges and riparian areas act as important refugia and corridors for macrofauna**.**

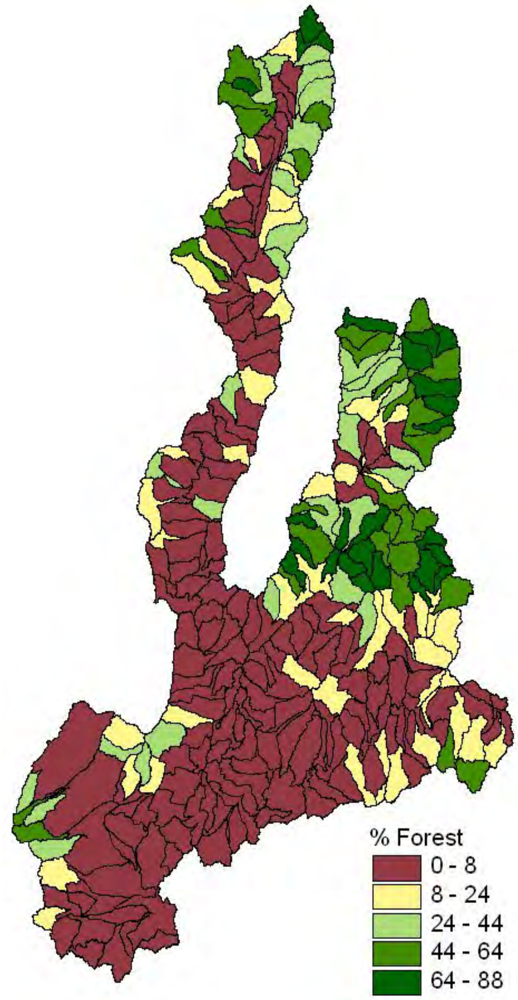

Figure 14. Percent Forest Cover in the Muddy-Virgin Project Area.

Historic use of wood in the Spring and Sheep Mountains Ranges north of Las Vegas was for charcoal production, construction and firewood. Today, the only permitted use is for non-commercial firewood from dead trees. In the northern portion of the area, forests, consisting of pine and mountain mahogany, also have historically been used for lumber mills, charcoal and fuel (Thompson & West, 1958). In the Muddy-Virgin Project Area, forest cover averaged 20% within the HUCs and 28% in the individual delineated sub-watersheds. The highest forest cover was found in the Meadow Valley in the Wilson Creek Range, and in the White Pine and Butte Mountain Ranges (Figure 14).

4.2 Shrubland

Shrubland (Figure 15) is the dominate land cover type with an average of 75% cover in the HUCs and 68% in the delineated sub-watersheds. Sagebrush (*Artemisia tridentate spp.*) is the leading vegetation, usually in association with other shrubs such as Bitterbrush (*Purshia tridentate*), ephedra (*Ephedra* sp.), and rabbitbrush (*Chrysothmanus nauseosus*). The height of these shrublands range from 0.3 (1.0 ft) to 2.0 m (6.6 ft) tall and may have pure stands of sagebrush or associated with other vegetation such as other types of shrubland or grasslands (Washington County Water Conservation District , 2006). Riparian shrubland, areas that are adjacent to waterways, consist of willows (*Salix* sp.), acacia (*Acacia* sp.) and arrowweed (*Pluchea sericea*).

The exotic, invasive species tamarisk (*Tamarix* sp.), also referred to as salt cedar, is a brushy vegetation that has invaded river corridors within the Muddy-Virgin Project Area by displacing native trees. Tamarisks excrete salts through their leaves as they grow making it increasingly difficult for native plants to survive. Because they use large quantities of groundwater, at which they are more efficient at capturing, they out compete the native vegetation. This results in higher salinity level and reduced flows. Dense stands create a monoculture offering little to wildlife and have become a fire hazard to communities. Finally, tamarisks are difficult to eliminate because of their longevity, large quantities of seeds and tolerance of environmental conditions.

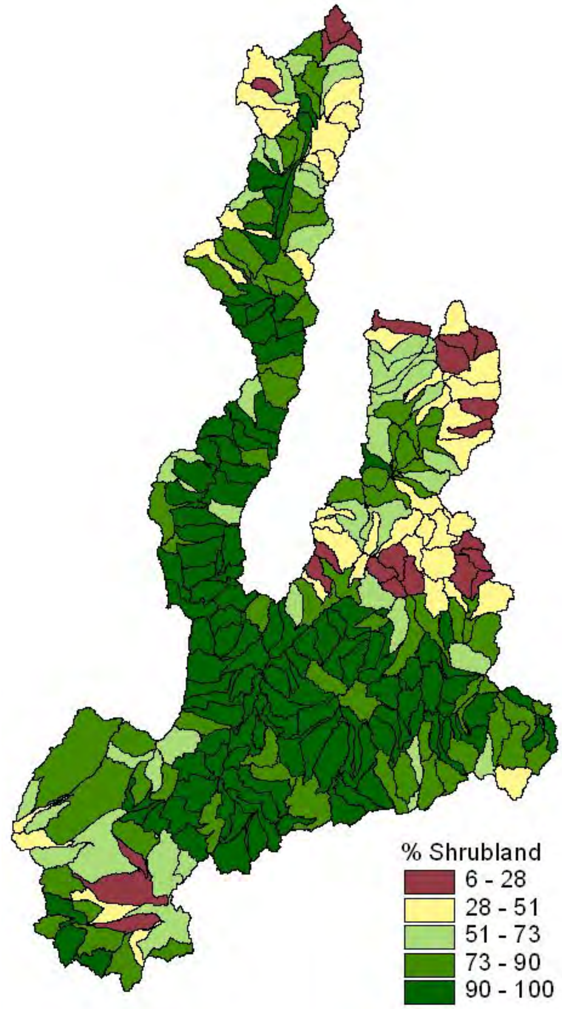

Figure 15. Percent Shrubland Cover in the Muddy-Virgin Project Area.

4.3 Grasslands

Grasslands are a minimal land use type with only an average of 1.5% cover in the HUCs and delineated sub-watersheds (Figure 16). The largest overall areas with grasslands are in the White Pine area to the north and the Beaver Dam Wash to the southeast. Grasses include squirreltail (*Sitanion hystrix*) and Great Basin wildrye (*Elymus cinereus*) with cheatgrass (*Bromus tectorum*), an invasive species, present in upland areas and rangelands.

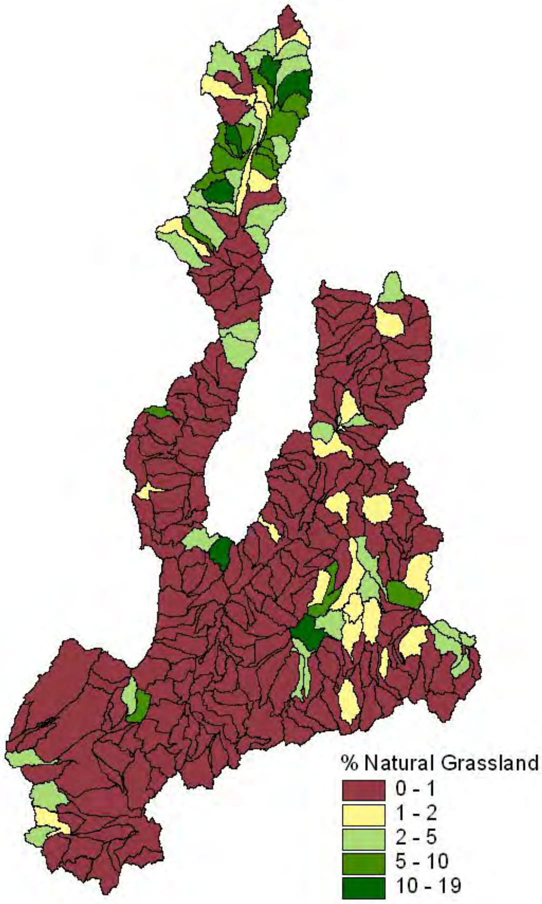

Figure 16. Percent Grassland in the Project Area.

The changing of native grasses to exotic species is a serious problem in Nevada. Halogeton, an herbaceous, toxic annual, arrived in the basin in the early 1900s and is able to survive high salt conditions, out-competing native forage. Cheatgrass, an annual grass which is used for forage, quickly turns the landscape into monocultures, displacing native grasses, is also highly flammable, susceptible to the recurrence of wildfires, does not provide adequate habitat for wildlife and threatens sensitive species in the area. Once a fire has burned an area, re-growth is dominated by the early germinating and rapidly growing cheatgrass. This trend has caused many problems in the lowland areas, increasing the severity of wildfires (Horton, 2000).

4.4 Agriculture Land Use

Agriculture in Nevada's semiarid climate is heavily directed to range livestock, primarily cattle production. Yet, a variety of other crops can be harvested where the landscape can be irrigated. This economic industry began to develop in Nevada from the mining boom in the mid 1800's. With the influx of settlers, agriculture and ranching erupted to provide for the miners. Commodities consist largely of alfalfa hay for cattle feed, but other crops such as onions, potatoes, nuts and vegetables are also harvested to a lesser extent.

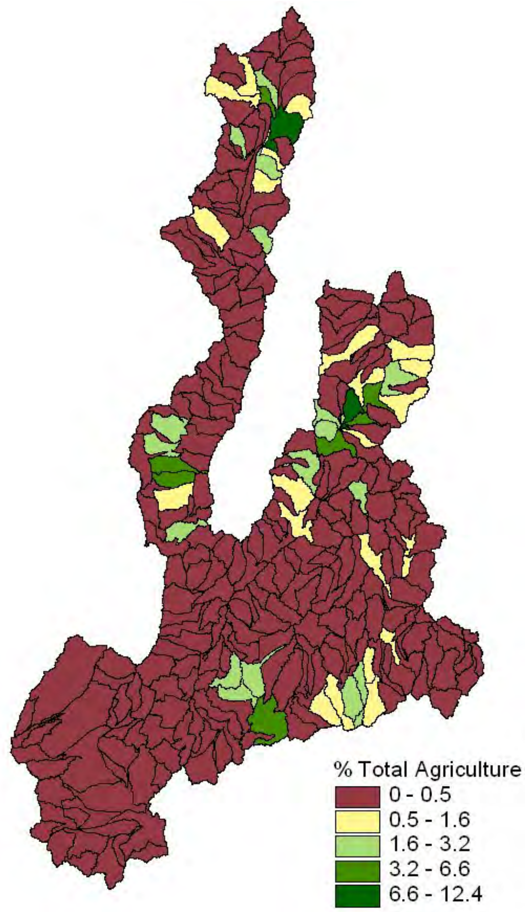

Figure 17. Percent Total Agriculture in the Project Area.

The natural ground-water springs in the project area supply water for irrigation. With irrigated land comes a myriad of potential negative environmental effects. In 2000, it was reported that agricultural nonpoint source pollution was the leading cause of water quality impacts on surveyed lakes and rivers. Irrigated runoff water may contain fertilizers and pesticides, which can contaminate water bodies, poison fish, and cause algal blooms which deplete oxygen. Irrigation water also can erode stream banks, washing soil off fields and into streams and water bodies, increasing turbidity, and decreasing critical sunlight for aquatic plants. A problem endemic to arid regions is increased soil salinity from evaporation due to the inability of the soil to filter minerals (USEPA, 2005).

The Muddy-Virgin project area is located in 6 counties: White Pine, NV, Nye, NV, Lincoln, NV, Clark, NV, Washington, UT and Mojave, AZ. Forage, alfalfa (hay), and grains (wheat, oats, and barley) are the largest commodities in the region followed by livestock and row crops (NDA, 2009). Total agriculture (includes row crops and pastures) is minimal with an average of less than 1% in the HUCs and delineated sub-watersheds (Figure 17). Agricultural areas are found along the riparian areas of all the major rivers. Moapa Valley, encompassing the lower part of the Muddy River, has 2016 hectares (4,982 acres) of irrigated, agricultural lands while the Virgin Valley, in the lower portion surrounding the Virgin River, had 1242 hectares (3,068 acres), as of 2000 (Clark County, Nevada, 2000).

4.5 Grazing

Historically, agriculture was largely directed toward livestock, and overgrazing had become problematic. The Virgin River specifically was used for grazing in the mid 1800's by Mexican livestock along the Spanish Trail and then was later settled by Europeans. Open range livestock grazing has since spread throughout Nevada State reaching virtually every lowland meadow and upland watershed. Livestock grazing can affect many aspects of riparian areas through erosion, sedimentation, and water quality, in turn affecting aquatic life downstream. Total phosphorus and nitrogen, as well as heavy metals, can also be transported, especially in dense cattle areas such as feedlots and dairies. Soil quality is changed by severe trampling and compaction, causing increased erosion and limiting sustainability of plants. This can make streams wider and shallower, and can increase suspended sediment concentrations (Bengeyfield, 2007). High shrubland cover may also be attributed to overgrazing. For example, the big sagebrush, was not foraged because of its high oil content, and the overgrazing of grasses did not allow for seed production and re-growth. As grasses decreased, shrubland cover expanded (Young & Sparks, 2002). Such land cover changes can result in habitat loss for endangered species such as the now endangered southwest willow flycatcher (*Empidomax trailii extimis*). Cattle eat or trample young riparian plants, preventing deciduous cottonwoods and willows from establishing. Although these flycatchers have been found to nest in tamarisk, mature cottonwoods and willows are preferred for nesting. Without the understory to replace the older trees, prime habitat is lost (Suckling et al, 1992).

As of 2000, northeast Clark County, much under the authority of the BLM, has nineteen grazing allotments, seven of which are now controlled by Clark County and are no longer in use. There have also been strict restrictions on livestock grazing by the USFWS due to potential impacts on desert tortoise habitat (Clark County Nevada, 2000). In the project area, grazing occurs primarily in the Lincoln and White Pine counties. Animals such as feral horses and burros are the main users of the rangelands. In 1971, the BLM was charged to manage wild horses and burros in specific areas in 10 states. Only areas that were found to have significant populations in 1971 are designated as management areas. This does not mean that the areas are designated for horses only, but areas where the BLM evaluates to determine if there is adequate food, water, cover and space to sustain healthy and diverse wild horse and burro populations over the long term. Currently, there are an estimated 38,000 wild horses and burros in the managed rangelands in the ten western states. In Nevada State there are an estimated 17,700 horses and 1,200 burros. With horse size doubling about every four years, removal of wild horses and burros occurs to ensure rangeland health, in accordance with land-use plans that are developed in an open, public process.

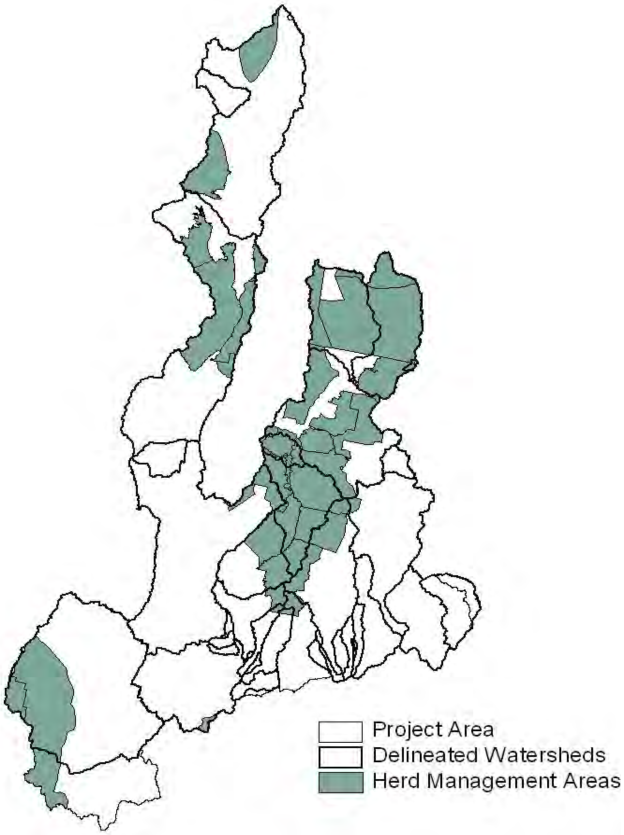

Figure 18. Herd Management Areas in the Project Area.

Rangeland health is also dependant on the proper management of the wild horse and burro population. Decisions are made when applying to establish livestock grazing regarding appropriate management levels for wild horse and burros. In the Muddy-Virgin project area, there are large sections designated as herd management areas located within the Meadow Valley Wash and around the White Pine River area (Figure 18). Wild horses and burros can quickly overpopulate an area, exceeding the capacity of the land. Degradation can include impacts on vegetation communities and effects on water quality. A typical result is the changing of the land cover from grasses to unpalatable shrubs (Smith, 1986). The BLM is responsible for keeping wild horse and burro populations within appropriate numbers to avoid these potential impacts.

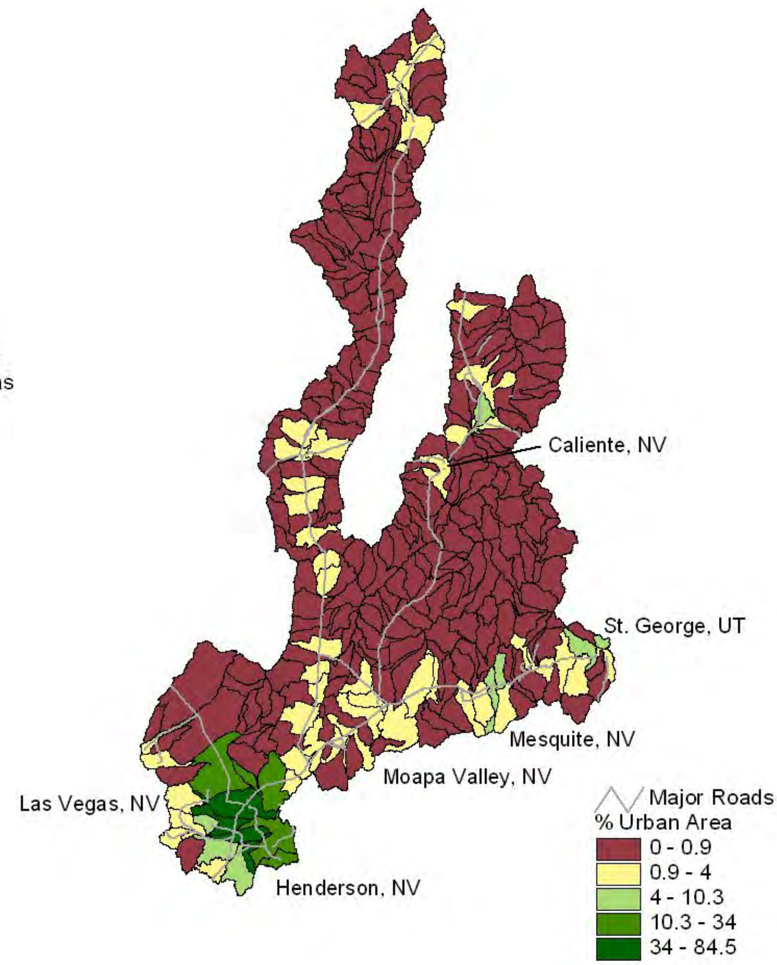

Figure 19. Percent Urban Areas in the Project Area.

4.6 Population Growth and Urban Development

Residential areas exist predominately in the southern portion of the project area. Las Vegas Valley is the largest urban area present with an estimated population of 1.3 million, located to the southwest. Other smaller communities are Mesquite, on the border of Nevada and Arizona, Hiko, along the Pahranagat, St. George in Utah and communities along the Muddy and Virgin River. Overall percent urban areas are minimal with most values less than 1% (Figure 19). Values range up to 84.5% for the densely populated Las Vegas Valley. According to the U.S. Census Bureau, in 2000 the population in the Muddy-River Project Area was about just under 2 million people covering an area of 40,656 km^2 (15,700 mi^2), with the majority located in the Las Vegas Valley (ESRI, 2010). The Las Vegas Valley is one of the fastest growing metropolitan areas in the US (U.S. Census Bureau, 2009) whose population doubled from 1980 to 1994 and then again from 1994 to 2007 in addition to the yearly tourist population of 36.4 million. Between 1980 and 2000, the city of Las Vegas itself grew from 165,000 to 478,000 people (Table 3). Mesquite has grown from a little more than

500 people to almost 10,000, while Henderson, a suburb of Las Vegas has grown from a population of 12,500 to 175,000 (Figure 20).

Table 3. Major Population Areas in the Muddy-Virgin Project Area.

Place	County	1980	1990	2000
Las Vegas, NV	Clark	164,674	258,295	478,434
Henderson, NV	Clark	24,363	64,942	175,381
N. Las Vegas, NV	Clark	42,739	47,707	115,488
St. George, UT	Washington	11,350	28,502	49,663
Mesquite, NV	Clark	992	1,871	9,389
Moapa Valley, NV	Clark	702	3,444	5,784
Caliente, NV	Lincoln	982	1,111	1,123

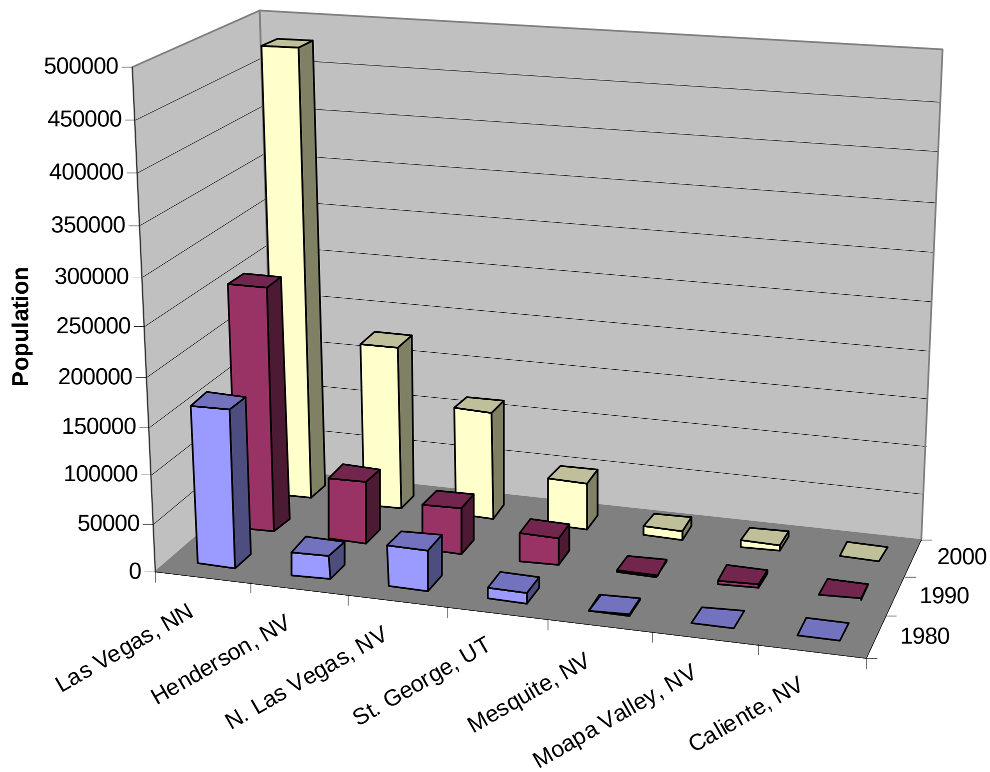

Figure 20. Population Change in Major Cities in the Muddy-Virgin Project Area.

In this arid landscape, increases in population can have major affects to water supply and the landscape**.** Currently, the Southern Nevada Water Authority (SNWA) is planning a pipeline to groundwater resources in valleys just outside the project area boundaries around Pahranagat and Meadow Valley areas. An Environmental Impact Statement is being prepared to assess the affects such a proposal would have to the land cover and current use of it by the resident population and native biota. High ground-water levels produce meadows and cover the desert floor with phreatophytes, which are groundwater dependent plants, that arrest erosion (Schlyer, 2007). A reduction of the water table could have adverse affects on the surrounding desert wildlife. Although the valleys are outside the Muddy-Virgin Project area, the carbonate-rock aquifer system, extends beneath numerous surface-water drainage basins, or hydrographic areas including a large portion of the MV Project Area. Long term effects of groundwater pumping could be significant drops in the water table and a loss of dependant plant life and the associated wildlife (Schlyer, 2007; Deacon et al., 2007).

4.7 Roads

Roads are necessary to join people with each other, recreational sites and other necessities. Yet, the network of roads with the associated traffic can result in environmental degradation. Roadways can change the adjacent natural habitat by impairment of species migration, be a source of pollution from runoff of vehicle-related chemicals, facilitate spread of exotic species, alter streams by sediment deposition from erosion, and change the stream hydrology by changing timing and routing of runoff (Transportation Research Board of the National Academies, 2002). Road density and number of roads crossing streams are important landscape indicators to include in environmental assessments. This study calculated road metrics from 1:100,000 USGS Digital Land Graph data (U.S. Census Bureau, 2009). According to the road map used in this study, which includes all types of roads (highways, country roads and city streets) road density was minimal with the highest density in the basin (9.4 km/km^2) in the Las Vegas Valley (Figure 21). The main road through the project area is Highway 93 traveling north-south down through Las Vegas. Other main roads are Highway 95 running NW-SE and I-15 running SW-NE, both intersecting Las Vegas. The density of roads crossing streams is relatively low with a range between 0.0 and 4.6 crossings per kilometer of stream with an average of 0.4. The only areas with densities greater than 1.0 are located in and around the Las Vegas Valley, to the north around White Pine River and to the east in Utah.

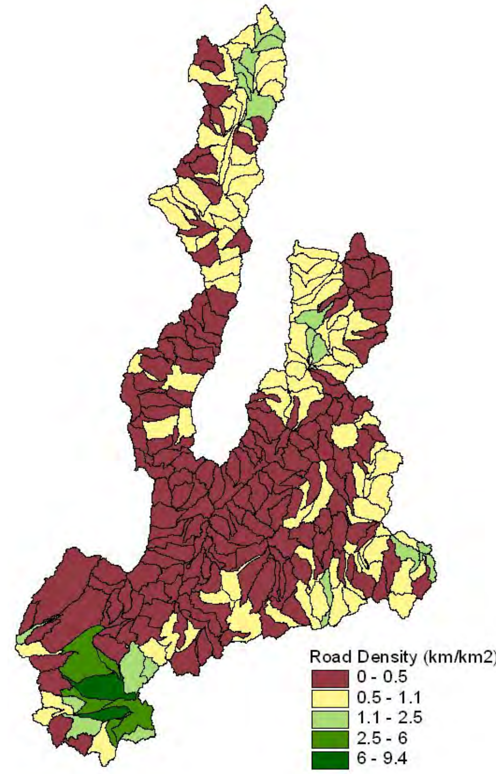

Figure 21. Road Density in the Project Area.

4.8 Mining

The Las Vegas area, originally a stop on the Spanish Trail, was known for its natural springs. Minerals were discovered in the 1850s, and mining began for metals such as gold, silver and lead, and nonmetallic minerals, as gypsum, limestone, silica sand and gravel (Clark County Nevada, 2000). The upper half of the project area has its history as a stopover on the Mormon Trail alternate route until ore was also discovered, primarily gold and silver. Yet, because the mining centers were remote, population influxes did not occur as they did further north in the Humboldt Basin.

Currently, there are many active mining areas in the

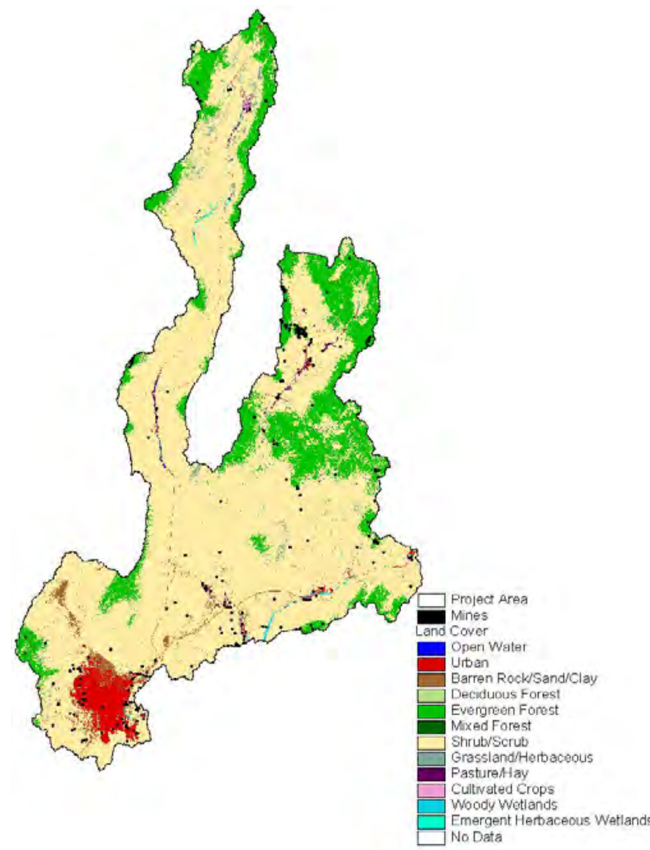

Figure 22. Muddy-Virgin River Project Area Land Cover Including Mines with 1km Buffer.

Muddy-Virgin River Project Area (MV PA) with nonmetallic mineral production exceeding metallic. Minerals include gypsum throughout the V and M mountains, limestone at Apex, NE of LV and others such as marble, mica, salt, borates and fluorspar (Clark County Nevada, 2000). Sand and gravel mining is one of the major mining operations in the project area. All industrial silica sand and gravel mines in the PA are now past producers. Today, sand and gravel mining is utilized for construction, providing necessary building supplies. Erosion, sediment deposition and air pollution through fugitive dust are the main concerns in this types of mining. Removing the vegetation cover and exposing the soil increases erosion rates and velocity of water runoff while releasing dust into the air.

Geothermal mines are increasing in number in Nevada. In the MV PA, wells and hot springs are being used to produce geothermal energy along the Muddy and Virgin River systems, to the north in Meadow Valley and in the Pahranagat Valley. Geothermal mines use the naturally heated water and steam for generation of electric power, direct heating or geothermal pumps. There are minimal amounts of emitted gases, spent water is pumped back into the wells and most mines are known to blend well with other land uses (University of Utah, 2001).

Using 2005 mine data created by USGS, a one kilometer diameter buffer was created around each mine to represent the relative affect of each mine. One kilometer was determined by comparing satellite imagery to land cover data to determine the extent of the mine's anthropological influence. Past producing gold mines, currently producing gold mines and processing plants have been included (Figure 22)**.**

4.9 Riparian Land Cover/Use

Riparian buffers, areas connected to or adjacent to a stream bank or other body of water, are complex ecosystems connecting the landscape to the stream system. These zones act as traps, filtering sediments and nutrients, slowing water flow and providing stable stream banks, and improving water quality. Thus, the surrounding land cover is related to stream productivity. Riparian buffers along stream banks can affect water quality through amount and type of cover, which can determine soil loss and sediment movement. Characterization of these conditions can identify areas in need of improvements. Vegetation moderates temperature and provides habitat and is a source of nutrients for wildlife. Buffers are most effective when they constitute native grasses and deep rooted trees and

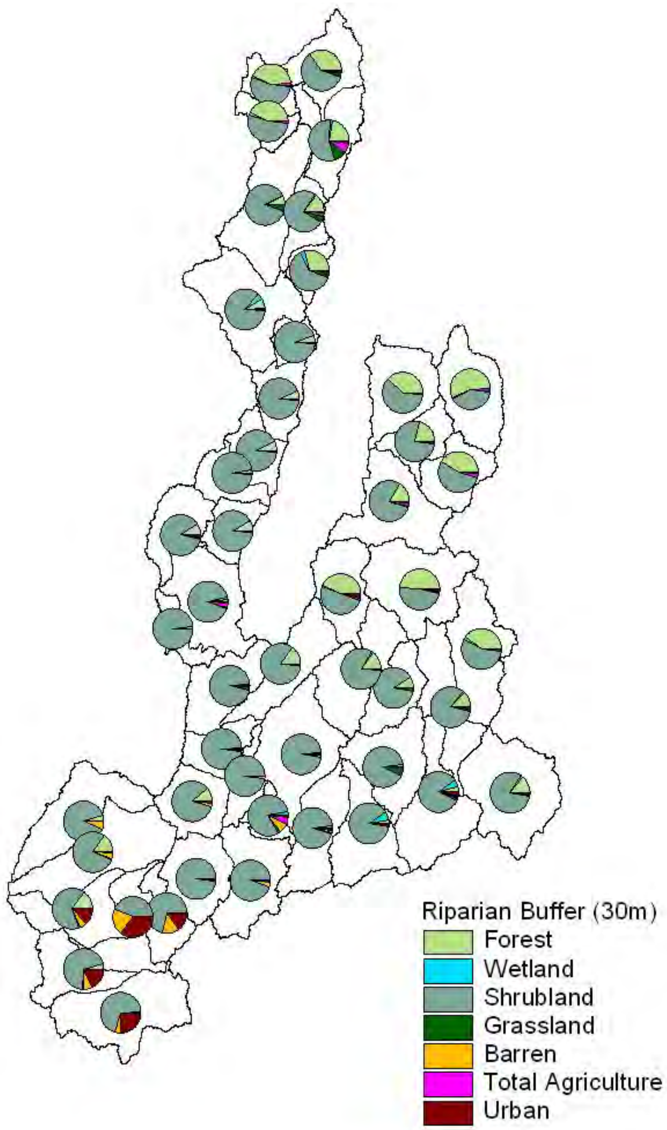

Figure 23. Percentage of Riparian Buffer in Forest, Wetland, Shrubland, Grassland, Barren, Total Agriculture and Urban Calculated within a 30m Buffer.

shrubs. Lack of necessary vegetation can result in increased erosion, reduction of water storage capacity, and a decrease in water quality (Snyder et al., 2003).

Buffer distances of 30 and 90 meters on both sides of the streams are used to calculate land cover metrics. The relative amount of land cover/use in a 30 meter riparian buffer (each side of streams) within the project area can be seen in Figure 23. Looking at the entire basin, riparian land cover/use is similar to the total watershed assessment. Percent wetlands, agriculture and urban areas had a slightly higher proportion in the riparian buffer area. Percent natural grasslands and forests were slightly lower. The descriptive statistics for total watershed assessment, as well as 30 m and 90 m riparian buffers are displayed in **Appendix 2**.

5.0 Land Cover Comparison

Over time, the landscape is changed from one cover type to another by natural changes, such as fires and flooding, and anthropogenic mechanisms, including urbanization, logging and farming.

The MRLC's NLCD 1992/2001 Retrofit Land Cover Change Product was developed to be an accurate analysis between the 1992 and 2001 land cover years. Because of new mapping technologies, new input data and mapping legend changes, direct pixel comparison between the two years would not be exact. This retrofit product was used to analyze changes in the landscape in the Muddy-Virgin Project Area. Two subset images are shown in **Figures 24a-b**. Average land cover/use change in the project area was very slight. Significant changes included decreases in forest cover in the Meadow Valley Wash area because of clear cutting which changed the land cover to shrubland. Other changes occurred changing from shrub/grassland to barren and urban land in the Las Vegas area because of increased development. Shrub/grasslands and agricultural patches were interchanged as well throughout all HUCs because of changes in farming and grazing. Wetlands increased slightly along the Las Vegas Wash and Lower Virgin and Muddy Rivers.

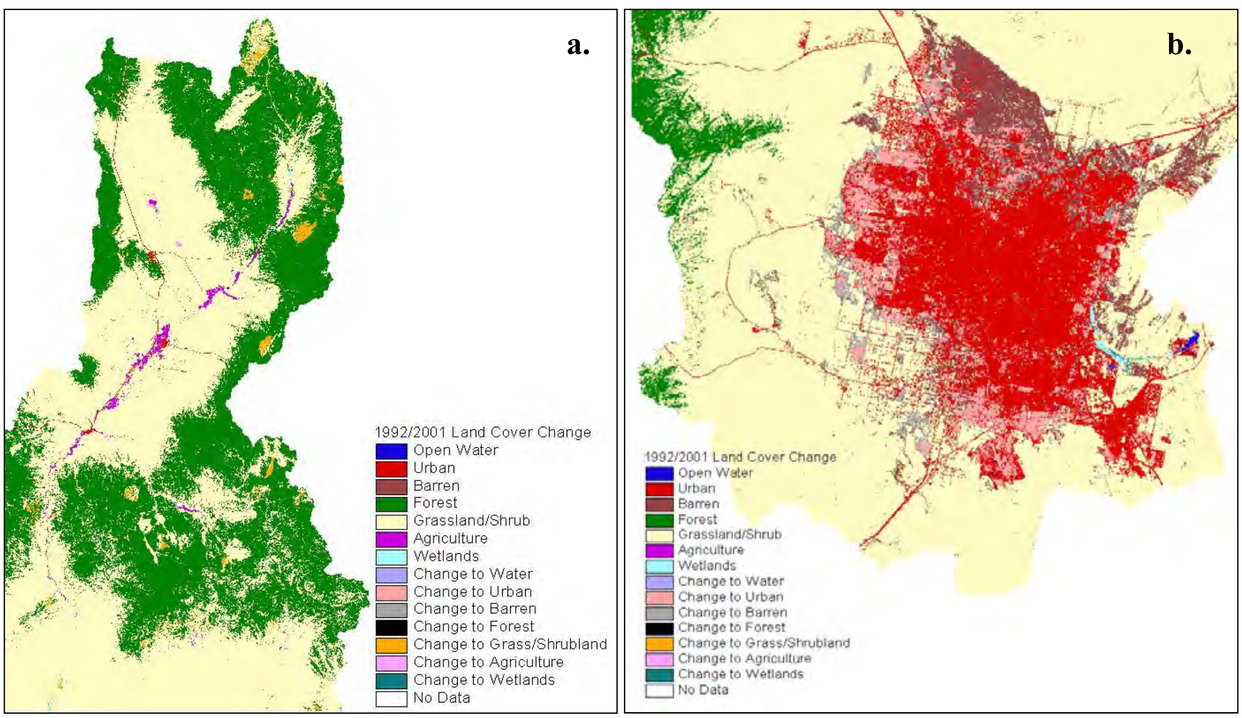

Figure 24a-b. Meadow Valley Wash and Las Vegas Valley Land Cover Change.

6.0 Soil Cover

The automated GIS Watershed Analysis Tool was used for soil erosion modeling. This program computes soil erosion and sediment delivery metrics based in the Revised Universal Soil Loss Equation (RUSLE 2) soil erosion framework and the Spatially Explicit Delivery Model (SEDMOD) sedimentation framework. Rainfall derived erosivity (R), soil surface cover characteristics (C), soil surface erodibility (K), slope length and steepness (LS), and soil management practices (P) are multiplied to reach the gross erosion rate (A) for each of the Project Area's 40 delineated sub-watersheds.

6.1 R Factor

The R factor, which represents the rainfall-runoff erosivity factor, is a measure of the erosion force of a rainfall event at particular locations with the final value quantifying the amount of runoff, as well as the intensity of the raindrops' effect. A cumulative summation of a normal year's rain is used to determine this index. Greater R factors can identify areas with greater potential for erosion.

In the entire project area, R factors ranged from 6 to 42, while in the individual delineated sub-watersheds, average R factor values ranged between 9 and 28 with the majority of values less than or equal to 14. The areas with the greatest potential for rainfall erosion are located in the surrounding mountain ranges and the Meadow Valley and Beaver Dam areas (Figure 25). For comparison, average R factors throughout the continental United States vary from less than one hundred in the arid Great Basin to a couple hundred along the pacific coast and up to 700 in the gulf coast (Troeh and Thompson, 2005) (Figure 26).

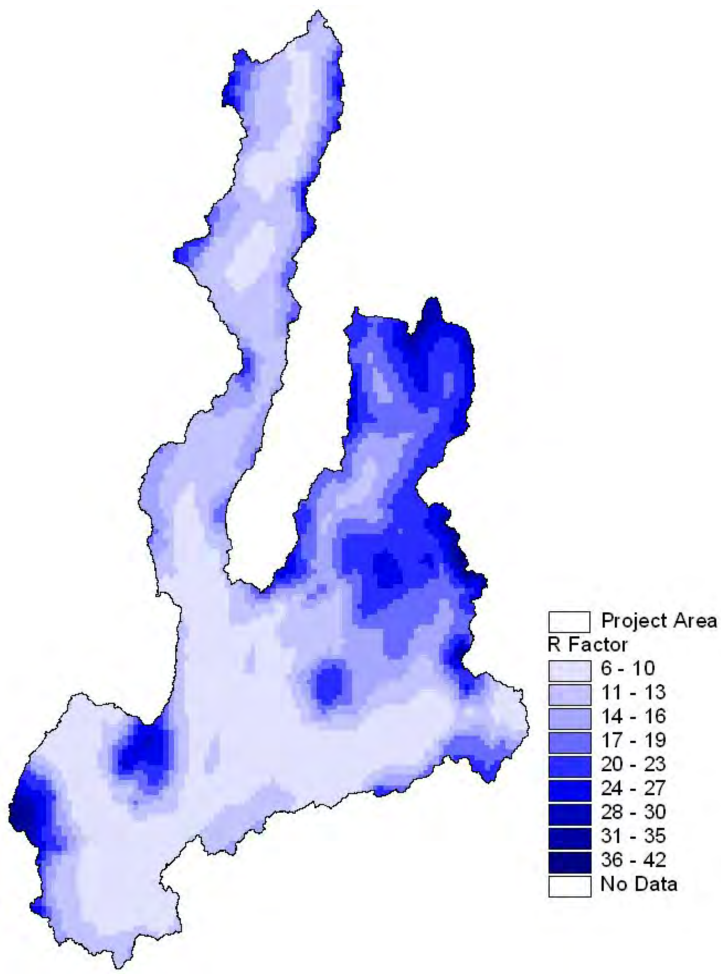

Figure 25. Rainfall Erosivity in the Muddy-Virgin Project Area.

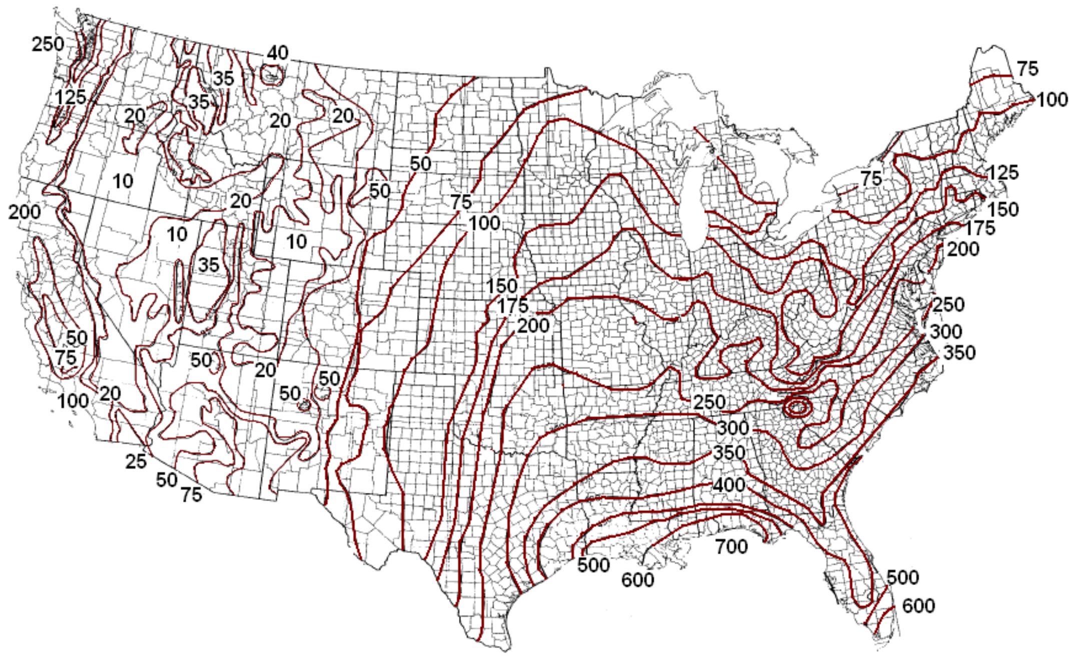

Figure 26. Average Rainfall Erosivity for the Continental United States (Troeh, 2005).

6.2 C Factor

The C factor, or cover management factor, reflects the effect of cropping and land management practices on erosion rates. Simply, the C factor indicates how conservation plans, such as changes in plant and soil cover and biomass will affect soil loss. For example, for most of the basin, values are less than 0.09. This signifies that erosion will be reduced up to 9% compared to the amount that would have occurred naturally (ARS, 2010). This is an important variable because it represents how conservation changes can reduce erosion. To calculate this factor, RUSLE 2 uses sub-factors canopy, surface cover, surface roughness and prior land use to compute a soil loss ratio. The C factor is an averaged soil loss ratio weighted by R factor distribution. In the delineated sub-watersheds, averaged values were very low ranging from 0.04 to 0.15 with an overall average of 0.09 (Figure 27). High individual values of up to 0.98 can be found in the southern areas around the Muddy and Virgin Rivers, locations to the north of Las Vegas and other places with heavy agriculture.

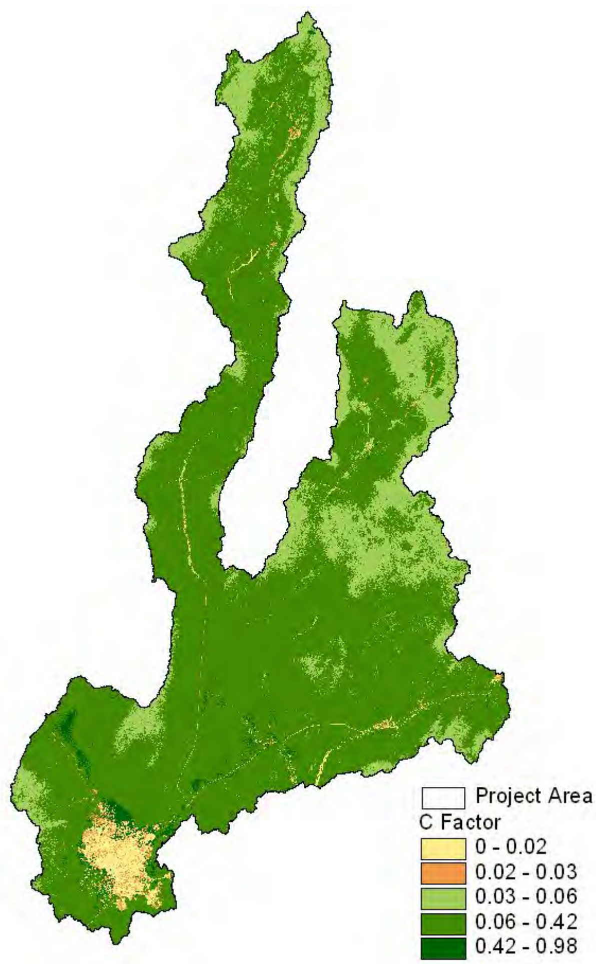

Figure 27. C Factor Values for the Muddy-Virgin Project Area.

6.3 K Factor

Soil erosion is an important environmental variable that can have profound effects on and off site. In the Muddy-Virgin River Project Area, grazing is a factor in erosion. Trampling of streambanks by livestock compress the soil, decreasing the vegetation and the soil's ability to absorb and hold water. This erodes the bank, adding sediment into the stream. Erosion of streambanks can result in the straightening of the river bed, increasing slope and flow velocity. Mining operations may dump large amounts of sediment directly into streams. Increased sedimentation can change the quality of the water affecting aquatic life and beneficial uses downstream. Large amounts of sediment reduce capacity and increases flood damage (Julien, 1998). Surface soil erosion can also affect soil productivity and ecosystem function. Since most nutrients and organic matter are most dense in the surface soil layer, erosion washes away the most productive layer. Soil erodibility, expresses here as the K factor, evaluates the potential for erosion using the NRCS STATSGO database soil data. The K factor represents the combination of soil type and detachability, as well as transportability of the eroded sediment. Table 3 describes the general relative distribution of K Factor values.

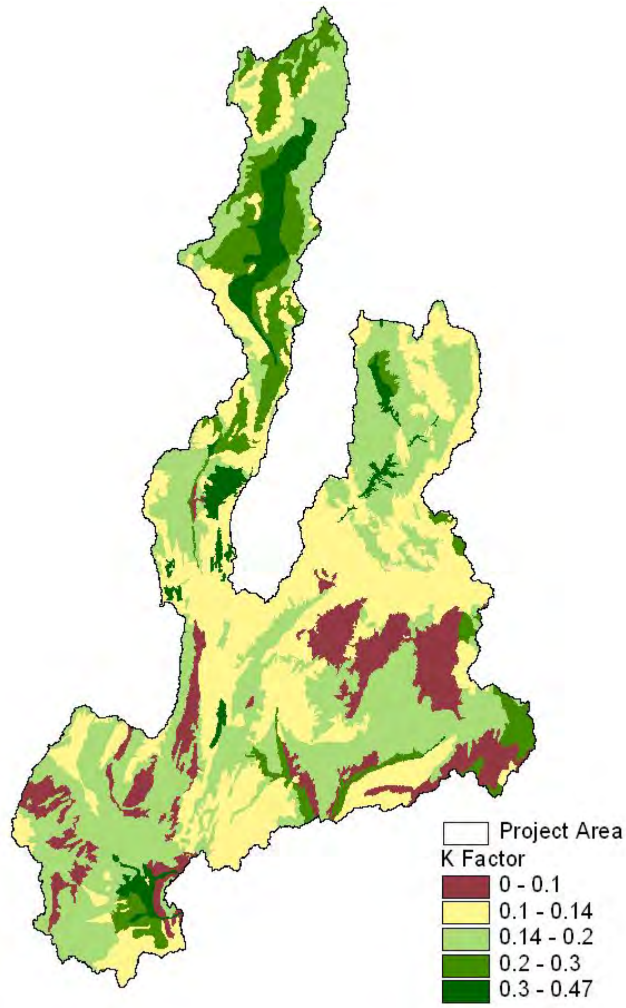

Figure 28. K Factor Values for the Muddy-Virgin Project Area.

Table 4. General Distribution of K Factor Values.

K Factor	Definition
0-0.15	Fine textured soils high in clay, resistant to detachment
0.05-0.2	Coarse textured soils which may be high in sand, low runoff
0.25-0.4	Moderately susceptible to detachment, moderate runoff
>0.4	High silt content, susceptible to detachment, high runoff rates, higher erodibility

In the project area, potential soil erodibility ranged from 0.00-0.47, while the delineated sub-watersheds have values between 0.13 and 0.23 (Figure 28). The areas with the highest erodibility are along the Pahranagat and White Pine Rivers and around the Las Vegas Valley. The predominant soil types are sandy loam with sand prevalent surrounding the Muddy and Virgin Rivers (Figure 29). For a list of the user-defined classes, see **Appendix 3.**

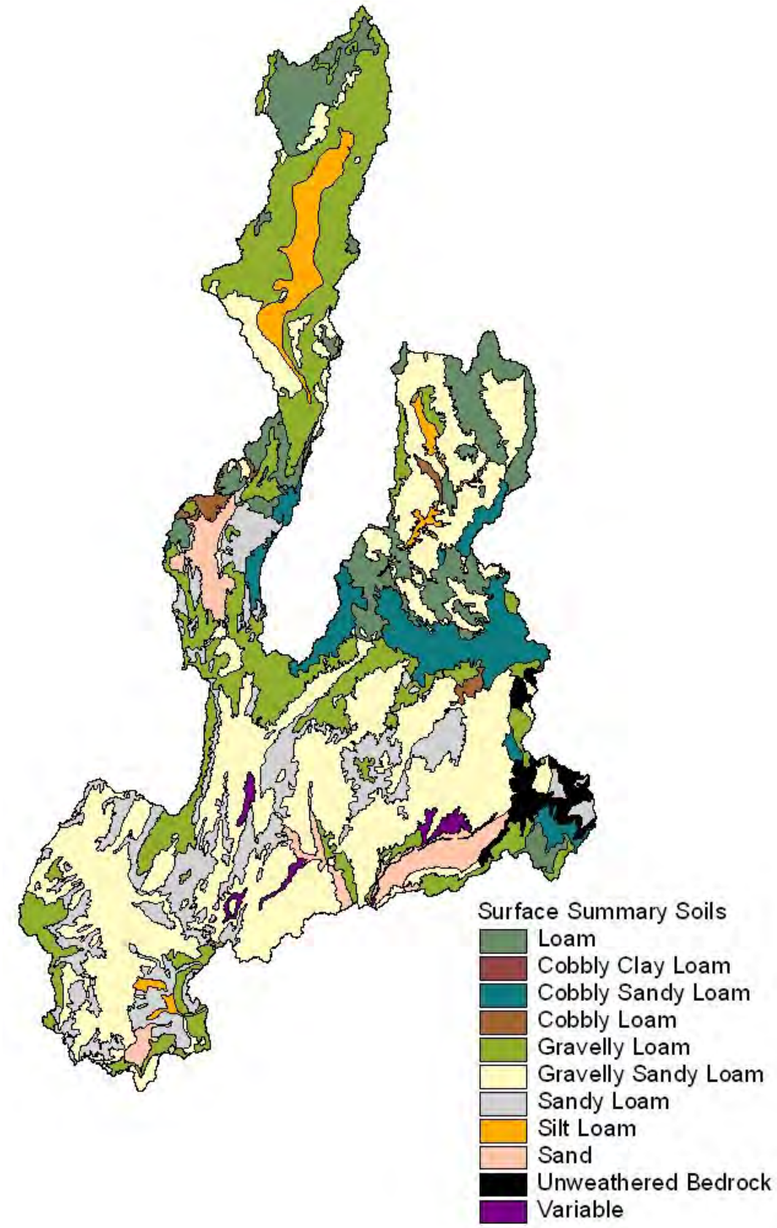

Figure 29. Map of Surface Layers in the Muddy-Virgin River Project Area.

6.4 P Factor

The P factor, computed as the ratio of soil loss, represents how management practices on surface conditions connected with upslope and downslope tillage affect erosion by modifying flow factors. Practices may include vegetation erosion management, contour farming, terracing, subsurface drainage or strip cropping. These practices affect erosion by directing runoff and increasing or decreasing erosivity. Factors included in the P factor involve runoff rate, management practices, and transport capacity affected by slope and roughness of the surface. Practices that do little to reduce soil erosion have numbers nearing 1.0 (Renard et al., 1997). In the Muddy-Virgin River Project Area, the P Factor for all delineated sub-watersheds is 1.0.

6.5 LS Factor

The LS factor consists of slope length, which is the distance of flow along its path, and steepness, which represents the effect of the slope gradient on erosion (Van Remortel et al., 2005). The LS factor examines the steepness of the slope, the susceptibility of soil to erode and the relationship between slope and length. As slope length increases, runoff accumulates and detachment potential and transport capacities increase, which can result in a considerable increase in soil loss. An LS value of 1.0 is equal to a 9% slope steepness for a 22.1m (72.6 ft) unit plot. The values are also determined by erosion susceptibility. Examples of the tables used to determine the LS factor, based on land use practices and land type, can be found in Renard et al., 1997. Values averages ranged from 0.94 to 6.49 in the delineated sub-watersheds. Because of the detailed resolution of the data, an entire basin map is not appropriate. Figure 30 displays the Virgin Valley area for LS values.

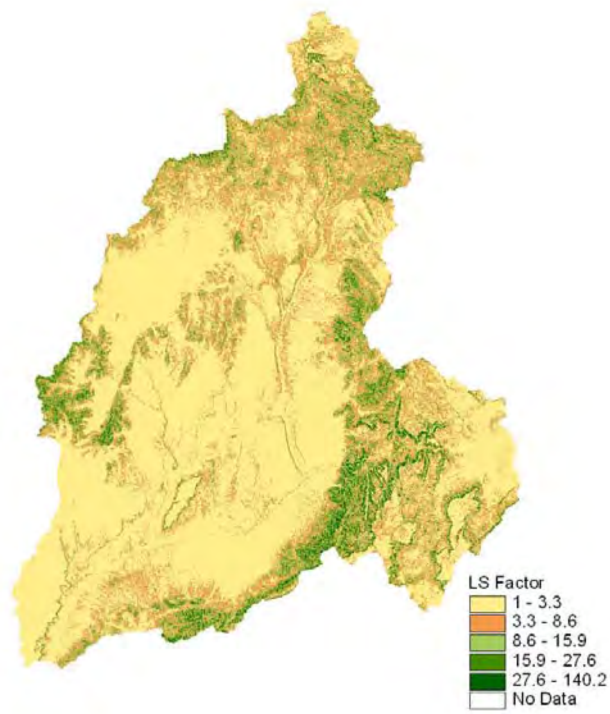

Figure 30. LS Factor for the Virgin Valley Area.

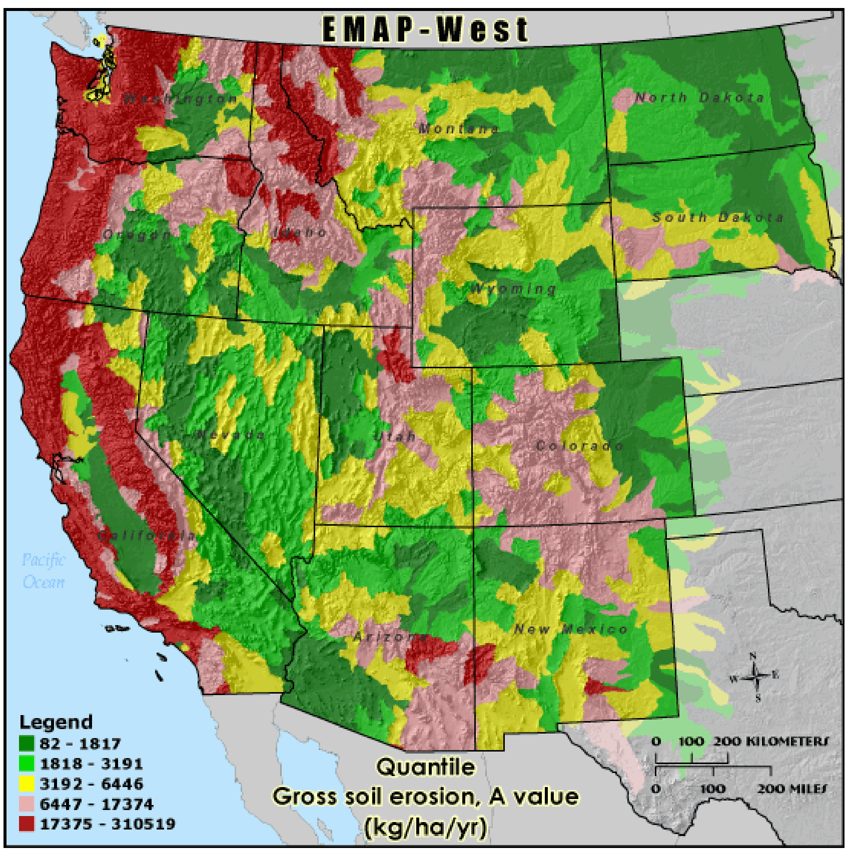

Figure 31. A Values Throughout the West (EPA, 2010).

6.6 A Value

The A value computes the gross soil erosion per unit area using the formula: R*K*LS*C*P. Values range depending on rainfall, soil type, slope, and conservation practices in the specific locations. As seen in Figure 31, overall values in the west are lowest in Nevada and North Dakota and highest along the coast of California, Oregon and Washington. In the Muddy-Virgin Area, individual values ranged from 281 kg/ha/y in the Virgin River, (site 1190) to 2621 kg/ha/y (site 19).

7.0 Ecological Indicators

The State of Nevada has established water quality standards for water quality criteria citing the maximum concentration of pollutants that are acceptable, if State waters are to meet their designated uses, such as use for irrigation, watering of livestock, industrial supply and recreation. The State of Nevada water quality standards are given in the Nevada Administrative Code (NAC) 445A.11704 through 445A.2234. (Table 5).

Table 5. Water Quality Standards for Nevada.

Indicator	Standards for Nevada
Dissolved Oxygen	≥5° mg/L (non-trout waters) ≥6° mg/L (trout waters)
pH	6.5-9.0
Total Phosphorous	≤0.1 mg/L

Considering that a large portion of the water flowing through the Basin is supplied by surface water runoff, the topography and land cover within the basin can affect the water entering the system, which in turn affects the biology of the stream. These ecological indicators are measurable characteristics of the environment and can provide information on ecological resources. In this chapter, variations of these ecological indicators are examined.

7.1 Dissolved Oxygen

Dissolved oxygen (DO) is simply the amount of gaseous oxygen dissolved in water and available for organisms' respiration. Decreases in DO can be associated with inputs of nitrogen and phosphorus (eutrophication), organic matter, increased temperature, and a reduction in stream flow. DO values ranged from 5.1 to 12.8 mg/L with a mean of 8.3 mg/L among samples as shown in Figure 32. Two sites, in Meadow Valley Wash (285) and Paharanagat Creek (875), had DO values that went below 6 mg/L, which represents the lower limit determined suitable for trout by Nevada State standards.

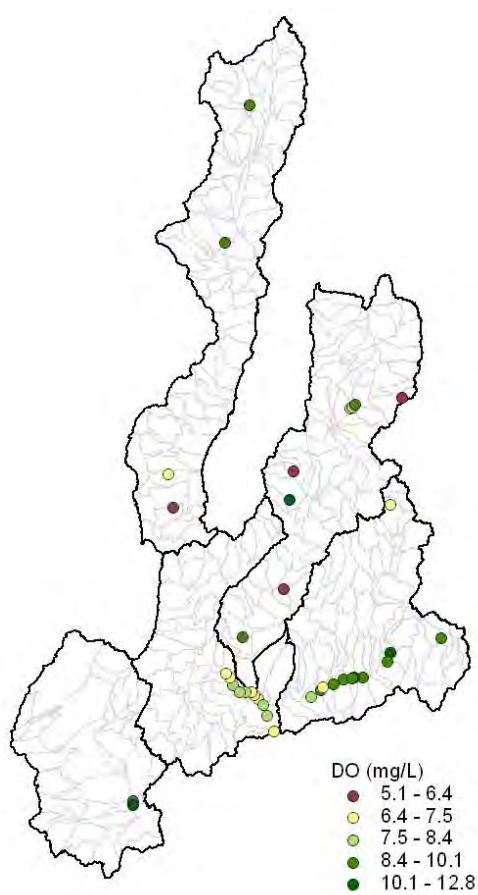

Figure 32. Dissolved Oxygen in the Muddy-Virgin River Study Area.

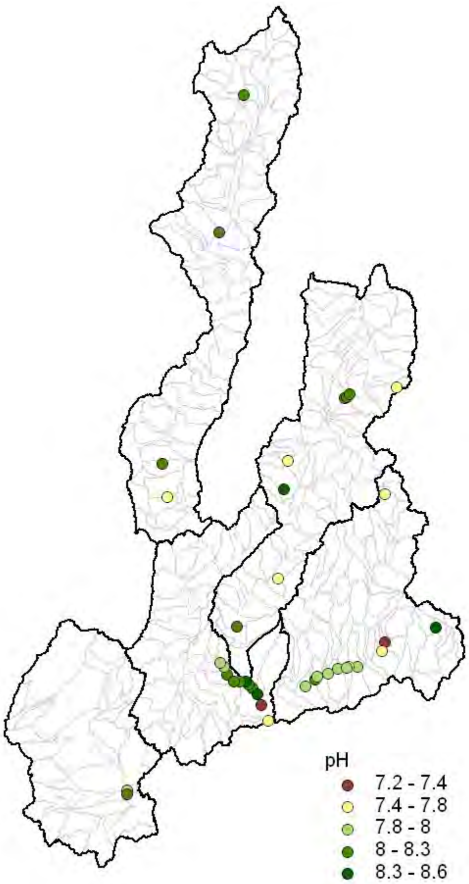

Figure 33. ph in the Muddy-Virgin River Study Area.

7.2 pH

Another important water column variable, hydrogen ion concentration (pH), is a numerical measure of the concentration of the constituents that determine water acidity, specifically hydrogen ion concentration. It is measured on a logarithmic scale of 1.0 (acidic) to 14.0 (basic) with 7.0 signifying neutral. The pH of the MV Basin watersheds ranges from 7.2 to 8.6 with a mean of 8.0 as indicated in Figure 33. All samples were within the standards set for Nevada.

7.3 Total Phosphorus

Phosphorus (Figure 34) is often a limiting factor in growth of aquatic vegetation as it is an essential nutrient for plant and bacterial activity. Yet, an excess of phosphorus may reduce habitat, disrupting ecological cycles and affecting macroinvertebrate communities. An increase in phosphorus, which could be the result of nutrient input from agriculture, is reflected in increased growth of algae. Samples for total phosphorous (TP) in the MV River Basin ranged from 0.01 to 0.43 mg/L with a mean of 0.06 mg/L. Three sites had TP levels above the Nevada water quality standard of $\leq$0.1 mg/L. Two sites (669 and 1009) are located along the agricultural corridor along the Muddy River adjacent to Lake Mead. The other site (289) is located on the Virgin River in Washington County, UT.

7.4 Total Nitrogen

Total Nitrogen, the sum of total kjeldahl nitrogen, nitrate and nitrite, is an important nutrient input to streams as an essential nutrient for plants and animals. Figure 35 shows the total nitrogen in the Muddy-Virgin River Study Area. However, substantial inputs (eutrophication) from anthropogenic sources can result in increased algal growth which can upset the ecological balance of the stream. Similarly, loss of nutrients from human activities can also reduce stream productivity. Sources of nitrogen can include agricultural processes, such as pesticides and fertilizers, runoff from animal manure, and sewage. With the proportion of land used for grazing and agriculture in the Muddy-Virgin Project Area, manure deposition from cattle and fertilizer runoff can add nutrients, to the streams. Values ranged from 0.09 to 4.02 mg/L with an average of 0.68 mg/L. Four sites had values greater than 1.0. Two sites (19 and 289) were located in the Virgin River, both in Washington County, UT. The Las Vegas Wash, site 232, had the highest value of 4.0 mg/L. The last site is located in the Meadow Valley Wash (site 215).

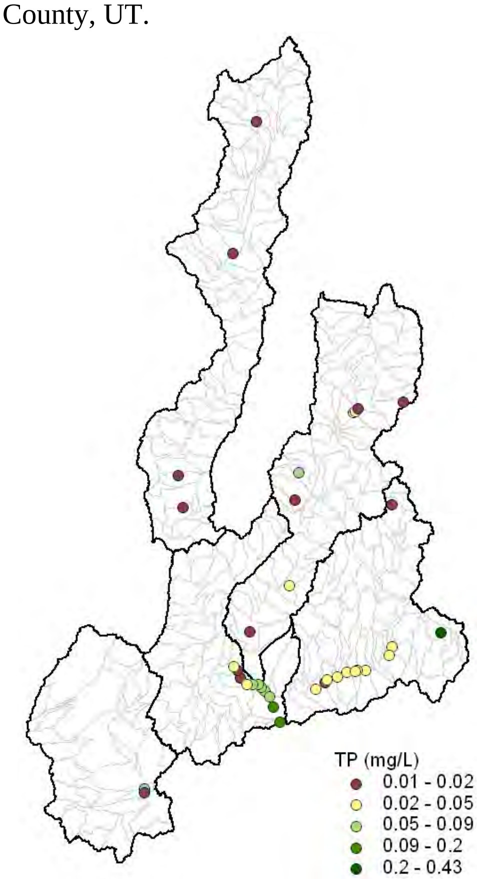

Figure 34. Total Phosphorus in the Muddy-Virgin River Study Area.

7.5 Chloride

Chloride, present in all natural waters at low levels (Hem, 1985), is considered a good tracer because it is involved in few reactions relative to other ions (Feth, 1981). Herlihy et al. (1998) found chloride to be an indicator of human disturbance in the Mid-Atlantic region of the United States. The worldwide chloride mean concentration in rivers is 7.8 mg/L, with a range from 1 to 280,000 mg/L (Hem, 1985). The national secondary drinking water regulation standard for chloride is 250 mg/L. While the variation in chloride concentrations in Nevada streams appears large, with a range of 1 to 675 mg/L, care should be taken to account for solute input from spring sources. Eleven sites were greater than 250 mg/L, all located on the Virgin River.

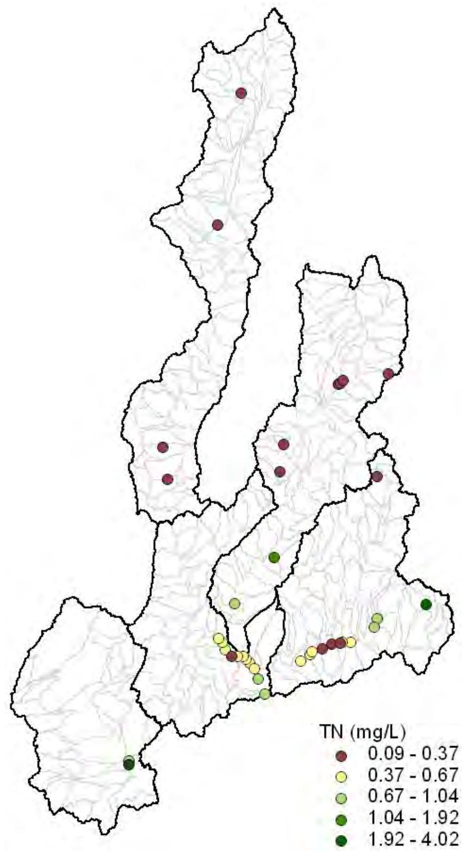

Figure 35. Total Nitrogen in the Muddy-Virgin River Study Area.

7.6 IBI

The Index of Biological Integrity (IBI) combines metrics sensitive to stressors representing diverse aspects of the biota in order to differentiate between stressed and unstressed conditions. (Peck et al., 2006). An IBI score is representative of the health of a stream. Changes in aquatic species can occur from a number of actions. Breakdown of stream banks change channel shape, structure and form, and decrease stream bank stability. This can lower the groundwater table, increase water turbidity, and change type of vegetation and aquatic habitat, thus changing habitat diversity (Bellows, 2003). In the delineated sub-watersheds values ranged from 4 to 84 with an average of 47.8 (Figure 37). Although there is no standard, higher values are indicative of more healthy systems**.** Two sites, 669 and 720, had scores below 30. Exceedances for each indicator are summarized in Table 5.

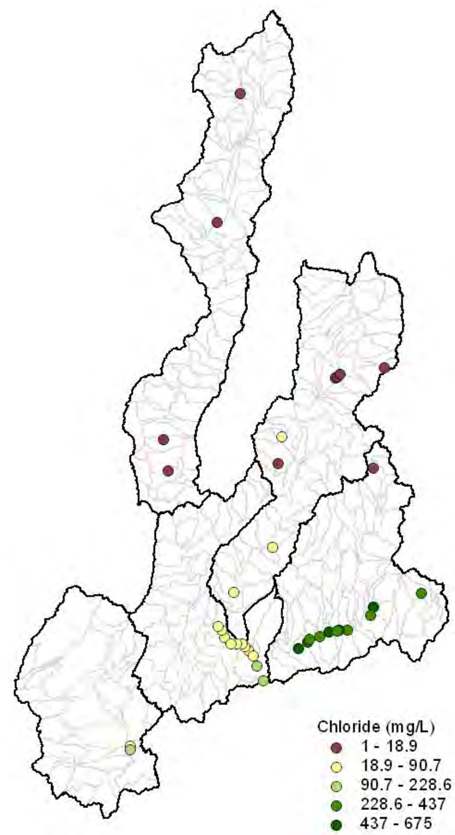

Figure 36. Chloride in the Muddy-Virgin River Study Area.

Table 6. Indicator Exceedances.

Site	DO (mg/L)	TP (mg/L)	TN (mg/L)	Chloride (mg/L)	IBI
19			1.0	543	
110				522	
119				512	
215			1.9		
232			4.0		
285	5.9				
289		0.43	3.3	378	
310				415	
319				422	
660				675	
669		0.20			24
720				358	4
790				437	
875	5.1				
1009		0.16			
1100				480	
1190				368	

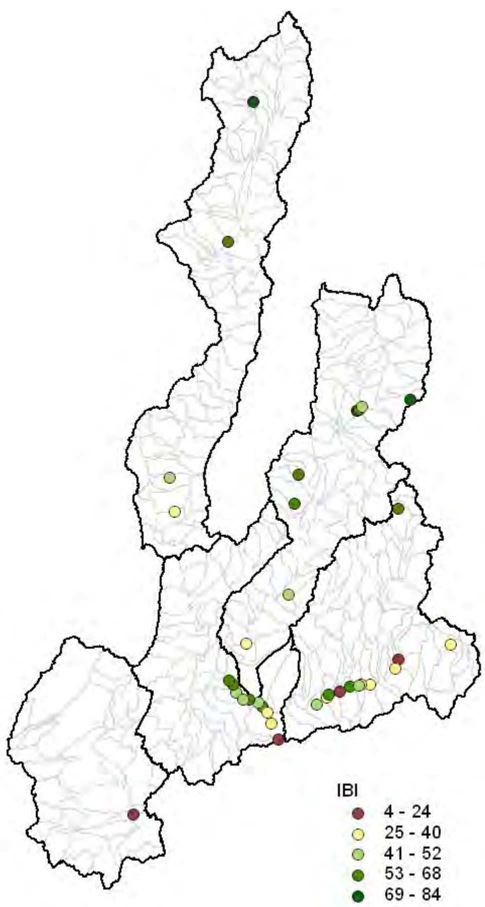

Figure 37. IBI in the Muddy-Virgin River Study Area.

8.0 Landscape and Water Relationships

8.1 Regression Models

In this highly modified, arid system, the inclusion of nested sites for analysis was unavoidable. Although it is preferable to not include them, this area is unique and must be treated that way. For regression models, we looked at the entire basin with all watersheds. Because virtually all sites were nested, analysis was not able to be performed only on non-nested sites.

Riparian metrics were highly correlated to whole watershed metrics and were thus eliminated, except for percent natural grassland (30m) and percent human use (30m) in the Muddy and Virgin River assessment. Percent shrub/scrubland was also eliminated, since the percent of shrub/scrubland in the delineated sub-watersheds is simply the inverse of the percentage of forest, grassland and other land uses that make up the area. Using shrub/scrubland would not further elucidate the relationships between the land cover and water quality indicators. RUSLE 2 R factor was eliminated also for its strong correlation with A value. Of the remaining landscape metrics six variables (A Value, K Factor, percent natural grassland, (strmdens) stream density, (rdlen) road length, (purb) percent urban and (pfor) percent forest) were used in the stepwise multiple regression. Different predictors were significantly related to each of the water quality metrics (Table 6). The amount of variability explained by models ranged from 36% to 62% (r^2, Table 6). Road length and road density are important factors in and around the populated areas of Las Vegas and Mesquite, Nevada and St. George Utah. The Index of Biotic Integrity (IBI) and total phosphorus remained low around all urban areas, Total nitrogen and total phosphorus had high values primarily around the more populated and agricultural areas. The formula metric abbreviations can be found in Ebert and Wade 2004.

Table 7. Multiple Regression Models "*" Denotes Log-Transformation.

Dependent Variable	R^2	Model p-value	Formula
TN	0.623	0.0000	p_lnTN=-5.315-0.0378*pfor-0.631*png+0.02*strmdens+0.0349*a value+0.0381*k factor
TP	0.367	0.0046	p_lnTP=0.235-0.362*png-0.162*purb-0.0454*strmdens+0.0176*rdlen
IBI	0.378	0.0005	p_IBI=62.42+0.477*pfor-0.431*a value

8.2 Model Application

Using the 2001 NLCD and averaged RUSLE 2 grids, estimates were made of potential IBI and water quality indicators in the Muddy-Virgin River Project Area within each 12-Digit HUC. Predicted total phosphorus had the higher values around the main Muddy and Virgin Rivers with the lowest values in the upper reaches of the White River, the Las Vegas area and Meadow Valley Wash. Predicted total nitrogen had very low values throughout the White River and Meadow Valley Wash systems as well as along the Muddy and Virgin Rivers and Las Vegas Valley. Higher values were along the Pahranagat area and the central portion of the project area. IBI values were highest in the Meadow Valley White and upper reaches of the White River. Low values existed sporadically around the Las Vegas Valley and the Virgin River. See Appendix 5 for the predicted model averages in each hydrologic unit.

9.0 Conclusion

Nevada has a basin and range physiography with a repeating pattern of fault block mountains and intervening valleys. Valley ecoregions are predominantly shrub or shrub- and grass-covered. Mountains may be brush-, woodland-, or pinion-juniper forested systems. The Muddy-Virgin River Project Area is in the southern portion of Nevada, and encompasses approximately 32,000 square miles. The Muddy-Virgin River Project Area is a part of the Colorado River system one of the largest and most important systems in the lower 48 states. The Colorado River system is used by well over 40 million people in the western United States and supplies much needed fresh water to the Las Vegas, Nevada area and highly populated southern California. A large portion of the Muddy-Virgin River Project Area is sparsely populated with two major land use types mining and agriculture (hay and cattle).

The Muddy-Virgin River Project Area, hydrologically, is fairly unique. The river trends north-south, and gains most of its water from snowmelt in the alpine regions of the Basin and Range ecosystem (Spring, Sheep, White Pine and Butte Mountains in the western part of the watershed, and Wilson Creek and Egan Mountains in the east). Proposals have been made to pipe water from this area to the southern Nevada area to supplement drinking water supplies. Agricultural activity in the valleys increases water withdrawals for irrigation. Water into the river comes from seasonal snowmelt. Flow is highly variable from season to season and year to year (depending on the amount of snow every winter). These unique features and the high desert environment contribute to the formation of a very large number of ephemeral and intermittent streams.

The objective of this study is to provide an additional supportive methodology tool using remote sensing and GIS to derive and connect land cover and human land use patterns in relationship to ecological features to support decision making. Physically, ecosystems are always in motion reacting to natural climatic and anthropogenic conditions. These changes, in environmental condition, will affect the chemical and biological community structure, which cause further alterations to the environment. Water quality issues in the Muddy-Virgin River Project Area are nutrients (nitrogen, phosphorus and sediment), temperature, total suspended solids and metals. Traditional water quality measures give some information but are very limited in time and space. A landscape metric analysis explains more about ecologic condition and function, because landscape metrics tend to integrate time and space. Landscape metric analysis and water quality measures used together provides a very powerful environmental condition and risk analysis tool. This report provides a full set of landscape metrics to analyze. This report demonstrates how to take those metrics and derive basin-wide water quality predictions, and make those predictions in places where there are no water quality measurements.

Finding environmental problems is sometimes easier than finding solutions. This study found that past grazing practices has impacted stream flood plain vegetation, which holds together the stream channel and stream banks during flood events, and holds the water on the landscape. Adding more knowledge through landscape analyses will help land managers find troubled areas and help to choose the correct adaptive management practices to mitigate problems. Through further study more relationships can be discovered and additional predictive models mapped.

Improved knowledge of aquatic and upland interactions, at local to watershed scales, is essential in evaluating and designing land management alternatives for stream and wetland resources. Nevada’s arid environment, coupled with the fact that most of the biodiversity in this state is associated with riparian or aquatic habitats, makes the management of these systems a matter of particular importance. The authors recommend that decision makers, stakeholders, ranchers, Federal, State, Tribes and local officials consider our approach and use this information to begin adaptive management practices.

Water quality in the Muddy-Virgin River Project Area had few cases of water quality standard exceedances. Percent forest and natural grasslands, in addition to stream density and gross soil erosion are the main contributors to potential water quality degradation, along with percent urban, road length and soil erodibility. Regression models demonstrate the watersheds that have a high potential for water quality impacts affected by one or more land cover use and/or erosion potential.

For the following maps, final metrics included in the prediction models are shown displaying their extreme values. For this, ten natural breaks were found for each variable, as defined by ATtILA, and the highest (or lowest) class was selected. Each variable was overlaid to show the HUCs that are affected (Figure 38 and 39). For the final joined map, all affected watersheds were joined and then overlaid (Figure 40). This shows the watersheds that have the most potential to be affected by the land cover/use and sedimentation. Significant watersheds lie in the lower portion in the basin specifically around the Las Vegas Valley and the Muddy and Virgin River head waters.

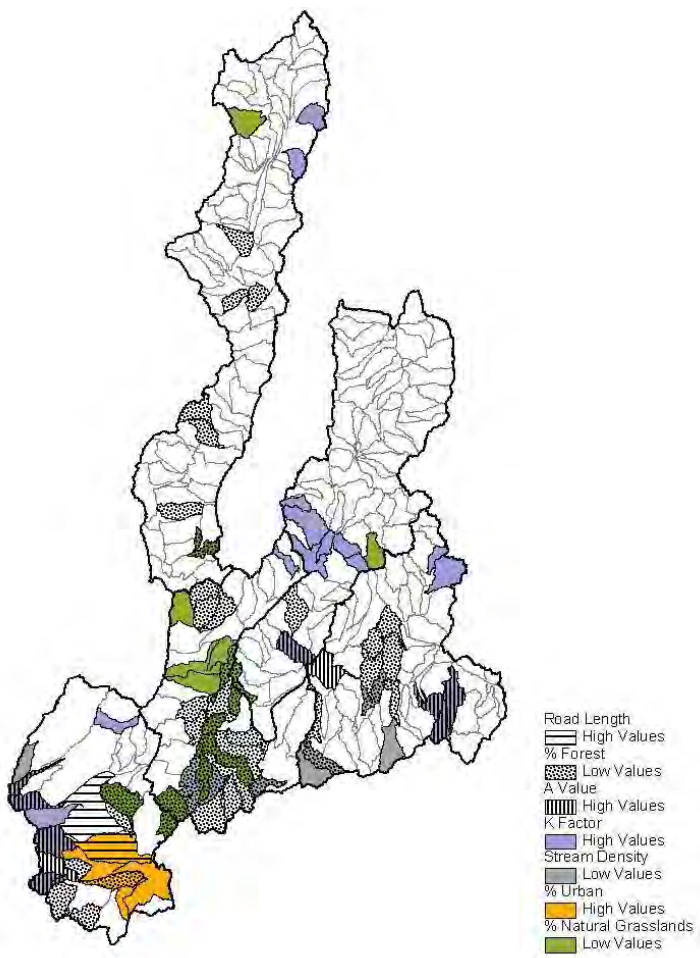

Figure 38. Land Cover/RUSLE 2 Extreme Values for 12-Digit HUCs.

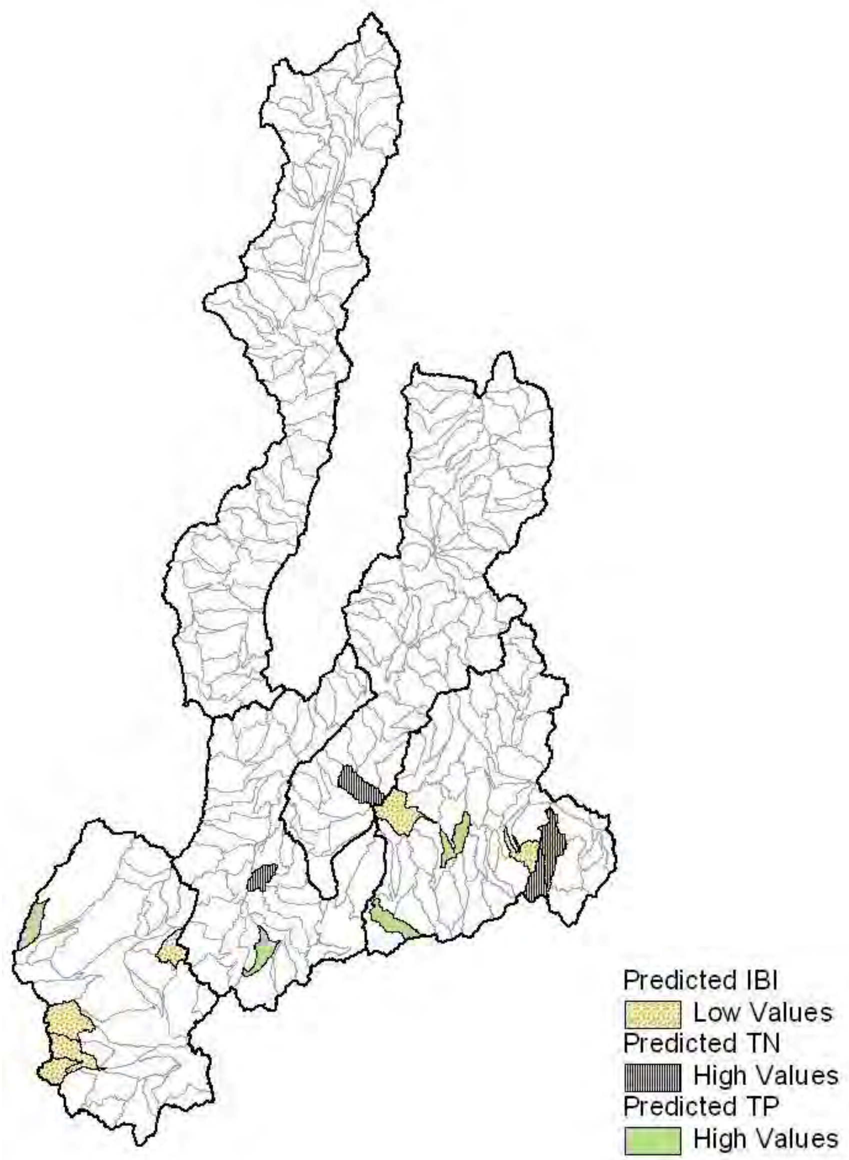

Figure 39. Predicted Water Quality Indicators Extreme Values.

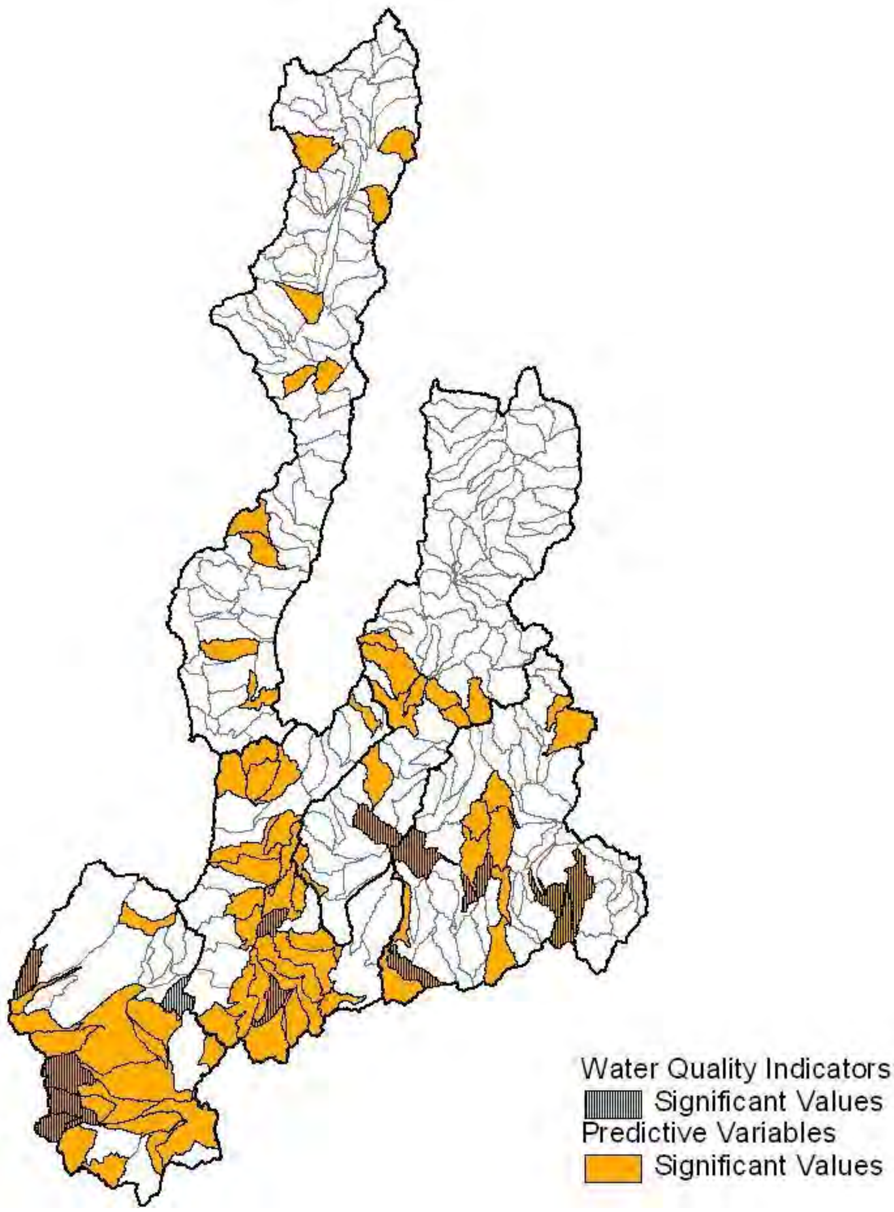

Figure 40. Muddy-Virgin River Project Area Subwatersheds Having Landscape Metrics Associated with Water Quality Degradation.

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Appendices

Appendix 1. List of Sites.

Site	Stream Order	Stream Name	Longitude	Latitude
8	3	Meadow Valley Wash	-114.3552778	37.834167
10	4	White River	-115.1608333	38.9325
19	5	Virgin River	-113.9191667	36.919167
95	5	Meadow Valley Wash	-114.5672222	37.436944
110	5	Virgin River	-114.2283333	36.723889
119	5	Virgin River	-114.2675	36.689444
128	3	Flatnose Wash	-114.102778	37.919167
144	1	Unnamed	-115.144444	38.379444
170	5	Muddy River	-114.52881	36.641667
173	3	Las Vegas Wash	-115.041944	36.148333
185	3	Pahranagat River	-115.191944	37.439444
207	5	Meadow Valley Wash	-114.664444	36.869444
215	5	Meadow Valley Wash	-114.510278	37.086944
232	4	Las Vegas Wash	-115.036111	36.134137
258	3	Beaver Dam Wash	-114.058056	37.49222
270	3	Muddy River	-114.666944	36.673889
285	5	Meadow Valley Wash	-114.57416	37.551389
289	5	Virgin River	-113.681944	37.013056
298	3	Meadow Valley Wash	-114.346667	37.841667
310	5	Virgin River	-114.033889	36.801667
319	5	Virgin River	-113.928056	36.883056
368	3	Meadow Valley Wash	-114.332778	37.853333
469	4	Muddy River	-114.496389	36.620556
519	3	Muddy River	-114.687222	36.704444
530	4	Muddy River	-114.551389	36.650833
660	5	Virgin River	-114.073611	36.795556
669	4	Muddy River	-114.417222	36.526389
720	5	Virgin River	-114.171667	36.756111
790	5	Virgin River	-114.219444	36.734167
875	3	Pahranagat River	-115.134444	37.314722
1009	4	Muddy River	-114.468333	36.582222
1069	3	Muddy River	-114.708889	36.714444
1100	5	Virgin River	-114.129722	36.782778
1190	5	Virgin River	-114.084167	36.791667
1260	5	Muddy River	-114.566944	36.661944
1300	3	Muddy River	114.598056	36.655556
1310	3	Muddy River	-114.626111	36.654167

Appendix 2. Ecoregions and Relating Physiography and Vegetation (USEPA, 2007).

Level III Ecoregion		Physiography and Vegetation	
14	Mojave Basin and Range	Composed of broad basins and scattered mountains that generally low, warm and dry. It has a creosote bush-dominated shrub community.	
22	Arizona/New Mexico Plateau	High plateau cut by canyons and punctuated by mountains, mesas and buttes. It's transitional between higher, forested, mountainous ecoregions and arid shrublands.	
Level IV Ecoregion		**Physiography**	**Vegetation**
13b	Shadscale-Dominated Saline Basin	Mostly gently sloping to nearly flat valleys and scattered sand dunes. Drained by a few small streams.	Mostly saltbrush-greasewood and Great Basin sagebrush community with stands of juniper.
13c	Sagebrush Basins and Slopes	Valleys and low hills drained by a few streams.	Great Basin sagebrush community along with scattered, invading Utah juniper.
13d	Woodland- and Shrub-Covered Low Mountains	Low mountain ranges, foothills, and alluvial fans. Streams are fed by snow-melt and springs.	Mostly juniper-pinyon woodland with Joshua trees. Sagebrush dominates the understory.
13e	High Elevation Carbonate Mountains	Partially glaciated, high, mountains. Headwaters for several streams fed by snow-melt and cold springs.	Spruce–fir pine forest communities with Mountain brush species and grasses. Areas of alpine meadows or tundra.
13g	Wetlands	Flat terrain with saline or freshwater wetlands.	Tule marshes Non-native tamarisk tree becoming common.
13p	Carbonate Sagebrush Valleys	Nearly flat to gently sloping basins.	Great Basin sagebrush community. Understory is composed of grasses.
13q	Carbonate Woodland Zone	Moderate sloping mountains and ridges with many springs occurring.	Mostly juniper–pinyon woodland and some Great Basin sagebrush community.
13u	Tonopah Basin	Rolling valleys containing scattered hills, sand dunes, and hot springs.	Great Basin sagebrush community with Mojave Desert plants becoming common.
13v	Tonopah Sagebrush Foothills	Foothills and low mountains. Ephemeral washes are common. Surface water comes from springs.	Great Basin sagebrush community with Mojave Desert plants becoming common and include yucca species
13w	Tonopah Uplands	Mountains and hills drained by ephemeral washes.	Juniper–pinyon woodland, sagebrush and chaparral.
14a	Creosote Bush-Dominated Basins	Valleys containing floodplains, isolated hills, and eroded washes. Alkaline warm streams and rivers occur.	Mostly creosote bush. Some areas are barren of vegetation.
14b	Arid Footslopes	Alluvial fans and low mountains drained by ephemeral streams.	Mix of Mojavean shrubs and succulents as well as cacti.
14c	Mojave Mountain Wood- and Shrubland	Mid-elevation mountain slopes drained by ephemeral streams, springs, and washes.	Juniper–pinyon woodland.
14d	Mojave High Elevation Mountains	Unglaciated, rugged, isolated, high elevation mountains. Water is primarily from snow-melt.	Great Basin pine forest. Small aspen groves occur.
14e	Arid Valleys and Canyonlands	Arid canyons, terraces, and floodplains in the Colorado River corridor.	Creosote bush and occasional Sonoran species with native riparian plants.
14f	Mojave Playas	Alluvial flats, muddy lake plains, and sand dunes. Saline lakes occur.	Mostly barren with scattered creosote bush and other salt-tolerant plants.
22d	Middle Elevation Mountains	Rugged mountains, steep ridges, mesas, buttes, and canyons.	Chaparral and juniper-pinyon woodland. Sagebrush in understory.

Appendix 3. Muddy-Virgin Project Area Delineated Sub-watershed Names with Numbers Corresponding to Figure 12.

8	Meadow Valley	298	Meadow Valley
10	White River	310	Virgin River
19	Virgin River	319	Virgin River
95	Meadow Valley Wash	368	Meadow Valley
11	Virgin River	469	Muddy River
11	Virgin River	519	Muddy River
12	Flatnose Wash	530	Muddy River
14	Kirch WMA	660	Virgin River
17	Muddy River	669	Virgin River
17	Las Vegas Wash	720	Virgin River
18	Pahranagat Creek	790	Virgin River
20	Meadow Valley	875	Pahranagat Valley
21	Meadow Valley	1009	Muddy River
23	Las Vegas Wash	1069	Muddy River
25	Beaver Dam	1100	Virgin River
27	Muddy River	1190	Virgin River
28	Meadow Valley Wash	1260	Muddy River
28	Virgin River	1300	Muddy River
		1310	Muddy River

Appendix 4. Descriptive Statistics for HUCs and Delineated Sub-Watersheds.

	HUCs			Delineated Sub-Watersheds		
	Mean	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**
% Forest	19.5	0.0	88.4	28.3	0.0	97.8
% Agriculture	0.4	0.0	12.4	1.0	0.0	1.7
% Shrubland	75.0	6.1	99.9	67.5	1.4	97.4
% Natural Grassland	1.5	0.0	19.3	1.5	0.1	5.0
% Urban Areas	2.0	0.0	84.5	0.8	0.0	11.2
% Wetlands	0.3	0.0	6.4	0.3	0.0	0.7
% Barren	1.2	0.0	73.2	0.7	0.0	7.3
Stream Density (km of Streams/Area in km2)	1.0	0.3	2.1	1.0	0.6	1.3
Road Density (km of Roads/Area in km2)	0.7	0.0	9.4	0.6	0.3	1.7
# Road/Stream Crossings per km of Stream in HUCs	0.4	0.0	4.6	0.4	0.0	0.9
Total # of Road/Stream Crossings in HUCs	44.3	0.0	652.0	2554.2	5.0	6681.0
% Stream Length Adjacent to Forest 30m	16.6	0.0	87.0	24.0	0.3	98.7
% Stream Length Adjacent to Agriculture 30m	0.8	0.0	17.0	0.9	0.0	2.5
% Stream Length Adjacent to Shrubland 30m	76.6	11.9	100.0	70.6	1.3	95.0
% Stream Length Adjacent to Natural Grasslands 30m	1.5	0.0	19.6	1.4	0.0	4.7
% Stream Length Adjacent to all Human Use 30m	2.9	0.0	79.5	2.2	0.0	11.1
% Stream Length Adjacent to Urban 30m	2.1	0.0	79.5	1.3	0.0	11.1
% Stream Length Adjacent to Wetlands 30m	1.2	0.0	40.4	1.1	0.0	4.0
% Stream Length Adjacent to Barren 30m	1.3	0.0	69.9	0.8	0.0	8.3
% Stream Length Adjacent to Forest 90m	16.8	0.0	87.1	24.5	0.1	99.0
% Stream Length Adjacent to Agriculture 90m	0.7	0.0	15.6	0.8	0.0	2.2
% Stream Length Adjacent to Shrubland 90m	76.6	9.4	100.0	70.5	1.5	96.1
% Stream Length Adjacent to Natural Grasslands 90m	1.5	0.0	21.6	1.5	0.0	4.8
% Stream Length Adjacent to all Human Use 90m	2.9	0.0	78.9	2.1	0.0	11.2
% Stream Length Adjacent to Urban 30m	2.1	0.0	78.9	1.3	0.0	11.2
% Stream Length Adjacent to Wetlands 90m	0.9	0.0	36.5	0.7	0.0	2.1
% Stream Length Adjacent to Barren 90m	1.3	0.0	70.9	0.8	0.0	8.3

Appendix 5. Land Cover/Use for the Muddy-Virgin Project Area Delineated Sub-Watersheds.

SITE	8 HUC	PFOR	PWETL	PSHRB	PNG	PNBAR	U_INDEX	PURB	PAGT
8	Meadow Valley	49.93	0.09	48.26	0.53	0.01	1.17	0.04	1.13
10	White River	58.06	0.18	39.60	1.19	0.04	0.93	0.37	0.56
19	Lower Virgin	16.17	0.30	80.48	1.37	0.44	1.24	0.39	0.85
95	Meadow Valley	45.92	0.11	51.66	0.73	0.11	1.49	0.06	1.43
110	Lower Virgin	17.25	0.37	79.16	1.92	0.32	0.99	0.28	0.72
119	Lower Virgin	17.03	0.39	79.35	1.90	0.33	1.00	0.27	0.73
128	Meadow Valley	97.76	0.00	1.43	0.81	0.00	0.00	0.00	0.00
144	White River	29.09	0.48	63.62	5.02	0.17	1.61	0.07	1.54
170	Muddy River	20.88	0.22	75.72	1.53	0.55	1.10	0.14	0.96
173	Las Vegas Wash	9.57	0.01	69.53	0.70	7.27	12.92	11.20	1.72
185	White River	18.86	0.37	76.25	3.16	0.12	1.24	0.09	1.14
207	Meadow Valley	37.83	0.13	60.17	0.64	0.11	1.13	0.05	1.08
215	Meadow Valley	42.92	0.13	54.89	0.68	0.10	1.28	0.05	1.22
232	Las Vegas Wash	9.57	0.01	69.53	0.70	7.27	12.92	11.20	1.72
258	Lower Virgin	81.96	0.72	16.85	0.23	0.04	0.19	0.00	0.19
270	Muddy River	14.62	0.30	81.30	2.35	0.35	1.08	0.17	0.91
285	Meadow Valley	45.22	0.10	52.36	0.72	0.09	1.50	0.06	1.44
289	Lower Virgin	3.62	0.67	90.28	2.15	0.91	2.37	1.10	1.27
298	Meadow Valley	59.19	0.16	38.62	0.79	0.01	1.22	0.00	1.22
310	Lower Virgin	22.81	0.35	74.35	1.40	0.30	0.79	0.19	0.60
319	Lower Virgin	26.01	0.29	71.16	1.49	0.29	0.76	0.22	0.55
368	Meadow Valley	59.40	0.16	38.43	0.79	0.01	1.22	0.00	1.22
469	Muddy River	20.86	0.22	75.74	1.53	0.55	1.10	0.14	0.96
519	Muddy River	14.69	0.30	81.29	2.36	0.30	1.07	0.17	0.90
530	Muddy River	21.06	0.22	75.53	1.54	0.55	1.10	0.14	0.97
660	Lower Virgin	22.20	0.40	74.73	1.37	0.33	0.97	0.29	0.69
669	Muddy River	20.40	0.22	76.06	1.52	0.63	1.17	0.16	1.01
720	Lower Virgin	21.47	0.46	75.08	1.36	0.37	1.26	0.37	0.89
790	Lower Virgin	17.15	0.37	79.25	1.94	0.32	0.98	0.28	0.70
875	White River	18.24	0.39	76.87	3.05	0.12	1.33	0.14	1.19
1009	Muddy River	20.55	0.22	75.97	1.52	0.61	1.13	0.14	0.98
1069	Muddy River	14.74	0.30	81.27	2.36	0.27	1.07	0.17	0.90
1100	Lower Virgin	21.92	0.43	74.73	1.36	0.37	1.19	0.37	0.82
1190	Lower Virgin	0.03	0.22	97.38	0.08	1.03	1.26	0.00	1.26
1260	Muddy River	21.07	0.22	75.52	1.54	0.55	1.10	0.14	0.96
1300	Muddy River	12.81	0.26	83.05	2.08	0.71	1.09	0.18	0.91
1310	Muddy River	14.56	0.30	81.29	2.35	0.41	1.10	0.17	0.92

Appendix 6. Land Cover/Use for the Muddy-Virgin Project Area Delineated Sub-Watersheds.

SITE	8 HUC	STRMLEN	STRMDENS	RDLEN	RDDENS	STXRD	STXRD_CNT
8	Meadow Valley	2423582.45	1.05	1436426.08	0.62	0.38	921
10	White River	154254.26	0.63	141920.55	0.58	0.36	55
19	Lower Virgin	963092.24	0.80	811744.44	0.67	0.47	449
95	Meadow Valley	5467628.76	1.22	2788137.74	0.62	0.40	2169
110	Lower Virgin	5078681.81	1.04	2879902.69	0.59	0.38	1913
119	Lower Virgin	5108970.88	1.03	2903409.33	0.59	0.38	1917
128	Meadow Valley	19012.80	1.19	4778.43	0.30	0.26	5
144	White River	2875639.82	0.88	2426968.04	0.74	0.54	1560
170	Muddy River	19945181.29	1.09	8905463.28	0.49	0.33	6567
173	Las Vegas Wash	2804311.55	0.76	6352202.27	1.73	0.88	2476
185	White River	6451375.61	0.99	4018447.83	0.62	0.43	2759
207	Meadow Valley	7708335.44	1.25	3082822.70	0.50	0.33	2523
215	Meadow Valley	6669238.81	1.24	2994234.90	0.56	0.36	2432
232	Las Vegas Wash	2804311.55	0.76	6352202.27	1.73	0.88	2476
258	Lower Virgin	181845.06	1.33	66983.22	0.49	0.38	70
270	Muddy River	10550809.85	1.05	5008062.92	0.50	0.35	3675
285	Meadow Valley	5259143.31	1.23	2753535.75	0.64	0.40	2113
289	Lower Virgin	325265.53	0.69	376314.41	0.79	0.64	207
298	Meadow Valley	1371029.21	1.12	513583.03	0.42	0.26	361
310	Lower Virgin	3338545.70	1.02	1947207.50	0.59	0.39	1318
319	Lower Virgin	2944031.44	1.07	1659301.98	0.60	0.40	1186
368	Meadow Valley	1365764.74	1.12	511837.66	0.42	0.26	361
469	Muddy River	19961936.98	1.09	8916381.06	0.49	0.33	6574
519	Muddy River	10517029.17	1.05	4969386.48	0.50	0.35	3668
530	Muddy River	19770074.23	1.09	8869144.96	0.49	0.33	6539
660	Lower Virgin	3410490.52	1.01	2058240.76	0.61	0.40	1358
669	Muddy River	20236558.31	1.08	9239756.83	0.49	0.33	6681
720	Lower Virgin	3548231.35	0.99	2281478.88	0.64	0.41	1446
790	Lower Virgin	5041513.52	1.04	2845065.70	0.59	0.38	1904
875	White River	6730211.43	0.99	4197681.15	0.62	0.43	2904
1009	Muddy River	20169052.84	1.09	9085934.73	0.49	0.33	6647
1069	Muddy River	10489332.67	1.05	4963822.39	0.50	0.35	3664
1100	Lower Virgin	3491383.50	1.00	2214627.97	0.63	0.41	1432
1190	Lower Virgin	6126.66	0.89	10166.14	1.48	0.82	5
1260	Muddy River	19764997.25	1.09	8864217.07	0.49	0.33	6537
1300	Muddy River	11535511.97	1.01	5629347.18	0.49	0.34	3953
1310	Muddy River	10580534.40	1.05	5033252.21	0.50	0.35	3682

Appendix 7. Land Cover/Use for the Muddy-Virgin Project Area Delineated Sub-Watershed Riparian Buffers.

SITE	RFOR30	RWETL30	RSHRB30	RNG30	RNBAR30	RHUM30	RURB30	RAGT30
8	42.04	0.25	55.21	0.32	0.00	2.18	0.45	1.73
10	44.10	1.40	53.66	0.08	0.00	0.76	0.54	0.21
19	13.69	1.63	81.09	1.16	0.34	2.08	2.05	0.04
95	37.71	0.34	58.66	0.63	0.03	2.62	0.72	1.90
110	15.74	1.62	78.55	2.72	0.31	1.06	0.72	0.34
119	15.64	1.69	78.56	2.72	0.31	1.08	0.72	0.36
128	98.75	0.00	1.25	0.00	0.00	0.00	0.00	0.00
144	21.17	1.82	69.47	4.66	0.24	2.63	0.66	1.97
170	17.34	0.74	78.52	1.22	0.45	1.73	0.63	1.10
173	8.47	0.02	71.43	0.75	8.27	11.06	11.06	0.00
185	13.37	1.25	80.89	2.48	0.12	1.89	0.62	1.28
207	30.97	0.45	66.01	0.58	0.03	1.96	0.56	1.40
215	35.60	0.45	61.08	0.58	0.03	2.26	0.65	1.61
232	8.47	0.02	71.43	0.75	8.27	11.06	11.06	0.00
258	72.28	4.03	22.65	0.35	0.01	0.68	0.00	0.68
270	10.24	0.98	84.83	1.83	0.44	1.69	0.67	1.02
285	36.87	0.32	59.53	0.63	0.03	2.62	0.68	1.93
289	2.65	2.79	88.81	1.92	0.74	3.09	2.98	0.11
298	50.32	0.42	46.12	0.37	0.01	2.76	0.23	2.53
310	20.82	1.61	74.65	1.66	0.29	0.96	0.71	0.25
319	23.29	1.36	72.45	1.70	0.23	0.96	0.71	0.25
368	50.52	0.42	45.92	0.37	0.01	2.76	0.23	2.53
469	17.33	0.76	78.51	1.22	0.45	1.73	0.63	1.10
519	10.28	0.98	84.83	1.81	0.43	1.67	0.67	1.01
530	17.50	0.74	78.35	1.23	0.45	1.74	0.63	1.11
660	20.44	1.83	74.64	1.65	0.32	1.13	0.87	0.26
669	17.09	0.76	78.67	1.23	0.49	1.75	0.64	1.11
720	19.93	2.15	74.33	1.81	0.36	1.41	0.97	0.45
790	15.64	1.61	78.65	2.74	0.31	1.05	0.72	0.33
875	12.92	1.31	81.15	2.39	0.13	2.10	0.70	1.40
1009	17.15	0.75	78.65	1.22	0.49	1.74	0.64	1.10
1069	10.31	0.98	84.87	1.81	0.39	1.65	0.66	0.99
1100	20.23	2.01	74.33	1.75	0.34	1.34	0.97	0.36
1190	0.26	2.11	94.99	0.00	2.64	0.00	0.00	0.00
1260	17.50	0.74	78.35	1.23	0.45	1.74	0.63	1.11
1300	9.40	0.91	85.70	1.69	0.66	1.65	0.70	0.95
1310	10.22	0.99	84.79	1.82	0.49	1.70	0.67	1.03

Appendix 8. Land Cover/Use for the Muddy-Virgin Project Area Delineated Sub-Watershed Riparian Buffers.

SITE	RFOR90	RWETL90	RSHRB90	RNG90	RNBAR90	RHUM90	RURB90	RAGT90
8	43.51	0.18	53.90	0.40	0.01	2.00	0.46	1.54
10	45.48	0.86	52.38	0.20	0.00	1.08	0.59	0.49
19	13.77	1.02	81.37	1.30	0.35	2.19	2.15	0.04
95	39.08	0.22	57.48	0.70	0.07	2.45	0.73	1.72
110	15.84	1.07	79.03	2.71	0.25	1.10	0.73	0.36
119	15.74	1.13	79.05	2.70	0.25	1.12	0.73	0.39
128	99.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
144	21.77	1.33	69.47	4.76	0.24	2.44	0.66	1.78
170	17.72	0.52	78.40	1.29	0.45	1.62	0.62	1.00
173	8.26	0.01	71.47	0.79	8.28	11.20	11.20	0.00
185	13.58	0.92	81.00	2.64	0.13	1.73	0.60	1.14
207	31.87	0.28	65.35	0.61	0.07	1.81	0.55	1.26
215	36.66	0.28	60.25	0.64	0.07	2.09	0.64	1.45
232	8.26	0.01	71.47	0.79	8.28	11.20	11.20	0.00
258	74.70	2.05	22.36	0.43	0.01	0.45	0.00	0.45
270	10.40	0.72	84.93	1.94	0.42	1.59	0.66	0.92
285	38.29	0.20	58.30	0.69	0.06	2.45	0.70	1.75
289	2.90	1.95	89.12	2.16	0.72	3.15	3.03	0.12
298	52.34	0.30	44.40	0.53	0.00	2.42	0.19	2.23
310	20.92	1.04	75.17	1.66	0.22	1.00	0.74	0.26
319	23.41	0.83	72.85	1.71	0.19	1.01	0.77	0.25
368	52.54	0.30	44.20	0.53	0.00	2.43	0.19	2.24
469	17.71	0.53	78.40	1.29	0.45	1.62	0.62	1.00
519	10.43	0.72	84.94	1.93	0.41	1.57	0.66	0.91
530	17.88	0.52	78.22	1.30	0.45	1.63	0.62	1.01
660	20.54	1.18	75.22	1.65	0.24	1.17	0.88	0.28
669	17.46	0.54	78.56	1.29	0.49	1.65	0.64	1.02
720	20.06	1.41	75.01	1.77	0.28	1.47	1.00	0.47
790	15.74	1.07	79.13	2.73	0.25	1.08	0.73	0.35
875	13.12	0.97	81.29	2.55	0.13	1.93	0.67	1.26
1009	17.52	0.53	78.54	1.29	0.49	1.64	0.63	1.00
1069	10.46	0.72	84.96	1.93	0.37	1.55	0.66	0.90
1100	20.35	1.30	74.97	1.72	0.27	1.39	1.00	0.39
1190	0.12	0.96	96.14	0.12	2.65	0.00	0.00	0.00
1260	17.88	0.52	78.22	1.30	0.45	1.62	0.62	1.00
1300	9.52	0.67	85.83	1.79	0.64	1.55	0.69	0.86
1310	10.37	0.72	84.90	1.94	0.47	1.60	0.66	0.93

Appendix 9. RUSLE 2 Variables.

Site	A Value	R Factor	K Factor	LS Factor	C Factor	P Factor
8	1462	22	0.18	3.20	0.069	1.000
10	1927	16	0.19	4.22	0.064	1.000
19	2621	14	0.15	6.28	0.092	1.000
95	1502	20	0.17	3.41	0.072	1.000
110	1916	15	0.13	4.66	0.091	1.000
119	1901	15	0.14	4.64	0.091	1.000
128	2204	26	0.14	6.49	0.041	1.000
144	1463	13	0.23	3.50	0.081	1.000
170	1563	14	0.17	3.87	0.091	1.000
173	2032	13	0.15	4.20	0.147	1.000
185	1440	13	0.21	3.34	0.087	1.000
207	1657	18	0.16	4.02	0.077	1.000
215	1619	20	0.16	3.90	0.074	1.000
232	2032	13	0.15	4.20	0.147	1.000
258	2108	28	0.16	4.83	0.051	1.000
270	1555	12	0.19	3.96	0.092	1.000
285	1432	20	0.17	3.14	0.072	1.000
289	1834	11	0.21	3.59	0.102	1.000
298	1811	23	0.17	3.91	0.063	1.000
310	2160	16	0.13	5.39	0.087	1.000
319	2287	17	0.13	5.63	0.085	1.000
368	1807	23	0.17	3.91	0.063	1.000
469	1564	14	0.17	3.87	0.091	1.000
519	1548	12	0.19	3.96	0.093	1.000
530	1565	14	0.17	3.88	0.091	1.000
660	2110	16	0.14	5.28	0.088	1.000
669	1548	14	0.17	3.83	0.092	1.000
720	2048	15	0.14	5.21	0.090	1.000
790	1925	16	0.13	4.72	0.090	1.000
875	1425	13	0.19	3.28	0.094	1.000
1009	1553	14	0.17	3.84	0.092	1.000
1069	1561	13	0.19	3.98	0.092	1.000
1100	2079	16	0.14	5.24	0.089	1.000
1190	281	9	0.14	0.94	0.108	1.000
1260	1565	14	0.17	3.88	0.091	1.000
1300	1523	12	0.18	3.84	0.097	1.000
1310	1526	12	0.19	3.93	0.097	1.000

Appendix 10. Descriptive Water Quality and IBI Statistics in the Muddy-Virgin Project Area.

Site	DO	pH	TP	TN	Cl	IBI
8	6.9	8.21	0.043	0.191	1.0	74
10	8.8	8.05	0.017	0.142	6.9	74
19	12.8	7.35	0.045	1.041	543.0	22
95	11.6	8.62	0.018	0.358	18.9	66
110	8.9	8.05	0.021	0.487	522.0	32
119	8.3	8.03	0.025	0.441	512.0	46
128	6.4	7.82	0.010	0.203	5.7	84
144	10.1	8.15	0.021	0.089	6.7	62
170	7.1	8.22	0.088	0.630	87.3	62
173	9.2	8.00	0.064	0.723	41.4	
185	6.6	8.08	0.010	0.238	4.8	46
207	9.3	8.26	0.012	0.858	61.8	30
215	6.3	7.84	0.027	1.916	36.2	52
232	12.8	8.23	0.010	4.024	151.6	24
258	7.4	7.75	0.010	0.251	8.9	54
270	7.7	8.25	0.024	0.530	46.7	52
285	5.9	7.72	0.074	0.257	53.5	58
289	9.1	8.49	0.426	3.280	378.0	34
298	7.8	8.30	0.051	0.238	1.0	64
310	9.0	8.04	0.027	0.446	415.0	38
319	8.9	7.82	0.027	0.704	422.0	36
368	8.6	8.19	0.019	0.258	1.0	44
469	8.4	8.44	0.065	0.636	54.2	38
519	7.5	8.03	0.023	0.576	48.2	68
530	7.1	8.21	0.088	0.674	82.4	42
660	11.4	7.73	0.037	0.563	675.0	40
669	7.4	7.57	0.204	0.708	228.6	24
720	8.9	8.02	0.054	0.374	358.0	4
790	7.5	7.90	0.052	0.503	437.0	56
875	5.1	7.63	0.010	0.303	8.7	40
1009	8.3	7.18	0.164	0.897	162.3	34
1069	6.7	7.94	0.026	0.461	58.3	64
1100	8.6	7.90	0.053	0.364	480.0	58
1190	9.3	7.93	0.030	0.250	368.0	48
1260	7.3	8.44	0.067	0.531	72.7	
1300	7.6	8.20	0.071	0.538	90.7	58
1310	7.8	8.34	0.043	0.337	65.9	46

Appendix 11. Indicators Summary Statistics.

Indicator	Units	Mean	Median	Min	Max
Dissolved Oxygen	mg/L	8.33	8.30	5.10	12.80
pH	pH units	8.03	8.04	7.18	8.62
Total Phosphorous	mg/L	0.06	0.03	0.01	0.43
Total Nitrogen	mg/L	0.68	0.49	0.09	4.02
Chloride	mg/L	173.08	65.93	1.00	675.00
Sulfate	mg/L	498.56	245.12	1.00	1854.00
IBI	Unitless	48.69	46.65	6.66	86.63

Appendix 12. User-Defined Summary of Surface Layers in the Muddy-Virgin Project Area.

Summary Soils	Soil Groups
Cobbly Sandy Loam	Very Cobbly Sandy Loam
Cobbly Clay Loam	Very Cobbly Clay Loam
Cobbly Loam	Extremely Cobbly Loam
Gravelly Loam	Very Gravelly Loam
	Gravelly Loam
Gravelly Sandy Loam	Gravelly Fine Sandy Loam
	Very Gravelly Fine Sandy Loam
	Extremely Gravelly Fine Sandy Loam
	Gravelly Sandy Loam
	Very Gravelly Sandy Loam
Loam	Loam
	Very Channery Loam
	Very Gravelly Sandy Clay Loam
Sand	Fine Sand
	Loamy Fine Sand
	Loamy Sand
	Very Gravelly Loamy Sand
	Loamy Coarse Sand
Sandy Loam	Fine Sandy Loam
	Extremely Stony Sandy Loam
	Very Fine Sandy Loam
Silt Loam	Silt Loam
Unweathered Bedrock	Unweathered Bedrock
Unknown	Unknown
Variable	Variable

Appendix 13. Predicted Models

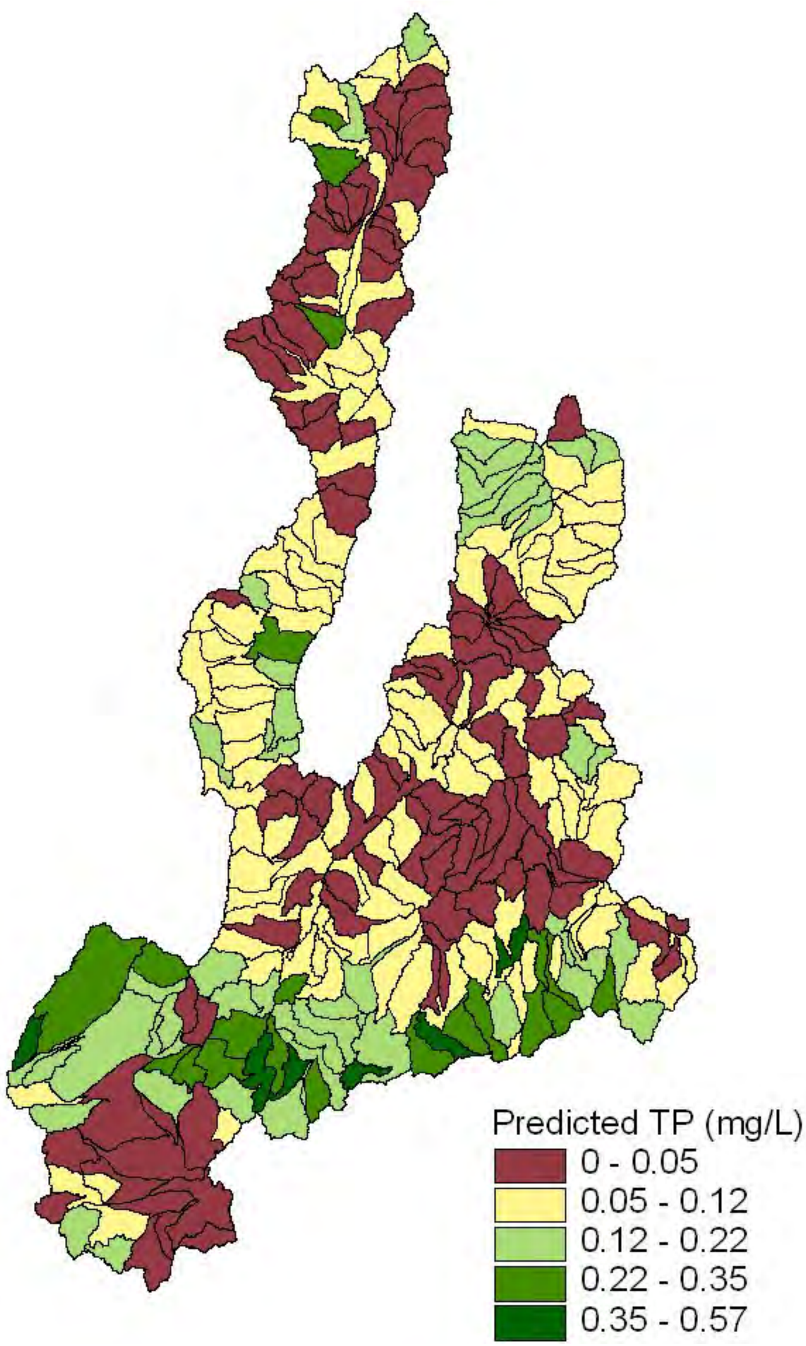

Figure 41. Predicted Total Phosphorus Values.

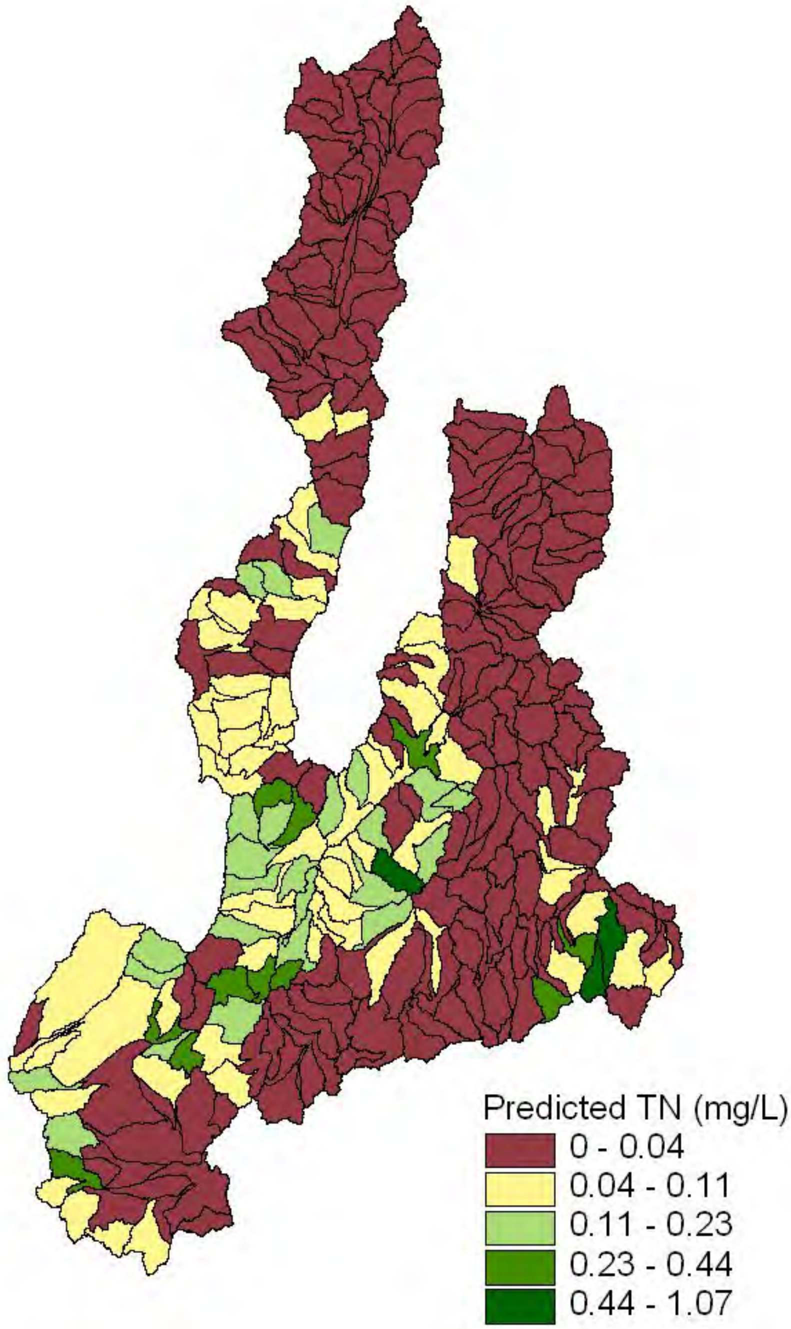

Figure 42. Predicted Total Nitrogen Values.

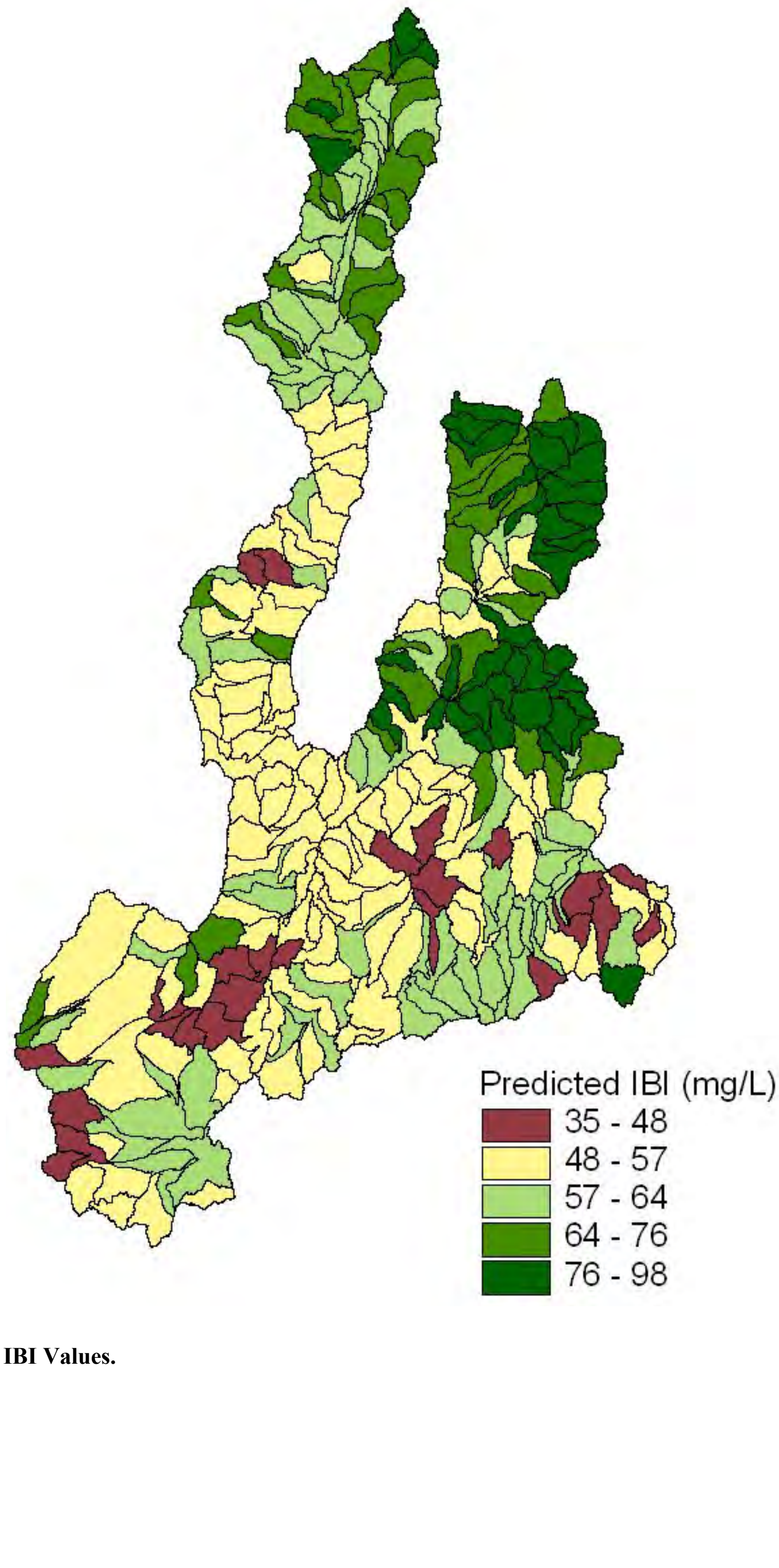

Figure 43. Predicted IBI Values.

United States
Environmental Protection
Agency

Office of Research
and Development (8101R)
Washington, DC 20460

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