NEMO Watershed Based Plan

Verde Watershed

ADEQ Arizona Department of Environmental Quality

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Arizona Cooperative Extension
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Water Resources Research Center

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The NEMO website is www.ArizonaNEMO.org.

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Verde Watershed
Executive Summary

The objective of this study was to develop a watershed based plan for the Verde Watershed that includes a characterization and classification of the watershed features. This watershed based plan identifies areas that are susceptible to water quality problems and nonpoint pollution sources that need to be controlled, and management measures that should be implemented to improve water quality throughout the watershed.

The first part of the project focused on watershed characterization identifying physical, biological and social characteristics of the Verde Watershed from publicly available information. ArcGIS (Environmental Systems Research Institute, Inc.) software was used to construct a spatial database including topography, land cover, soil types and characteristics, geology, vegetation, hydrologic features, and population characteristics.

After developing the GIS database, watershed classifications were performed in order to identify important resources and rank 10-digit HUC (hydrologic unit code) subwatershed areas based on likelihood of nonpoint source pollutant contribution to stream water quality degradation. A HUC is a means of subdividing watersheds into successively smaller hydrologic units of surface water drainage features.

To achieve the objective of developing a watershed based plan, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types. Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized as a method by which to quantify common sense. This methodology has been selected as the basis by which subwatershed areas and stream reaches were prioritized for proposed implementation of Best Management Practices to assure load reductions of constituents of concern.

The water quality results reported in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2003), and EPA's (U.S. Environmental Protection Agency) revisions of Arizona's final 2004 303d List for water quality results were reviewed and summarized for each monitored stream reach in the Verde Watershed. Based on exceedances in each reach and the designated use classification system, each stream reach was classified as extreme, high, medium or low risk of impairment. Each subwatershed was then ranked using a scale of 0-1 based on the stream reach condition in each 10-digit HUC and downstream reach condition.

Subwatershed classification ranking data were then created based on calculated parameters for each of the water quality constituents groups and by simulating hydrologic response within the GIS

environment. For each constituent group several parameters were calculated in each subwatershed and a fuzzy membership function (FMV) was developed in order to assign a ranked value (0-1) to each 10-digit HUC subwatershed. The FMV for each of the parameters in each subwatershed, along with the ranked water quality assessment data, were combined and each subwatershed was ranked and categorized as either low or high risk for nonpoint source pollution problems.

The Revised Universal Soil Loss Equation (RUSLE) model (USDA, 1997) was used to estimate sediment yield due to land use or land use change. The Soil and Water Assessment Tool (SWAT) hydrologic model (Arnold et al., 1994) within the Automated Geospatial Watershed Assessment Tool (AGWA) (Burns et al., 2004) was also applied to simulate sediment yield and runoff for each 10-digit HUC subwatershed area.

Unique waters of the state, mapped wilderness areas and preserves, riparian areas, and critical habitat for endangered species were used to identify important Natural Resource Areas (NRA) at the scale of 10-digit HUC subwatershed in the Verde Watershed. These were then used to recommend management actions specific to the conditions in each NRA.

Best Management Practices for each subwatershed were proposed based on the watershed assessment data and available ADEQ TMDL reports.

The management section of the document includes general watershed management methods, recommended strategies for addressing existing impairment in the watershed, stream channel and riparian restoration, and proposed education programs.

As a result of this study, the primary sources for nonpoint source pollutant concerns in the Verde Watershed include abandoned mine sites, new development and increased urbanization, and new road construction. The Lower Big Chino Wash Natural Resource Area is particularly at risk of nonpoint source pollutants due to the large percentage of private land within the area and the potential for private development. Livestock grazing and mining can contribute to sediment erosion within the Fossil Creek – Lower Verde River and Cherry Creek – Upper Verde River subwatersheds, resulting in a ranking of elevated risk. Animal wastes and the failure of residential septic systems are found to be the primary sources of nonpoint source organic contaminants across the watershed.

Based on the watershed classifications, a watershed-based plan was proposed that included potential water quality improvement projects for subwatersheds that were most susceptible to known water quality concerns. The plan discusses the pollutant type and source, load reduction calculations, and sample management measures.

References:

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Section 1: Introduction

Background

The Southwestern United States, including the State of Arizona, is the fastest growing region in the country. Because the region is undergoing rapid development, there is a need to address health and quality of life issues that result from contamination of water resources from nonpoint sources of pollution. Nonpoint source pollution is the leading cause of water quality degradation across the United States, and is differentiated from point source pollution in that, for some states such as Arizona, there are no regulatory mechanisms by which to enforce clean up of nonpoint source pollution.

Nonpoint source pollution originates from many different sources, usually associated with rainfall runoff moving over and through the ground, carrying natural and manmade pollutants into lakes, rivers, streams, wetlands, estuaries, coastal waters and ground water.

Nationally, the Nonpoint Education for Municipal Officials (NEMO) program has been very successful in helping to mitigate nonpoint source pollution. The goal of NEMO is to educate land-use decision makers to take proactive voluntary actions that will mitigate nonpoint source pollution and protect natural resources. In the eastern United States (where the NEMO concept originated), land use authority is concentrated in municipal (village, town and city) government. In Arizona, where nearly 80% of the land is managed by state, tribal and federal entities, land use authorities include county, state and federal agencies, in addition to municipal officials and private citizens.

In partnership with the Arizona Department of Environmental Quality (ADEQ), Arizona Cooperative Extension at the University of Arizona (U of A) has initiated the Arizona NEMO program. Arizona NEMO is an attempt to adopt the NEMO program to the conditions in the semiarid, western United States, where water supply is limited and many natural resource problems are related to the lack of water, as well as water quality.

Working within a watershed template, Arizona NEMO includes: comprehensive and integrated watershed planning support, identification and publication of Best Management Practices (BMP), education on water conservation, and riparian water quality restoration.

In collaboration with watershed partnerships and ADEQ, NEMO will help improve water quality by developing a realistic watershed-based plan to achieve water quality standards and protection goals for the Verde Watershed. This plan will identify:

- Areas that are susceptible to water quality problems and pollution;
- Sources that need to be controlled; and

- Management measures that should be implemented to protect or improve water quality.

Based on EPA's *2003 Guidelines for the Award of Section 319 Nonpoint Source Grants*, a watershed-based plan should include all nine of the elements listed below.

- Element 1: *Causes and Sources* - Clearly define the causes and sources of impairment (physical, chemical, and biological).
- Element 2: *Expected Load Reductions* - An estimate of the load reductions expected for each of the management measures or best management practices to be implemented (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).
- Element 3: *Management Measures* - A description of the management measures or best management practices and associated costs that will need to be implemented to achieve the load reductions estimated in this plan and an identification (using a map or a description) of the critical areas where those measures are needed.
- Element 4: *Technical and Financial Assistance* - An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan.
- Element 5: *Information / Education Component* - An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing management measures.
- Element 6: *Schedule* - A schedule for implementing management measures identified in this plan that is reasonably expeditious.
- Element 7: *Measurable Milestones* - A schedule of interim, measurable milestones for determining whether the management measures, Best Management Practices, or other control actions are being implemented.
- Element 8: *Evaluation of Progress* - A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the plan needs to be revised or, if a Total Maximum Daily Load (TMDL) has been established, whether the TMDL needs to be revised.
- Element 9: *Effectiveness Monitoring* - A monitoring

component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established in the Evaluation of Progress element.

These nine elements help provide reasonable assurance that the nonpoint source of pollution will be managed to improve and protect water quality and to assure that public funds to address impaired waters are used effectively.

Watershed-based plans are holistic documents that are designed to protect and restore a watershed. These plans provide a careful analysis of the sources of water quality problems, their relative contributions to the problems, and alternatives to solve those problems. Furthermore, watershed-based plans will deliver proactive measures to protect water bodies. In watersheds where a TMDL has been developed and approved or is in the process of being developed, watershed-based plans must be designed to achieve the load reductions called for in the TMDL.

Purpose and Scope

This watershed-based plan includes a watershed classification that has been developed for the Verde Watershed. The classification supports the watershed-based plan and provides educational outreach material to stakeholders and watershed partnerships. It provides an inventory of natural resources and environmental conditions that affect primarily surface water quality.

In addition to the classification, this plan provides methods and tools to identify problem sources and locations for implementation of Best Management Practices to mitigate nonpoint source pollution. Although these chapters are written based on current information, the tools developed can be used to update this plan and reevaluate water quality concerns as new information becomes available.

The watershed characterization includes physical, biological, and social data in a geographic information system (GIS) database format, as both mapped and tabulated data, as collected from available existing and published data sources. No additional data were collected.

The characterization also includes descriptions of environmental attributes and identification of water quality problems by incorporating water quality data reported in *The DRAFT Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report* (ADEQ, 2005), ADEQ's biennial report consolidating water quality reporting requirements under the federal Clean Water Act. The ADEQ water quality data, TMDL definitions, and further information for each stream reach and the surface water sampling sites across the state can be found at: www.adeq.state.az.us/environ/water/assessment/assess.html.

The watershed classification includes the identification of and mapping of important resources, and ranking of 10-digit HUC subwatersheds (defined later in this section) based on the likelihood of nonpoint source pollutant contribution to stream water quality degradation.

Following the classification, this watershed plan includes a management section with general discussions of recommended nonpoint source Best Management Practices that will need to be implemented to achieve load reductions, as well as to achieve other watershed goals. These watershed management activities are proposed with the understanding that the land-use decision makers and stakeholders within the watershed can select the BMPs they feel are most appropriate and revise management activities as conditions within the watershed change.

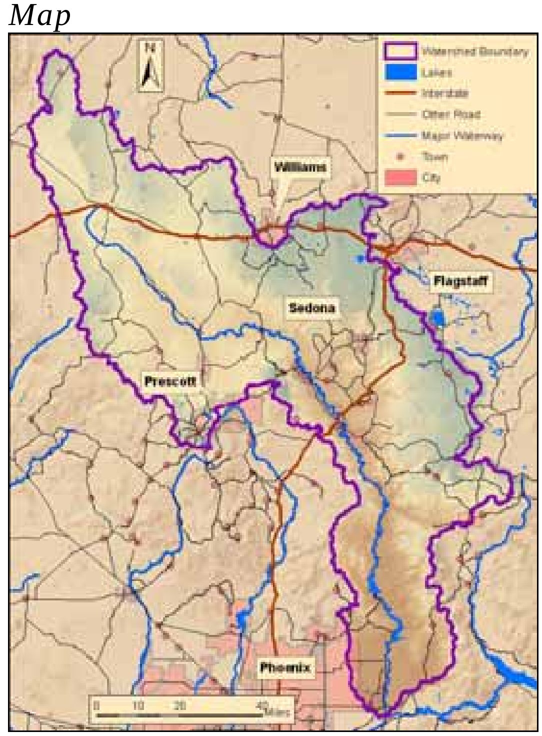
Based on the watershed classification, a watershed-based plan is proposed that includes potential water quality improvement projects for subwatersheds that were determined to be most susceptible to known water quality concerns. The plan discusses the pollutant type and source, load reduction calculations, and sample management measures.

The Verde Watershed is located in the north-central portion of the state of Arizona, bounded by the cities of Williams, Flagstaff, Prescott, and Phoenix, as shown in Figure 1-1.

<u>Methods</u>

GIS and hydrologic modeling were the major tools used to develop this watershed plan. In a GIS, two types of information represent geographic features: locational and descriptive data. Locational (spatial) data are stored using a vector or a raster data structure. Vector data are object based data models which show spatial features as points, lines, and/or polygons. Raster data models represent geographical space by dividing it into a series of units, each of which is limited and defined by an equal amount of earth's surface. These units are of different shapes, i.e. triangular or hexagonal, but the most commonly used shape is the square, called a cell. Corresponding descriptive (attribute) data for each geographic feature are stored in a set of tables. The spatial and descriptive data are linked so that both sets of information are always available.

Figure 1-1: Verde Watershed Location Map



Planning and assessment in land and water resource management requires spatial modeling tools so as to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Verde Watershed included AGWA, SWAT, and RUSLE, as described below.

The Automated Geospatial Watershed Assessment Tool (AGWA) is a GIS-based hydrologic modeling tool designed to evaluate the effects of land use change (Burns et. al., 2004). AGWA provides the functionality to conduct all phases of a watershed assessment. It facilitates the use of the Soil and Water Assessment Tool (SWAT), a hydrologic model, by preparing the inputs, running the model, and presenting the results visually in the GIS. AGWA has been used to illustrate the impacts of urbanization and other landscape changes, and to simulate sediment load in the watershed. AGWA was developed under a joint project between the Environmental Protection Agency (EPA), Agricultural Research Service (ARS), and the University of Arizona. SWAT was developed by the ARS, and is able to predict the impacts of land management practices on water, sediment and chemical yields in complex watersheds with varying soils, land use and management conditions (Arnold et al., 1994) . The Revised Universal Soil Loss Equation (RUSLE) was also used to estimate soil loss from different land use types (Renard et al., 1997).

The watershed classification incorporates GIS-based hydrologic modeling results and other data to describe watershed conditions upstream from an impaired stream reach identified within Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), and simulate impacts due to mine sites (erosion and metals pollution) and grazing (erosion and pollutant nutrients).

The Verde Watershed is defined and mapped by the U.S. Geological Survey using the six-digit Hydrologic Unit Code (HUC). The United States is divided and sub-divided into successively smaller hydrologic units of surface water drainage features, which are classified into four levels, each identified by a unique hydrologic unit code consisting of two to eight digits: regions (2 digit), sub-regions (4 digit), accounting units (6 digit), and cataloging units (8 digit) (Seaber et al., 1987).

Within the six-digit HUC, subwatershed areas were delineated on the basis of the eight-digit cataloging HUC. The classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

Within this report, both HUC units and subwatershed names are used to clarify location. This watershed plan uses the following HUC watersheds:

- Verde Watershed (H150602)
  - Big Chino Wash (H15060201)
  - Upper Verde River (H15060202)
    - Granite Creek-Upper Verde River (H1506020201)
    - Hell Canyon (H1506020202)
    - Sycamore Creek (H1506020203)
    - Grindstone Wash-Upper Verde River (H1506020204)
    - Oak Creek (H1506020205)
    - Beaver Creek (H1506020206)
    - Cherry Creek-Upper Verde River (H1506020207)

Lower Verde River (H15060203)

To rank the 10-digit HUC subwatershed areas that are susceptible to water quality problems and pollution, and to identify sources that need to be controlled, a fuzzy logic knowledge-based methodology was applied to integrate the various spatial and non-spatial data types (Guertin et al., 2000; Miller et al., 2002; Reynolds et al., 2001). This methodology has been selected as the basis by which subwatershed areas and stream reaches are prioritized for the implementation of BMPs to assure nonpoint source pollution is managed.

Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized as a method by which to quantify common sense. In classical set theory, an object is either a member of the set or excluded from the set. For example, one is either tall or short, with the class of tall men being those over the height of 6'0". Using this method, a man who is 5' 11" tall would not be placed in the tall class, although he could not be considered 'not-tall'. This is unsatisfactory, for example, if one has to describe or quantify an object that may be a partial member of a set. In fuzzy logic, membership in a set is described as a value between 0 (non-membership in the set) and 1 (full membership in the set). For instance, the individual who is 5' 11" is not classified as short or tall, but is classified as tall to a degree of 0.8. Likewise, an individual of height 5' 10" would be tall to a degree of 0.6.

In fuzzy logic, the range in values between different data factors are converted to the same scale (0-1) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the characteristics of the input. In the illustration above the degree of tallness was iteratively added in intervals of 0.2. An example of a continuous data set would be to graph the heights of all individuals and correlate a continuous fuzzy member value to that graph. A user defines their membership functions to describe the relationship between an individual factor and the achievement of the stated goal.

The development of a fuzzy membership function can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. Another benefit of this approach is that it provides for the use of different methods for combining individual factors to create the final classification, and the goal set. Fuzzy membership functions and weighting schemes can also be changed based on watershed concerns and conditions.

Our general approach was to integrate watershed characteristics, water quality measurements, and modeling results within a multi-parameter ranking system based on the fuzzy logic knowledge-based approach, as shown schematically in Figure 1-2.

This approach requires that a goal be defined according to the desired outcome, and that the classification be defined as a function of the goal and is therefore reflective of the management objective. For the watershed classification, the goal is to identify critical subwatersheds in which BMPs should be implemented to reduce nonpoint source pollution.

The process was implemented within a GIS interface to create the subwatershed classifications using five primary steps:

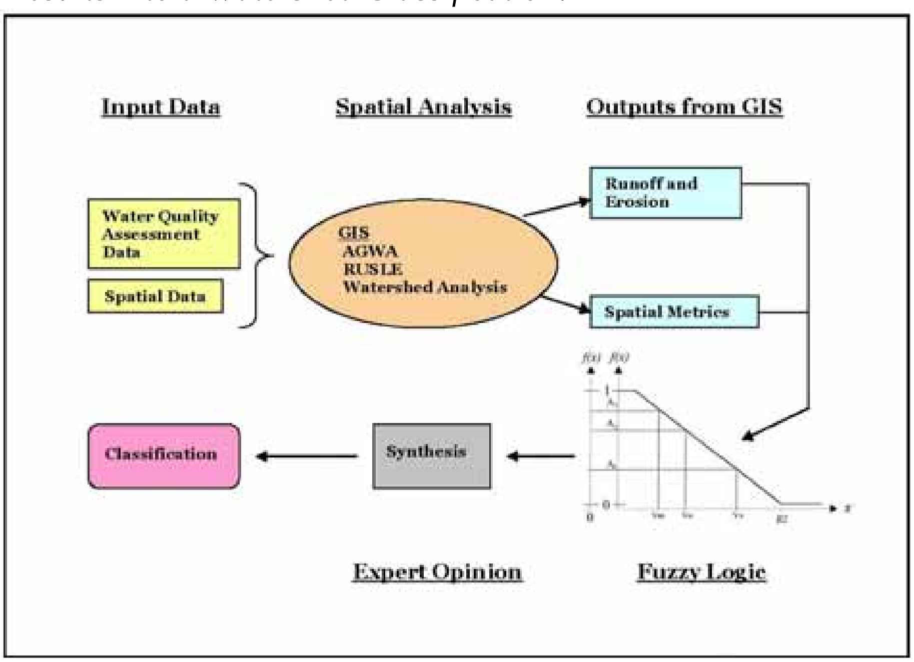
1. Define the goal of the watershed classification (For the Verde Watershed, dissolved / total metals water quality impairment to streams due to mine activity);

2. Assemble GIS data and other observational data;
3. Define watershed characteristics through:
    a. Water quality data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report;
    b. GIS mapping analysis; and
    c. Modeling / simulation of erosion vulnerability / potential for stream impairment (in this case, from soils in mine site areas and proximity to abandoned mine sites).

4. Use fuzzy membership functions to transform the vulnerability / impairment metrics into fuzzy membership values; and

5. Determine a composite fuzzy score representing the ranking of the combined attributes, and interpret the results.

Figure 1-2: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.



Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), was used to classify each monitored stream reach based on its relative risk of impairment for each of the chemical constituent groups. The constituent groups include metals, organics, nutrients, and turbidity/sediment. Two levels of risk were defined: high and low. For example, if elevated concentrations of metals, such as copper and mercury, are found above standards, the water body would be classified as 'high' risk if ADEQ has currently assessed it as being "impaired" for that constituent group. Conversely, a water body is classified as 'low' risk if there are no exceedences in a constituent group and there are sufficient data to make a classification.

Classifications were conducted at the 10-digit HUC subwatershed scale, resulting in the ranking of twenty-two subwatershed areas within the 6,600 square mile area of the Verde Watershed.

Structure of this Watershed Based Plan

Watershed characterizations, including physical, biological, and social characteristics, are discussed in Sections 2 through 4. Important environmental resources are discussed in Section 5, and subwatershed classifications based on water quality attributes including concentrations of metals, sediment/turbidity, organics, and nutrients are found in Section 6. Watershed management strategies and BMPs are provided in Section 7, and the Watershed Plan is presented in Section 8. The full tabulation of the ADEQ water quality data and assessment status is provided in Appendix A.

Summary discussions of the modeling software, as well as suggested technical references of studies completed across the Verde Watershed are included in the remaining appendices.

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Arizona Department of Environmental Quality, ADEQ. 2005. The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, 1110 West Washington Ave., Phoenix, Arizona, 85007, from http://www.azdeq.gov/environ/water/assessment/2004.html.

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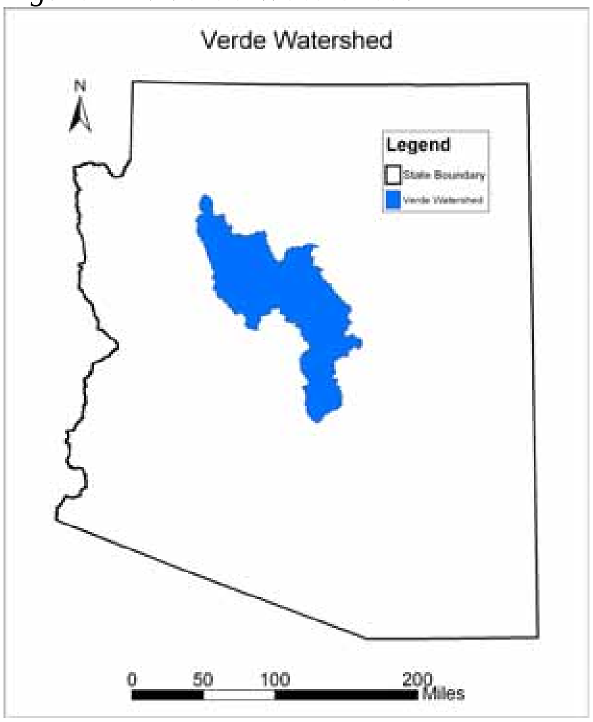
Section 2: Physical Features

The Verde Watershed in Arizona is defined as the area drained by the Verde River into the Salt River. The watershed is located in the northwestern part of the state, as shown in Figure 2-1.

Figure 2-1: Verde Watershed.



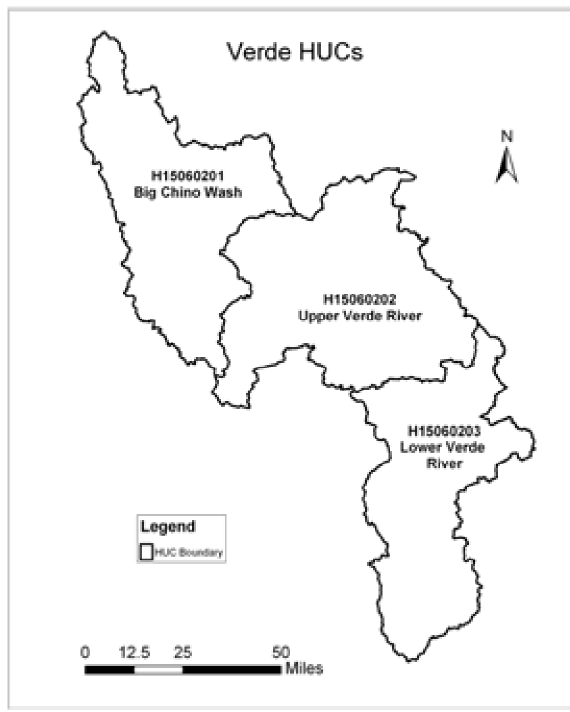
Watershed Size

The Verde Watershed covers approximately 6,622 square miles, representing almost 6% of the state of Arizona. The watershed has a maximum approximate width of 120 miles east-west, and a maximum length of 160 miles north-south.

The watershed was delineated by the U.S. Geological Survey and has been subdivided into subwatersheds or drainage areas. Each drainage area has a unique hydrologic unit code number, or HUC, and a name based on the primary surface water within the HUC. These drainage areas can be further subdivided as needed. This report will work with two levels: an eight-digit cataloging HUC, and a subdivision of these, a 10-digit HUC. The subwatershed areas were delineated on the basis of the eight-digit HUC, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

The eight-digit subwatershed HUCs are listed in Table 2-1 with both the unique HUC digital classification and the subwatershed basin name. The subwatershed areas are delineated in Figure 2-2.

Figure 2-2: Verde Watershed Subwatershed Names and HUCs.



Topography

Topography and land slope, as well as soil characteristics, are important when assessing the vulnerability of the subwatershed to erosion, as will be discussed later in this document.

Table 2-1: Verde Watershed HUCs, Subwatershed Areas.

HUC Designation and Subwatershed Name	Area (square miles)
Big Chino Wash H15060201	**2,153**
Upper Verde River H15060202	**2,501**
Lower Verde River H15060203	**1,968**
Verde Watershed	***6,622***

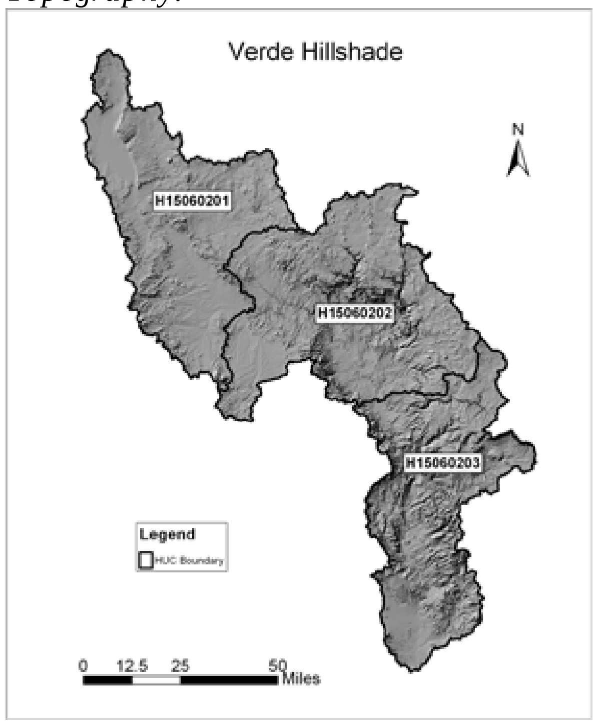
The land surface elevation of the Verde Watershed ranges between 1,323 and 12,617 feet above sea level. The tallest feature in the watershed is Humphrey's Peak at 12,617 feet. The lowest point in the watershed is at the outlet of the Verde River, at the very southern tip of the watershed. Mean elevation for the whole Verde Watershed is 5,159 feet (Table 2-2). The Lower Verde River Subwatershed (HUC 15060203) is lower than the rest of the watershed with a mean elevation of 4,200 feet, almost 1,000 feet lower than the mean for the entire watershed (Figure 2-3).

Table 2-2: Verde Watershed Elevation Range.

Subwatershed Name	Min (feet)	Max (feet)	Mean (feet)
Big Chino Wash H15060201	**4,358**	**8,862**	**5,513**
Upper Verde River H15060202	**3,056**	**12,617**	**5,595**
Lower Verde River H15060203	**1,323**	**8,522**	**4,219**
Verde Watershed	***1,323***	***12,617***	***5,159***

Approximately 50% of the Verde Watershed has a slope greater than 15%, while 32% of the watershed has a slope less than 5%. The Big Chino Wash Subwatershed is flatter than the watershed mean with only 35% of its area over 15% slope, and 44% less than 5% slope. The Lower Verde River Subwatershed by contrast is steeper than the watershed mean. Sixty-nine percent of its area has a slope greater than 15%, while only 18% is less than 5% slope (Table 2-3 and Figure 2-4).

Figure 2-3: Verde Watershed Topography.



<u>Water Resources</u>

Lakes and Reservoirs

There are 102 lakes and five reservoirs in the Verde Watershed. Horseshoe Reservoir, which forms behind Horseshoe Dam, has the largest open surface water area of about 2,610 acres. The next largest reservoir, Bartlett Reservoir, is formed by the Bartlett Dam and covers 2,376 acres.

Table 2-4 lists the major lakes and reservoirs and their associated areas.

Table 2-3: Verde Watershed Slope Classes.

Subwatershed Name	Area (sq. miles)	0-5%	5-15%	>15%
Big Chino Wash H15060201	**2,153**	**43.7%**	**21.4%**	**34.9%**
Upper Verde River H15060202	**2,501**	**33.3%**	**20.1%**	**46.6%**
Lower Verde River H15060203	**1,968**	**18.3%**	**12.4%**	**69.3%**
Verde Watershed	***6,622***	***32.2%***	***18.3%***	***49.5%***

Figure 2-4: Verde Watershed Slope Classes.

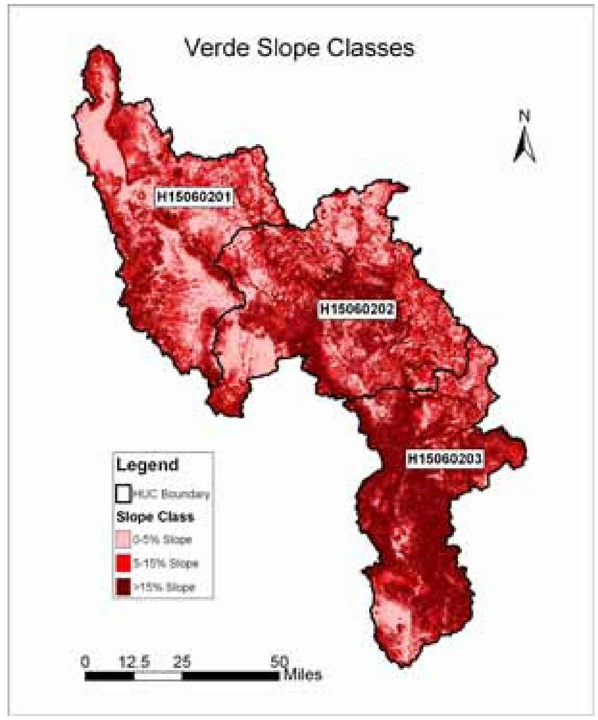


Table 2-4: Verde Watershed Major Lakes and Reservoirs.

Lake Name	Subwatershed	Surface Area (acre)	Elevation (feet above mean sea level)	Dam Name (if known)
Horseshoe Reservoir	**Lower Verde River**	**2,610**	**1,998**	**Horseshoe Dam**
Bartlett Reservoir	**Lower Verde River**	**2,376**	**1,752**	**Bartlett Dam**
Rogers Lake	**Upper Verde River**	**1,134**	**7,259**	**not known**
Willow Creek Reservoir	**Upper Verde River**	**294**	**5,140**	**Willow Creek Dam**
Watson Lake	**Upper Verde River**	**152**	**5,163**	**Granite Creek Dam**
Willow Valley Lake	**Lower Verde River**	**141**	**6,780**	**Willow Valley Dam**
Unnamed Reservoir	**Upper Verde River**	**133**	**6,940**	**not known**
Stoneman Lake	**Upper Verde River**	**128**	**6,839**	**not known**
Davenport Lake	**Upper Verde River**	**118**	**6,940**	**not known**

Stream Type

The Verde Watershed contains a total of 9,037 miles of streams. There are three different stream types: perennial, intermittent and ephemeral (Table 2-5).

- Perennial stream means surface water that flows continuously throughout the year.

- Intermittent stream means a stream or reach of a stream that flows continuously only at certain times of the year, as when it receives water from a seasonal spring or from another source, such as melting spring snow.

- An ephemeral stream is at all times above the ground water table, has no base flow, and flows only in direct response to precipitation.

Table 2-5: Verde Watershed Stream Types Length.

Stream Type	Stream Length (miles)	Percent of Total Stream Length
Intermittent	**9**	**<1%**
Perennial	**578**	**6%**
Ephemeral	**8,450**	**94%**
Total Length	***9,037***	***100.00%***

Most of the streams in desert regions are intermittent or ephemeral. Some channels are dry for years at a time, but are subject to flash flooding during high-intensity storms (Gordon et al., 1992). Table 2-6 and Figure 2-5 show the major lakes and streams in the Verde Watershed.

Ninety five percent of the streams in the Verde Watershed are ephemeral with a total length of 8,450 miles. Only 6% (578 miles) of streams are perennial, and are mostly restricted to the main stem of the Verde River.

Figure 2-5: Verde Watershed Major Lakes and Streams.

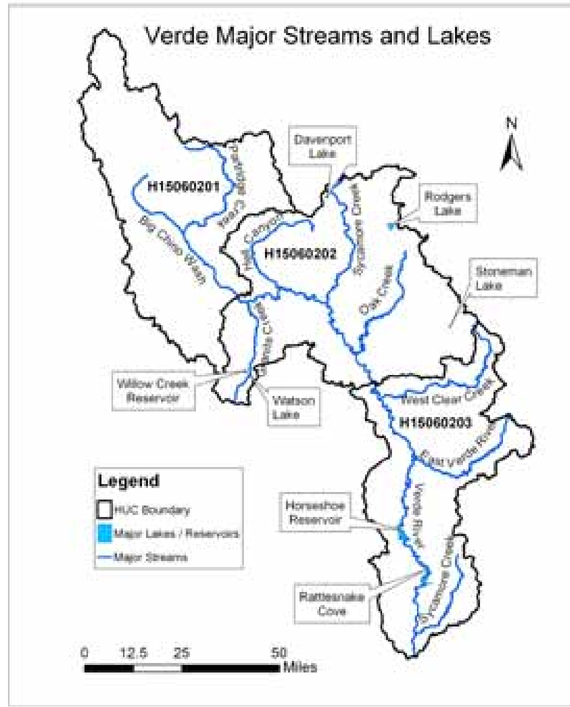
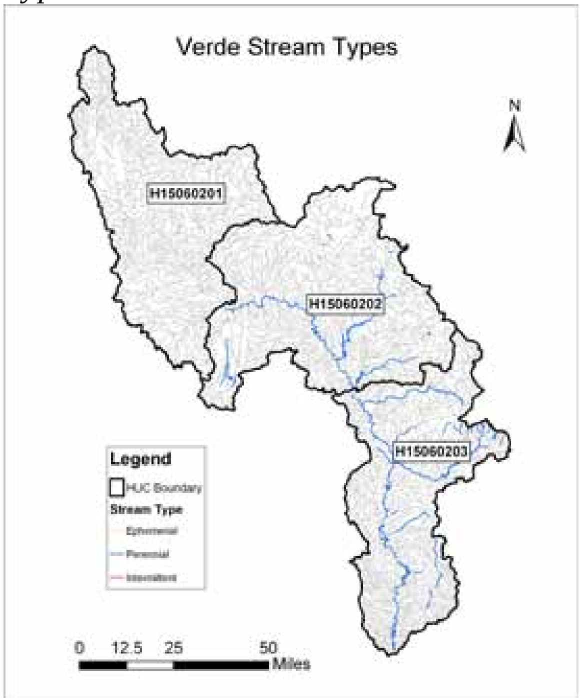


Table 2-6: Verde Watershed Major Streams.

Stream Name	Subwatershed	Stream Length (miles)
Verde River	**Upper Verde River - Lower Verde River**	**229**
West Clear Creek	**Lower Verde River**	**65**
Big Chino Wash	**Big Chino Wash**	**55**
Partridge Creek	**Big Chino Wash**	**55**
Oak Creek	**Upper Verde River**	**54**
East Verde River	**Lower Verde River**	**54**
Sycamore Creek	**Upper Verde River**	**52**
Hell Canyon	**Upper Verde River**	**42**
Granite Creek	**Upper Verde River**	**38**
Sycamore Creek	**Lower Verde River**	**34**

Figure 2-6: Verde Watershed Stream Types.



Stream Density

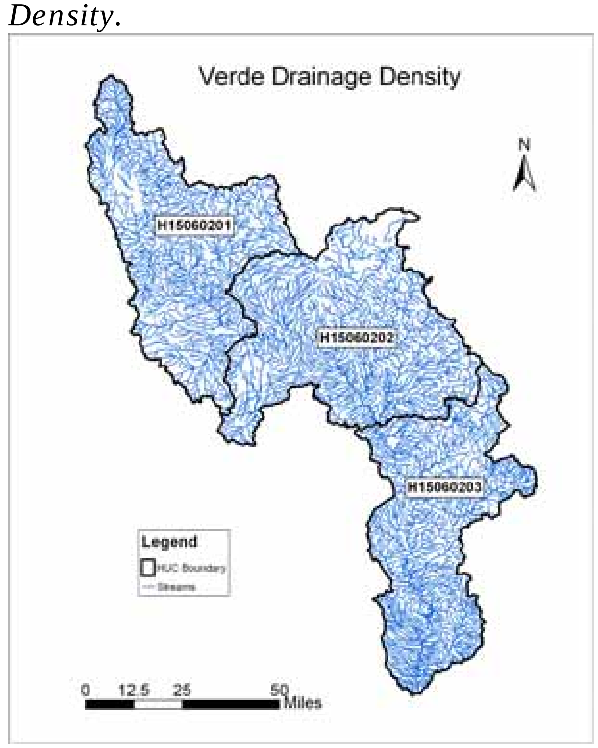
The density of channels in the landscape is a measure of the dissection of the terrain. The stream density is defined as the length of all channels in the watershed divided by the watershed area. Areas with high stream density are associated with high flood peaks and high sediment production, due to increased efficiency in the routing of water from the watershed. Since the ability to detect and map streams is a function of scale, stream densities should only be compared at equivalent scales (Dunne and Leopold, 1978).

Figure 2-7 shows stream density for the Verde Watershed, and Table 2-7 gives the stream density for each subwatershed in feet of stream length per acre. The average stream density for the Verde Watershed is 11.12 feet/acre. The Lower Verde River subwatershed has the highest drainage density at 12.50 feet/acre. The Upper Verde River subwatershed exhibits the lowest drainage density at 10.44 feet/acre.

Table 2-7: Verde Watershed Stream Density.

Subwatershed Name	Area (acres)	Stream Length (feet)	Drainage Density (feet / acre)
Big Chino Wash H15060201	**1,378,127**	**14,667,877**	**10.64**
Upper Verde River H15060202	**1,600,421**	**16,701,989**	**10.44**
Lower Verde River H15060203	**1,259,722**	**15,747,478**	**12.50**
Verde Watershed	***4,238,269***	***47,117,344***	***11.12***

Figure 2-7: Verde Watershed Stream Density.



Annual Stream Flow

Annual stream flows for twenty three gages were calculated for the Verde Watershed. These gages were selected based on their location, length of date record, and representativeness of watershed response. Figure 2-8 shows the locations of these gages. The gage at Verde River below the Bartlett Dam had the highest measured annual mean stream flow with 662 cubic feet per second (cfs).

Figure 2-8: Verde Watershed USGS Stream Gages.

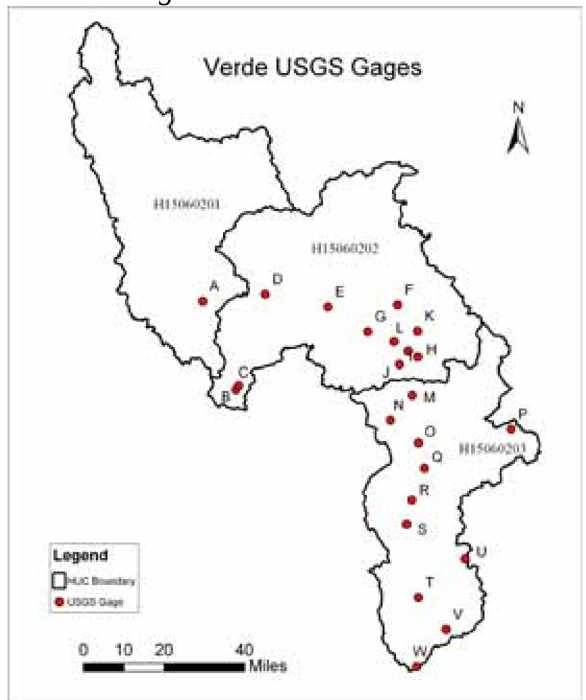


Table 2-8: Verde Watershed USGS Stream Gages.

ID	Site Name	Daily flow data begin date	Daily flow data end date	Annual Mean Stream flow (cfs)
A	Williamson Valley Wash Near Paulden	3/26/1965	9/30/2003	14.25
B	Granite Creek at Prescott	11/16/1994	9/30/2003	5.39
C	Granite Creek Near Prescott	7/1/1932	9/30/2003	5.88
D	Verde River Near Paulden	7/17/1963	9/30/2003	42.45
E	Verde River Near Clarkdale	6/18/1915	9/30/2003	176.84
F	Oak Creek Near Sedona	10/1/1981	9/30/2003	86.17
G	Oak Creek Near Cornville	7/1/1940	9/30/2003	87.49
H	Wet Beaver Creek Near Rimrock	10/1/1961	9/30/2003	33.67
I	Red Tank Draw Near Rimrock	4/15/1957	9/30/1978	6.44
J	Montezuma Well Outlet Near Rimrock	4/1/1977	9/30/1992	2.17
K	Rattlesnake Canyon Near Rimrock	6/9/1957	9/30/1980	7.96
L	Dry Beaver Creek Near Rimrock	10/1/1960	9/30/2003	43.18
M	West Clear Creek Near Camp Verde	12/5/1964	9/30/2003	63.33
N	Verde River Near Camp Verde	4/1/1934	9/30/2003	413.75
O	Fossil Creek Div. to Childs Power Plant, Near Camp Verde	1/1/1952	9/30/2003	42.23
P	East Verde River Div. From East Clear Creek Near Pine	10/21/1965	9/30/2003	11.00
Q	East Verde River Near Childs	9/1/1961	9/30/2003	64.45

ID	Site Name	Daily flow data begin date	Daily flow data end date	Annual Mean Stream flow (cfs)
R	Wet Bottom Creek Near Childs	10/1/1967	9/30/2003	14.06
S	Verde River Below Tangle Creek, Above Horseshoe Dam	8/22/1945	9/30/2003	566.00
T	Verde River Below Bartlett Dam	1/1/1904	9/30/2003	662.62
U	East Fork Sycamore Creek Near Sunflower	10/1/1961	5/31/1986	0.94
V	Sycamore Creek Near Fort McDowell	10/1/1960	9/30/2003	27.05
W	Verde River Near Scottsdale	2/13/1961	9/30/2003	621.02

Figure 2-9: USGS Gage 09504500 (Oak Creek Near Cornville) Hydrograph.

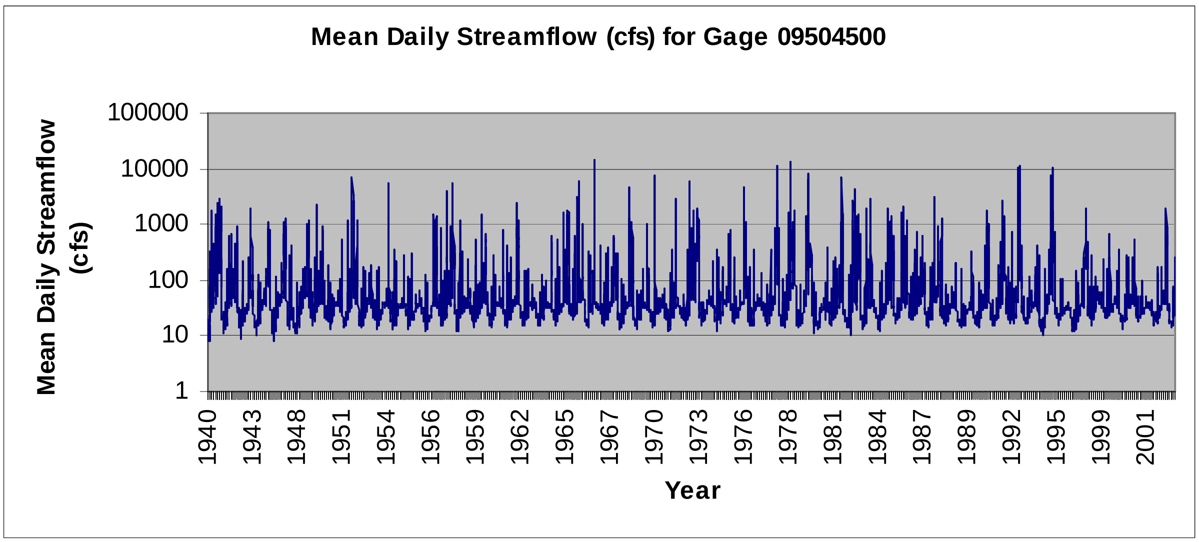


Figure 2-10: USGS Gage 09508500 (Verde River Below Tangle Creek, Above Horseshoe Dam) Hydrograph.

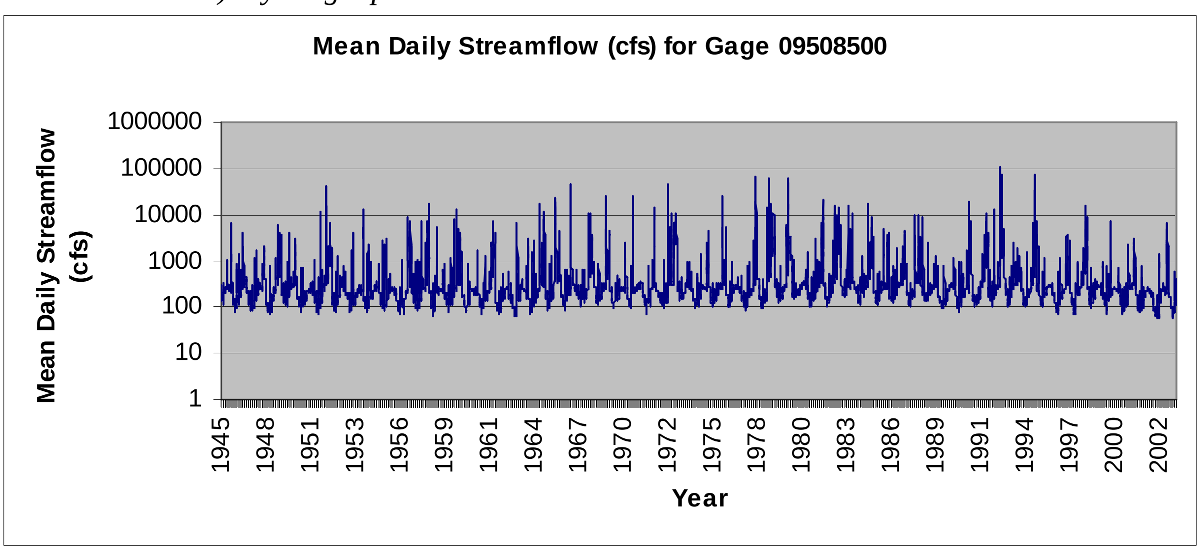


Figure 2-11: USGS Gage 09510000 (Verde River Below Bartlett Dam) Hydrograph.

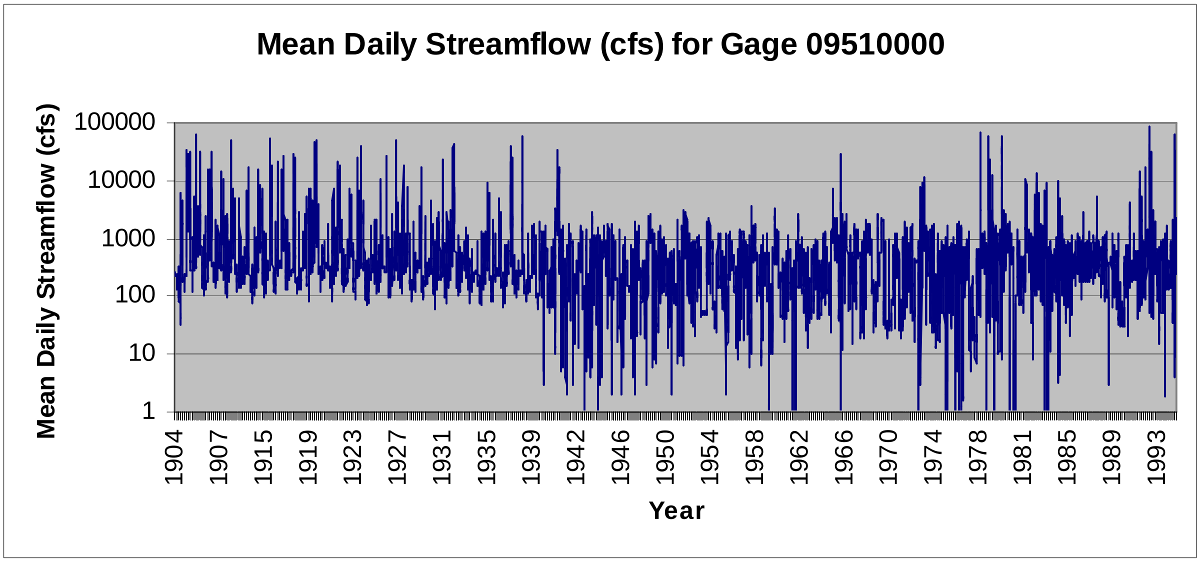


Figure 2-12: USGS Gage 09510000 (Verde River Below Bartlett Dam) Five Year Moving Average Stream Flow (cfs).

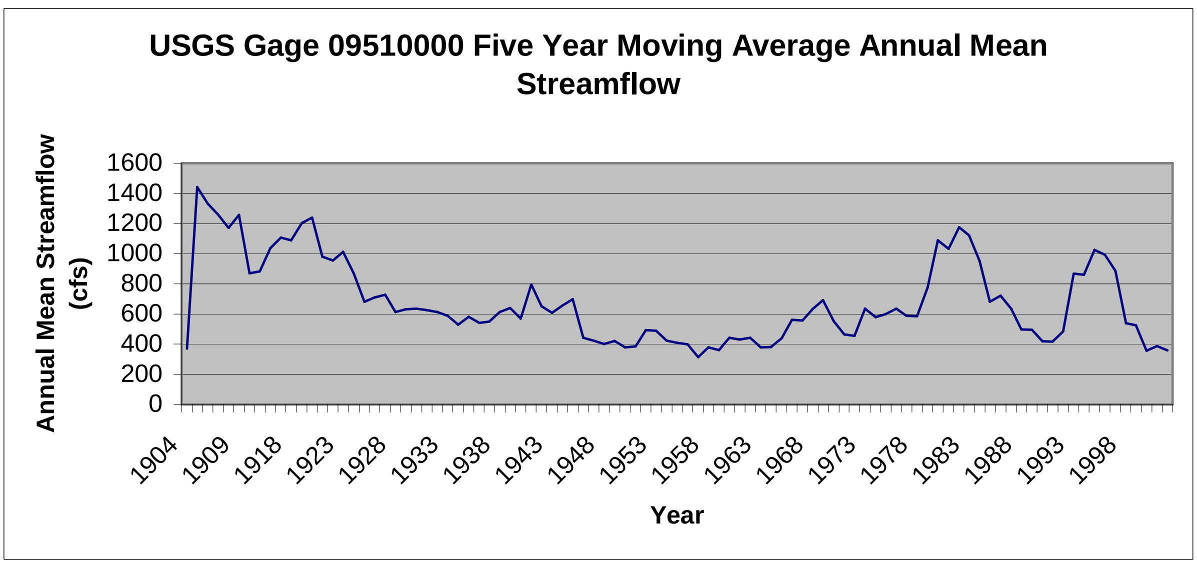
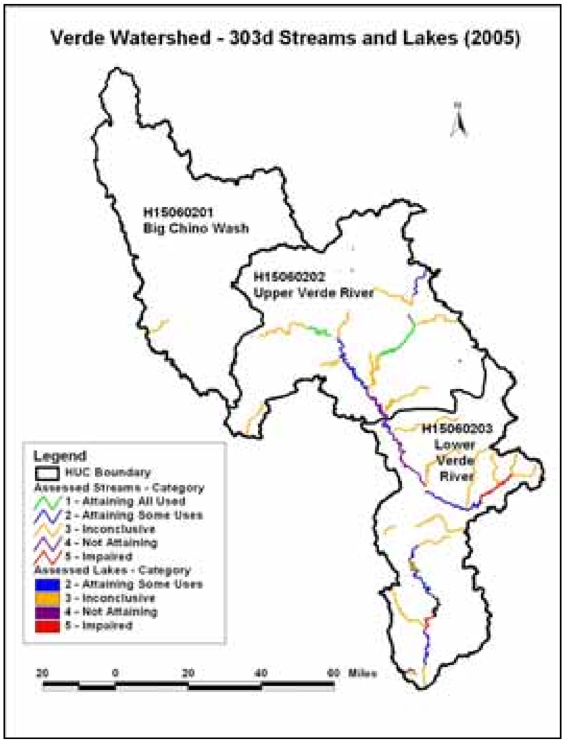


Figure 2-13: Verde Watershed 303d Streams and Lakes



Water Quality

In the Verde Watershed, eight stream reaches and four lakes are assessed as impaired in 2004 (ADEQ, 2005):

- Grande Wash (*E. coli* bacteria);
- Granite Creek, from headwaters to Willow Creek (low dissolved oxygen);
- East Verde River, from Ellison Creek to American Gulch (selenium);
- Oak Creek at Slide Rock (*E. coli* bacteria);
- Pecks Lake (low dissolved oxygen);
- Stoneman Lake (narrative nutrients);
- Verde River, three segments between Oak Creek and Fossil Creek (turbidity/suspended sediments);
- Verde River from Bartlett Dam to Camp Creek (selenium, copper);
- Whitehorse Lake (dissolved oxygen); and
- Watson Lake (nutrients, low dissolved oxygen, high pH).

A reach of Oak Creek and the Verde River were listed as "Attaining All Uses," and are therefore not considered environmentally degraded.

An explanation of the 303d listing process is found in Section 1, Introduction, and a tabulation of the water quality attributes can be found in Section 6, Watershed Assessment. An explanation of the 303d listing process is found in Section 1, Introduction, and a tabulation of the water quality attributes can be found in Section 6, Watershed Assessment.

<u>Geology</u>

Most of the Verde River Watershed is located within the transition zone between the Basin and Range Physiographic Province to the south and southwest and the Colorado Plateau to the north and northeast. The uplands generally consist of Precambrian intrusive, volcanic, and metamorphic rocks overlain by Paleozoic sedimentary layers and capped by Cenozoic volcanic rocks. Scattered outcrops of Mesozoic rocks are found above the Paleozoic layers in the upper parts of the Sycamore Creek and Oak Creek subwatersheds

The Big Chino Wash subwatershed and the Verde River subwatershed from Clarkdale to Camp Verde, exhibit broad valleys and are composed of late Cenozoic basin fill and alluvium underlain by Paleozoic sedimentary rocks. The fill varies from fine grained to coarse grained and is greater than 2,500 ft thick in some parts of Chino Valley. Lacustrine (lake) sediments and volcanic rocks are interbedded with the basin fill. From the Verde River headwaters to Clarkdale, the river flows in a narrow canyon incised into Paleozoic rocks that contains little or no alluvium.

The predominant structural features of the watershed are northwest- to north-trending normal faults that include the Big Chino fault along the northeast margin of Chino Valley and the Verde fault zone along the southwest side of the Verde River Valley. These Cenozoic faults are the primary influence on the present-day topography in the region. The Mormon Mountain anticline northeast of Sedona has a maximum dip of 4 degrees, but is noteworthy because it forms a ground-water divide (adapted from Woodhouse et. al., 2002).

Figure 2-14 shows the geology of the Verde Watershed. Table 2-9 lists the geologic units by subwatershed, and Table 2-10 lists the percentage of each rock type.

Figure 2-14: Verde Watershed Geology.

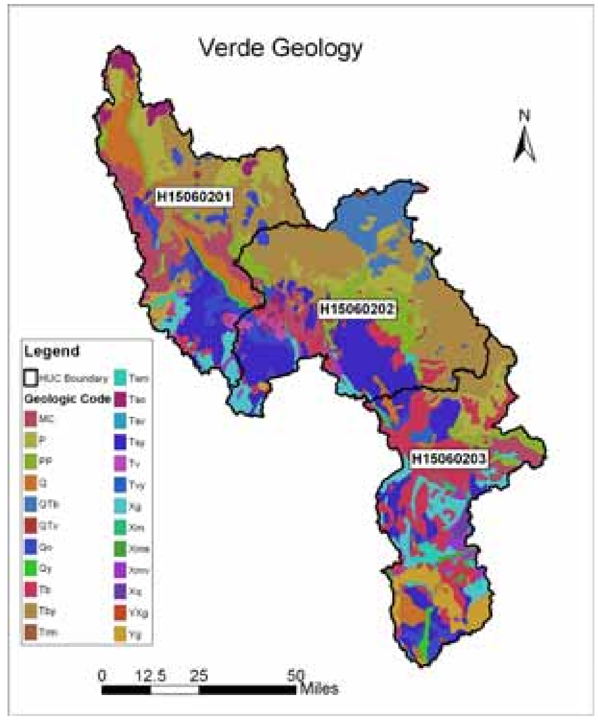


Table 2-9: Verde Watershed Geology

Geologic Unit	Geologic Code	Big Chino Wash H15060201	Upper Verde River H15050202	Lower Verde River H15060203	*Verde Watershed*
SEDIMENTARY ROCKS (Mississippian to Cambrian)	**MC**	**13.58%**	**4.67%**	**6.19%**	***8.02%***
SEDIMENTARY ROCKS (Permian)	**P**	**14.14%**	**8.35%**	**6.57%**	***9.70%***
SEDIMENTARY ROCKS (Permian and Pennsylvanian)	**PP**	**3.59%**	**10.73%**	**3.31%**	***6.20%***
SURFICIAL DEPOSITS (Holocene to middle Pleistocene)	**Q**	**11.43%**	**0.41%**	**4.38%**	***5.17%***
BASALTIC ROCKS (Holocene to late Pliocene: 0 to 4 Ma.)	**QTb**	**-**	**11.38%**	**-**	***4.30%***
VOLCANIC ROCKS (Quaternary to late Pliocene)	**QTv**	**0.25%**	**0.51%**	**-**	***0.27%***
OLDER SURFICIAL DEPOSITS (middle Pleistocene to latest Pliocene)	**Qo**	**7.16%**	**2.45%**	**3.00%**	***4.15%***
YOUNG ALLUVIUM (Holocene to latest Pleistocene)	**Qy**	**0.95%**	**0.01%**	**1.09%**	***0.64%***
BASALTIC ROCKS (late to middle Miocene; 8 to 16 Ma.)	**Tb**	**2.02%**	**6.04%**	**26.50%**	***10.81%***
BASALTIC ROCKS (Pliocene to late Miocene; 4 to 8 Ma.)	**Tby**	**24.72%**	**30.33%**	**5.86%**	***21.23%***
MOENKOPI FORMATION (middle[?]and early Triassic)	**TrM**	**0.28%**	**-**	**-**	***0.09%***
SEDIMENTARY ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tsm**	**0.68%**	**0.45%**	**2.66%**	***1.18%***
SEDIMENTARY ROCKS (Oligocene to Eocene or locally Paleocene)	**Tso**	**4.07%**	**0.76%**	**0.02%**	***1.62%***
VOLCANIC AND SEDIMENTARY ROCKS (middle Miocene to Oligocene)	**Tsv**	**-**	**0.09%**	**-**	***0.03%***
SEDIMENTARY ROCKS (Pliocene to middle Miocene)	**Tsy**	**8.96%**	**18.49%**	**13.66%**	***13.95%***
VOLCANIC ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tv**	**1.17%**	**1.12%**	**0.16%**	***0.85%***
VOLCANIC ROCKS (Pliocene to middle Miocene; 4 to 15 Ma.)	**Tvy**	**0.41%**	**0.16%**	**0.97%**	***0.48%***
GRANITOID ROCKS (early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Xg**	**4.33%**	**2.90%**	**9.97%**	***5.47%***
METAMORPHIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xm**	**0.00%**	**-**	**1.08%**	***0.32%***
METASEDIMENTARY ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xms**	**-**	**0.05%**	**1.19%**	***0.37%***
METAVOLCANIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xmv**	**0.25%**	**0.78%**	**3.01%**	***1.27%***
QUARTZITE (early Proterozoic; 1700 Ma.)	**Xq**	**-**	**0.15%**	**1.65%**	***0.55%***
GRANITOID ROCKS (middle or early Proterozoic; 1400 Ma or 1650 to 1750 Ma.)	**Yxg**	**0.20%**	**-**	**0.32%**	***0.16%***
GRANITOID ROCKS (middle Proterozoic; 1400 Ma.)	**Yg**	**1.80%**	**0.19%**	**8.43%**	***3.16%***
Area (square miles)		***2,153***	***2,501***	***1,968***	***6,622***

Table 2-10: Verde Watershed Rock Types (percent by Subwatershed).

Rock Type	**Geologic Code**	**Big Chino Wash H15060201**	**Upper Verde River H15050202**	**Lower Verde River H15060203**	***Verde Watershed***
Alluvium	**A**	**19.54%**	**2.87%**	**8.47%**	***10%***
Igneous Rocks	**I**	**35.14%**	**53.48%**	**55.21%**	***48%***
Metamorphic Rocks	**M**	**-**	**0.20%**	**3.91%**	***1%***
Sedimentary Rocks	**S**	**45.32%**	**43.44%**	**32.41%**	***41%***
Area (square miles)		***2,153***	***2,501***	***1,968***	***6,622***

Soils

Based on the soil characteristics for the Verde Watershed two types of maps were created: a soil texture map (Figure 2-15) and a soil erodibility factor map (Figure 2-16). Soil erodibility is generated from the soil texture characteristics.

There are 32 different soil textures in the Verde Watershed (Table 2-11). Clay loam is the most prominent, covering 14% of the watershed. Gravelly loam and gravelly clay loam are the next most common soil textures, each covering approximately 12% of the watershed.

Soil erosion is a naturally occurring process, however, accelerated erosion occurs when soils are disturbed by agriculture, mining, construction, or when natural ground cover is removed and the soil is left unprotected. Erosion and sedimentation in streams are major environmental problems in the western United States.

Soils differ in their susceptibility to disturbance by water due to different inherent physical, chemical and mineralogical properties. Properties known to affect erodibility include particle size distribution, organic matter content, soil structure, texture, moisture content, vegetation cover, and precipitation amount and intensity.

Erosion caused by precipitation and running water and the factors affecting soil loss have been summarized in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The USLE is a model for predicting long-term average soil losses based in part on factors of slope and erosive energy. Within the equation, the Soil Erodibility Factor (K), is estimated in the units of mass/unit area, and is based on soil texture, with a range of values between 0.0 (no erosion potential) to 1.0 (USDA, 1997). Table 2-12 shows these values for each subwatershed.

The Big Chino Wash subwatershed exhibits the highest weighted mean for Soil Erodibility Factor, with K = 0.18. The Lower Verde River subwatershed has the lowest weighted mean for K at 0.13. The weighted mean K for the whole Verde Watershed is 0.15.

Table 2-11: Verde Watershed Soil Texture.

Soil Texture	Big Chino Wash H15060201	Upper Verde River H15050202	Lower Verde River H15060203	*Verde Watershed*
clay	1.09%	0.31%	0.12%	*0.51%*
cobbly loam	0	3.38%	1.25%	*1.65%*
cobbly sandy clay	7.48%	2.18%	0	*3.26%*
cobbly sandy clay loam	0.58%	0	0	*0.19%*
very cobbly fine sandy loam	1.16%	2.33%	1.89%	*1.82%*
very cobbly loam	6.57%	1.47%	0	*2.69%*
very cobbly sandy clay	3.97%	5.41%	1.37%	*3.74%*
very cobbly sandy loam	0	0	0	*0.00%*
clay loam	9.34%	4.55%	30.64%	*13.86%*
very channery fine sandy loam	0.05%	0.31%	0	*0.13%*
very channery loam	2.53%	13.55%	9.94%	*8.89%*
very flaggy sandy loam	0.78%	2.13%	16.04%	*5.82%*
fine sandy loam	0	0	1.12%	*0.33%*
gravelly clay loam	26.05%	8.61%	0	*11.72%*
gravelly fine sandy loam	2.21%	0	2.32%	*1.41%*
gravelly loam	1.03%	27.60%	4.59%	*12.12%*
gravelly sandy loam	0.88%	5.60%	3.75%	*3.52%*
very gravelly clay loam	0	0	3.92%	*1.16%*
very gravelly loam	3.22%	0	0	*1.05%*
very gravelly sand	0	1.08%	1.70%	*0.91%*
very gravelly sandy clay loam	0.55%	0	0	*0.18%*
very gravelly sandy loam	0	0.16%	0	*0.06%*
extremely gravelly loamy sand	0	5.98%	1.88%	*2.82%*
extremely gravelly sandy loam	1.22%	0	0	*0.40%*
loam	0.06%	0	2.51%	*0.76%*
sand	0.80%	0	0	*0.26%*
sandy clay loam	0	0	0.72%	*0.21%*
sandy loam	1.05%	2.60%	11.81%	*4.83%*
stratified	0	0	0.01%	*0.00%*
stony clay loam	0.09%	2.85%	0	*1.11%*
unweathered bedrock	29.30%	2.20%	4.42%	*11.67%*
variable	0.00%	7.74%	0	*2.92%*
total	*100%*	*100%*	*100%*	

Figure 2-15: Verde Watershed Soil Texture.

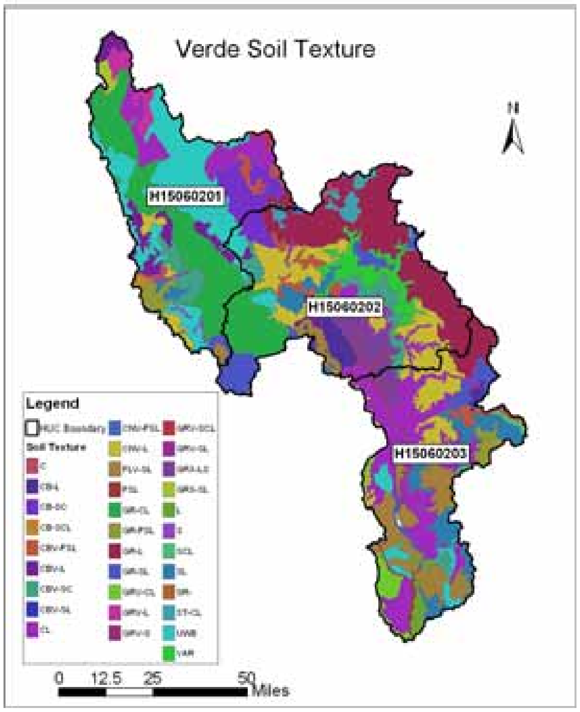


Figure 2-16: Verde Watershed Soil Erodibility Factor.

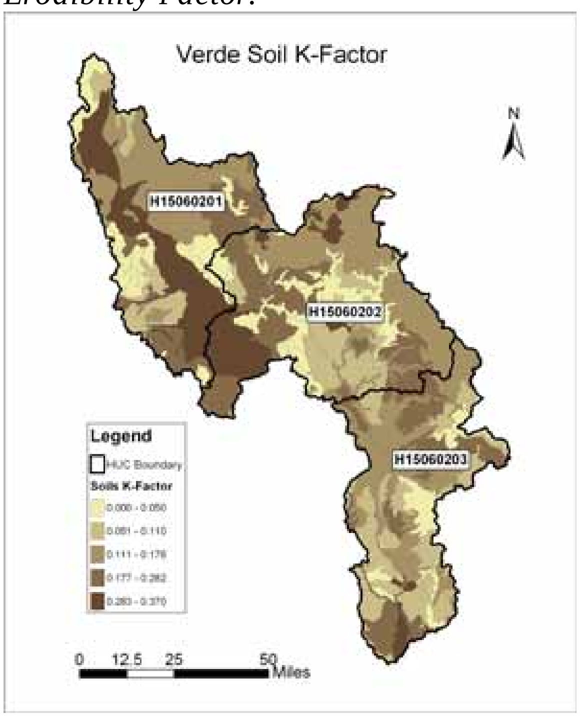


Table 2-12: Verde Watershed Soil Erodibility Factor K.

Subwatershed Name	Min K	Max K	Weighted Average K
Big Chino Wash H15060201	**0.00**	**0.31**	**0.18**
Upper Verde River H15060202	**0.00**	**0.31**	**0.15**
Lower Verde River H15060203	**0.00**	**0.32**	**0.13**
Verde Watershed	***0.00***	***0.32***	***0.15***

Climate

Precipitation

For the 30 years (1961-1990) of precipitation data used in this report, the average annual precipitation for the Verde Watershed is 18.6 inches. The Upper Verde River and Lower Verde River subwatersheds both receive more than 20 inches of rain in the average year, while the Big Chino Wash subwatershed typically receives only 15 inches. The valley floor surrounding the Verde main channel receives less rain than the surrounding mountains. Figure 2-17 shows the distribution of precipitation over the watershed, and Table 2-13 shows the average annual precipitation in inches per year.

Temperature

Six weather stations in the Verde Watershed are shown in Figure 2-18. Data from these locations were used for watershed modeling (Table 2-14). Although there are additional weather stations in the watershed, these stations were selected for modeling because of consistency and duration of the data.

For the 30 years of temperature data, the average annual temperature for the Verde Watershed is 55.1° Fahrenheit. The Lower Verde River subwatershed has the highest annual average temperature (59.4°). Table 2-15 shows the annual average temperatures for each subwatershed and Figure 2-19 is a map of the temperature ranges.

Table 2-13: Verde Watershed Average Annual Precipitation (inches/year)

Subwatershed Name	Min	Max	Weighted Average
Big Chino Wash H15060201	**11.00**	**35.00**	**15.17**
Upper Verde River H15060202	**11.00**	**35.00**	**20.41**
Lower Verde River H15060203	**9.00**	**37.00**	**20.19**
Verde Watershed	***9.00***	***37.00***	***18.64***

Table 2-14: Summary of Temperature Data for Six Temperature Gages in the Verde Watershed.

Gage	Annual Mean Max. Temperature (F)	Annual Mean Min Temperature (F)	Annual Mean Daily Temperature (ºF)
Ash Fork 6 N	**71.5**	**36.6**	**54.1**
Bartlett Dam	**84.8**	**56.3**	**70.6**
Jerome	**70.1**	**49.1**	**59.6**
Payson	**72.6**	**38.9**	**55.8**
Seligman	**71.1**	**35.9**	**53.5**
Walnut Creek	**70.8**	**34.4**	**52.6**

Table 2-15: Verde Watershed Average Annual Temperature (F).

Subwatershed	Average Annual Temperature (ºF)
Big Chino Wash H15060201	**52.1**
Upper Verde River H15060202	**53.9**
Lower Verde River H15060203	**59.4**
Verde Watershed	***55.1***

Figure 2-17: Verde Watershed Average Annual Precipitation (inches/year).

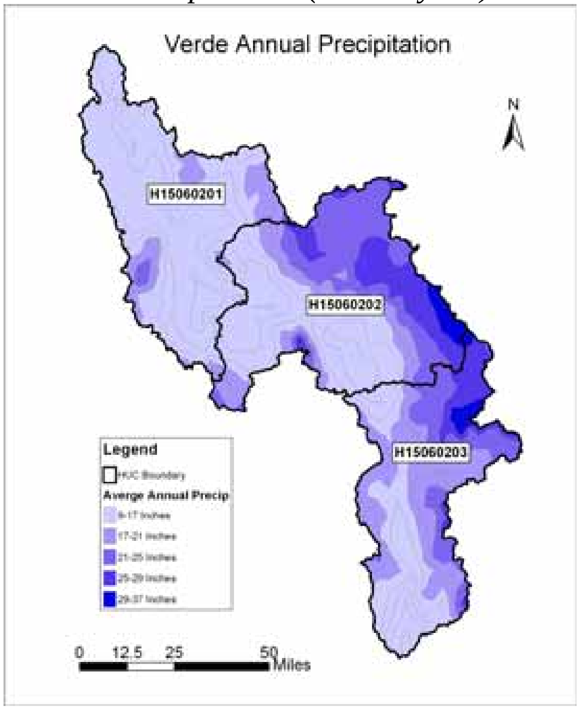


Figure 2-18: Verde Watershed Weather Stations.

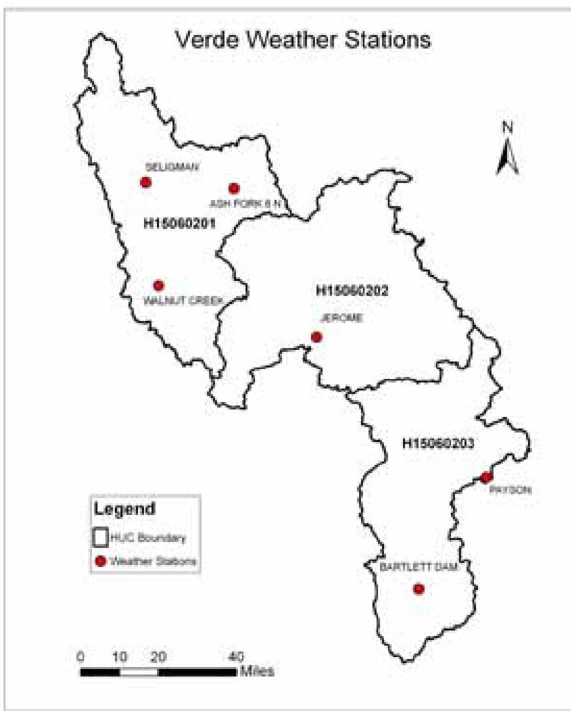
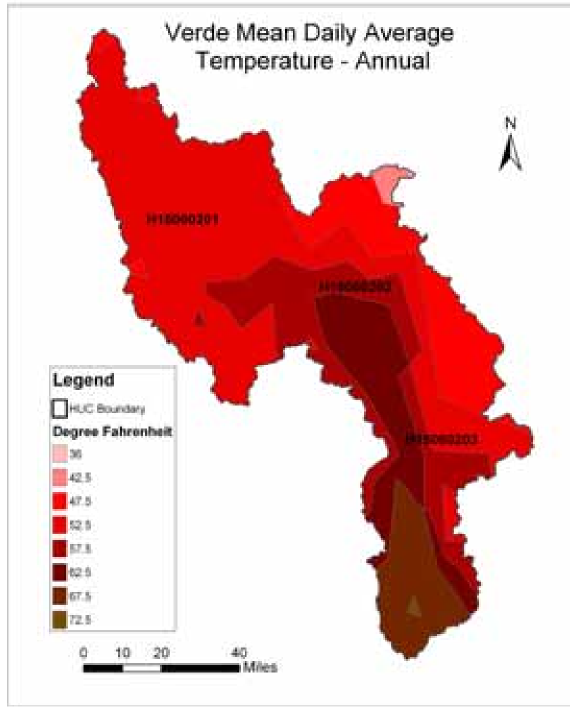


Figure 2-19: Verde Watershed Annual Average Temperature (°F).



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**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Section 3: Biological Resources

<u>Ecoregions</u>

The effects of latitude, continental position, and elevation, together with other climatic factors, combine to form the world's ecoclimatic zones, which are referred to as an ecosystem region or ecoregion. Ecoregion maps show climatically determined ecological units.

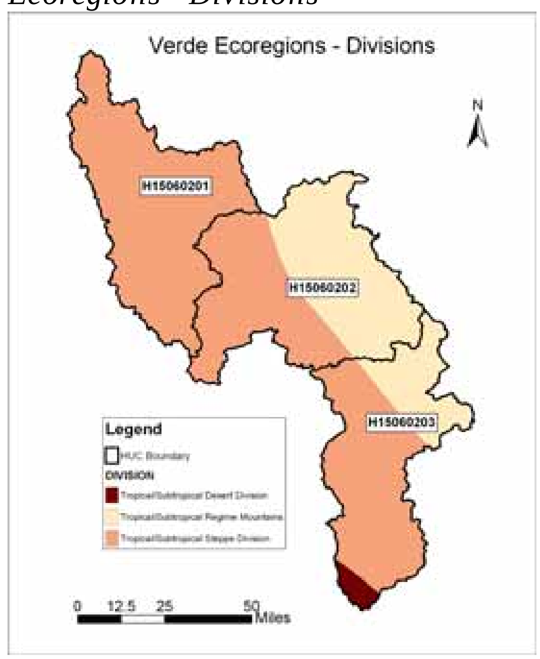
Because macroclimates are among the most significant factors affecting the distribution of life on earth, as the macroclimate changes, the other components of the ecosystem change in response. Bailey's Ecoregion classification (Bailey, 1976) provides a general description of the ecosystem geography of the United States.

In Bailey's classification system, there are four *Domain* groups. Three of the groups are humid, thermally differentiated, and are named polar, humid temperate and humid tropical. The dry domain, which is defined on the basis of moisture alone, is the fourth domain. Each domain is divided into divisions, which are further subdivided into provinces, on the basis of macrofeatures of the vegetation.

This classification places all of the Verde Watershed into the Dry Domain. There are three different divisions in the watershed. The most prominent division is the Tropical/Subtropical Steppe Division, which covers over 70% of the watershed. The watershed can be further divided into Provinces and Sections using the Bailey's classification, as shown in Figures 3-1, 3-2 and 3-3.
The subwatersheds are identified using the USGS Hydrologic Unit Codes (HUC). Subwatershed areas were delineated on the basis of the eight-digit cataloging HUC, and the classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

The essential feature of a dry climate is that annual losses of water through evaporation at the earth's surface exceed annual water gain from precipitation. Dry climates occupy one-forth or more of the earth's land surface.

Figure 3-1: Verde Watershed Ecoregions - Divisions



Note: See Table 3-1 for subwatershed names.

Commonly, two divisions of dry climates are recognized: the arid desert and the semi arid steppe. Generally, the steppe is a transitional belt surrounding the desert and separating it from the humid climates beyond (Bailey 1995).

Figure 3-2: Verde Watershed Ecoregions – Provinces

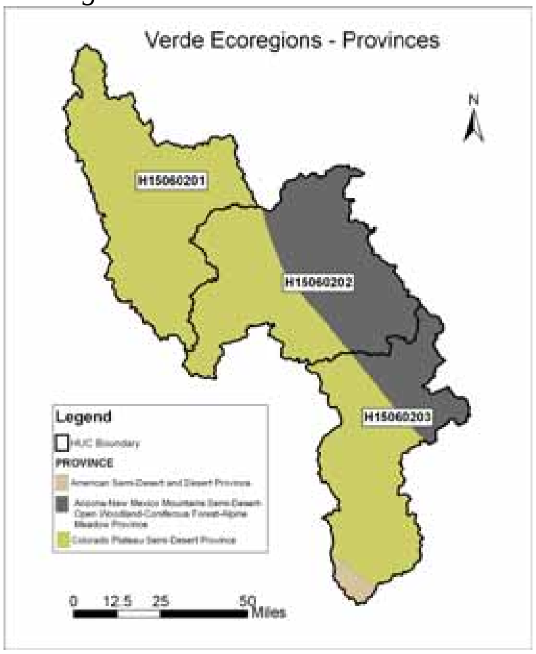


Figure 3-3: Verde Watershed Ecoregions – Sections

The boundary between arid and semi arid climates is arbitrary but is commonly defined as one-half the amount of precipitation separating steppe from humid climates (Bailey 1995). Steppes typically are grasslands of short grasses and other herbs and with locally developed shrub and woodland. Soils are commonly Mollisols and Aridisols containing some humus.

In desert areas xerophytic plants provide negligible ground cover. In dry periods, visible vegetation is limited to small, hard-leaved or spiny shrubs, cacti, or hard grasses. Many species of small annuals may be present, but they appear only after the rare but heavy rains have saturated the soil (Bailey, 1995).

Soils in desert areas are mostly Aridisols (dry, high in calcium-carbonate, clays and salts, not suitable for agriculture without irrigation), and dry Entisols (young, diverse, some suitable for agriculture). The dominant pedogenic (soil-forming) process is salinization which produces areas of salt crust where only salt-loving plants can survive. Salinization occurs in areas where evapotranspiration exceeds precipitation. Calcification, the accumulation of calcium carbonate in soil surface layers, is conspicuous on well drained uplands (Bailey, 1995).

Table 3-1: Verde Watershed Ecoregions – Divisions

Subwatershed Name & HUC	Area (square miles)	Tropical/ Subtropical Desert Division	Tropical/ Subtropical Regime Mountains	Tropical/ Subtropical Steppe Division
Big Chino Wash H15060201	**2,153**	**-0-**	**-0-**	**100.0%**
Upper Verde River H15060202	**2,501**	**-0-**	**52.9%**	**47.1%**
Lower Verde River H15060203	**1,968**	**4.4%**	**27.4%**	**68.2%**

Table 3-2: Verde Watershed Ecoregions – Provinces

Subwatershed Name	Area (square miles)	American Semi-Desert and Desert Province	Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province	Colorado Plateau Semi-Desert Province
Big Chino Wash H15060201	**2,153**	**-0-**	**-0-**	**100.0%**
Upper Verde River H15060202	**2,501**	**-0-**	**52.9%**	**47.1%**
Lower Verde River H15060203	**1,968**	**4.4%**	**27.4%**	**68.2%**
Verde Watershed	***6,622***	***1.3%***	***28.1%***	***70.6%***

Table3-3: Verde Watershed Ecoregions – Sections

Subwatershed Name	Area (square miles)	Grand Canyon Lands Section	Sonoran Mojave Desert Section	Tonto Transition Section	White Mountain-San Francisco Peaks Section
Big Chino Wash H15060201	**2,153**	**2.5%**	**-0-**	**97.5%**	**-0-**
Upper Verde River H15060202	**2,501**	**-0-**	**-0-**	**47.1%**	**52.9%**
Lower Verde River H15060203	**1,968**	**-0-**	**4.4%**	**68.2%**	**27.4%**
Verde Watershed	***6,622***	***0.8%***	***1.3%***	***69.8%***	***28.1%***

Vegetation

Two different vegetation maps were created for the Verde Watershed, one based on biotic (vegetation) communities (Figure 3-4) and the other based on vegetative cover (Figure 3-5).

The first map is based on the classification of biotic communities that was published by Brown, Lowe and Pace (Brown et al., 1979). These biotic zones are general categories indicating where vegetation communities would most likely exist. Under this classification there are nine different biotic communities in the Verde Watershed. Great Basin Conifer Woodland covers 40% of the watershed. Petran Montane Conifer Forest and Plains & Great Basin Grassland each cover more than 15% of the watershed area. Table 3-4 shows the percentage of each biotic community in each subwatershed.

The second vegetation map was created based on the GAP Vegetation cover which shows vegetation communities or land cover (Halvorson et al., 2001). Based on this map, twenty-one different vegetation cover types are found within the watershed, including: urban landscape, surface water features, and agriculture. Great Basin Conifer Woodland is the most common vegetation type, covering 41% of the watershed. Also prevalent are Rocky Mountain Montane Conifer Forest (19%), Sonoran Desertscrub (12%), Plains Grassland (11%) and Mogollon Chaparral Scrubland (10%). Table 3-5 lists the distribution of vegetation cover types by subwatershed.

Figure 3-4: Verde Watershed Brown, Lowe and Pace Vegetation

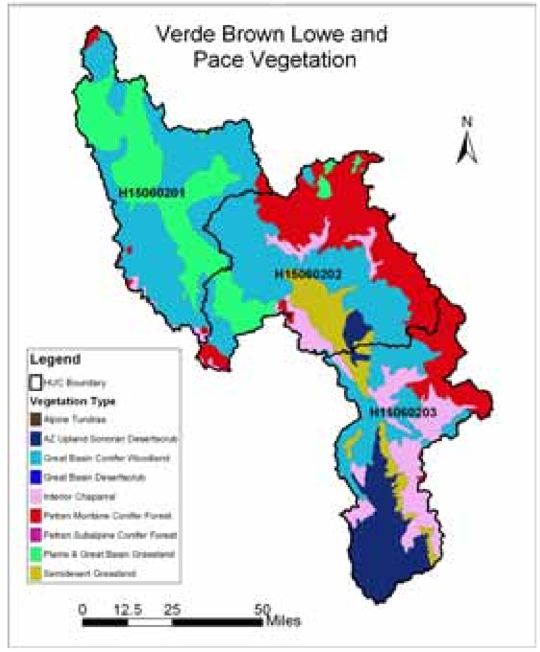


Figure 3-5: Verde Watershed GAP Vegetation

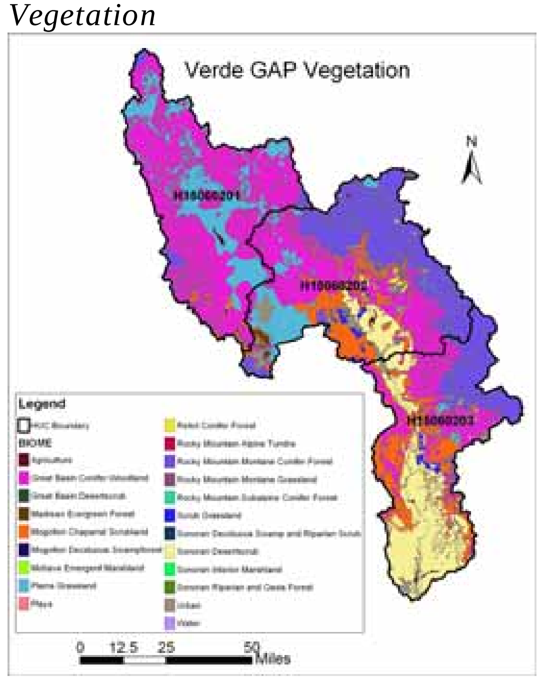


Table 3-4: Verde Watershed - Brown, Lowe and Pace Biotic Communities

Biotic Communities	**Big Chino Wash H15060201**	**Upper Verde River H15060202**	**Lower Verde River H15060203**	***Verde Watershed***
Alpine Tundras	**-0-**	**-0-**	**-0-**	***<1%***
AZ Upland Sonoran Desertscrub	**-0-**	**2.01%**	**26.51%**	***9%***
Great Basin Conifer Woodland	**56.13%**	**38.47%**	**24.53%**	***40%***
Great Basin Desertscrub	**0.01%**	**-0-**	**-0-**	***<1%***
Interior Chaparral	**1.36%**	**7.54%**	**25.65%**	***11%***
Petran Montane Conifer Forest	**2.04%**	**34.81%**	**15.46%**	***18%***
Petran Subalpine Conifer Forest	**-0-**	**0.05%**	**-0-**	***<1%***
Plains & Great Basin Grassland	**40.46%**	**8.15%**	**-0-**	***16%***
Semi-desert Grassland	**-0-**	**8.96%**	**7.85%**	***6%***
Area (square miles)	***2,153***	***2,501***	***1,968***	***6,622***

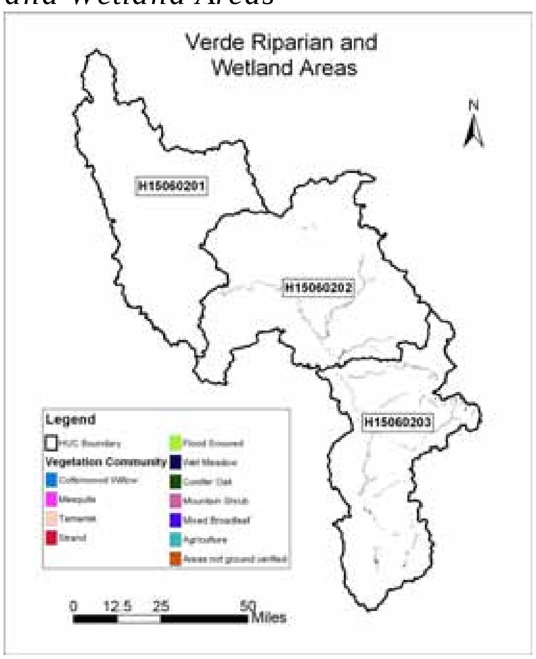
Table 3-5: Verde Watershed - GAP Vegetation

Vegetation Cover	**Big Chino Wash H15060201**	**Upper Verde River H15060202**	**Lower Verde River H15060203**	***Verde Watershed***
Agriculture	**0.29%**	**0.48%**	**0.26%**	**<1%**
Great Basin Conifer Woodland	**70.82%**	**30.16%**	**23.24%**	**41%**
Great Basin Desertscrub	**0.00%**	**-0-**	**-0-**	**<1%**
Madrean Evergreen Forest	**0.19%**	**0.79%**	**0.00%**	**<1%**
Mogollon Chaparral Scrubland	**1.38%**	**12.58%**	**18.72%**	**11%**
Mogollon Deciduous Swampforest	**-0-**	**0.19%**	**0.46%**	**<1%**
Mohave Emergent Marshland	**-0-**	**0.03%**	**-0-**	**<1%**
Plains Grassland	**24.47%**	**9.24%**	**1.14%**	**12%**
Playa	**0.02%**	**0.02%**	**0.01%**	**<1%**
Relict Conifer Forest	**-0-**	**0.54%**	**0.30%**	**<1%**
Rocky Mountain Alpine Tundra	**-0-**	**0.01%**	**-0-**	**<1%**
Rocky Mountain Montane Conifer Forest	**2.69%**	**34.94%**	**18.37%**	**20%**
Rocky Mountain Montane Grassland	**-0-**	**0.15%**	**-0-**	**<1%**
Rocky Mountain Subalpine Conifer Forest	**-0-**	**0.05%**	**-0-**	**<1%**
Scrub Grassland	**-0-**	**1.08%**	**1.14%**	**<1%**
Sonoran Deciduous Swamp and Riparian Scrub	**-0-**	**0.03%**	**0.10%**	**<1%**
Sonoran Desertscrub	**0.05%**	**5.84%**	**34.32%**	**12%**
Sonoran Interior Marshland	**-0-**	**-0-**	**0.00%**	**<1%**
Sonoran Riparian and Oasis Forest	**-0-**	**0.07%**	**0.21%**	**<1%**
Urban	**0.05%**	**3.58%**	**1.51%**	**2%**
Water	**0.04%**	**0.21%**	**0.21%**	**<1%**
Area (square miles)	***2,153***	***2,501***	***1,968***	***6,622***

<u>Habitats (Riparian and Wetland Areas)</u>

The Arizona Game & Fish Department has identified riparian vegetation associated with perennial waters and has mapped the data in response to the requirements of the state Riparian Protection Program. This map was used to identify riparian areas in the Verde Watershed (Figure 3-6). There are eleven different types of riparian areas within the watershed (Table 3-6) encompassing almost fourteen thousand acres. Mixed Broadleaf and Mesquite are the largest types of riparian areas, each comprising over three thousand acres. Table 3-6 lists the percentage of each riparian area type within each subwatershed.

Figure 3-6: Verde Watershed Riparian and Wetland Areas



<u>Major Land Resource Areas (MLRA's)</u>

There are four different MLRA's in the Verde Watershed. The dominant MLRA is Arizona and New Mexico Mountains. This area comprises over 49% of the total watershed area (Figure 3-7 and Table 3-7).

Figure 3-7: Verde Watershed Major Land Resource Areas.

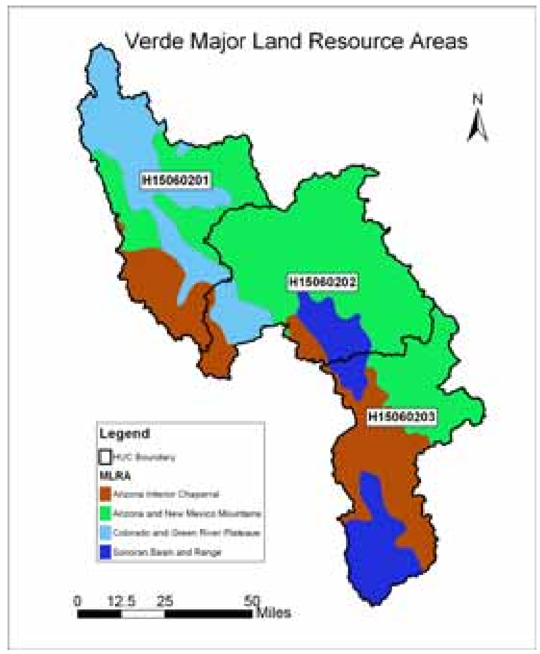


Table 3-6: Verde Watershed Riparian and Wetland Areas (acres)

Vegetation Community	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Cottonwood Willow	-0-	375	692	1,066
Mesquite	-0-	909	2,323	3,232
Tamarisk	-0-	9	59	67
Strand	-0-	426	536	961
Flood Scoured	-0-	495	410	905
Wet Meadow	-0-	12	-0-	12
Conifer Oak	-0-	129	2,392	2,521
Mountain Shrub	-0-	-0-	39	39
Mixed Broadleaf	-0-	3,024	1,782	4,806
Agriculture	-0-	47	4	51
Areas not ground verified	*-0-*	163	84	247
Total Riparian Acres	*-0-*	*5,587*	*8,321*	*13,908*

Table 3-7: Verde Watershed Major Land Resource Areas.

Major Land Resource Areas	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Arizona Interior Chaparral	19.63%	8.38%	39.88%	*21%*
Arizona and New Mexico Mountains	35.95%	74.10%	32.73%	*49%*
Colorado and Green River Plateaus	44.42%	7.95%	-0-	*17%*
Sonoran Basin and Range	-0-	9.57%	27.39%	*12%*
Area (square miles)	*2,153*	*2,501*	*1,968*	*6,622*

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Bailey's Ecoregions - Provinces map. June 12, 2003.
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U.S. Department of Agriculture, Natural Resources Conservation Service.
ftp-fc.sc.egov.usda.gov/NHQ/pub/land/arc_export/us48mlra.e00.zip
Major Land Resource Area Map. July 15, 2003.

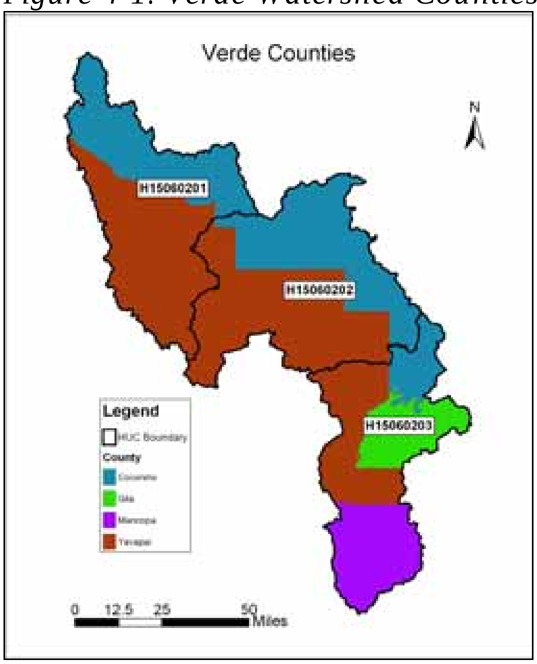
**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Section 4: Social/Economic Characteristics

County Governments

Understanding which governmental entities occupy the land in a given watershed helps a partnership understand the significance of each stakeholders influence on the watershed. The Verde Watershed is comprised of four Counties: Coconino, Gila, Maricopa, and Yavapai. Yavapai and Coconino cover the bulk of the watershed with 50% and 34% of the total area respectively. The county boundary map (Figure 4-1) illustrates which counties are within the watershed.

Figure 4-1: Verde Watershed Counties.



Note: See Table 4-1 for subwatershed names.

Council of Governments (COGs)

Three Councils of Governments are present in the Verde Watershed (figure 4-2). These are the Northern Arizona Council of Governments (NACOG), the Central Arizona Association of Governments (CAAG), and the Maricopa Association of Governments (MAG). NACOG covers over 84% of the watershed including all of the Big Chino Wash and Lower Verde River subwatersheds.

Figure 4-2: Verde Watershed Council of Governments.

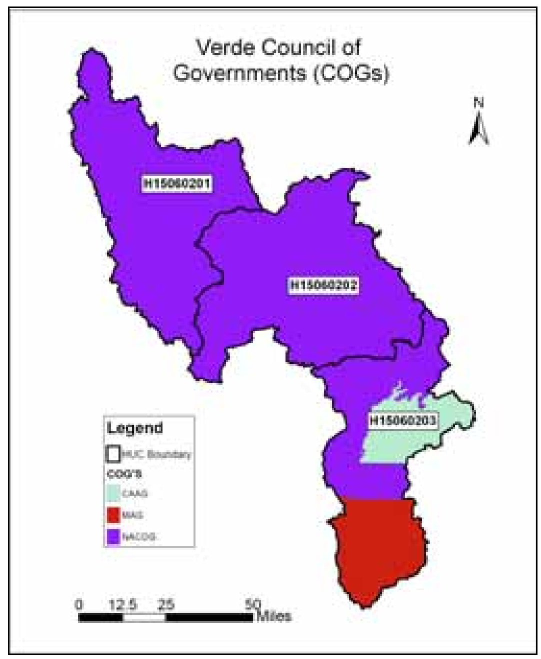


Table 4-1: Verde Watershed Counties

County	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Coconino	**42.12%**	**43.45%**	**13.10%**	***34%***
Gila	**-**	**-**	**22.51%**	***7%***
Maricopa	**-**	**-**	**31.88%**	***9%***
Yavapai	**57.88%**	**56.55%**	**32.51%**	***50%***
Area (square miles)	***2,153***	***2,501***	***1,968***	***6,622***

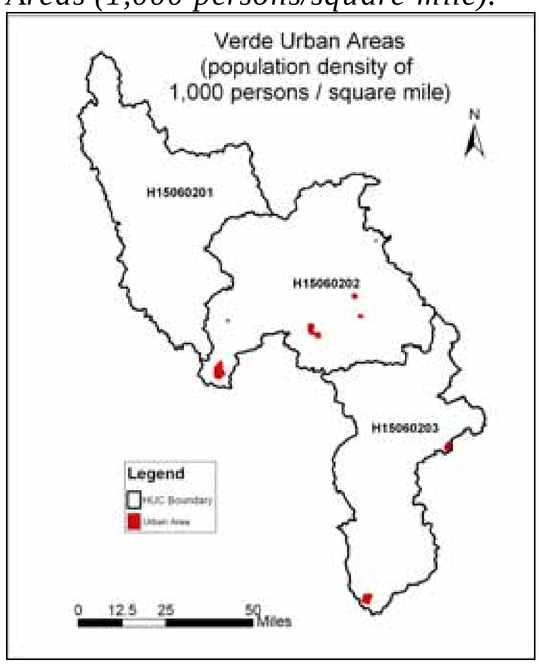
Table 4-2: Verde Watershed Council of Governments

Council of Governments	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
CAAG	**-**	**-**	**22.51%**	**7%**
MAG	**-**	**-**	**31.88%**	**9%**
NACOG	**100.00%**	**100.00%**	**45.61%**	**84%**
Area (square miles)	***2,153***	***2,501***	***1,968***	***6,622***

Urban Areas

A population density map was created for the Verde Watershed based on 2000 Census block group population data. From this map, areas with a population density greater than 1,000 persons per square mile were designated as urban. This classification yielded several urban areas within the Upper Verde River and Lower Verde River subwatersheds. The largest urban areas are Sedona, Prescott and part of Scottsdale. The Big Chino Wash subwatershed did not contain any urban areas under this classification.

Figure 4-3: Verde Watershed Urban Areas (1,000 persons/square mile).



Roads

The total road length in the Verde Watershed is 1,186 miles, representing approximately 7% of all roads in Arizona (Table 4-4). The predominant road type based on the Census classification is neighborhoods roads with almost 47% of the total roads (Table 4-3). The Upper Verde River subwatershed has almost half of the roads in the watershed (Figure 4-4).

Figure 4-4: Verde Watershed Road Types.

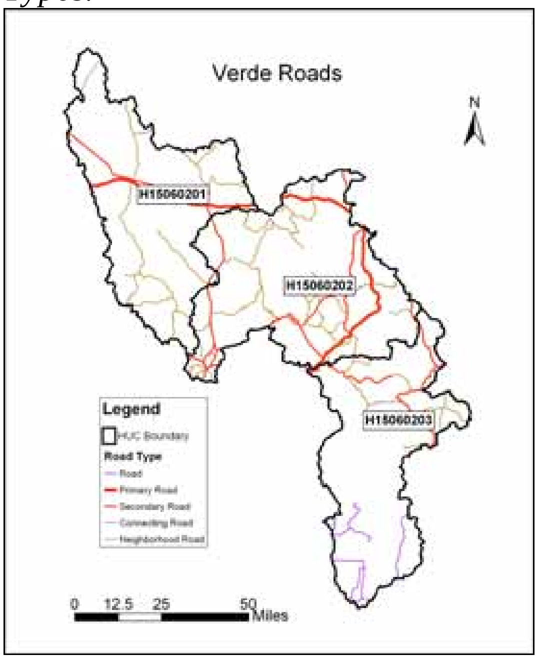


Table 4-3: Verde Watershed Road Types.

Census Classification Code	Road Length (miles)	Percent of Total Length
Road	**109**	**9%**
Primary Road	**129**	**11%**
Secondary Road	**307**	**26%**
Connecting Road	**81**	**7%**
Neighborhood Road	**561**	**47%**
All Roads (total)	***1186***	***100.00%***

Table 4-4: Verde Watershed Roads By Subwatershed.

Subwatershed	Road Length (miles)	Percent of Total Length
Big Chino Wash H15060201	**323**	**27%**
Upper Verde River H15060202	**558**	**47%**
Lower Verde River H15060203	**305**	**26%**
Verde Watershed	***1186***	***100.00%***

Population

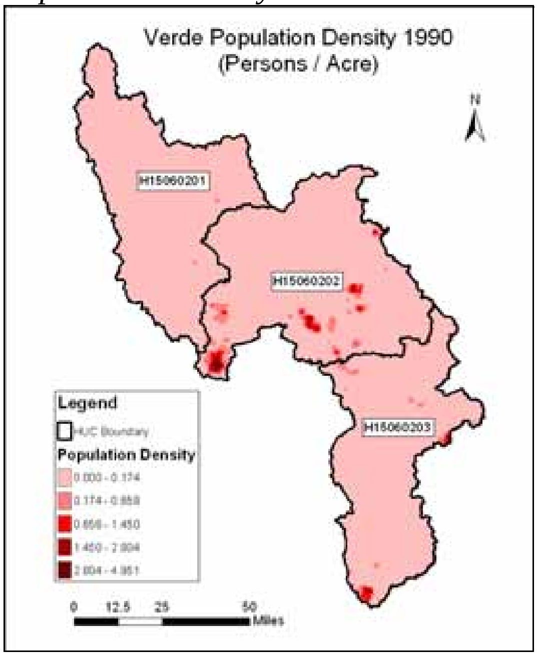
Census Population Densities in 1990

Census block statistics for 1990 were compiled from the Census 1990 CD (Geo-Lytics, 1998). These data (Table 4-5) were linked with census block centroids, and used to create a density map (Figure 4-5) which shows the number of individuals per acre.

Table 4-5: Verde Watershed 1990 Population Density (persons / acre).

Subwatershed	Area (square miles)	Min	Max	Mean
Big Chino Wash H15060201	**2,153**	**0.000**	**0.533**	**0.002**
Upper Verde River H15060202	**2,501**	**0.000**	**4.951**	**0.051**
Lower Verde River H15060203	**1,968**	**0.000**	**3.177**	**0.022**
Verde Watershed	***6,622***	***0.000***	***4.951***	***0.027***

Figure 4-5: Verde Watershed 1990 Population Density.



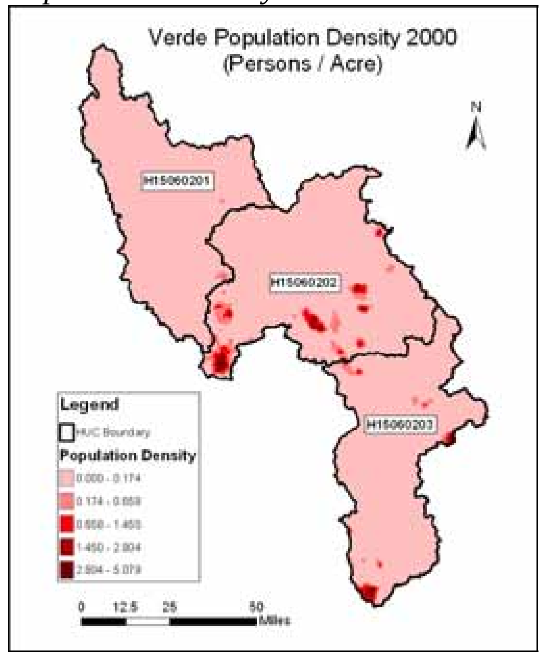
Census Population Densities in 2000

The census block statistics shapefile and table were downloaded from the ESRI website (ESRI Data Products, 2003), and a density map was created (Figure 4-6).

Table 4-6: Verde Watershed Population Density 2000 (persons / acre).

Sub-watershed	Area (sq. miles)	Min	Max	Mean
Big Chino Wash H15060201	**2,153**	**0.000**	**0.752**	**0.005**
Upper Verde River H15060202	**2,501**	**0.000**	**5.080**	**0.074**
Lower Verde River H15060203	**1,968**	**0.000**	**4.881**	**0.039**
Verde Watershed	***6,622***	***0.000***	***5.080***	***0.041***

Figure 4-6: Verde Watershed 2000 Population Density.



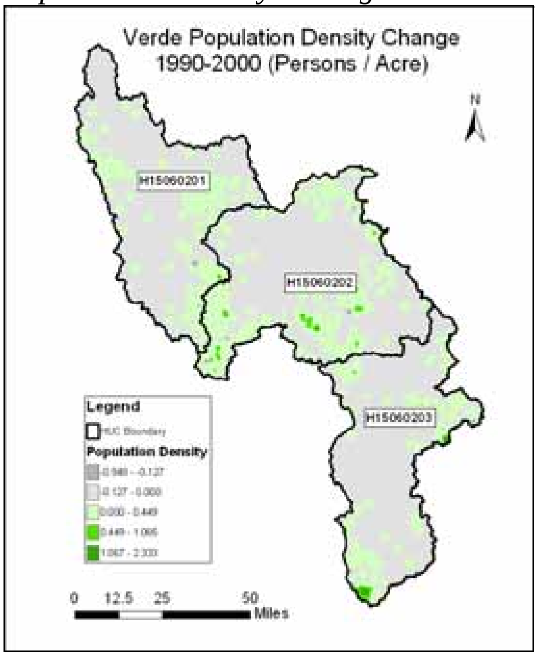
Population Change

The 1990 and 2000 population density maps were differenced to create a population density change map (Figure 4-7) that shows population increase or decrease over the ten year time frame. Table 4-7 lists the persons per acre change for each subwatershed.

Table 4-7: Verde Watershed Population Density Change 1990-2000 (persons / acre).

Subwatershed	Area (sq. miles)	Min	Max	Mean
Big Chino Wash H15060201	**2,153**	**-0.382**	**0.671**	**0.003**
Upper Verde River H15060202	**2,501**	**-0.440**	**1.876**	**0.023**
Lower Verde River H15060203	**1,968**	**-0.949**	**2.334**	**0.017**
Verde Watershed	***6,622***	***-0.949***	***2.334***	***0.014***

Figure 4-7: Verde Watershed Population Density Change 1990-2000.



Mines

There are 585 mines in the Verde Watershed, representing seven different mine types (Table 4-8 and Figure 4-8). The bulk of the mines (99%) are surface mines, although most are no longer producing (Figure 4-9). Copper and gold are the most common ores mined in the Verde Watershed (Table 4-10 and Figure 4-10), and are found in 214 locations.

Figure 4-8: Verde Watershed Mines: Type.

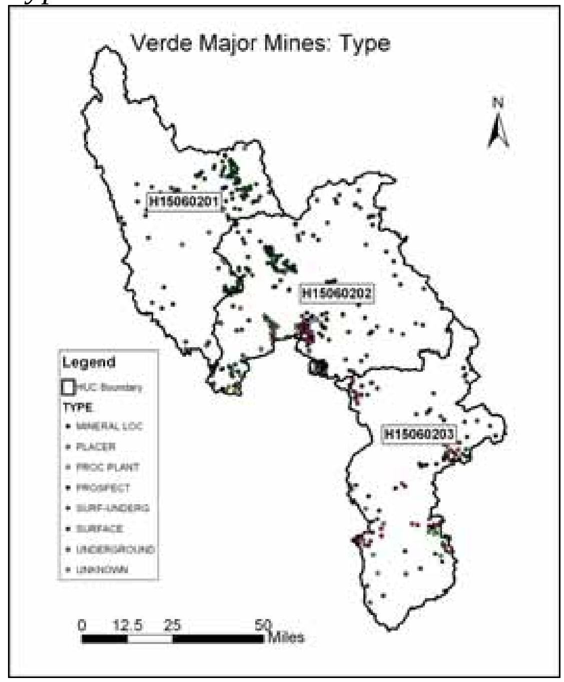


Figure 4-9: Verde Watershed Mines: Status.

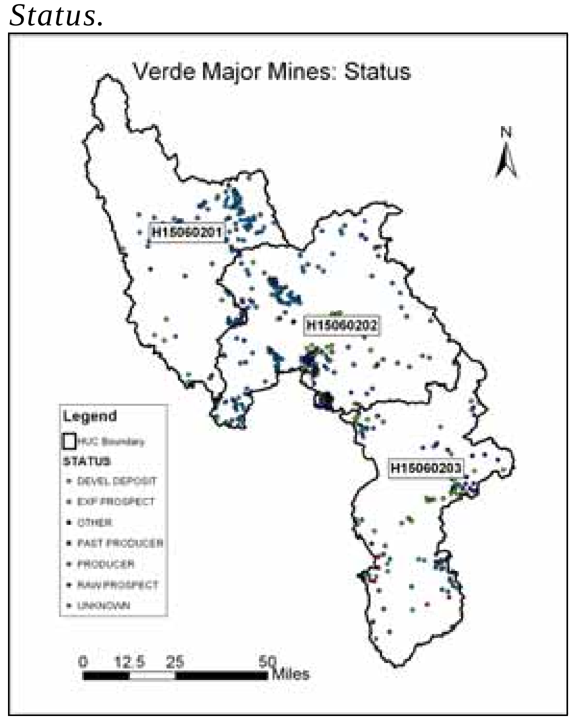


Figure 4-10: Verde Watershed Mines: Primary Ore.

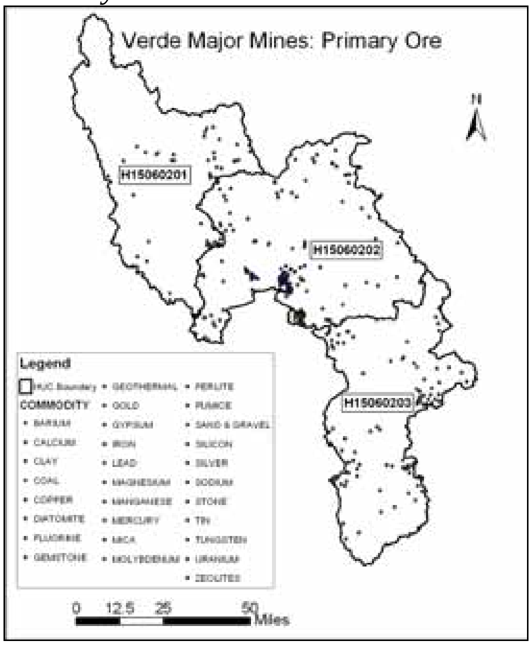


Table 4-8: Verde Watershed Mines: Type.

Type	**Big Chino Wash**	**Upper Verde River**	**Lower Verde River**	***Verde Watershed***
Mineral Loc.	**5**	**2**	**3**	***10***
Placer	**1**	**3**	**3**	***7***
Processing Plant	**-**	**3**	**1**	***4***
Prospect	**5**	**41**	**25**	***71***
Surface / Underground	**4**	**13**	**17**	***34***
Surface	**99**	**151**	**41**	***291***
Underground	**3**	**68**	**26**	***97***
Unknown	**7**	**45**	**19**	***71***
Total Mines	***124***	***326***	***135***	***585***

Table 4-9: Verde Watershed Mines: Status.

Status	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Developed Prospect	2	15	9	*26*
Explored Prospect	8	43	34	*85*
Past Producer	5	63	36	*104*
Producer	5	16	4	*25*
Raw Prospect	1	2	10	*13*
Other	-	1	-	*1*
Unknown	103	186	42	*331*
Total Mines	*124*	*326*	*135*	*585*

Table 4-10: Verde Watershed Mines: Ore Type

Ore Type	Total Number of Mines	Ore Type	Total Number of Mines
Copper	109	Silicon	3
Gold	105	Mica	2
Sand & Gravel	60	Quartz Crystal	2
Pumice	57	Vanadium	2
Silver	57	Barium	1
Stone	20	Beryllium	1
Lead	19	Coal	1
Iron	17	Diatomite	1
Mercury	11	Gemstone	1
Gypsum	9	Geothermal	1
Manganese	8	Graphite	1
Uranium	8	Kyanite Group	1
Clay	7	Magnesium	1
Zinc	6	Nickel	1
Calcium	5	Perlite	1
Fluorine	4	Phosphate	1
Molybdenum	4	Platinum Group	1
Sodium	4	Thorium	1
Tungsten	4	Tin	1
Feldspar	3	Zeolites	1

Land Cover

The land cover condition in the early 1990's was determined using the National Land Cover Dataset (NLCD). The NLCD classification contains 21 different land cover categories from which 20 classes are represented within the Verde watershed (Figure 4-11). Shrubland and evergreen forest dominate the land cover in the Verde Watershed, at 51% and 41% of the watershed area respectively (Table 4-11).

Figure 4-11: Verde Watershed Land Cover.

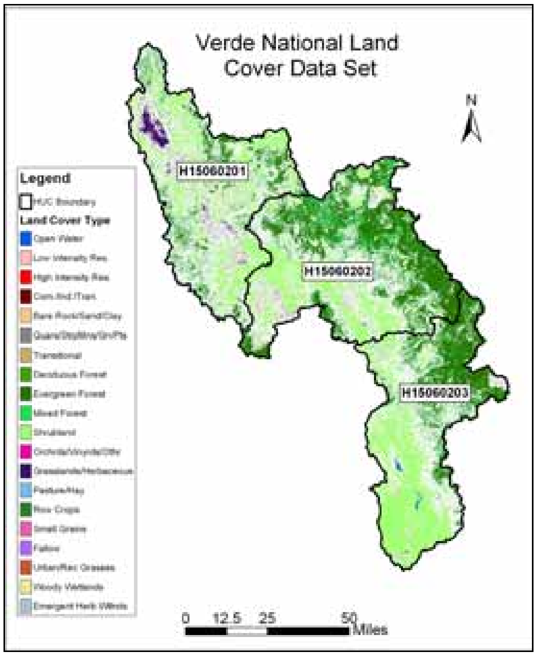


Table 4-11: Verde Watershed Land Cover.

Land Cover	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Open Water	0.010%	0.078%	0.493%	*<1%*
Low Intensity Residential	0.011%	0.478%	0.168%	*<1%*
High Intensity Residential	0.000%	-	-	*<1%*
Commercial/Industrial/Transportation	0.099%	0.226%	0.149%	*<1%*
Bare Rock/Sand/Clay	1.068%	0.059%	0.348%	*<1%*
Quarries/Strip Mines/Gravel Pits	0.042%	0.149%	0.048%	*<1%*
Transitional	-	-	0.097%	*<1%*
Deciduous Forest	0.197%	0.184%	0.724%	*<1%*
Evergreen Forest	32.406%	50.291%	38.358%	*41%*
Mixed Forest	0.076%	2.604%	0.177%	*1%*
Shrubland	56.506%	40.963%	56.533%	*51%*
Orchards/Vineyards/Other	0.000%	0.007%	-	*<1%*
Grasslands/Herbaceous	9.288%	4.440%	2.479%	*5%*
Pasture/Hay	0.127%	0.305%	0.138%	*<1%*
Row Crops	0.152%	0.073%	0.136%	*<1%*
Small Grains	0.008%	0.005%	0.012%	*<1%*
Fallow	0.000%	-	-	*<1%*
Urban/Recreational Grasses	0.000%	0.092%	0.063%	*<1%*

Land Cover	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Woody Wetlands	**0.007%**	**0.007%**	**0.077%**	***<1%***
Emergent Herbaceous Wetlands	**0.001%**	**0.040%**	**0.000%**	***<1%***
Area (square miles)	***2,153***	***2,501***	***1,968***	***6,622***

Table 4-12: Verde Watershed Land Ownership

Land Owner	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Private	**50.39%**	**14.92%**	**4.68%**	***23%***
State Trust	**20.94%**	**5.67%**	**0.71%**	***9%***
BLM	**-**	**0.05%**	**-**	***<1%***
Prescott N.F.	**15.99%**	**22.00%**	**3.39%**	***15%***
Military Reservation	**-**	**0.04%**	**-**	***<1%***
Parks & Recreation	**-**	**-**	**1.67%**	***<1%***
Kaibab N.F.	**8.24%**	**15.80%**	**-**	***9%***
Tonto N.F.	**-**	**-**	**63.97%**	***19%***
Coconino N.F.	**-**	**39.57%**	**23.27%**	***22%***
Salt River Indian Reservation	**-**	**-**	**0.25%**	***<1%***
Fort McDowell Indian Reservation	**-**	**-**	**1.97%**	***<1%***
Hualapai Indian Reservation	**4.44%**	**-**	**-**	***1%***
Yavapai Prescott Indian Res.	**-**	**0.09%**	**-**	***<1%***
Navajo Army Depot	**-**	**1.62%**	**-**	***<1%***
Tuzigoot N.M.	**-**	**0.00%**	**-**	***<1%***
Montezuma Castle	**-**	**0.04%**	**-**	***<1%***
Montezuma Well	**-**	**0.02%**	**-**	***<1%***
Game and Fish	**-**	**0.01%**	**-**	***<1%***
County Land	**-**	**0.02%**	**0.08%**	***<1%***
Indian Allotments	**-**	**-**	**0.01%**	***<1%***
Yavapai Tonto Apache Res.	**-**	**-**	**0.00%**	***<1%***
Yavapai Apache Indian Res.	**-**	**0.15%**	**0.00%**	***<1%***

Land Ownership

In the Verde Watershed there are 22 different land ownership entities (Table 4-12). Private land owners make up the largest category at 23%. Between the Coconino, Prescott, and Tonto National Forests, the National Forest Service holds over 56% of the land in the watershed (Figure 4-12).

Figure 4-12: Verde Watershed Land Ownership.

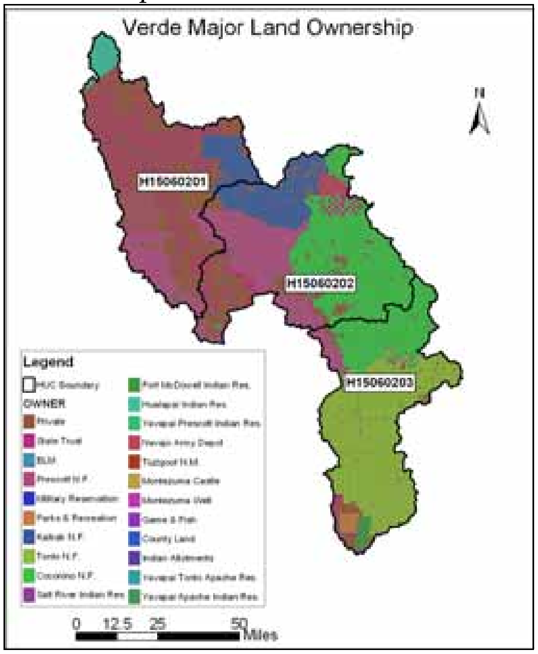
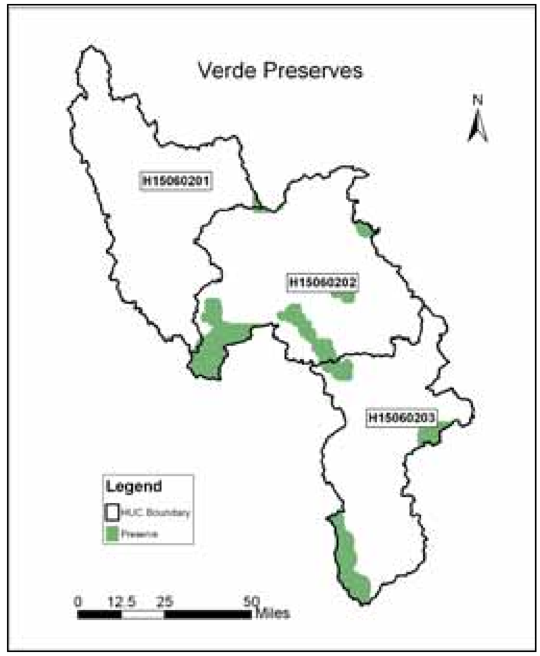


Figure 4-13: Verde Watershed Preserves



Special Areas

Preserves

Based on data from the Arizona Land Resource Information System (ALRIS, 2003), there are almost 400,000 acres of preserves within the Verde Watershed. Most of the preserve lands are in the Upper Verde River and Lower Verde River subwatersheds (Figure 4-13 and Table 4-13).

Table 4-13: Verde Watershed Preserves

Subwatershed	Area (square miles)	Preserve Area (acres)
Big Chino Wash	**2,153**	**30,043**
Upper Verde River	**2,501**	**261,695**
Lower Verde River	**1,968**	**146,016**
Verde Watershed	***6,622***	***395,169***

Golf Courses

Based on data from the ESRI GIS data disks (ESRI Data and Maps, 2001), there are four golf courses in the Verde Watershed. There are two each in the Upper Verde River and Lower Verde River subwatersheds (Figure 4-14).

Wilderness

There are 16 wilderness areas within the Verde Watershed (Table 4-14 and Figure 4-15). The total area of these wilderness areas is 454,316 acres. The largest wilderness area in the watershed is the Mazatzal Wilderness, which covers approximately 232,937 acres.

Figure 4-14: Verde Watershed Golf Courses

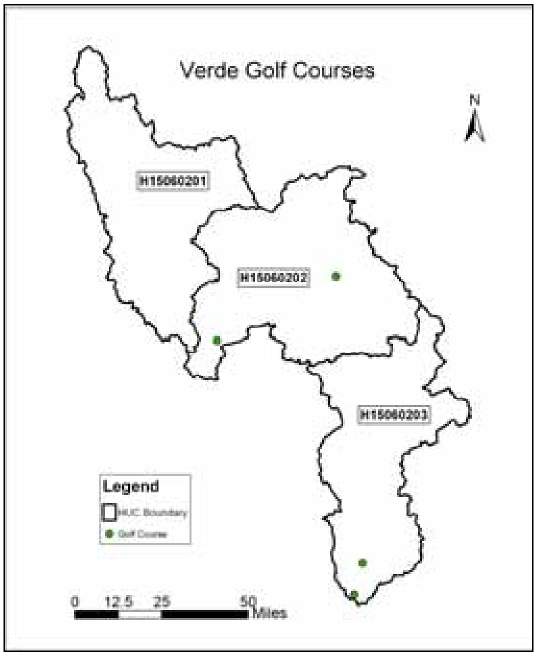
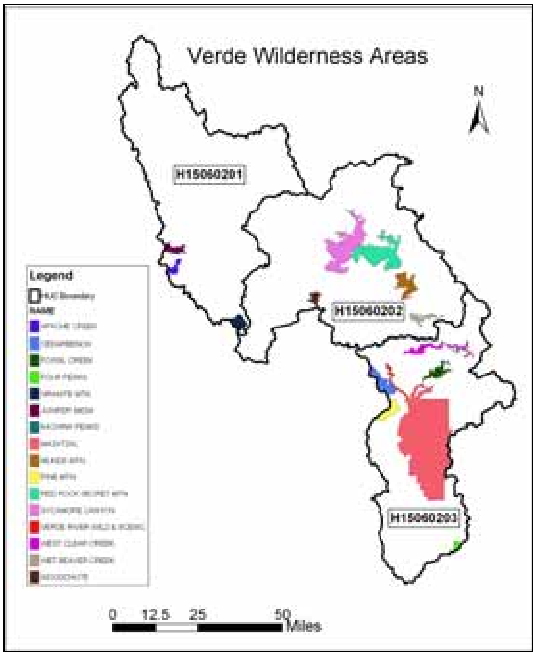


Table 4-14: Verde Watershed Wilderness Areas (acres)

Wilderness Area	Big Chino Wash H15060201	Upper Verde River H15060202	Lower Verde River H15060203	*Verde Watershed*
Apache Creek	**5,437**	**-**	**-**	***5,437***
Cedar Bench	**-**	**-**	**15,973**	***15,973***
Fossil Creek	**-**	**-**	**10,400**	***10,400***
Four Peaks	**-**	**-**	**3,314**	***3,314***
Granite Mtn.	**9,450**	**-**	**-**	***9,450***
Juniper Mesa	**7,523**	**-**	**-**	***7,523***
Kachina Peaks	**-**	**1,737**	**-**	***1,737***
Mazatzal	**-**	**-**	**232,937**	***232,937***
Munds Mtn.	**-**	**18,069**	**-**	***18,069***
Pine Mtn.	**-**	**-**	**11,318**	***11,318***
Red Rock - Secret Mtn.	**-**	**48,263**	**-**	***48,263***
Sycamore Canyon	**-**	**57,916**	**-**	***57,916***
Verde River Wild & Scenic	**-**	**-**	**4,981**	***4,981***
West Clear Creek	**-**	**-**	**15,267**	***15,267***
Wet Beaver	**-**	**6,178**	**-**	***6,178***
Woodchute	**-**	**5,553**	**-**	***5,553***
Total Wilderness Areas	***22,410***	***137,716***	***294,190***	***454,316***

Figure 4-15: Verde Watershed Wilderness Areas



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U.S. Department of the Interior, U.S. Geological Survey, http://landcover.usgs.gov/natllandcover.asp
Landuse. July 21, 2003.

**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and a general description of the data.*

Section 5: Important Resources

The Verde Watershed has extensive and important natural resources with national, regional and local significance. The Verde Watershed contains critical riparian habitat for several rare and endangered species, including the Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004). It also contains important recreational resources such as extensive wilderness areas with hiking, bird watching and fishing opportunities.

Based on our analysis of the combination of natural resource values, five Natural Resources Areas (NRAs) have been identified for protection. Factors that were considered in delineating these Natural Resource Areas include: legal status (Unique Waters, critical habitat for threatened and endangered species, and wilderness), the presence of perennial waters and riparian areas, recreational resources, and local values.

The five identified Natural Resource Areas (Figure 5-1) are:

- Lower Verde River
- Upper Verde River
- Mesquite Wash-Sycamore Creek
- Lower Big Chino Wash
- Camp Creek-Lower Verde River

The NRA's have been categorized within the 10-digit HUC watershed area where they are located, and the significance of each area is discussed below.

Lower Verde River NRA

The Lower Verde River NRA (LVR-NRA) includes five 10-digit HUC watersheds: West Clear Creek, East Verde River, Fossil Creek-Lower Verde River, Tangle Creek-Lower Verde River, and Lower Verde River-Horseshoe. The NRA is one of the most significant natural resource areas in Arizona, containing a designated Wild and Scenic River, five wilderness areas, extensive riparian forests, important recreation areas, and critical wildlife habitat. Many of the important resource values in the LVR-NRA are water dependent.

The segment of the Verde River classified as a Wild & Scenic River runs for 40 miles from T13N, R5E, Sections 26 and 27, to the confluence of the Verde River with Red Creek. Most of this length falls within the Mazatzal Wilderness Area. This section of the Verde was designated a Wild and Scenic River under the Wild and Scenic Rivers Act (P.L. 90-542) in 1981 after an Environmental Impact Statement found that it contained outstandingly remarkable scenic, fish and wildlife, and historic and cultural values. It is Arizona's only Wild & Scenic River and covers 12,500 acres. This area has some of Arizona's most important riparian forests. These riparian vegetation communities serve as a haven to many types of birds. Eight native fish species are found here including the threatened and endangered Razorback Sucker. This section of the Verde also provides excellent boating opportunities.

All but the eastern tip of the 252,500 acre Mazatzal Wilderness falls inside the LVR-NRA. This wilderness area is part of both the Tonto and Coconino National Forests. The eastern side of Mazatzal is mainly brush and pine covered mountains with vertical walled canyons. The west side is comprised of steep brush covered foothills and the Verde River Valley.

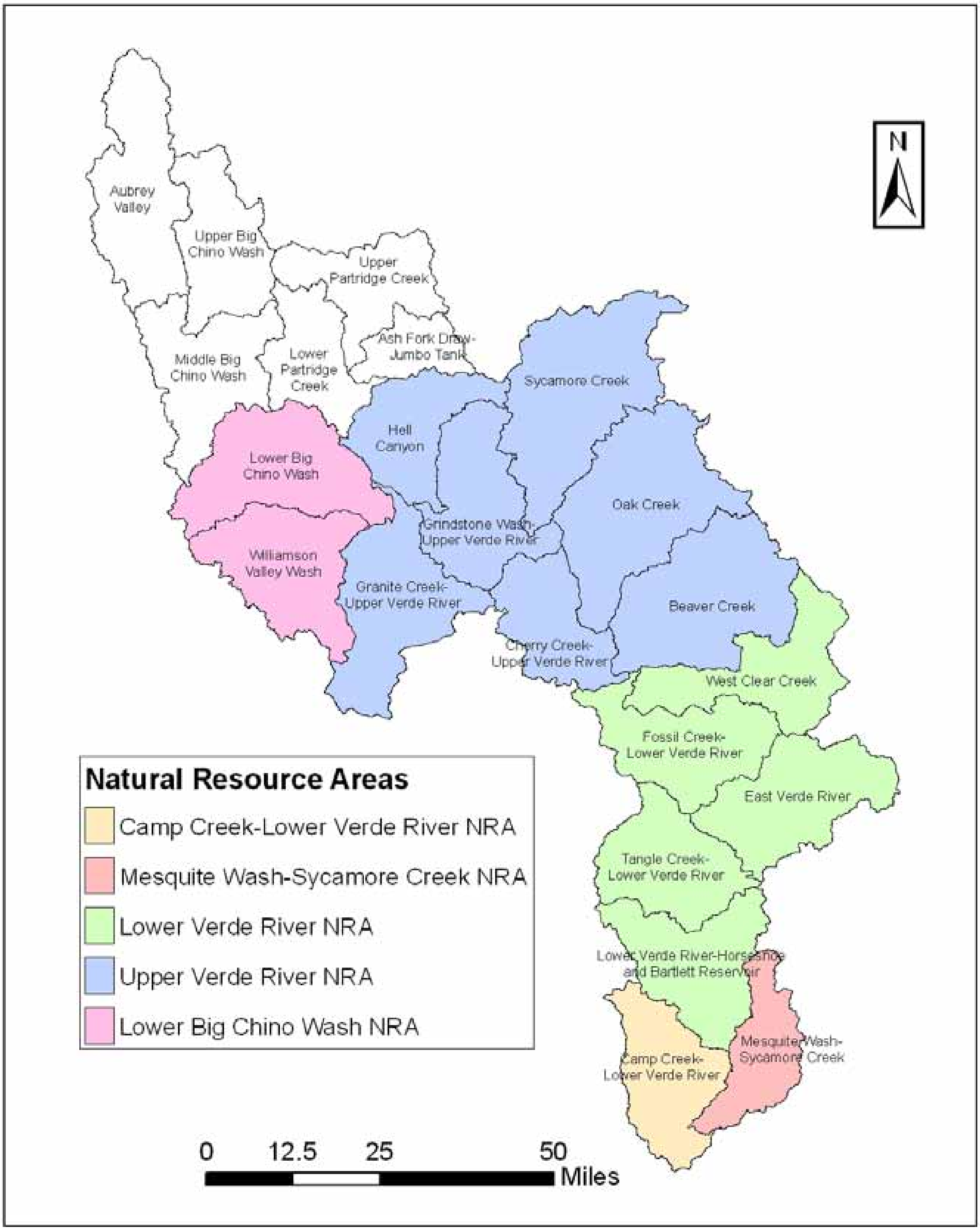


Figure 5-1: Natural Resource Areas in the Verde River Watershed.

The West Clear Creek Wilderness is located 52 miles south of Flagstaff and 12 miles east of Camp Verde and is quite remote. It is 15,000 acres in size and falls within the Coconino National Forest. This area provides excellent swimming opportunities in the many pools along West Clear Creek. Fishing and hiking opportunities are also abundant.

The Cedar Bench Wilderness is located along the Verde Rim on the dividing line of the Verde and Agua Fria Watersheds. It covers 16,000 acres and is within the Prescott National Forest. The Verde Wild and Scenic River forms part of the eastern boundary of this wilderness. The primary vegetation types are chaparral, pinyon pine and Utah Juniper. This area offers many hiking options.

The Fossil Creek Wilderness is within the Prescott National Forest and covers 10,400 acres. This wilderness area offers significant hiking and fishing opportunities.

The Pine Mountain Wilderness rests on the western border of the watershed, with half of its 20,000 acres in the LVR-NRA. It is managed by the Tonto and Prescott National Forests. The portion in the Verde Watershed consists of steep chaparral covered slopes leading down to the Verde River.

In addition to wilderness areas, the LVR-NRA contains much important riparian vegetation and critical habitat for the threatened and endangered Razorback Sucker, Sonoran Chub, and Mexican Spotted Owl.

Lower Verde River NRA Protection Needs

Based on Arizona's 303(d) List of Impaired Waters (ADEQ, 2005), much of the LVR-NRA is at high risk for metals and sediment. Livestock grazing, an important land use in the LVR-NRA, can result in impacts to riparian areas where livestock graze. Increasing development in the cities of Camp Verde and Payson can also result in water quality impacts.

Most of the resource values in the Lower Verde River NRA depend on the protection and restoration of the Lower Verde River riparian forest. The riparian forest provides critical habitat for several protected wildlife species, as well as recreation opportunities, as discussed above. It is important to note that five Forest Service wildernesses contain a portion of the Lower Verde River and that the riparian forest and river are important components of the wilderness experience.

Water quality monitoring should be expanded, especially where perennial water occurs, and appropriate Best Management Practices should be implemented to maintain water quality. Special attention should be given to protecting the riparian areas and critical habitat.

Based on the watershed classification results, this area should be monitored especially for sediment, metals, selenium and organics constituents (See section 6). To address the protection needs of the LVR-NRA, nonpoint source pollutant management measures should be taken to control all the constituents.

Upper Verde River NRA

The Upper Verde River NRA (UVR-NRA) is made up of seven 10-digit HUC watersheds: Beaver Creek, Cherry Creek-Upper Verde River, Grindstone Wash-Upper Verde River, Hell Canyon, Oak Creek, Granite Creek-Upper Verde River, and Sycamore Creek. The UVR contains Oak Creek, a Unique Water. It also has five wilderness areas and critical habitat for three threatened and endangered species: Gila Chub, Razorback Sucker, and the Mexican Spotted Owl.

Sycamore Canyon Wilderness covers 56,000 acres and is part of the Prescott National Forest. This canyon environment cuts through the Mogollon Rim where wind and water have exposed seven geological associations. This area has many hiking and camping opportunities.

The Red Rock - Secret Mountain Wilderness is located 12 miles south of Flagstaff and covers 44,000 acres of the Coconino National Forest. Red rock pinnacles, windows, arches, and slot canyons are plentiful, as is rock art and abandoned dwellings. Hiking opportunities abound in this area. Red Rock - Secret Mountain Wilderness is adjacent to Oak Creek and Slide Rock State Park, where many people come to swim and enjoy the natural slides of rock.

Munds Mountain Wilderness is located 30 miles south of Flagstaff and covers 18,150 acres of the Coconino National Forest. It stretches from the Munds and Lee Mountains to the bottom of Jacks, Woods, and Rattlesnake Canyons. Munds Mountain Wilderness offers ample hiking, wildlife watching and horseback riding.

Woodchute Wilderness covers 5,500 acres of the Coconino National Forest and offers hiking opportunities through red rock formations.

Wet Beaver Creek Wilderness is located 43 miles south of Flagstaff and covers 6,200 acres of the Coconino National Forest. This wilderness affords hiking, fishing, camping and wildlife viewing opportunities.

Upper Verde River NRA Protection Needs

Most of the resource values in the UVR-NRA depend on the protection and restoration of the riparian forest. The riparian forest provides critical habitat for several protected wildlife species, as well as recreation opportunities, as discussed above. Five Forest Service wilderness areas contain a portion of the Upper Verde River and it is important to note that the riparian forests and rivers are important components of the wilderness experience. Nonpoint source pollutant management measures should be taken to protect and restore the channel and riparian systems.

Based on current water quality assessment results (ADEQ, 2005), the Verde River from Oak Creek to Beaver Creek and the Verde River from Beaver Creek to HUC 15060202-001 are classified as “not attaining” for sediment. Whitehorse Lake, Peck’s Lake, Watson Lake, and Granite Creek from headwaters to Willow Creek are classified as “not attaining” for dissolved oxygen. Oak Creek at Slide

Rock State Park is classified as "not attaining" for E. coli. Stoneman Lake was impaired due to pH exceedances (Appendix, A).

To address the protection needs of the UVR-NRA, nonpoint source pollutant management measures should be taken to control metals, sediment, organics and selenium (See Section 6). Human use of Slide Rock State Park should continue to be monitored for E. coli contamination to Oak Creek.

Livestock grazing is an important land use in the UVR-NRA and special attention should be given to protecting and restoring the riparian areas where livestock graze. Many communities in the NRA, including Prescott, Camp Verde, and Sedona are experiencing increasing development. Potential impacts to water quality should be monitored and mitigation actions should be taken, as discussed in Section 7, Watershed Management.

Mesquite Wash – Sycamore Creek NRA

The Mesquite Wash – Sycamore Creek NRA (MWSC-NRA) consists of only one 10-digit HUC watershed, Mesquite-Wash – Sycamore Creek. The MWSC-NRA has significant riparian vegetation communities, critical habitat for the endangered Mexican Spotted Owl, and portions of two wilderness areas within its boundaries.

Four Peaks Wilderness covers 61,000 acres of the Tonto National Forest, of which only a small portion of the northwest corner is located within the MWSC-NRA. The far southeastern portion of the Mazatzal Wilderness is included in the MWSC-NRA.

Mesquite Wash - Sycamore Creek NRA Protection Needs

Most of the resource values in the MWSC-NRA depend on the protection and restoration of the Mesquite Wash-Sycamore Creek riparian forest. The riparian forest provides critical habitat for several protected wildlife species, as well as recreation opportunities.

Based on watershed classification results, this area is classified as high risk for sediment and selenium (See section 6). To address the protection needs of the MWSC-NRA, nonpoint source pollutant management measures should be taken to control sediment and selenium.

Lower Big Chino Wash NRA

The Lower Big Chino Wash NRA (LBCW-NRA) consists of two 10-digit HUC watershed: Lower Big Chino Wash and Williamson Valley Wash. The LBCW-NRA has a reach of critical habitat for the endangered Gila Chub and three Wilderness areas within its boundaries.

Apache Creek Wilderness covers 5,600 acres of the Prescott National Forest. Rolling hills of juniper and pinyon interspersed with granite outcrops characterize this small and remote wilderness. It provides excellent habitat for mountain lion and many species of birds.

Granite Mountain Wilderness, located near Prescott, covers 10,000 acres of the Prescott Nation Forest. Stacks of large granite boulders characterize the wilderness. Hiking and rock climbing opportunities are plentiful.

Juniper Mesa Wilderness covers 7,500 acres of the Prescott National Forest. The wilderness is characterized by the flat topped mesa from which it draws its name. Wildlife is abundant, including black bear, elk, mule deer, bobcat and squirrel.

Lower Big Chino Wash NRA Protection Needs

Based on the watershed classification results, this area is classified as high risk for organics (see section 6). To address the protection needs of the LBCW-NRA, nonpoint source pollutant management measures should be taken to control organics.

Livestock grazing is an important land use in the LBCW-NRA and special attention should be given to protecting and restoring the riparian areas where livestock graze.

Camp Creek - Lower Verde River NRA

The Camp Creek - Lower Verde River NRA (CCLVR-NRA) consists of one 10-digit HUC watershed, Camp Creek - Lower Verde. The CCLVR-NRA was designated as an NRA due to local concern regarding the riparian and stream environments. This area has a rapidly growing population due to development pressures from Phoenix to the south.

The portion of the Verde River running through this HUC has miles of perennial stream and is an important local resource for recreation and aesthetics.

Camp Creek-Lower Verde River NRA Protection Needs

Water quality and quantity are concerns within the CCLVR-NRA. Based on current water quality assessment results (ADEQ, 2005), the Verde River from Bartlett Dam to Camp Creek is listed as "impaired" for copper, and selenium. Grande Wash from the headwaters to Ashbrook Wash is listed as "impaired" for E. coli.

This NRA is classified as high risk for metals, sediment, organics and selenium. To address the protection needs of the NRA, nonpoint source pollutant management measures should be taken to control metals, sediment, organics and selenium.

References:

Arizona Department of Environmental Quality, ADEQ. 2005. The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report. 1110 West Washington Ave., Phoenix, Arizona, 85007. http://www.azdeq.gov/environ/water/assessment/2004.html.

U.S. Fish & Wildlife Service, July 14, 2004. U.S. Fish & Wildlife Service, Arizona Ecological Services Field Office, Threatened and Endangered Species. http://arizonaes.fws.gov/threaten.htm (Feb. 7, 2005).

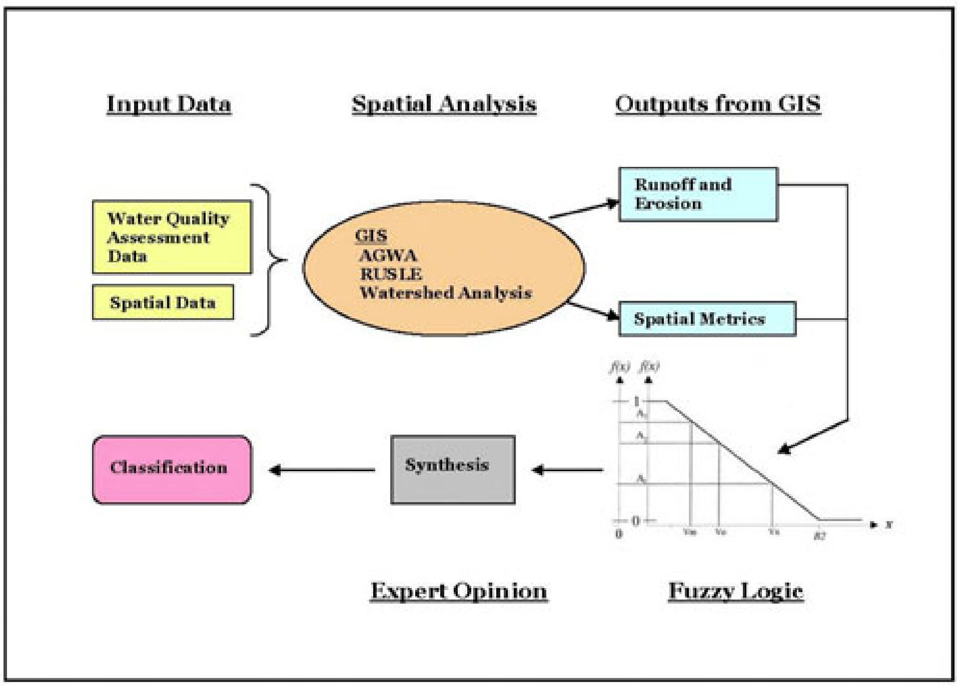
Section 6: Watershed Classification

In this section, each 10-digit subwatershed in the Verde Watershed is classified or ranked based on susceptibility to water quality problems and pollution sources that need to be controlled through implementation of nonpoint source Best Management Practices (BMPs). This classification also prioritizes subwatersheds for available water quality improvement grants, based on known water quality concerns.

Methods

The general approach used to classify subwatersheds was to integrate watershed characteristics, water quality measurements, and results from modeling within a multi-parameter ranking system based on the fuzzy logic knowledge-based approach (described below), as shown schematically in Figure 6-1.

Figure 6-1: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.



The process was implemented within a GIS interface to create the subwatershed classifications using five primary steps:

- Define the goal of the watershed classification: to prioritize which 10-digit subwatersheds are most susceptible to known water quality concerns, and therefore, where BMPs should be implemented to reduce nonpoint source pollution;

- Assemble GIS data and other observational data;

- Define watershed characteristics through:

  - ✓ Water quality assessment data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005);
  - ✓ GIS mapping analysis; and
  - ✓ Modeling / simulation of erosion vulnerability and potential for stream impairment (in this case, from soils in mine site areas and proximity to abandoned mine sites).

- Use fuzzy membership functions to transform the potential vulnerability / impairment metrics into fuzzy membership values with scales from 0 to 1; and

- Determine a composite fuzzy score representing the ranking of the combined attributes, and interpret the results.

Fuzzy Logic

The "fuzzy logic" method is used to integrate different types of data (Guertin et al., 2000; Reynolds, 2001). Using fuzzy logic, a watershed tool was developed that can be updated as new water quality information becomes available. In this tool, the "weight" or priority given a specific factor used in the classification can be changed or adjusted, making the tool more valuable because underlying bias in interpreting the data can be uncovered and evaluated.

Fuzzy logic is an approach to handle vagueness or uncertainty, and has been characterized as a method by which to quantify common sense. In classical set theory, an object is either a member of the set or excluded from the set. For example, one is either tall or short, with the class of tall men being those over the height of 6'0". Using this method, a man who is 5' 11" tall would not be considered in the tall class, although he could not be considered 'not-tall'. This is not satisfactory, for example, if one has to describe or quantify an object that may be a partial member of a set. In fuzzy logic, membership in a set is described as a value between 0 (non-membership in the set) and 1 (full membership in the set). For instance, the individual who is 5' 11" is not classified as short or tall, but is classified as tall to a degree of 0.8. Likewise, an individual of height 5' 10" would be tall to a degree of 0.6.

In fuzzy logic, the range in value between different data factors are converted to the same scale (0-1) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the characteristics of the input. In the case above, the degree of tallness was iteratively added in intervals of 0.2. An example of a continuous data set would be graphing heights of all individuals and correlating a continuous fuzzy member value to that graph. A user defines their membership functions to describe the relationship between an individual factor and the achievement of the stated goal.

The development of a fuzzy membership function can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. A benefit of this approach is that it provides for the use of different methods for combining individual factors to create the final classification and the goal set. Fuzzy membership functions and weighting schemes can also be changed based on watershed concerns and conditions.

Subwatershed Classifications

The classification was conducted at the 10-digit HUC subwatershed scale. Table 6-1 lists the HUC numerical identifications and subwatershed names.

Classifications were conducted for individual or groups of water quality parameters, and potential for impairment for a water quality parameter based on the biophysical characteristics of the watershed.

Constituent groups evaluated for the Verde Watershed are:

- Metals (mercury, copper, zinc, lead, arsenic), with mercury used as an index since it is the most common parameter sampled in the watershed;
- Sediment (turbidity is used as an index since it was the previous standard and represents most of the sampling data);
- Organics (Escherichia coli, nutrients, high pH factors and dissolved oxygen are concerns and are related to organic material being introduced into the aquatic system); and
- Selenium.

The development of the fuzzy logic approach for each constituent is described below.

Table 6-1: HUC Numerical Designation and Subwatershed Name.

HUC	Subwatershed Name
1506020101	Aubrey Valley
1506020102	Upper Big Chino Wash
1506020103	Ash Fork Draw-Jumbo Tank
1506020104	Upper Partridge Creek
1506020105	Lower Partridge Creek
1506020106	Middle Big Chino Wash
1506020107	Williamson Valley Wash
1506020108	Lower Big Chino Wash
1506020201	Granite Creek-Upper Verde River
1506020202	Hell Canyon
1506020203	Sycamore Creek
1506020204	Grindstone Wash-Upper Verde River
1506020205	Oak Creek
1506020206	Beaver Creek
1506020207	Cherry Creek-Upper Verde River
1506020301	West Clear Creek
1506020302	East Verde River
1506020303	Fossil Creek-Lower Verde River
1506020304	Tangle Creek-Lower Verde River
1506020305	Lower Verde River-Horseshoe and Bartlett Reservoir
1506020306	Mesquite Wash-Sycamore Creek
1506020307	Camp Creek-Lower Verde River

Water Quality Assessment Data

Data collected and used for Arizona's 2004 Integrated 305(b) Assessment and

303(d) Listing Report (ADEQ, 2005) was used to define the current level of impairment based on water quality sampling results from several entities and volunteer groups in Arizona. In assigning fuzzy membership values the location of a subwatershed relative to an impaired water was considered.

Appendix A Table 1, is a summary of the water quality monitoring and classification data collected on the Verde Watershed.

ADEQ's assessment criteria and assessment definitions are found in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005). Surface waters assessed as "impaired" are included in Arizona's 303(d) List of Impaired Waters and are scheduled for completion of a Total Maximum Daily Load (TMDL) quantitative and analysis plan. A TMDL is the maximum amount (load) of a water quality parameter which can be carried by a surface water body, on a daily basis, without causing an exceedance of surface water quality standards (ADEQ, 2004).

The water quality data were used to classify each monitored stream reach based on its relative risk of impairment for the constituent groups described above.

To classify each 10-digit subwatershed, based on its relative risk of impairment for the constituent groups described above, four levels of risk were defined: Extreme, High, Moderate and Low.

- Extreme risk - If a surface water within the subwatershed is currently assessed as being "impaired" by ADEQ for one of the constituent groups.

- High risk - If a surface water within the subwatershed is assessed as "inconclusive" because of limited data, but the available sampling indicates water quality exceedances occurred.

- Moderate risk - If either:
  - A surface water within the subwatershed was assessed as "inconclusive" or "attaining", but there are still a low number of samples exceeding standards for a constituent group; or
  - There were no water quality measurements available for a constituent group at any site within the subwatershed.

- Low risk - If no exceedances exist in a constituent group and there were sufficient data to make an assessment.

For more information on the Verde Watershed Water Quality Classification see the ADEQ Website: http://www.adeq.state.az.us/environ/water/classification/assess.html

Each 10-digit HUC watershed is assigned a fuzzy membership value (FMV) based on the water quality parameters and classification results. Table 6-2 contains the FMVs used for different watershed conditions based on these results. It should be noted that not every 10-digit HUC watershed contained a water quality measurement site.

The FMVs are based on two considerations: 1) relative risk of impairment (described above), and 2) assessed water quality status of downstream surface waters if the subwatershed has either "high" or "moderate" condition.

The status of downstream surface waters provides a way to evaluate the potential that the subwatershed is contributing to downstream water quality problems. This is particularly important where water quality data is limited and few surface water quality samples may have been collected within the subwatershed.

Reaches classified as either extreme or low risk were given precedence over high or moderate classified reaches in determining downstream water quality condition because of their ambiguity. For example, if a downstream water body was classified as extreme risk, it was used to define the downstream water quality condition. However, if a reach along the pathway was classified as low risk, then the low risk reach was used to define the downstream water quality condition.

Table 6-2: Fuzzy Membership Values for HUC-10 Subwatersheds Based on ADEQ Water Quality Assessment Results

Reach Condition	Downstream Condition	FMV
Extreme	**N/A**	**1.0**
High	**Extreme**	**1.0**
High	**High**	**0.8**
High	**Moderate /Low**	**0.7**
Moderate	**Extreme**	**0.7**
Moderate	**High**	**0.6**
Moderate	**Moderate**	**0.5**
Moderate	**Low**	**0.3**
Low	**N/A**	**0.0**

Table 1 in Appendix A provides more clarification on the ADEQ Water Quality Assessment results, and defines the basis for classification as extreme, high, moderate, and low risk.

<u>Metals</u>

Metals are one of the most significant water quality problems in the Verde Watershed because of the potential toxicity to aquatic life. The Verde River from Bartlett Dam to Camp Creek in the Camp Creek – Lower Verde River subwatershed is impaired for copper, and several reaches exceed water quality standards for other metals. However, some stream reaches have not been sampled for metals.

The primary sources for metals in the Verde Watershed are probably runoff and erosion from active and abandoned mines. Developed urban areas should also be considered as a nonpoint source for metals pollutants. However, the current population density of the Verde Watershed is moderate and is therefore not seen as a major source of metals. Although "development" was not used at this time as a classification factor, this may need to be considered as population continues to grow.

The factors used for the metals classification were:

- ADEQ water quality assessment results;
- Presence of mines within a watershed;
- Presence of mines within the riparian zone; and
- Potential contribution of mines to sediment yield.

Water Quality Assessment Data - Metals

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) was used to define the current level of impairment based on water quality measurements. In assigning fuzzy membership values, the location of a watershed relative to an impaired water was considered.

Table 6-2 contains the fuzzy membership values used for different watershed conditions based on the water quality assessment results. Table 6-3 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed for metals, based on the criteria defined in Table 6-2.

Table 6-3: Fuzzy Membership Values Assigned to each 10-digit HUC Subwatershed in the Verde Watershed, Based on Water Quality Classification Results for Metals.

Subwatershed Name	FMV	Justification
Aubrey Valley	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Upper Big Chino Wash	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Ash Fork Draw - Jumbo Tank	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Upper Partridge Creek	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Lower Partridge Creek	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Middle Big Chino Wash	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Williamson Valley Wash	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Lower Big Chino Wash	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Granite Creek-Upper Verde River	0.8	Classified as a high risk (Mercury in Granite Creek is inconclusive with a high rate of exceedance), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Hell Canyon	0.6	Classified as moderate risk (no data), drains into Grindstone Wash - Upper Verde River that is classified as a high risk
Sycamore Creek	0.8	Classified as high risk (Lead in Scholz Lake is inconclusive with a high rate of exceedance), drains into Grindstone Wash - Upper Verde River that is classified as high risk
Grindstone Wash-Upper Verde River	0.8	Classified as high risk (Mercury in Verde River (Sycamore Creek to Oak Creek) is inconclusive with a high rate of exceedance), drains into Cherry Creek - Upper Verde River that is classified as high risk
Oak Creek	0.6	Classified as moderate risk (exceedances), drains into Cherry Creek - Upper Verde River that is classified as high risk
Beaver Creek	0.8	Classified as high risk (exceedances), drains into Cherry Creek - Upper Verde River that is classified as high risk

Subwatershed Name	FMV	Justification
Cherry Creek-Upper Verde River	**1.0**	**Classified as high risk (Mercury in Verde River (Sycamore Creek to Oak Creek) is inconclusive with a high rate of exceedance), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
West Clear Creek	**0.7**	**Classified as moderate risk (no data), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
East Verde River	**1.0**	**Classified as high risk (exceedances), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
Fossil Creek-Lower Verde River	**0.7**	**Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as extreme risk**
Tangle Creek-Lower Verde River	**0.7**	**Classified as moderate risk (lack of data), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
Lower Verde River-Horseshoe and Bartlett Reservoir	**0.7**	**Classified as moderate risk (exceedances), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
Mesquite Wash-Sycamore Creek	**0.7**	**Classified as moderate risk (no data), drains into Camp Creek - Lower Verde River that is classified as extreme risk**
Camp Creek-Lower Verde River	**1.0**	**Classified as extreme (Verde River (Bartlett Dam to Camp Creek) Not Attaining for Copper), drains out of the Verde Watershed**

Note: This table is cross-referenced to Table 1 of Appendix A where the 10-digit HUC names are tabulated with the subwatershed name.

Location of Mining Activities

Section 2, Physical Characteristics and Section 4, Social Characteristics of the Verde Watershed contain a more thorough discussion of the geologic conditions and location of mine sites and mine type across the watershed. The subwatersheds were classified using the fuzzy logic methodology by incorporating the spatial data from Sections 2 and 4 with the tabulated ADEQ water quality assessment data.

The number of mines in a subwatershed and number of mines within the riparian zone (<= 250 m from a stream) of a subwatershed were used to assess the relative impact of mining on the concentration of dissolved and total metals in the subwatershed. The fuzzy membership functions for both conditions are:

Number of mines/watershed:

FMV = 0 if (# of mines <= 2)
FMV = (# of mines – 2) / 8
FMV = 1 if (# of mines >= 10)

Number of mines/riparian:

FMV = 0 if (# of mines < 1)
FMV = (# of mines) / 5
FMV = 1 if (# of mines >= 5)

Table 6-4 contains the fuzzy membership values assigned to each 10-digit HUC subwatersheds in the Verde Watershed based on the number of and location of mines.

Table 6-4: Fuzzy Membership Values Assigned to Each Subwatershed Based on the Number and Location of Mines.

Subwatershed	FMV # mines /watershed	FMV # mines /riparian
Aubrey Valley	0.000	0.000
Upper Big Chino Wash	0.000	0.200
Ash Fork Draw-Jumbo Tank	1.000	1.000
Upper Partridge Creek	1.000	1.000
Lower Partridge Creek	1.000	0.400
Middle Big Chino Wash	1.000	0.600
Williamson Valley Wash	1.000	1.000
Lower Big Chino Wash	1.000	1.000
Granite Creek-Upper Verde River	1.000	1.000
Hell Canyon	1.000	1.000
Sycamore Creek	1.000	0.400
Grindstone Wash-Upper Verde River	1.000	1.000
Oak Creek	1.000	1.000
Beaver Creek	1.000	0.800
Cherry Creek-Upper Verde River	1.000	1.000
West Clear Creek	1.000	1.000
East Verde River	1.000	1.000
Fossil Creek-Lower Verde River	1.000	1.000
Tangle Creek-Lower Verde River	0.625	0.400
Lower Verde River-Horseshoe and Bartlett Reservoir	1.000	1.000
Mesquite Wash-Sycamore Creek	1.000	1.000
Camp Creek-Lower Verde River	1.000	1.000

Table 6-5: FMVs per Erosion Category.

Subwatershed	Category	FMV
Aubrey Valley	2	0.2
Upper Big Chino Wash	4	0.6
Ash Fork Draw-Jumbo Tank	5	0.8
Upper Partridge Creek	3	0.4
Lower Partridge Creek	4	0.6
Middle Big Chino Wash	2	0.2
Williamson Valley Wash	2	0.2
Lower Big Chino Wash	2	0.2
Granite Creek-Upper Verde River	5	0.8
Hell Canyon	4	0.6
Sycamore Creek	5	0.8
Grindstone Wash-Upper Verde River	4	0.6
Oak Creek	3	0.4
Beaver Creek	3	0.4
Cherry Creek-Upper Verde River	6	1.0
West Clear Creek	4	0.6
East Verde River	2	0.2
Fossil Creek-Lower Verde River	4	0.6
Tangle Creek-Lower Verde River	2	0.2
Lower Verde River-Horseshoe and Bartlett Reservoir	2	0.2
Mesquite Wash-Sycamore Creek	2	0.2
Camp Creek – Lower Verde River	3	0.4

Potential Contribution of Mines to Sediment Yield

Based on RUSLE modeling (Renard et al., 1997; see Appendix C) the potential for erosion from mines to contribute to the sediment yield for a watershed was evaluated. The modeling results were reclassified into 6 categories. The first category represented zero potential for contribution (i.e. no mines) and was given a fuzzy membership value of 0.0.

The fuzzy membership values were increased by 0.2 for each higher erosion category. Table 6-5 contains the results.

Metals Results

The fuzzy membership values were used to create a combined fuzzy score for each subwatershed and were incorporated into the weighted combination method. The results are found in Table 6-6, and the weights are listed at the bottom of the table.

Weights were developed in cooperation with ADEQ and were ranked to emphasis the proximity of mines to the riparian area, the susceptibility to erosion, and the ADEQ water quality results. The overall number of mines within the subwatershed (but removed from the riparian area) was not considered as pertinent to the classification, so the weight assigned was 0.1, as opposed to 0.3 for the other categories. Each of the assigned weights were multiplied with the FMV, and then added to result in the weighted ranking.

Table 6-6: Results for Metals Based on the Fuzzy Logic Approach.

Subwatershed	WQA[1]	# Mines / HUC	# Mines / Riparian	Erosion Category	FMV Weighted
Aubrey Valley	0.600	0.000	0.000	0.400	0.300
Upper Big Chino Wash	0.600	0.000	0.200	0.200	0.300
Ash Fork Draw-Jumbo Tank	0.600	1.000	1.000	0.600	0.760
Upper Partridge Creek	0.600	1.000	1.000	0.800	0.820
Lower Partridge Creek	0.600	1.000	0.400	0.400	0.520
Middle Big Chino Wash	0.600	1.000	0.600	0.600	0.640
Williamson Valley Wash	0.600	1.000	1.000	0.200	0.640
Lower Big Chino Wash	0.600	1.000	1.000	0.200	0.640
Granite Creek-Upper Verde River	0.800	1.000	1.000	0.200	0.700
Hell Canyon	0.600	1.000	1.000	0.800	0.820
Sycamore Creek	0.800	1.000	0.400	0.600	0.640
Grindstone Wash-Upper Verde River	0.800	1.000	1.000	0.800	0.880
Oak Creek	0.600	1.000	1.000	0.600	0.760
Beaver Creek	0.800	1.000	0.800	0.400	0.700
Cherry Creek-Upper Verde River	1.000	1.000	1.000	0.400	0.820
West Clear Creek	0.700	1.000	1.000	1.000	0.910
East Verde River	1.000	1.000	1.000	0.600	0.880
Fossil Creek-Lower Verde River	0.700	1.000	1.000	0.200	0.670
Tangle Creek-Lower Verde River	0.700	0.625	0.400	0.600	0.573
Lower Verde River-Horseshoe and Bartlett Reservoir	0.700	1.000	1.000	0.200	0.670
Mesquite Wash-Sycamore Creek	0.700	1.000	1.000	0.200	0.670
Camp Creek-Lower Verde River	1.000	1.000	1.000	0.200	0.760
Weights	***0.300***	***0.100***	***0.300***	***0.300***	

[1]Water Quality Assessment results

Subwatershed areas ranking greater than a calculated 0.5 value were ranked ‘High’ and lower than 0.5 were ranked ‘Low” for impairment due to metals. Figure 6-2 shows the results of the weighted combination method classified into high and low priority for metals.

Sediment

Erosion and sedimentation are major environmental concerns in arid and semiarid environments. Sediment is the chief source of impairment in the southwestern United States, not only to our few aquatic systems, but also to our riparian systems which are at risk from channel degradation.

The factors used for the sediment classification are:

- ADEQ water quality assessment results (note that turbidity data is used where sediment results are not available);
- Estimated current runoff and sediment yield;
- Human use within a subwatershed and riparian area;
- Land ownership.

Since the available water quality data is limited, more weight was placed on subwatershed characteristics and modeling results in doing the classification.

Water Quality Assessment Data - Sediment

Arizona’s Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) were used to define the current water quality based on water monitoring results. In assigning fuzzy membership values, the location of a subwatershed relative to an impaired water was considered. As discussed under the metals classification section, Table 6-2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results. Table 6-7 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on turbidity data.

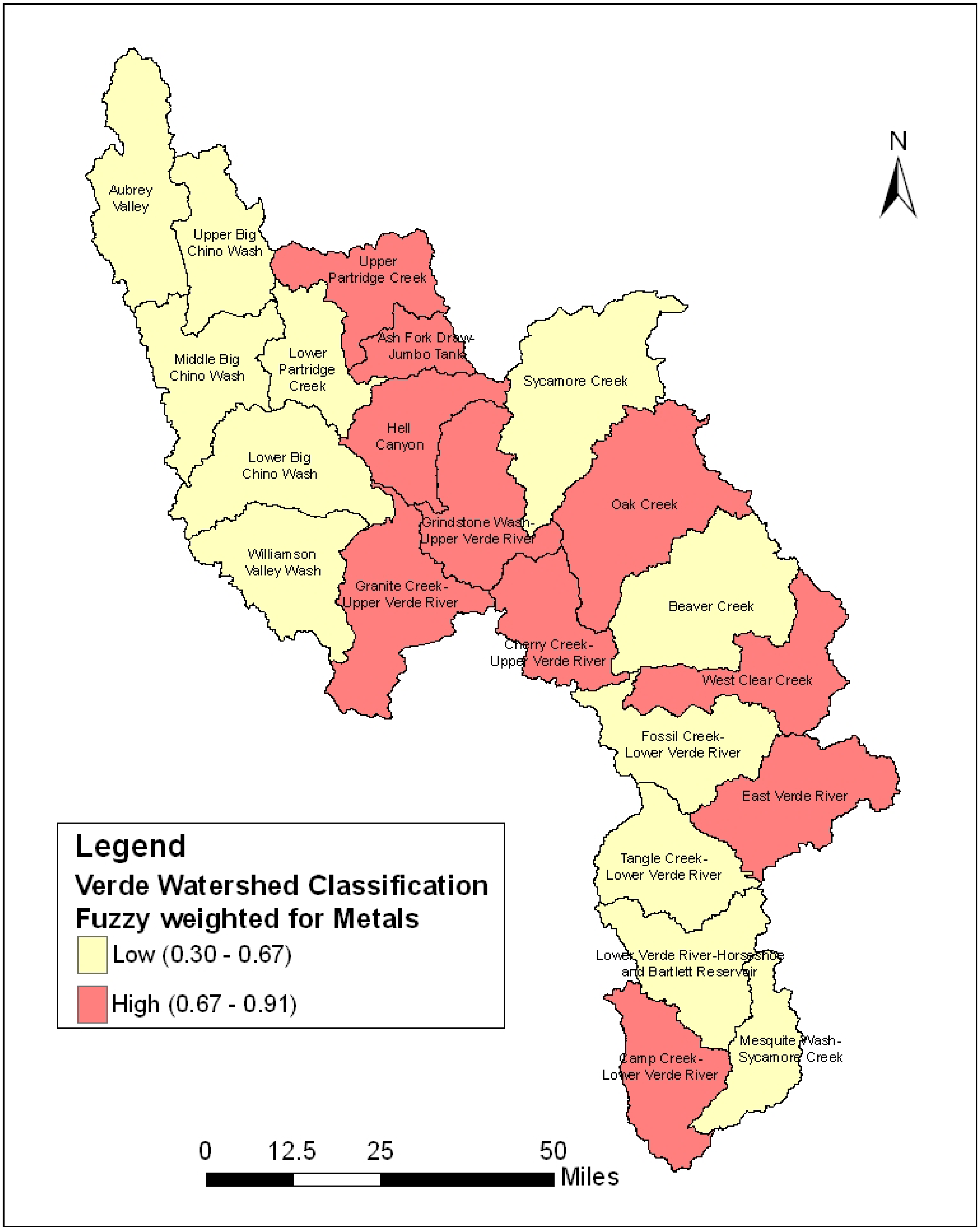


Figure 6-2: Results for the Fuzzy Logic Classification for Metals Based on the Weighted Combination Approach.

Table 6-7: Fuzzy Membership Values for Sediment Assigned to each 10-Digit HUC Subwatershed in the Verde Watershed Based on Water Quality Assessment Results.

Subwatershed Name	FMV	Justification
Aubrey Valley	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Upper Big Chino Wash	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Ash Fork Draw-Jumbo Tank	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Upper Partridge Creek	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Lower Partridge Creek	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Middle Big Chino Wash	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Williamson Valley Wash	0.0	Classified as a low risk
Lower Big Chino Wash	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Granite Creek-Upper Verde River	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Hell Canyon	0.7	Classified as moderate risk (no data), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Sycamore Creek	1.0	Classified as high risk (Turbidity in Whitehorse Lake is inconclusive with a high rate of exceedance), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Grindstone Wash-Upper Verde River	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River which is classified as extreme risk
Oak Creek	1.0	Classified as high risk (inconclusive with high rate of exceedances), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Beaver Creek	1.0	Classified as high risk (inconclusive with a high rate of exceedance), drains into Cherry Creek-Upper Verde River which is classified as an extreme risk
Cherry Creek-Upper Verde River	1.0	Classified as extreme risk (Verde River 15060202-015 Not Attaining)
West Clear Creek	0.0	Classified as a low risk
East Verde River	0.8	Classified as high risk (Turbidity in East Verde River 15060203-022B is inconclusive with a high rate of exceedance), drains Tangle Creek-Lower Verde River that is classified as a high risk

Subwatershed Name	FMV	Justification
Fossil Creek-Lower Verde River	**1.0**	**Classified as extreme risk (Verde River 15060203-025 Not Attaining)**
Tangle Creek-Lower Verde River	**0.8**	**Classified as high risk, drains Lower Verde River-Horseshoe and Bartlett Reservoir that is classified as a high risk**
Lower Verde River-Horseshoe and Bartlett Reservoir	**0.7**	**Classified as high risk, drains Camp Creek-Lower Verde River that is classified as a moderate risk**
Mesquite Wash-Sycamore Creek	**0.5**	**Classified as moderate risk (no data), drains Camp Creek-Lower Verde River that is classified as a moderate risk**
Camp Creek-Lower Verde River	**0.5**	**Classified as moderate risk (lack of samples), drains out of the watershed**

Land ownership - Sediment

One of the principal land uses in the Verde Watershed is livestock grazing. Livestock grazing occurs primarily on land owned by the federal government (Bureau of Land Management (BLM), and U.S. Forest Service (USFS)), which comprises approximately 64% of the total watershed area. The remaining lands where grazing occurs are Arizona State Trust Lands (approximately 9%), and privately owned land (approximately 23%). Section 4, Social Characteristics contains a brief discussion of land ownership, with more detail provided in Section 7, Watershed Management, where individual management practices and target stakeholders are discussed.

Given that Federal lands must have management plans that include best management practices, the following classification will highlight State and private lands that may not have a water management control plan in place. The fuzzy membership function for the percentage of land in state or private ownership within a 10-digit HUC subwatershed is below. State and Private ownership over the watershed area:

FMV = 0 if (%State + private < = 10)
FMV = (%State + private – 10) / 15
FMV = 1 if (%State + private > = 25)

Table 6-8 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Verde Watershed based on land ownership.

Table 6-8: Fuzzy Membership Values Assigned Based on Land Ownership.

Subwatershed	% State + Private	FMV
Aubrey Valley	**99.87%**	**1.00**
Upper Big Chino Wash	**99.80%**	**1.00**
Ash Fork Draw-Jumbo Tank	**21.50%**	**0.77**
Upper Partridge Creek	**64.90%**	**1.00**
Lower Partridge Creek	**97.62%**	**1.00**
Middle Big Chino Wash	**87.18%**	**1.00**
Williamson Valley Wash	**47.42%**	**1.00**
Lower Big Chino Wash	**62.50%**	**1.00**
Granite Creek-Upper Verde River	**79.79%**	**1.00**
Hell Canyon	**9.72%**	**0.00**
Sycamore Creek	**9.46%**	**0.00**

Subwatershed	% State + Private	FMV
Grindstone Wash-Upper Verde River	1.02%	0.00
Oak Creek	14.61%	0.31
Beaver Creek	4.85%	0.00
Cherry Creek-Upper Verde River	33.18%	1.00
West Clear Creek	2.10%	0.00
East Verde River	4.68%	0.00
Fossil Creek-Lower Verde River	3.62%	0.00
Tangle Creek-Lower Verde River	0.24%	0.00
Lower Verde River-Horseshoe and Bartlett Reservoir	0.16%	0.00
Mesquite Wash-Sycamore Creek	2.15%	0.00
Camp Creek-Lower Verde River	41.95%	1.00

Human Use Index - Sediment

The Human Use Index was used to assess the relative impact of urban development on sediment load in streams. The Human Use Index is defined as the percentage of a subwatershed that is characterized as developed for human use. In the Verde Watershed, human use consists of developed areas as defined by the National Land Cover Data set as residential land use, mining and roads (USGS, 2003).
Human use was assessed at both the subwatershed and riparian scale (< = 250 meters from a stream). The fuzzy membership functions for both conditions are:

Human Use Index (HUI)/watershed:

FMV = 0 if (HUI < = 5%)
FMV = (HUI – 5) / 15
FMV = 1 if (HUI > = 20%)

Human Use Index/riparian:

FMV = 0 if (HUI < = 1%)
FMV = (HUI - 1) / 4
FMV = 1 if (HUI > = 5%)

Table 6-9 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Verde Watershed based on the Human Use Index.

Runoff

Based on SWAT modeling (see Appendix D) the potential runoff for a subwatershed area was evaluated. The modeling results were reclassified into 5 categories, with the first category given a fuzzy membership value of 0.2. The fuzzy membership values were increased by 0.2 for each higher erosion category, as shown in Table 6-10.

Erosion

Sediment yield is a measure of the rate of erosion, and depends on a combination of soil properties, topography, climate and land cover.

SWAT was used to evaluate the potential sediment yield for each subwatershed (see Appendix D). The modeling results were reclassified into 5 categories, with the first category given a fuzzy membership value of 0.2. The fuzzy membership values were increased by 0.2 for each higher erosion category, as shown in Table 6-11.

Table 6-9: Fuzzy Membership Values Assigned to Each Subwatershed Based on the Human Use Index.

Subwatershed	FMV HU Index Watershed	FMV HU Index Riparian
Aubrey Valley	0.00	0.00
Upper Big Chino Wash	0.00	0.00
Ash Fork Draw-Jumbo Tank	0.00	0.00
Upper Partridge Creek	0.00	0.00
Lower Partridge Creek	0.00	0.00
Middle Big Chino Wash	0.00	0.00
Williamson Valley Wash	0.00	0.18
Lower Big Chino Wash	0.00	0.31
Granite Creek-Upper Verde River	0.00	0.58
Hell Canyon	0.00	0.00
Sycamore Creek	0.00	0.00
Grindstone Wash-Upper Verde River	0.00	0.00
Oak Creek	0.00	0.33
Beaver Creek	0.00	0.05
Cherry Creek-Upper Verde River	0.04	1.00
West Clear Creek	0.00	0.01
East Verde River	0.00	0.04
Fossil Creek-Lower Verde River	0.00	0.39
Tangle Creek-Lower Verde River	0.00	0.00
Lower Verde River-Horseshoe and Bartlett Reservoir	0.00	0.00
Mesquite Wash-Sycamore Creek	0.00	0.00
Camp Creek-Lower Verde River	0.00	0.32

Sediment Results

The weighted combination approach was used to create combined fuzzy scores to rank sediment results, as shown on Table 6-12. Figure 6-3 shows the results of the weighted combination method classified into high and low priority for sediment. The weights used in the classification are also found in Table 6-12.

Table 6-10: Fuzzy Membership Values and Runoff Categories.

Subwatershed	Runoff Category	FMV
Aubrey Valley	1	0.2
Upper Big Chino Wash	2	0.4
Ash Fork Draw-Jumbo Tank	1	0.2
Upper Partridge Creek	2	0.4
Lower Partridge Creek	1	0.2
Middle Big Chino Wash	1	0.2
Williamson Valley Wash	2	0.4
Lower Big Chino Wash	2	0.4
Granite Creek-Upper Verde River	3	0.6
Hell Canyon	1	0.2
Sycamore Creek	5	1.0
Grindstone Wash-Upper Verde River	1	0.2
Oak Creek	5	1.0
Beaver Creek	5	1.0
Cherry Creek-Upper Verde River	1	0.2
West Clear Creek	4	0.8
East Verde River	3	0.6
Fossil Creek-Lower Verde River	4	0.8
Tangle Creek-Lower Verde River	4	0.8
Lower Verde River-Horseshoe and Bartlett Reservoir	4	0.8
Mesquite Wash-Sycamore Creek	4	0.8
Camp Creek-Lower Verde River	4	0.8

Table 6-11: Fuzzy Membership Values and Erosion Categories.

Subwatershed	Erosion Category	FMV
Aubrey Valley	1	0.2
Upper Big Chino Wash	1	0.2
Ash Fork Draw-Jumbo Tank	1	0.2
Upper Partridge Creek	1	0.2
Lower Partridge Creek	1	0.2
Middle Big Chino Wash	1	0.2
Williamson Valley Wash	1	0.2
Lower Big Chino Wash	1	0.2
Granite Creek-Upper Verde River	1	0.2
Hell Canyon	1	0.2
Sycamore Creek	2	0.4
Grindstone Wash-Upper Verde River	2	0.4
Oak Creek	4	0.8
Beaver Creek	3	0.6
Cherry Creek-Upper Verde River	3	0.6
West Clear Creek	3	0.6
East Verde River	3	0.6
Fossil Creek-Lower Verde River	5	1.0
Tangle Creek-Lower Verde River	4	0.8
Lower Verde River-Horseshoe and Bartlett Reservoir	4	0.8
Mesquite Wash-Sycamore Creek	5	1.0
Camp Creek-Lower Verde River	4	0.8

Table 6-12: Results for Sediment Based on the Fuzzy Logic Approach.

Subwatershed Name	WQA[1]	Owner	HU Index / HUC	HU Index / Riparian	Runoff	Erosion	FMV Weighted
Aubrey Valley	0.7	1.00	0.00	0.00	0.2	0.2	0.16
Upper Big Chino Wash	0.7	1.00	0.00	0.00	0.4	0.2	0.22
Ash Fork Draw-Jumbo Tank	0.7	1.00	0.00	0.00	0.2	0.2	0.31
Upper Partridge Creek	0.7	1.00	0.00	0.00	0.4	0.2	0.22
Lower Partridge Creek	0.7	1.00	0.00	0.00	0.2	0.2	0.16
Middle Big Chino Wash	0.7	1.00	0.00	0.00	0.2	0.2	0.16
Williamson Valley Wash	0.0	1.00	0.00	0.18	0.4	0.2	0.22
Lower Big Chino Wash	0.7	1.00	0.00	0.31	0.4	0.2	0.28
Granite Creek-Upper Verde River	0.7	1.00	0.00	0.58	0.6	0.2	0.39
Hell Canyon	0.7	0.00	0.00	0.00	0.2	0.2	0.16
Sycamore Creek	1.0	0.00	0.00	0.00	1.0	0.4	0.47
Grindstone Wash-Upper Verde River	0.7	0.00	0.00	0.00	0.2	0.4	0.23
Oak Creek	1.0	1.00	0.00	0.33	1.0	0.8	0.91
Beaver Creek	1.0	0.00	0.00	0.05	1.0	0.6	0.54
Cherry Creek-Upper Verde River	1.0	1.00	0.04	1.00	0.2	0.6	0.49
West Clear Creek	0.0	0.00	0.00	0.01	0.8	0.6	0.42
East Verde River	0.8	0.00	0.00	0.04	0.6	0.6	0.41
Fossil Creek-Lower Verde River	1.0	0.00	0.00	0.39	0.8	1.0	0.67
Tangle Creek-Lower Verde River	0.8	0.00	0.00	0.00	0.8	0.8	0.52
Lower Verde River-Horseshoe and Bartlett Reservoir	0.7	0.00	0.00	0.00	0.8	0.8	0.52
Mesquite Wash-Sycamore Creek	0.5	0.00	0.00	0.00	0.8	1.0	0.57
Camp Creek-Lower Verde River	0.5	1.00	0.00	0.32	0.8	0.8	0.57
Weights	*0.05*	*0.05*	*0.1*	*0.2*	*0.3*	*0.3*	

[1]WQA = Water Quality Assessment results

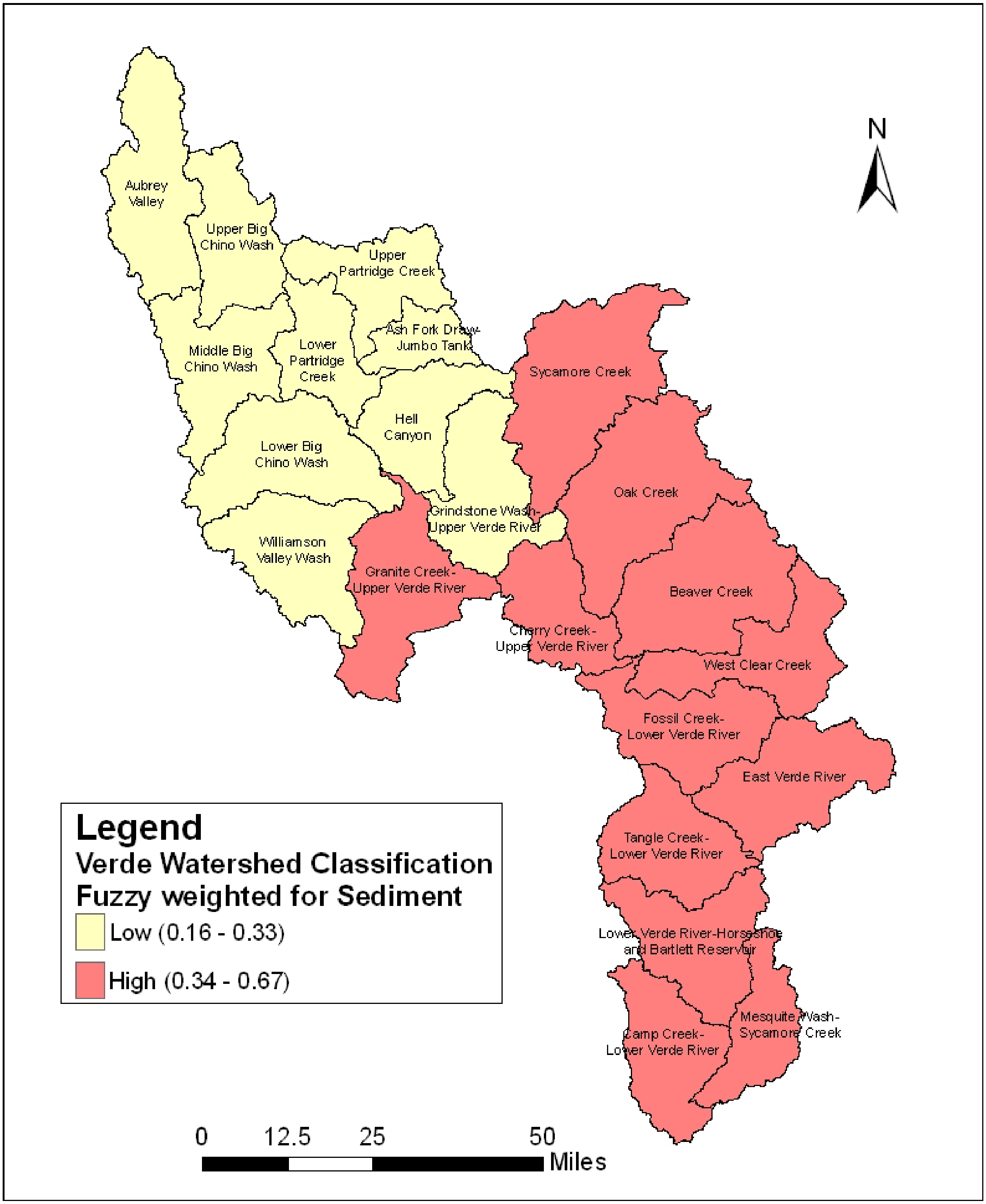


Figure 6-3: Results for the Fuzzy Logic Classification for Sediment Based on the Weighted Combination Approach.

Organics

Several water quality parameters that have been identified as concerns in the Verde Watershed are related to the introduction of organic material to a water body. Seven reaches and lakes have been classified as not attaining for dissolved oxygen or E. coli: Granite Creek from headwaters to Willow Creek, Watson Lake, Whitehorse Lake, Oak Creek at Slide Rock State Park, Stoneman Lake, Peck's Lake, and Grande Wash.

The factors that were used for organic material classification are:

- ADEQ water quality assessment results for organic parameters, including dissolved oxygen, nitrates and TDS;
- Human use index within both the overall subwatershed and within the riparian area; and
- Land use, including grazing and agriculture.

Water Quality Assessment Data - Organics

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005) was used to define the current water quality conditions based on water quality measurements. In assigning fuzzy membership values, the location of the 10-digit HUC subwatershed relative to an impaired water or reach was considered. Table 6-2 contains the fuzzy membership values used for different subwatershed conditions based on the water quality assessment results. Table 6-13 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed for organics classification.

Human Use Index - Organics

The Human Use Index was used to assess the relative impact of urban development on the presence of organics in stream water. The Human Use Index is defined as the percentage of a subwatershed that is disturbed by development and human use. In the Verde Watershed, human use consists of developed areas as defined by National Land Cover Data as residential land use, mining and roads.

Human activity can introduce organic material to a water body by disposal of organic compounds and sewage. Most of the residential development outside of cities in the Verde River Watershed utilizes onsite septic sewage systems. Currently, the construction of new septic systems requires a permit from ADEQ in the State of Arizona (some exemptions apply), and an inspection of the septic system is required when a property is sold if it was originally approved for use on or after Jan. 1, 2001 by ADEQ or a delegated county agency (http://www.azdeq.gov/environ/water/permits/wastewater.html).

Table 6-13: Fuzzy Membership Values Assigned to each 10-digit HUC Subwatershed in the Verde Watershed Based on Water Quality Assessment Results for Organics.

Subwatershed Name	FMV	Justification
Aubrey Valley	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Upper Big Chino Wash	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Ash Fork Draw-Jumbo Tank	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Upper Partridge Creek	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Lower Partridge Creek	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Middle Big Chino Wash	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Williamson Valley Wash	1.0	Classified as high risk, drains into Granite Creek-Upper Verde River that is classified as an extreme risk
Lower Big Chino Wash	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Granite Creek-Upper Verde River	1.0	Classified as extreme risk
Hell Canyon	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Sycamore Creek	1.0	Classified as extreme risk
Grindstone Wash-Upper Verde River	0.7	Classified as moderate risk, drains into Cherry Creek-Upper Verde River that is classified as an extreme risk
Oak Creek	1.0	Classified as extreme risk
Beaver Creek	1.0	Classified as extreme risk
Cherry Creek-Upper Verde River	1.0	Classified as extreme risk
West Clear Creek	0.0	Classified as low risk
East Verde River	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Fossil Creek-Lower Verde River	1.0	Classified as high risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Tangle Creek-Lower Verde River	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Lower Verde River-Horseshoe and Bartlett Reservoir	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Mesquite Wash-Sycamore Creek	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Camp Creek-Lower Verde River	1.0	Classified as extreme risk

However, there are no requirements for regular inspections of older septic systems and as a result, rural areas may have a significant impact on the introduction of organic material to the environment.

Human use has been assessed at both the subwatershed and riparian area scale (< = 250 meters from a stream). The fuzzy membership functions for both conditions are as follows:

Human Use Index (HUI)/ HUC watershed:

FMV = 0 if (HUI < = 1%)
FMV = (HUI – 1) / 3
FMV = 1 if (HUI > = 4%)

Human Use Index/Riparian:

FMV = 0 if (HUI < = 0%)
FMV = (HUI - 0) / 4
FMV = 1 if (HUI > = 4%)

Table 6-14 contains the fuzzy membership values assigned to each 10- digit HUC subwatershed in the Verde Watershed for organics based on the Human Use Index.

Land Use - Organics

The principal land use in the Verde Watershed is livestock grazing. Livestock grazing occurs primarily on federal government land (BLM and USFS), Arizona State Trust Land and privately owned land.

Each 10-digit HUC watershed was assigned a fuzzy membership value based on its primary land use relative to livestock grazing. The Tangle Creek-Lower Verde River watershed was assigned a value of 0.0 because the Mazatzal Wilderness Area covers much of it, which suggests that the land is managed and nonpoint source pollution is controlled.

Table 6-14: Fuzzy Membership Values for Organics Based on the Human Use Index.

Subwatershed	FMV HU Index Watershed	FMV HU Index Riparian
Aubrey Valley	**0.00**	**0.08**
Upper Big Chino Wash	**0.00**	**0.15**
Ash Fork Draw-Jumbo Tank	**0.05**	**0.25**
Upper Partridge Creek	**0.00**	**0.17**
Lower Partridge Creek	**0.00**	**0.06**
Middle Big Chino Wash	**0.00**	**0.19**
Williamson Valley Wash	**0.03**	**0.43**
Lower Big Chino Wash	**0.15**	**0.56**
Granite Creek-Upper Verde River	**0.87**	**0.83**
Hell Canyon	**0.00**	**0.12**
Sycamore Creek	**0.00**	**0.19**
Grindstone Wash-Upper Verde River	**0.00**	**0.12**
Oak Creek	**0.21**	**0.58**
Beaver Creek	**0.00**	**0.30**
Cherry Creek-Upper Verde River	**1.00**	**1.00**
West Clear Creek	**0.00**	**0.26**
East Verde River	**0.12**	**0.29**
Fossil Creek-Lower Verde River	**0.27**	**0.64**
Tangle Creek-Lower Verde River	**0.00**	**0.00**
Lower Verde River-Horseshoe and Bartlett Reservoir	**0.00**	**0.10**
Mesquite Wash-Sycamore Creek	**0.00**	**0.07**
Camp Creek-Lower Verde River	**0.33**	**0.57**

Grindstone Wash-Upper Verde River and Cherry-Creek-Upper Verde River were also assigned a value of 0.0

because Arizona Preserve Initiative Preserves cover most of their area, which suggests that the land is managed and nonpoint source pollution is controlled. All other watersheds were initially assigned a value of 1.0 as land was assumed to be primarily used for livestock grazing.

Nutrients

According to Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), three stream reaches have exceedances for nitrogen and phosphorus, but the rates of exceedance for these reaches are low. Two lakes, Watson and Scholz Lakes, have high rates of exceedance for nitrogen. The source of nutrients for Watson Lake, located on the outskirts of Prescott, is likely runoff from residential areas where landscapes are fertilized. The nitrogen exceedances at Scholz Lake, located in the northern portion of the watershed where cattle grazing is prevalent, are likely related to animal waste.

Granite Basin Lake and Whitehorse Lake have exceedances for ammonia. This problem is most likely caused by decomposition of organic material under anaerobic conditions, and is not likely to be the result of a direct flush of ammonia into the system. Ammonia is highly volatile and typically does not persist in a water body. Coupled with the observation of reported low levels of dissolved oxygen and high pH found at these lakes, the likely explanation is due to organic material decomposition.

pH

According to Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2005), seven lakes have exceedances for pH (caustic) levels. Caustic pH measurements can be an indication of lake eutrophication. Typical unpolluted flowing water will have pH values ranging from 6.5 to 8.5 (unitless); however, where photosynthesis by aquatic organisms takes up dissolved carbon dioxide during daylight hours, a diurnal pH fluctuation may occur and the maximum pH value may sometimes reach as high as 9.0. Studies have found that in poorly buffered lake water, pH fluctuations occur with maximum pH values exceeding 12 (Hem, 1970). The fluctuation in pH has been found to be more pronounced in warm, arid lakes.

Organics Results

The weighted combination approach was used to create the combined fuzzy score, and the results are found in Table 6-15. Figure 6-4 shows the results of the weighted combination method classified into high and low priority for organics. The weights used in the classification are found in Table 6-15.

<u>Selenium</u>

Two stream reaches, Verde River (Bartlett Dam – Camp Creek) and East Verde River (Ellison Creek – American Gulch), were classified as "not attaining" for selenium. The Verde River from West Clear Creek to Fossil Creek also showed high exceedances for selenium and assessed as "inconclusive" in the ADEQ Water Quality report.

High values for selenium are associated with high values for metals in both reaches, and are likely to be naturally occurring in the highly mineralized soils of the region. In addition, high values may be associated with mining evaporation or tailing ponds, where evaporation would increase the relative concentration of selenium, as well as other constituents. One common source of elevated selenium in the western United States is drainage water from seleniferous irrigated soils (Hem, 1970).

Water Quality Assessment Data-Selenium

The ADEQ Water Quality Assessment results were used to define the current water quality based on water monitoring results. In assigning fuzzy membership values, the location of a subwatershed relative to an impaired water was considered. Table 6-16 contains the fuzzy membership values for selenium for each subwatershed based on the water quality assessment results.

Table 6-15: Results for Organics Based on the Fuzzy Logic Approach.

Subwatershed	WQA[1]	Owner	HUI / HUC	HUI / Riparian	Weighted
Aubrey Valley	0.7	1.0	0.00	0.08	0.43
Upper Big Chino Wash	0.7	1.0	0.00	0.15	0.46
Ash Fork Draw-Jumbo Tank	0.7	1.0	0.05	0.25	0.49
Upper Partridge Creek	0.7	1.0	0.00	0.17	0.46
Lower Partridge Creek	0.7	1.0	0.00	0.06	0.43
Middle Big Chino Wash	0.7	1.0	0.00	0.19	0.47
Williamson Valley Wash	1.0	1.0	0.03	0.43	0.64
Lower Big Chino Wash	0.7	1.0	0.15	0.56	0.61
Granite Creek-Upper Verde River	1.0	1.0	0.87	0.83	0.92
Hell Canyon	0.7	1.0	0.00	0.12	0.45
Sycamore Creek	1.0	1.0	0.00	0.19	0.56
Grindstone Wash-Upper Verde River	0.7	0.0	0.00	0.12	0.25
Oak Creek	1.0	1.0	0.21	0.58	0.72
Beaver Creek	1.0	1.0	0.00	0.30	0.60
Cherry Creek-Upper Verde River	1.0	0.0	1.00	1.00	0.80
West Clear Creek	0.0	1.0	0.00	0.26	0.28
East Verde River	0.7	1.0	0.12	0.29	0.52
Fossil Creek-Lower Verde River	1.0	1.0	0.27	0.64	0.74
Tangle Creek-Lower Verde River	0.7	0.0	0.00	0.00	0.21
Lower Verde River-Horseshoe and Bartlett Reservoir	0.7	1.0	0.00	0.10	0.44
Mesquite Wash-Sycamore Creek	0.7	1.0	0.00	0.07	0.43

Subwatershed	WQA[1]	Owner	HUI / HUC	HUI / Riparian	Weighted
Camp Creek-Lower Verde River	**1.0**	**1.0**	**0.33**	**0.57**	**0.74**
Weights	***0.3***	***0.2***	***0.2***	***0.3***	

[1]WQA = Water Quality Data results

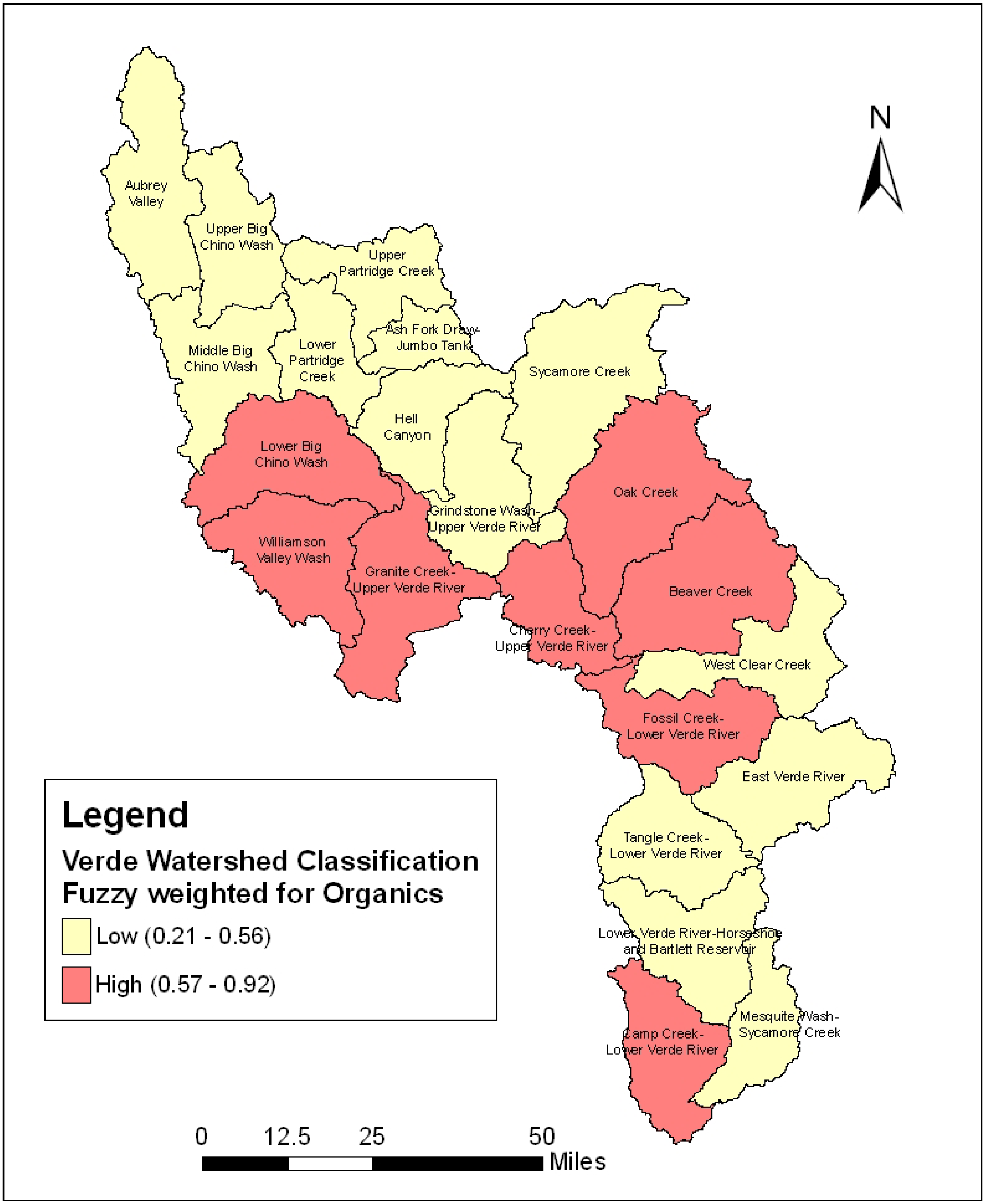


Figure 6-4: Results for the Fuzzy Logic Classification for Organics Based on the Weighted Combination Approach.

Table 6-16: Fuzzy Membership Values Assigned to each 10-digit HUC Subwatershed in the Verde Watershed Based on Water Quality Classification Results for Selenium.

Subwatershed Name	FMV	Justification
Aubrey Valley	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Upper Big Chino Wash	0.6	Classified as moderate risk, drains into Fossil Creek -Upper Verde River that is classified as high risk
Ash Fork Draw-Jumbo Tank	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Upper Partridge Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Lower Partridge Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Middle Big Chino Wash	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Williamson Valley Wash	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Lower Big Chino Wash	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Granite Creek-Upper Verde River	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Hell Canyon	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Sycamore Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Grindstone Wash-Upper Verde River	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Oak Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Beaver Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
Cherry Creek-Upper Verde River	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
West Clear Creek	0.6	Classified as moderate risk, drains into Fossil Creek-Lower Verde River that is classified as high risk
East Verde River	1.0	Classified as extreme risk
Fossil Creek-Lower Verde River	1.0	Classified as high risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Tangle Creek-Lower Verde River	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as extreme risk
Lower Verde River-Horseshoe and Bartlett Reservoir	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Mesquite Wash-Sycamore Creek	0.7	Classified as moderate risk, drains into Camp Creek - Lower Verde River that is classified as an extreme risk
Camp Creek-Lower Verde River	1.0	Classified as extreme risk

Agricultural Lands

The percentage of the agricultural lands in each 10-digit HUC subwatershed was calculated as shown in Table 6-17.

Since the percentage of agricultural land in each subwatershed is small, this result shows that there is no correlation between the percentage of agricultural land and selenium impairment in the watershed. Therefore another index based on prevalence of metalliferous mines within the subwatershed was used to represent the relationship.

Number of Mines per Watershed

Elevated concentrations of selenium in the waters of the Verde Watershed are likely due to naturally occurring selenium in the metal-rich soils and rocks. To classify subwatersheds likely to exhibit exceedance in Selenium, the number of mines in each 10-digit HUC subwatershed was calculated and a fuzzy membership value assigned as shown in Table 6-18.

Table 6-18: Fuzzy Membership Values Based on Number of Mines in each 10-digit HUC Subwatershed.

Number of Mines in Each Subwatershed	FMV
0-10	0.00
11-25	0.33
26-50	0.66
> 50	1.00

Table 6-17: Percentage of Agricultural Lands in each Subwatershed.

Subwatershed Name	Percentage of Agricultural Land
Aubrey Valley	0.002%
Upper Big Chino Wash	0.004%
Ash Fork Draw-Jumbo Tank	0.016%
Upper Partridge Creek	0.001%
Lower Partridge Creek	0.003%
Middle Big Chino Wash	0.050%
Williamson Valley Wash	0.612%
Lower Big Chino Wash	1.108%
Granite Creek-Upper Verde River	1.095%
Hell Canyon	0.001%
Sycamore Creek	0.002%
Grindstone Wash-Upper Verde River	0.004%
Oak Creek	0.267%
Beaver Creek	0.053%
Cherry Creek-Upper Verde River	1.853%
West Clear Creek	0.227%
East Verde River	0.080%
Fossil Creek-Lower Verde River	0.953%
Tangle Creek-Lower Verde River	0.000%
Lower Verde River-Horseshoe and Bartlett Reservoir	0.117%
Mesquite Wash-Sycamore Creek	0.000%
Camp Creek-Lower Verde River	0.534%

Table 6-19 shows the fuzzy membership values for each 10-digit HUC subwatershed based on the number of mines.

Selenium Results

The fuzzy membership values were used to create a combined fuzzy score for each subwatershed and were incorporated into the weighted combination method (Figure 6-5). These results are found in Table 6-20, and the weights are listed at the bottom of the table.

Table 6-19: Fuzzy Membership Values for each 10-digit HUC Subwatershed Based on the Number of Mines.

Subwatershed Name	Number of mines	FMV for mines/HUC
Aubrey Valley	0	0.000
Upper Big Chino Wash	1	0.000
Ash Fork Draw-Jumbo Tank	21	0.330
Upper Partridge Creek	35	0.660
Lower Partridge Creek	15	0.330
Middle Big Chino Wash	11	0.330
Williamson Valley Wash	11	0.330
Lower Big Chino Wash	10	0.000
Granite Creek-Upper Verde River	61	1.000
Hell Canyon	14	0.330
Sycamore Creek	17	0.330
Grindstone Wash-Upper Verde River	50	0.660
Oak Creek	11	0.330
Beaver Creek	11	0.330
Cherry Creek-Upper Verde River	117	1.000
West Clear Creek	6	0.000
East Verde River	25	0.330
Fossil Creek-Lower Verde River	12	0.330
Tangle Creek-Lower Verde River	7	0.000
Lower Verde River-Horseshoe and Bartlett Reservoir	10	0.000
Mesquite Wash-Sycamore Creek	30	0.660
Camp Creek-Lower Verde River	15	0.330

Table 6-20: Weighted Combination Method Results for Selenium Based on the Fuzzy Logic Approach.

Subwatershed Name	WQA[1]	FMV for mines/HUC	FMV Weighted
Aubrey Valley	0.6	0.000	0.300
Upper Big Chino Wash	0.6	0.000	0.300
Ash Fork Draw-Jumbo Tank	0.6	0.330	0.465
Upper Partridge Creek	0.6	0.660	0.630
Lower Partridge Creek	0.6	0.330	0.465
Middle Big Chino Wash	0.6	0.330	0.465
Williamson Valley Wash	0.6	0.330	0.465
Lower Big Chino Wash	0.6	0.000	0.300
Granite Creek-Upper Verde River	0.6	1.000	0.800
Hell Canyon	0.6	0.330	0.465
Sycamore Creek	0.6	0.330	0.465
Grindstone Wash-Upper Verde River	0.6	0.660	0.630
Oak Creek	0.6	0.330	0.465
Beaver Creek	0.6	0.330	0.465
Cherry Creek-Upper Verde River	0.6	1.000	0.800
West Clear Creek	0.6	0.000	0.300
East Verde River	1.0	0.330	0.665
Fossil Creek-Lower Verde River	1.0	0.330	0.665
Tangle Creek-Lower Verde River	0.7	0.000	0.350
Lower Verde River-Horseshoe and Bartlett Reservoir	0.7	0.000	0.350
Mesquite Wash-Sycamore Creek	0.7	0.660	0.680
Camp Creek-Lower Verde River	1.0	0.330	0.665
Weights	0.5	0.5	

1WQA = Water Quality Assessment results

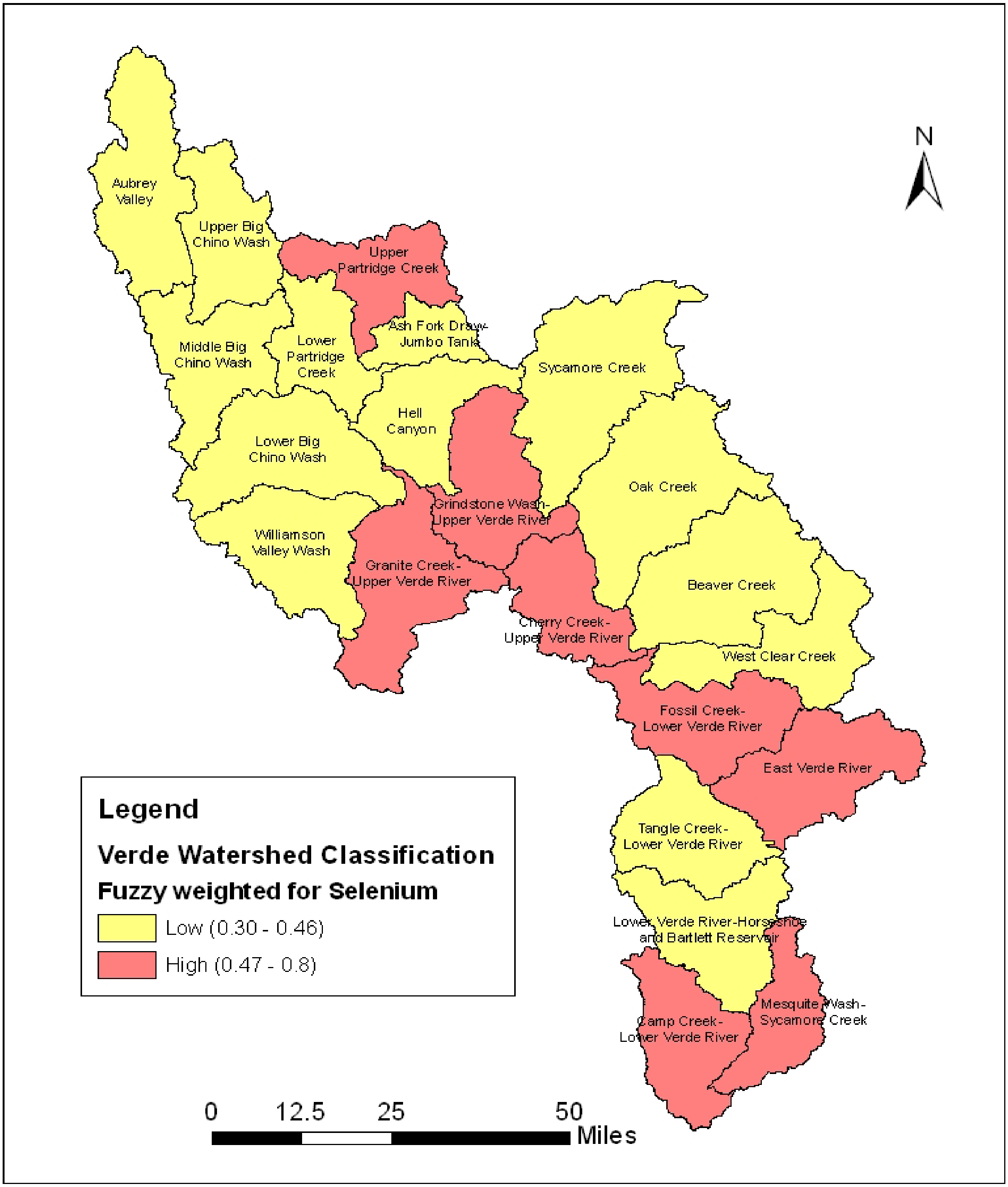


Figure 6-5: Results for the Fuzzy Logic Classification for Selenium Based on the Weighted Combination Approach.

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**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Section 7: Watershed Management

This section discusses the recommended watershed management activities to address nonpoint source pollution concerns in the Verde Watershed. These recommendations are subject to revision by land use decision makers and stakeholders, and may be revised based on new data as it becomes available. It is understood that the application of any management activities will require site-specific design and may require licensed engineering design. These recommendations are only general in nature and are presented herein so as to allow land use decision makers and watershed stakeholders to conceptualize how best to address watershed management.

Three reaches and three lakes in the Verde Watershed are in ADEQ's TMDL list (ADEQ, 2004). A TMDL plan is a study for an impaired water body that defines the maximum amount of a specified water quality parameter or pollutant that can be carried by a waterbody without causing an exceedance of water quality standards.

Management Methods

The section includes general watershed management methods, recommended strategies for addressing existing impairment in the watershed, stream channel and riparian restoration, and proposed education programs. The general watershed management methods include:

- Site management on new development;
- Monitoring and enforcement activities;
- Water quality improvement and restoration projects; and
- Education.

Each of these methods is defined further below, and is addressed within each of the three classifications: metals, organics, and nutrient nonpoint source pollutant water quality concerns.

Site Management on New Development:

Control the quantity and quality of water run-off from new development sites. The primary sources for future development in the Verde Watershed include the mining industry, new housing developments and increased urbanization, and new road construction. The Lower Big Chino Wash, Upper Verde River, and Camp Creek-Lower Verde River Natural Resource Areas are particularly at risk to future housing development due to the large percentage of private land within the area.

Although it is recognized that ADEQ requires Aquifer Protection Permitting and the issuance of Stormwater Management Plans for active mine sites, new mine development in the watersheds should continue to be monitored. It is important to promote the application of nonpoint source management measures on all new development sites through cooperation with local government, developers and private land owners.

Monitoring and Enforcement Activities:

- Continue and expand water quality monitoring programs in the watershed to measure the effectiveness of management practices on protecting and restoring the waters of the Verde Watershed.
- Promote septic tank inspections and certification of septic systems by local government entities.
- Promote construction site inspection and enforcement action for new development.

Water Quality Improvement and Restoration Projects:

- Promote efforts to protect and restore the natural functions and characteristics of impaired water bodies. Potential projects are discussed below.
- Integrate adaptive management methods and activities across the watershed to address existing and future problems.

Education:

- Develop programs to increase the awareness and participation of citizens, developers and local decision makers in the watershed management efforts. Education programs are discussed below.

<u>Strategy for Addressing Existing Impairment</u>

The major sources of water quality impairment and environmental damage in the Verde waters are elevated concentrations of dissolved and particulate metals, sediment and organics. The high priority 10-digit HUC subwatersheds were identified for each constituent group in the previous section on Watershed Classification (Section 6).

The goal of this section is to describe a strategy for dealing with the sources of impairment for each constituent group. The management measures discussed herein are brief and meant to provide initial guidance to the land use decision makers and watershed stakeholders.

Detailed descriptions of the following management measures, in addition to a manual of nonpoint source best management practices (BMPs), can be found at the NEMO website www.srnr.arizona.edu/nemo.

<u>Metals</u>

The primary nonpoint source of anthropogenic metals in the Verde Watershed is abandoned mines, although it is recognized that naturally occurring metals originating from local highly mineralized soils may contribute to elevated background concentrations in streams and lakes. Industrial and urban sources of metals are also important due to the amount of development in the watershed. The Verde Watershed has a long history of mining, with many abandoned and several active mines found across the watershed. In most cases the original owner or responsible party for an abandoned mine is unknown and the responsibility for the orphaned mine falls to the current landowner.

Abandoned / orphaned mines are found on all classes of land ownership in the Verde Watershed, including federal, state and private lands, with a majority of the mines located on land administered by the Private sector, Federal government, and the State of Arizona. Surface runoff and erosion from mine waste / tailings is the principal source of nonpoint source contamination. Subsurface drainage from mine waste / tailings can also be a concern. The recommended actions include:

- Inventory of existing abandoned mines;
- Revegetation of disturbed mined lands;
- Erosion control;
- Runoff and sediment capture;
- Tailings and mine waste removal; and
- Education.

Load reduction potential, maintenance, cost and estimated life of revegetation and erosion control treatments for addressing metals from abandoned mines is found in Table 7-1.

Table 7-1. Proposed Treatments for Addressing Metals from Abandoned Mines.

Action	Load Reduction Potential	Estimated Time Load Reduction	Expected Maintenance	Expected Cost	Estimated Life of Treatment
Revegetation	**Medium**	**< 2 years**	**Low**	**Low-Medium**	**Long**
Erosion Control Fabric	**High**	**Immediate**	**Low**	**Low-Medium**	**Short**
Plant Mulch	**Low**	**Immediate**	**Low**	**Low**	**Short**
Rock Mulch	**High**	**Immediate**	**Medium**	**Low-High**	**Long**
Toe Drains	**High**	**Immediate**	**Medium**	**Medium**	**Medium**
Detention Basin	**High**	**Immediate**	**High**	**High**	**Medium-Long**
Silt Fence	**Medium**	**Immediate**	**Medium**	**Low**	**Short-Medium**
Straw Roll/bale	**Medium**	**Immediate**	**High**	**Low**	**Short**
Removal	**High**	**Immediate**	**Low**	**High**	**Long**

NOTE: The actual cost, load reduction, or life expectancy of any treatment is dependent on site specific conditions. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Inventory of Existing Abandoned Mines:

All existing abandoned mines are not equal sources for elevated concentrations of metals. One of the difficulties in developing this assessment is the lack of thorough and centralized data on abandoned mine sites. Some of the mapped abandoned mine sites are prospector claims with limited land disturbance, while others are remote and disconnected from natural drainage features and represent a low risk pollutant source.

At sites where water and oxygen are in contact with waste rock containing sulfates, sulfuric acid is formed. As the water becomes more acidic, metals are leached from the soils and rock, generating toxic concentrations of heavy metals in the water. Acid rock drainage, also known as acid mine drainage, can be a significant water quality concern. Management of this important source of watershed impairment begins with compiling available information from the responsible agencies. This information can be used to conduct an onsite inventory to clarify the degree of risk the site exhibits towards discharging elevated concentrations of metals to a water body.

Risk factors to be assessed include: area and volume of waste/tailings; metal species present and toxicity; site drainage features and metal transport characteristics (air dispersion, sediment transport, acid mine drainage, etc.); distance to a water body; and evidence of active site erosion. Abandoned mine sites can then be ranked and prioritized for site management and restoration.

Revegetation:

Revegetation of the mine site is the only long-term, low maintenance restoration alternative in the absence of funding to install engineered site containment and capping. In semiarid environments, revegetation of a disturbed site is relatively difficult even under optimal conditions. The amount of effort required to revegetate an abandoned mine site depends on the chemical composition of the mine waste/tailings, which may be too toxic to sustain growth.

The addition of soil amendments, buffering agents, or capping with top soil to sustain vegetation often approaches the costs associated with engineered capping. If acid mine drainage is a significant concern, intercepting and managing the acidic water may necessitate extensive site drainage control systems and water treatment, a significant increase in cost and requiring on-going site operation and maintenance.

Reclaimed Mine Site
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/awardwy.htm)

Erosion Control:

If revegetation of the mine site is impractical, site drainage and erosion control treatments are alternatives. Erosion control actions can also be applied in combination with revegetation to control erosion as the vegetation cover is established. Erosion control fabric and plant mulch are two short-term treatments that are usually applied in combination with revegetation.

Rock mulch (i.e. rock riprap) is a long-term treatment, but can be costly and impractical on an isolated site. Rock mulch can be an inexpensive acid buffering treatment if carbonate rocks (limestone) are locally available. As the acidic mine drainage comes in contact with the rock mulch, the water looses it's acidity and dissolved metals precipitate out of the water column. A disadvantage of erosion control treatments is that they do not assist in dewatering a site and may have little impact on subsurface acidic leaching.

Table 7-2. Proposed Treatments for Addressing Erosion and Sedimentation.

Action	Load Reduction Potential	Estimated Time to Load Reduction	Expected Maintenance	Expected Cost	Estimated Life of Treatment
Grazing Mgt.	Medium	< 2 years	Low	Low	Long
Filter Strips	High	< 2 years	Low	Low	Long
Fencing	Low	Immediate	Low	Low	Medium
Watering Facility	Medium	Immediate	Low	Low-Medium	Medium
Rock Riprap	High	Immediate	Medium	Medium-High	Long
Erosion Control Fabric	High	Immediate	Low	Low-Medium	Short
Toe Rock	High	Immediate	Low	Medium	Long
Water Bars	Medium	Immediate	Medium	Medium	Medium
Road Surface	High	Immediate	Medium	High	Long

Note: The actual cost, load reduction, or life expectancy of any treatment is dependant on site specific conditions. Low costs could range from nominal to $10,000, medium costs could range between $5,000 and $50,000, and high costs could be anything greater than $25,000. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Runoff and Sediment Capture:

The capture and containment of site runoff and sediment, and prevention of the waste rock and tailings from contact with a water body are other management approaches. Short-term treatments include installing straw roll/bale or silt fence barriers at the toe of the source area to capture sediment.

Long-term treatments include trenching the toe of the source area to capture the runoff and sediment. If the source area is large, the construction of a detention basin may be warranted.
Disadvantages of runoff and sediment capture and containment treatments are that they may concentrate the contaminated material, especially if dissolved metals are concentrated by evaporation in retention ponds. Structural failure can lead to downstream transport of pollutants. The retention / detention of site runoff can also escalate subsurface drainage problems by ponding water.

Rock Rip-Rap Sediment Control
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/ocphoto.htm)

Load reduction potential, maintenance, cost and estimated life of runoff and sediment control treatments such as toe drains, basins, and silt fences are found in Table 7-2.

Removal:

The mine waste/tailing material can be excavated and removed. This treatment is very expensive and infeasible for some sites due to lack of accessibility.

Rock Structure for Runoff Control
(Dept. of the Interior, Office of Surface Mining, http://www.osmre.gov/ocphoto.htm)

Education:

Land use decision makers and stakeholders need to be educated on the problems associated with abandoned mines and the available treatments to mitigate the problems. In addition, abandoned mine sites are health and safety concerns and the public should be warned about entering open shafts that may collapse, or traversing unstable slopes. Due to the financial liability associated with site restoration, legal and regulatory constraints must also be addressed.

The target audiences for education programs are private land owners, watershed groups, local officials and land management agencies (U.S. Forest Service, Bureau of Land Management, Tribal entities).

Figure 7-1 shows land ownership across the 10-digit HUCs, and Table 7-3 provides a listing of percentage of land ownership as distributed across the subwatershed areas. This table provides a basis from which to identify stakeholders pertinent to each subwatershed area, and is repeated here in more detail after a brief discussion of land ownership in Section 4, Social and Economic Characteristics of the watershed.

Subwatershed areas prioritized for educational outreach to address metals include Upper Partridge Creek, Ash Fork Draw-Jumbo Tank, Hell Canyon, Grindstone Wash-Upper Verde River, Granite Creek-Upper Verde River, Oak Creek, Cherry Creek- Upper Verde River, West Clear Creek, East Verde River, and Camp Creek-Lower Verde River.

Sediment

Erosion and sedimentation are major environment problems in the western United States, including the Verde Watershed. In semiarid regions, the primary source of sediment is from channel scour. Excessive channel scour and down-cutting can lead to deterioration of riparian systems' extent and condition. Increases in channel scour are caused by increased surface runoff produced by changing watershed conditions. Restoration of impaired channel riparian systems can also mitigate erosion damage.

The primary land uses in the Verde Watershed that can contribute to erosion are livestock grazing and mining. Development, which also contributes to erosion, is increasing in some portions of the watershed. Impervious land surfaces accelerate surface runoff, increase flow velocity, and exacerbates channel scour. Dirt roads can be an important source of sediment as well. The recommended sediment management actions (see Table 7-2) are:

- Grazing Management
- Filter Strips
- Fencing
- Watering Facilities
- Rock Riprap
- Erosion Control Fabrics
- Toe Rock
- Water Bars
- Erosion Control on Dirt Roads
- Education

Grazing Management:

Livestock grazing is currently the primary land use in the Verde Watershed. Implementing grazing management practices to improve or maintain the health and vigor of plant communities will lead to reductions in surface runoff and erosion. Sustainable livestock grazing can be achieved in all plant communities by changing the duration, frequency and intensity of grazing.

Management may include exclusion of the land from grazing, seasonal rotation, rest or some combination of these options. Proper grazing land management provides for a healthy riparian plant community that stabilizes stream banks, creates habitat and slows flood velocities.

Filter Strips:

Creating a filter strip along a waterbody will retard the movement of sediment into the waterbody, and may remove pollutants from runoff before the material enters the body of water. Filter strips will reduce sedimentation of streams, lakes and other bodies of water, and protect channel and riparian systems from livestock grazing and tramping. Fencing the filter strip is usually required when livestock are present. Filter strips and fencing can be used to protect other sensitive ecological resources.

Filter Strip near Waterbody
U.S. E.P.A. (http://www.epa.gov/owow/nps/ex-bmps.html)

Fencing:

Restricting access to riparian corridors by fencing will allow for the reestablishment of riparian vegetation. Straw bale fencing slows runoff and traps sediment from sheet flow or channelized flow in areas of soil disturbance.

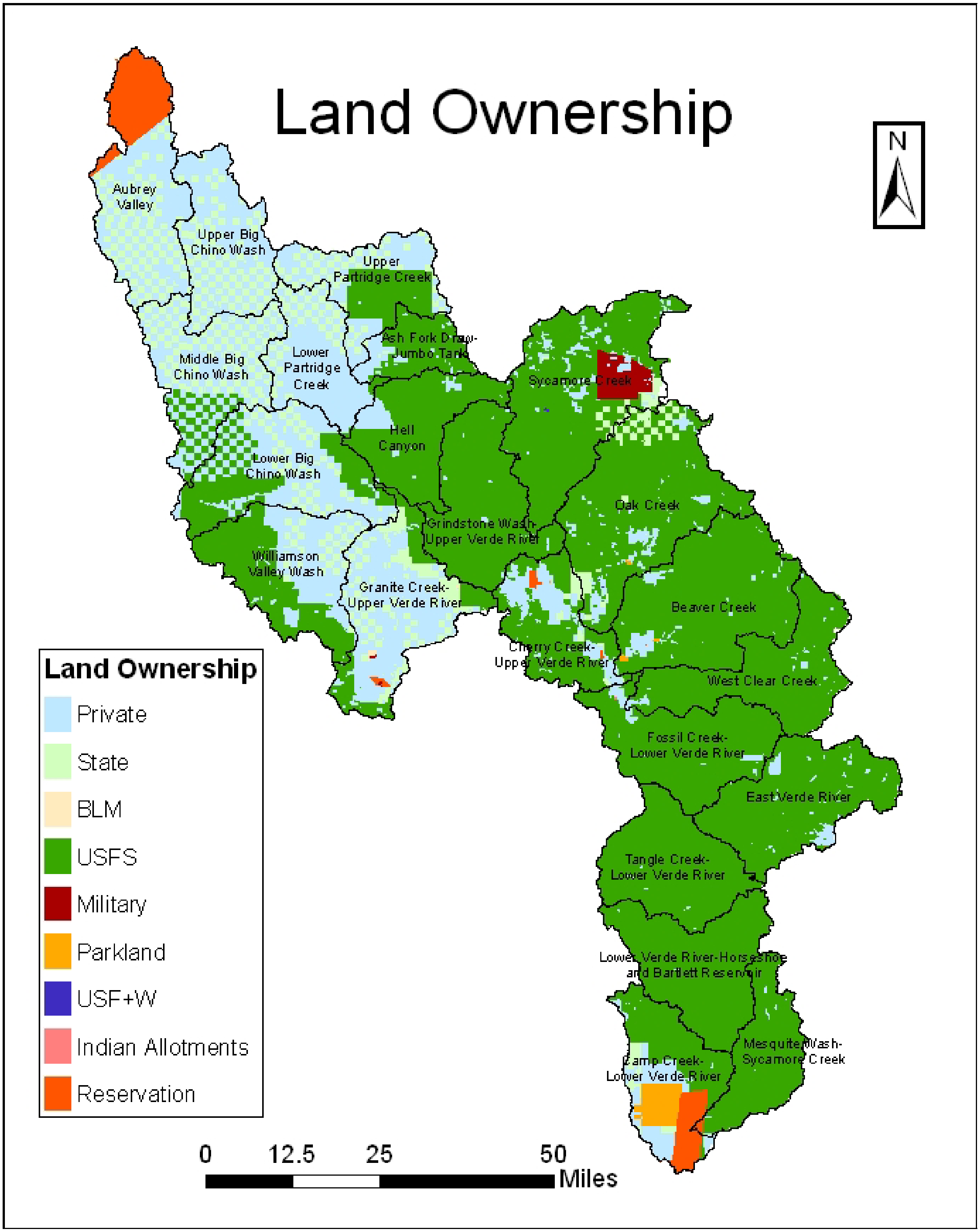


Figure 7-1: Verde Watershed Land Ownership by Subwatershed

Table 7-3: Percentage Land Ownership by Subwatershed in the Verde Watershed.

Subwatershed	Private	State Trust Lands	U.S. Bureau of Land Mgmt	U.S. Forest Service	Military Reserv.	Nat'l Park Service	U.S, Fish & Wildlife Service	Indian Allotment (1)	Indian Reserv.
Aubrey Valley	**46.10**	**27.15**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**26.75**
Upper Big Chino Wash	**66.52**	**33.48**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Ash Fork Draw-Jumbo Tank	**20.02**	**1.60**	**0.00**	**78.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Upper Partridge Creek	**43.15**	**21.90**	**0.00**	**34.96**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Lower Partridge Creek	**77.75**	**19.89**	**0.00**	**2.36**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Middle Big Chino Wash	**55.35**	**31.92**	**0.00**	**12.73**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Williamson Valley Wash	**37.87**	**9.58**	**0.00**	**52.55**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Lower Big Chino Wash	**49.27**	**13.23**	**0.00**	**37.49**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Granite Creek-Upper Verde River	**55.48**	**23.92**	**0.36**	**19.38**	**0.26**	**0.00**	**0.00**	**0.00**	**0.60**
Hell Canyon	**9.73**	**0.00**	**0.00**	**90.27**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Sycamore Creek	**6.39**	**3.12**	**0.00**	**81.89**	**8.55**	**0.00**	**0.05**	**0.00**	**0.00**
Grindstone Wash-Upper Verde River	**0.95**	**0.07**	**0.00**	**98.98**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Oak Creek	**7.73**	**6.79**	**0.00**	**85.35**	**0.00**	**0.11**	**0.02**	**0.00**	**0.00**
Beaver Creek	**4.82**	**0.00**	**0.00**	**94.85**	**0.00**	**0.31**	**0.00**	**0.00**	**0.03**
Cherry Creek-Upper Verde River	**27.36**	**4.21**	**0.00**	**66.77**	**0.00**	**0.03**	**0.00**	**0.00**	**1.64**
West Clear Creek	**2.12**	**0.00**	**0.00**	**97.88**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
East Verde River	**4.66**	**0.02**	**0.00**	**95.31**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**
Fossil Creek-Lower Verde River	**3.53**	**0.04**	**0.00**	**96.37**	**0.00**	**0.00**	**0.00**	**0.05**	**0.01**
Tangle Creek-Lower Verde River	**0.24**	**0.00**	**0.00**	**99.76**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Lower Verde River-Horseshoe and Bartlett Reservoir	**0.16**	**0.00**	**0.00**	**99.84**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Mesquite Wash-Sycamore Creek	**0.84**	**0.00**	**0.00**	**97.84**	**0.00**	**0.00**	**0.00**	**0.00**	**1.32**
Camp Creek-Lower Verde River	**20.98**	**5.09**	**0.00**	**45.60**	**0.00**	**12.92**	**0.00**	**0.00**	**15.41**
Percentage of Verde	***23.42***	***9.17***	***0.02***	***64.02***	***0.63***	***0.55***	***0.01***	***0.00***	***2.19***

(1) Non-Federally designated Indian Tribal land allotments.

Watering Facilities:

Alternative watering facilities, such as a tank, trough, or other watertight container at a location removed from the waterbody, can provide animal access to water, protect and enhance vegetative cover, provide erosion control through better management of grazing stock and wildlife, and protect streams, ponds and water supplies from biological contamination. Providing alternative water sources is usually required when creating filter strips.

Alternative Livestock Watering Facility
(EC Bar Ranch http://www.ecbarranch.com)

Rock Riprap:

Large diameter rock riprap reduces erosion when installed along stream channels and in areas subject to head cutting. Regrading may be necessary before placing the rocks, boulders or coarse stones, and best management practices should be applied to reduce erosion during regrading.

Erosion Control Fabric:

Geotextile filter fabrics reduce the potential for soil erosion as well as volunteer (weed) vegetation, and are often installed beneath rock riprap.

Rock Riprap and Jute Matting Erosion Control along a stream.
(Photo: Lainie Levick)

Toe Rock:

Placement of rock and riprap along the toe of soil slopes reduces erosion and increases slop stability.

Water Bars:

A water bar is a shallow trench with mounding long the down-slope edge that intercepts and redirects runoff water in areas of soil disturbance (tailings piles, dirt roads).

Erosion Control on Dirt Roads:

In collaboration with responsible parties, implement runoff and erosion control treatments on dirt roads and other disturbed areas. Dirt roads can contribute significant quantities of runoff and sediment if not properly constructed and managed. Water bars and surfacing are potential treatments. When a road is adjacent to a stream, it may be necessary to use engineered road stabilization treatments.

The stabilization of roads and embankments reduces sediment input from erosion and protects the related infrastructure. Traditional stabilization relied on expensive rock (riprap) treatments. Other options to stabilize banks include the use of erosion control fabric, toe rock and revegetation.

Bank Stabilization and Erosion Control along a highway
(Photo: Lainie Levick)

Channel and Riparian Restoration:

Restoration or reconstruction of a stream reach is used when the stream reach has approached or crossed a threshold of stability from which natural recovery may take too long or be unachievable. This practice significantly reduces sediment input to a system and will promote the riparian recovery process. Channel and riparian restoration will be discussed in more detail below.

Education:

The development of education programs will help address the impact of livestock grazing and promote the implementation of erosion control treatments. Education programs should address stormwater management from land development and target citizen groups, developers and watershed partnerships.

Based on the sediment and erosion classification completed in Section 6, subwatershed areas prioritized for educational outreach to address erosion control include Oak Creek, Beaver Creek, Cherry Creek-Upper Verde River, Granite Creek-Upper Verde River, West Clear Creek, East Verde River, Fossil Creek-Lower Verde River, Tangle Creek-Lower Verde River, Lower Verde River-Horseshoe and Bartlett Reservoir, Mesquite Wash-Sycamore Creek, and Camp Creek-Lower Verde River.

Verde River TMDL Implementation Plan for Sediment:

A turbidity/suspended sediment TMDL was developed for two reaches along the upper portion of the Verde River: a) from Oak Creek to Beaver Creek, and b) from West Clear Creek to Fossil Creek. Excessive suspended sediment and sedimentation negatively impact the aquatic ecosystem and is a detraction from recreation uses.

In the TMDL analysis, a targeted loading capacity is first calculated, which is the maximum pollutant load that the system can handle and still meet the surface water quality standards. Then this load is allocated among all sources, including an allocation set aside as a margin of safety to handle natural variation. Sources include waste load allocations for point sources and load allocations for nonpoint sources. Natural conditions are included in the nonpoint source load allocation. A TMDL Implementation Plan identifies strategies to reduce pollutant loadings and eventually meet the standard.

The TMDL analysis showed that surface water impairment in the Verde River was correlated to large storm events. The Verde River TMDL Implementation Plan (ADEQ, 2002) defined strategies and Best Management Practices that should be implemented to reduce sediment loading during storm events. These strategies include improving vegetative ground cover, maintaining and closing unimproved forest roads, and improving grazing practices throughout the watershed.

<u>Organics</u>

At several locations within the Verde Watershed, water quality problems associated with the introduction of animal waste were observed. The two primary sources of animal waste in the watershed are livestock grazing in riparian areas and failing septic systems. Livestock grazing is common across the entire watershed.

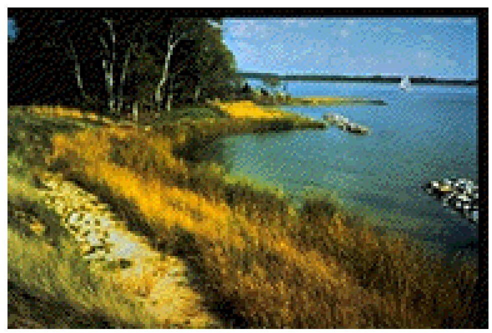
The Oak Creek, Peck's Lake, and Stoneman Lake TMDL plans are also summarized within this section. A TMDL is a study for an impaired water body that defines the maximum amount of a specified water quality parameter or pollutant that can be carried by a waterbody without causing an exceedance of water quality standards.

The recommended actions (see Table 7-4) for management of organics are:

- Filter Strips
- Fencing
- Watering Facilities
- Septic System Repair
- Education

Filter Strips:

Creating a filter strip along a water body will reduce and may remove pollutants from runoff before the material enters a body of water. Filter strips have been found to be very effective in removing animal waste due to livestock grazing, allowing the organics to bio-attenuate (i.e. be used by the plants) and degrade. Fencing the filter strip is usually required when dealing with livestock.



Filter Strip near Waterbody
U.S. E.P.A. (http://www.epa.gov/owow/nps/ex-bmps.html)

Fencing:

Restricting access to riparian corridors by fencing will allow for the reestablishment of riparian vegetation. Straw bale or silt fencing slows runoff and traps organics from sheet flow or channelized flow in areas of soil disturbance.

Watering Facilities:

Alternative watering facilities, such as a tank, trough, or other watertight container at a location removed from the waterbody, can provide animal access to water and protect streams, ponds and water supplies from biological contamination by grazing cattle. Providing alternative water sources is usually required when creating filter strips.

Table 7-4. Proposed Treatments for Addressing Organics.

Action	Load Reduction Potential	Estimated Time to Load Reduction	Expected Maintenance	Expected Cost	Estimated Life of Treatment
Filter Strips	**High**	**< 2 years**	**Low**	**Low**	**Long**
Fencing	**Low**	**Immediate**	**Low**	**Low**	**Medium**
Watering Facility	**Medium**	**Immediate**	**Low**	**Low-Medium**	**Medium**
Septic System Repair	**High**	**Medium**	**High**	**High**	**Medium**

Note: The actual cost, load reduction, or life expectancy of any treatment is dependant on site specific conditions. Low costs could range from nominal to $10,000, medium costs could range between $5,000 and $20,000, and high costs could be anything greater than $15,000. The terms used in this table express relative differences between treatments to assist users in evaluating potential alternatives. Only after a site-specific evaluation can these factors be quantified more rigorously.

Septic System Repair:

One of the difficulties in assessing the impact of failing septic systems to streams is the lack of thorough and centralized data on septic systems. Although it can be assumed that residential development in areas not served by sanitary sewers will rely on private, on-site septic systems, the status of the systems are usually unknown until failure is obvious to the home owner.

Currently, the construction of new septic systems requires a permit from ADEQ in the State of Arizona (some exemptions apply). In addition, ADEQ requires that the septic system be inspected when a property is sold if it was originally approved for use on or after Jan. 1, 2001 by ADEQ or a delegated county agency. This is to help selling and buying property owners understand the physical and operational condition of the septic system serving the home or business. The ADEQ website http://www.azdeq.gov/environ/water/permits/wastewater.html contains more information on permitting septic systems.

Although not required by ADEQ, older septic systems should be inspected when purchasing a home with an existing system.

At a minimum, conduct an inventory of locations where private septic systems occur to clarify the degree of risk a stream reach may exhibit due to failure of these systems. Risk factors can be assessed with GIS mapping tools, such as: proximity to a waterbody, soil type, depth to the water table, and density of development. Septic system sites can then be ranked and prioritized for further evaluation.

Education:

Develop educational programs that explain the sources of organics, address the impacts of livestock grazing, and promote the implementation of filter strips, fencing and alternative watering facilities. In addition, the programs should promote residential septic system maintenance, septic tank inspections and certification of septic systems by local municipalities or government entities.

Based on the results of the organics classification and ranking in Section 6, subwatershed areas that are prioritized for educational outreach to address organics include Lower Big Chino Wash, Williamson Valley Wash, Granite Creek-Upper Verde River, Oak Creek, Cherry Creek-Upper Verde River, Fossil Creek-Lower Verde River, Beaver Creek and Camp Creek-Lower Verde River.

TMDL Implementation Plans for Organics

The TMDL Plans for Oak Creek, Peck's Lake and Stoneman Lake are discussed below. In the TMDL analysis, a targeted loading capacity is first calculated, which is the maximum pollutant load that the system can handle and still meet surface water quality standards. This load is then allocated among all sources, including an allocation set aside as a margin of safety to handle natural variation. Sources include waste load allocations for point sources and load allocations for nonpoint sources. Natural conditions are included in the nonpoint source load allocation. A TMDL Implementation Plan identifies strategies to reduce pollutant loadings and eventually meet the standard.

Oak Creek TMDL Implementation Plan:

A bacteria TMDL was developed in 1999 for Oak Creek based on *E. coli* contamination at Slide Rock State Park. *E. coli* is recognized as a human health risk, and the 1999 TMDL analysis showed that the elevated *E. coli* was frequently correlated to holidays with heavy recreational use, stormwater flows and warm weather. Although Oak Creek is prized as a recreation destination, because of the potential human health risk, the State Parks Department closes Slide Rock when they find elevated *E. coli*; however, other segments of the stream remain open for recreational use. A Phase II TMDL is currently being developed to further determine the extent of contamination and other information that may help reduce health risks.

A variety of potential sources were identified based on a DNA study of the *E. coli* found in the sediment: humans (possibly from failing septic systems or inadequate toilet facilities) and domestic and wild animals (skunks, raccoons, dogs, horses, cows, llamas, etc.).

The 1999 TMDL Implementation plan identified strategies, including BMPs, that would reduce pollutant loading, such as identifying and replacing failing septic systems, reducing the amount of waste left at recreational sites along the river, reducing runoff from farms, picking up pet wastes, and providing more and cleaner toilet facilities. As the Phase II TMDL is completed, the Implementation Plan will also be revised, and may identify additional strategies for reducing *E. coli.*

Peck's Lake TMDL Implementation Plan:

Peck's Lake is actually an old oxbow in the Verde River near Clarkdale, Arizona. A nutrient TMDL was approved by EPA in 2000 due to excessive pH and low dissolved oxygen in the lake, which are stressors to aquatic ecosystems, and if associated with severe algae blooms or aquatic weeds, can result in fish kills.

The TMDL analysis identified that excessive nutrients in the water were related to internal cycling (nutrients not flushing out of the system) and nutrient loadings primarily from native vegetation in the immediate watershed.

The Peck's Lake TMDL Implementation Plan identified several strategies, including BMPs to maintain very low nutrient loadings from stormwater runoff from nearby residential and commercial areas (ADEQ, 2002).

Stoneman Lake TMDL Implementation Plan:

Stoneman Lake is a 120 acre natural lake located in the Coconino National Forest. A nutrient TMDL was approved by EPA in 2000 due to excessive pH and low dissolved oxygen, which are stressors to aquatic ecosystems, and if associated with severe algae blooms or aquatic weeds, can result in fish kills.

Similar to Peck's Lake, the TMDL analysis identified that excessive nutrients in the water were related to internal cycling of nutrients, exacerbated by the lake not having an outlet and marginal inflow. During droughts the lake frequently goes completely dry.

The TMDL Implementation Plan was developed as part of the TMDL, and it identified several strategies to improve lake management so that water quality standards could be met. These strategies included removing vegetation, increasing water inflow to the lake, and upgrading undersized or failing septic systems at the lake.

Selenium

Selenium occurs naturally in the environment; however, it can enter groundwater or surface water from hazardous waste-sites or irrigated farmland. The recommended action for the management of selenium is to avoid flood irrigation of croplands, and install a mechanized irrigation system.

Mechanized irrigation systems include center pivot, linear move, gated pipe, wheelline or drip irrigation. Based on a 1998 study (Hoffman and Willett, 1998) costs range from a low of $340 per acre for the PVC gated pipe to a high of $1,095 per acre for the linear move. The center pivot cost per acre is $550, and wheelline is $805 per acre.

Education:

Develop educational programs that explain the sources of selenium, and illustrate the various alternative irrigation systems.

Based on the results of the selenium classification and ranking in Section 6, subwatershed areas that are prioritized for educational outreach to address selenium include Upper Partridge Creek, Grindstone Wash-Upper Verde River, Granite Creek-Upper Verde River, Cherry Creek-Upper Verde River, Fossil Creek-Lower Verde River, East Verde River, Mesquite Wash-Sycamore Creek, and Camp Creek-Lower Verde River.

Strategy for Channel and Riparian Protection and Restoration

Riparian areas are one of the most critical resources in the Verde Watershed. Healthy riparian areas stabilize stream banks, decrease channel erosion and sedimentation, remove pollutants from surface runoff, create wildlife habitat, slow flood velocities, promote aquifer recharge and provide recreational opportunities. As ground water resources are tapped for water supply, many riparian areas across the watershed are in danger of being dewatered as the water table drops below the base of the stream channel. A large portion of the riparian systems in the watershed are managed by federal agencies, principally the U.S. Forest Service. In cooperation with responsible management agencies, riparian protection and restoration efforts should be implemented across the watershed.

The creation of filter strips should be considered surrounding all important water bodies and riparian systems within the five natural resource areas, including: the extensive riparian forests and perennial streams of the Upper Verde, Lower Verde, Mesquite Wash-Sycamore Creek, and Camp Creek-Lower Verde River Natural Resource Areas. This will require fencing and, in many cases, providing alternative water sources for livestock and wildlife. Riparian areas have been an important source of forage for most livestock growers, but to protect these delicate ecosystems, low impact riparian grazing systems should be developed and applied where feasible.

In impaired stream reaches restoration treatments maybe necessary. Treatments may involve engineered channel re-alignment, grade control and bank stabilization structures and a variety of revegetation and other bio-engineering practices.

Additional information will need to be collected on the existing impairment of stream reaches and riparian areas to better understand which stream segments should be prioritized for restoration projects. Data needs include:

- Studying the existing stream corridor structure, function and disturbances.
- Determining the natural stream conditions before disturbance. This entails identifying a "reference site" that illustrates the potential pristine stream conditions.
- Identifying the causes for the impairment and restoration alternatives.

- Identifying stream reaches that have a high potential to successfully respond to restoration treatments.

This watershed classification is one method used to identify stream impairment and restoration alternatives, but other data needs may also include identifying important issues, examining historic conditions, evaluating present conditions and processes, and determining the effects of human activities. It can mean describing the parts and processes of the whole watershed and analyzing their functions in general or relative to some standard (such as a water quality standard or historic condition). It also can mean focusing on particular concerns about human activities, conditions or processes in the watershed.

Stream and riparian restoration projects are costly and should be viewed as a long-term endeavor. Stream and riparian restoration projects cannot be conducted in isolation from other watershed activities. If the root cause of channel and riparian impairment is due to upstream watershed conditions, onsite restoration efforts are likely to fail unless the overall watershed conditions are also improved. This requires an integrated approach that crosses the entire watershed.

Citizen groups also have a role in the restoration efforts. Volunteers can be used in the tree planting and seeding treatments, and can also be used for grade control and bank stabilization construction. Education programs, such as 'Adopt A Stream', should be developed to encourage public understanding of the importance of maintaining natural riparian systems and restoration of degraded streams.

Education Programs:

The education effort will be partly conducted by the Arizona Nonpoint Education of Municipal Officials (NEMO) program. Arizona NEMO works through the University of Arizona Cooperative Extension Service, in partnership with the Arizona Department of Environmental Quality (ADEQ) Water Quality Division, and the Water Resources Research Center. The goal of Arizona NEMO is to educate land use decision-makers to take voluntary actions that will mitigate nonpoint source pollution and protect our natural resources.

Education needs:

Education programs need to be developed for land use decision makers and stakeholders that will address the various sources of water quality degradation and present management options. The key sources of concern for educational programs are:

- *Abandoned Mines* (control of runoff and sediment)

- *Grazing Management* (erosion control treatments and riparian area protection)

- *Streamside Protection* (filter strips and alternative watering facilities)

- *Riparian Management*

- *Septic Systems* (residential septic system maintenance, licensing and inspection programs)
- *Stormwater Management* (control of stormwater runoff from urbanized and developing areas)
- *Water Conservation* (for private residents and to prevent dewatering of natural stream flow and riparian areas)

Target Audiences:

The targeted audiences will include developers, private land owners and managers, livestock growers, home owners and citizen groups. Several programs, including those addressing septic systems, stormwater management and water conservation, will target the Chase Creek subwatershed. Development of an 'Adopt a Stream' Program will be considered.

References

ADEQ, Arizona Department of Environmental Quality, 2002. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Verde Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/305-02/18v.pdf

ADEQ, Arizona Department of Environmental Quality, 2004. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Verde Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/303-04/vd.pdf

Hoffman, T.R. and G.S. Willett. 1998. The Economics Of Alternative Irrigation Systems In The Kittitas Valley Of Washington State. Cooperative Extension, Washington State University, pub. EB1875. http://cru84.cahe.wsu.edu/cgi-bin/pubs/EB1875.html

Data Sources*:

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/index.html
Land ownership. February 7, 2002.

**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, it's geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Section 8: Local Watershed Planning

The first component of the watershed-based planning process is to summarize all readily available natural resource information and other data for a given watershed. As seen in Sections 2 though 5 of this document, these data are at a broad-based, large watershed scale and include information on water quality, land use and cover, natural resources and wildlife habitat.

It is anticipated that stakeholder-groups will develop their own planning documents. The stakeholder-group watershed-based plans may cover a subwatershed area within the NEMO Watershed-based Plan, or include the entire 6-digit HUC watershed area.

In addition, stakeholder-group local watershed-based plans should incorporate local knowledge and concerns gleaned from stakeholder involvement and could include:

- A description of the stakeholder / partnership process;
- A well-stated, overarching goal aimed at protecting, preserving, and restoring habitat and water quality, and encouragement of land stewardship;
- A plan to coordinate natural resource protection and planning efforts;
- A detailed and prioritized description of natural resource management objectives; and
- A detailed and prioritized discussion of best management practices, strategies and projects to be implemented by the partnership.

EPA's *2003 Guidelines for the Award of Section 319 Nonpoint Source Grants* (EPA, 2003) suggests that a watershed-based plan should include all nine elements listed in Section 1 of this document to be considered for funding. The nine planning elements help provide reasonable assurance that the nonpoint source of pollution will be managed to improve and protect water quality, and to assure that public funds to address impaired waters are used effectively.

<u>Potential Water Quality Improvement Projects</u>

GIS, hydrologic modeling and fuzzy logic were used to rank and prioritize the 10-digit HUC subwatersheds for known water quality concerns (Section 6, Watershed Classification). These rankings are used to identify where water quality improvement projects should be implemented to reduce nonpoint source pollution in the Verde Watershed. This methodology ranked twenty-two subwatersheds for four key nonpoint source water quality concerns:

1. Metals originating from abandoned mine sites;
2. Stream sedimentation due to land use activities;
3. Organic and nutrient pollution due to land use activities; and
4. Selenium due to agricultural practices.

Table 8-1 lists all twenty-two subwatersheds and their final weighted fuzzy membership value for each of these four constituents. Values highlighted with a shaded box indicate high risk for water quality degradation. The highest ranking value in each category is highlighted with a bold cell outline. The rankings range from a low risk of 0.0 to higher risk values approaching 1.0. See Section 6 for a full discussion on the derivation of these values.

Table 8-1. Summary of Weighted Fuzzy Membership Values for each Subwatershed

	FMV Weighted			
Subwatershed	**Metals**	**Sediment**	**Organics**	**Selenium**
Aubrey Valley	**0.300**	**0.16**	**0.43**	**0.300**
Upper Big Chino Wash	**0.300**	**0.22**	**0.46**	**0.300**
Ash Fork Draw-Jumbo Tank	**0.760**	**0.31**	**0.49**	**0.465**
Upper Partridge Creek	**0.820**	**0.22**	**0.46**	**0.630**
Lower Partridge Creek	**0.520**	**0.16**	**0.43**	**0.465**
Middle Big Chino Wash	**0.640**	**0.16**	**0.47**	**0.465**
Williamson Valley Wash	**0.640**	**0.22**	**0.64**	**0.465**
Lower Big Chino Wash	**0.640**	**0.28**	**0.61**	**0.300**
Granite Creek-Upper Verde River	**0.700**	**0.39**	**0.92**	**0.800**
Hell Canyon	**0.820**	**0.16**	**0.45**	**0.465**
Sycamore Creek	**0.640**	**0.47**	**0.56**	**0.465**
Grindstone Wash-Upper Verde River	**0.880**	**0.23**	**0.25**	**0.630**
Oak Creek	**0.760**	**0.91**	**0.72**	**0.465**
Beaver Creek	**0.700**	**0.54**	**0.60**	**0.465**
Cherry Creek-Upper Verde River	**0.820**	**0.49**	**0.80**	**0.800**
West Clear Creek	**0.910**	**0.42**	**0.28**	**0.300**
East Verde River	**0.880**	**0.41**	**0.52**	**0.665**
Fossil Creek-Lower Verde River	**0.670**	**0.67**	**0.74**	**0.665**
Tangle Creek-Lower Verde River	**0.573**	**0.52**	**0.21**	**0.350**
Lower Verde River-Horseshoe and Bartlett Reservoir	**0.670**	**0.52**	**0.44**	**0.350**
Mesquite Wash-Sycamore Creek	**0.670**	**0.57**	**0.43**	**0.680**
Camp Creek-Lower Verde River	**0.760**	**0.57**	**0.74**	**0.665**

Based on these fuzzy membership values, the subwatershed that ranked the highest for each of the nonpoint sources was selected for an example water quality improvement project. The four example subwatershed projects that will be discussed here are:

1. West Clear Creek Subwatershed, for metals pollution;

2. Oak Creek Subwatershed, for sediment pollution;

3. Granite Creek – Upper Verde River Subwatershed, for

pollutants due to organics and nutrients derived from land use; and,

4. Both Granite Creek – Upper Verde River and Cherry Creek – Upper Verde River Subwatersheds, for selenium due to agricultural practices.

Example projects with best management practices to reduce metals, sediment, organic, nutrient and selenium pollution are discussed below. Management measures and their associated costs must be designed and calculated based on site-specific conditions; however, sample costs are included in Section 7.

Methods for calculating and documenting pollutant reductions for sediment, sediment-borne phosphorus and nitrogen, feedlot runoff, and commercial fertilizer, pesticides and manure utilization can be found on the NEMO web site in the Best Management Practices (BMP) Manual, under Links (www.ArizonaNEMO.org). It is expected that the local stakeholder partnership watershed-based plan will identify projects and locations important to their community, and may differ from the example project locations proposed here.

1. West Clear Creek Subwatershed Example Project

Pollutant Type and Source:
Metal-laden sediment originating from an abandoned tailings or spoil pile at an assumed abandoned mine site within the riparian area.

The West Clear Creek Subwatershed of the Verde River ranked as the most critical area in the Verde Watershed impacted by metals related to an abandoned mine site (i.e. highest fuzzy membership value for metals), and a project to control the movement of metal-laden sediment is recommended. The major land owner within this subwatershed is the U.S. Forest Service, although a little over 2% of the land is held by private owners (Table 7-3) near Camp Verde. Projects implemented on private, federal or state lands must obtain the permission of the owner and must comply with all local, state and federal permits.

Load Reductions:
Calculate and document sediment delivery and pollutant reductions for sediment-borne metals using Michigan DEQ (1999) methodology (found in the NEMO BMP Manual under “Links”). Although this manual addresses sediment reduction with respect to nutrients, the methods can be applied when addressing metals. Particulate metals that generate dissolved metals in the water column and dissolved metals have a tendency to behave like nutrients in the water column.

Management Measures:
Various options are available to restore a mine site, ranging from erosion control fabrics and revegetation to the removal and relocation of the tailings material. Section 7 and Table 7-1 present these management measures along with associated load reduction potential, maintenance, and anticipated costs. It should be recognized that only after a site-specific evaluation can the best treatment option be identified and that the installation of engineered

erosion control systems and/or the relocation of the tailings will necessitate project design by a licensed engineer.

2. Oak Creek Subwatershed Example Project

Pollutant Type and Source:
Sediment pollution presumed to be due to increased urbanization and associated land use activities.

The Oak Creek subwatershed of the Upper Verde River ranked as the most critical area impacted by land use activities. It had the highest fuzzy membership value for sediment (Table 8-1), and implementation of best management practices related to stormwater management is recommended. In rapidly growing urban areas, such as Sedona, new construction and increasing population growth result in increased soil disturbance and stormwater sediment loading.

The land owners within this subwatershed (Table 7-3) include the U.S. Forest Service, U.S. Fish & Wildlife Service, the National Park Service, and State Trust Land, but the rapidly growing municipality of Sedona and nearby private lands have been exhibiting watershed stress due to increased urbanization.

Load Reductions:
The goal of this example is to reduce sediment pollution to the Oak Creek subwatershed. Because increased sediment load in Oak Creek is assumed to be the result of increased urban stormwater concerns, some background information on current stormwater regulations is necessary.

The Environmental Protection Agency (EPA) has estimated that about 30 percent of known pollution to our nation's waters is attributable to stormwater runoff. In 1987, Congress directed EPA to develop a regulatory program to address the stormwater problem. EPA issued regulations in 1990 authorizing the creation of a National Pollutant Discharge Elimination System (NPDES) permitting system for stormwater discharges. In Arizona, this program is called AZPDES, which stands for Arizona Pollutant Discharge Elimination System. Because stormwater runoff can transport pollutants to either a municipal storm sewer system or to a water of the United States, permits are required for those discharges.

Stormwater Phase II Regulations established by EPA in 1999 required some smaller municipalities to obtain a permit for their municipal stormwater discharges (Phase I Regulations addressed large metropolitan cities, such as Phoenix). Sedona is a regulated municipality as designated by ADEQ Phase II Stormwater Regulations (see 40 CFR 122.32(a)(2)). Within the Verde Watershed, Sedona, in addition to Yavapai, Coconino, and Maricopa Counties and the municipalities of Prescott, Prescott Valley, Camp Verde and Cottonwood, were required to submit their Notice of Intent and Stormwater Management Program to ADEQ by December 2003.

Stormwater discharges generated during construction activities can also

cause an array of physical, chemical and biological water quality impacts. Water quality impairment occurs, in part, because a number of pollutants are preferentially absorbed onto mineral or organic particles found in fine sediment. The interconnected process of erosion (detachment of the soil particles) and sediment transport during storm events results in water quality degradation.
Stormwater runoff from construction sites can include pollutants other than sediment that may become mobilized when land surfaces are disturbed. These include phosphorous, nitrogen, pesticides, petroleum derivatives, construction chemicals and solid wastes.

ADEQ stormwater regulations address both small and large construction sites. Large construction activity refers to the disturbance of 5 or more acres. It also refers to the disturbance of less than 5 acres of total land area that is a part of a larger common plan of development or sale if the larger common plan will ultimately disturb five acres or more (see 40 CFR 122.26(b)(14)(x)).

Small construction activity refers to the disturbance of 1 or more, but less than 5 acres of land. It also refers to the disturbance of less than 1 acre of total land area that is part of a larger common plan of development or sale if the larger common plan will ultimately disturb 1 or more, but less than 5 acres. (see 40 CFR 122.26(b)(15).

To obtain authorization for discharges of stormwater associated with construction activity, the operator must comply with all the requirements of the general permit and submit a Notice of Intent (NOI) and a Stormwater Management Plan (SWMP). More information about Arizona Stormwater regulations and permitting can be found at:
http://azdeq.gov/environ/water/permits/stormwater.html

Management Measures:
Municipal Ordinances addressing stormwater retention/detention, construction site management, housing density, drainage buffers, impermeable surfaces, and grading are the most effective management measures to address sediment pollution due to stormwater runoff. New ordinance proposals can be initiated by citizen groups within the jurisdiction of the municipality, such as the stakeholder-group local watershed partnership.

In Sedona, the Assistant Director of Public Works/Assistant City Engineer oversees the Engineering Division. This division's scope of responsibility includes review of construction site and development proposals as they impact public infrastructure, grading plans, management of City construction projects, inspections related to abandonment of private sewer systems and connection to the City wastewater collection system, and overseeing the design of roads, storm drainage facilities, and wastewater facilities.

Generally, properly implemented and enforced construction site ordinances effectively reduce sediment pollution. In many areas, however, the effectiveness of ordinances in reducing pollutants is limited due to inadequate enforcement or incomplete compliance with local ordinances by construction site operators. Reporting of obvious construction site violations of local ordinances, for example, failure to manage site waste (messy housekeeping) and tracking of mud onto the roadways can be performed by local citizens.

In addition to ordinances as a best management practice to address stormwater sediment, the ADEQ Phase II Stormwater Regulations require an outreach education component to the Stormwater Management Plans. Stakeholder-group local watershed partnerships can play an important role in educating the public about individual property owner responsibilities in protecting stream water quality.

3. Granite Creek-Upper Verde River Subwatershed Example Project

Pollutant Type and Source:
Organic pollutants, specifically *E. coli,* assumed to originate from cattle watering in the stream channel.

Prior to initiating a project to reduce *E. coli* bacteria pollution, it may benefit the watershed partnership to determine the source of the bacterial contamination. The field of bacteria source tracking continues to evolve rapidly and there are numerous methods available, each of which has its limitations and benefits.

Despite the rapid and intensive research into existing methods, EPA recommends that bacteria source tracking "should be used by federal and state agencies to address sources of fecal pollution in water… [because it] represents the best tools available to determine pathogen TMDL load allocations and TMDL implementation plan development" (EPA, 2001). For example, implementation of DNA fingerprinting technology will identify the actual sources of bacterial and clarify how best to target an implementation plan and project.

The results of a study funded from Section 319 Nonpoint Source Grant funds for Oak Creek Canyon within the Verde Watershed found that most of the fecal pollution came from natural animal populations in the canyon with sporadic and seasonal impacts from human, dog, cattle, house and llama sources (NAU, 2000). The Oak Creek Task Force (a locally led watershed group) suggested implementing locally approved grazing modifications to decrease the inflow of sediment carrying fecal material, as well as public education and increased toilet facilities within the canyon to reduce nonpoint source bacterial pollutants.

The Granite Creek subwatershed of the Upper Verde River ranked as the most critical area impacted by land use activities. It had the highest fuzzy membership values for organics, which are highly correlated to land use activities (Table 8-1).

In the Granite Creek subwatershed, pathogens are assumed to most likely originate from grazing practices because livestock grazing is the primary land use. Therefore, load reduction should concentrate on grazing management.

For this example project it will be assumed that grazing within the riparian area has exacerbated erosion (sediment pollution) and introduced fecal matter into the stream (organic pollution in the form of *E. coli*). The land owners within this subwatershed (Table 7-3) are primarily private and State Trust Lands, although the U.S. Forest Service, Bureau of Land Management, American Indian Tribal entities, and the U.S. Military hold property in the watershed. Projects implemented on private, federal or state lands must obtain the permission of the 1owner and must comply with all local, state and federal permits.

Load Reductions:
The goal of this example project is to reduce bacterial (organic) pollution to the Granite Creek subwatershed. Organic pollution load reductions can be calculated and documented using the Michigan DEQ (1999) methodology, available at the NEMO website, under BMP Manual, Links (www.ArizonaNEMO.org).

Management Measures:
Implementing grazing management practices to improve or maintain riparian health will help reduce excess surface runoff and accelerated erosion, and reduce the amount of bacterial pollution to the stream. Sustainable livestock grazing can be achieved in all plant communities by changing the duration, frequency and intensity of grazing.

In addition, livestock management may include exclusion of the land from grazing and/or restricting access to riparian corridors by fencing, which will also reduce the introduction of fecal matter to the stream. Alternative watering facilities at a location removed from the waterbody may be necessary. Section 7 discusses these management measures. Tables 7-2 and 7-4 present load reduction potential, required maintenance and anticipated costs associated with various management options. It should be recognized that only after a site-specific evaluation can the best treatment option be identified and that the installation of engineered erosion control systems or the installation of an alternative water source may necessitate project design by a licensed engineer.

4. Granite Creek – Upper Verde River and Cherry Creek – Upper Verde River Subwatershed Example Project

Pollutant Type and Source:
Selenium pollution due to irrigation practices.

The Granite Creek and Cherry Creek subwatersheds of the Upper Verde River ranked as the most critical areas impacted by agricultural land use practices that exacerbate the concentration of naturally occurring selenium (i.e. highest fuzzy membership values for Selenium, Table 8-1).

For this example project it will be assumed that irrigation tail water has introduced elevated concentrations of selenium into the stream. The land owners within the Granite Creek subwatershed (Table 7-3) are primarily private and State Trust Lands, although the U.S. Forest Service, Bureau of Land Management, American Indian Tribal entities, and the U.S. Military hold property in the watershed. Within the Cherry Creek subwatershed, primary land owners include the U.S. Forest Service, private owners, State Trust lands, American Indian Tribal entities, and the National Park Service. Projects implemented on private, federal, tribal, or state lands must obtain the permission of the owner and must comply with all local, state and federal permits.

Load Reductions:
Naturally occurring selenium is concentrated in water by evaporation, and also when irrigation water leaches selenium from the soil. To calculate the load reduction resulting from implementation of a best management practice, an estimate of the reduction in volume of irrigation tail water that returns to the stream is required.

Support for calculating load reductions can be obtained from the local Agricultural Research Service or County Cooperative Extension office (http://cals.arizona.edu/extension/).

Management Measures:
Implementing agricultural irrigation practices to reduce tail water pollution will necessitate dramatic changes from the typical practice of flood irrigation. This may involve the installation of mechanized irrigation systems or on-site treatment.

As an example of a situation where drainage water must be managed, some watersheds in California have agricultural drainage water containing levels of selenium that approach the numeric criterion defining hazardous waste (above 1,000 parts per billion). This situation is being considered for permit regulation to manage drainage at the farm level (San Joaquin Valley Drainage Implementation Program, 1999).

Currently, Arizona is not considering such extreme measures, but selenium remains an important nonpoint source contaminant and a known risk to wildlife. The use of treatment technologies to reduce selenium concentrations include ion exchange, reverse osmosis, solar ponds, chemical reduction with iron, microalgal-bacterial treatment, biological precipitation, and constructed wetlands. Engineered water treatment systems, however, may be beyond the scope of a proposed best management practices project, and technologies are still in the research stage.

Section 7 briefly discusses load reduction potential, maintenance, and anticipated costs associated with the installation of mechanized irrigation systems. These types of systems allow for improved water conservation and improved management of limited water resources. It should be recognized that only after a site-specific evaluation can the best treatment option be identified and that the installation of mechanized irrigation systems involve capital expense and may necessitate project design by a licensed engineer.

Technical and Financial Assistance

Stakeholder-group local watershed-based plans should identify specific projects important to their partnership, and during the planning process should estimate the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement the plan. Technical support sources include NEMO, University of Arizona Cooperative Extension, government agencies, engineering contractors, volunteers, and other environmental professionals. Funding sources may include:

- Clean Water Act Section 319(h) funds;
- State revolving funds though the Arizona Department of Environmental Quality;
- Central Hazardous Materials Fund;
- USDA Environmental Quality Incentives Program and Conservation Security Program;
- Arizona Water Protection Fund through the Arizona Department of Water Resources;
- Water Infrastructure Finance Authority;
- Arizona Heritage Fund though Arizona State Parks and Arizona Game and Fish; and
- Private donations or non-profit organization donations.

In addition to the extensive listing of funding and grant sources on the NEMO web site (www.ArizonaNEMO.org), searchable grant funding databases can be found at the EPA grant opportunity web site www.grants.gov or www.epa.gov/owow/funding.html.

In Arizona, Clean Water Act Section 319(h) funds are managed by ADEQ and the funding cycle and grant application data can be found at: http://www.azdeq.gov/environ/water/watershed/fin.html

The Arizona legislature allocates funding to the Arizona Water Protection Fund. In addition, the fund is supplemented by income generated by water-banking agreements with the Central Arizona Project. Information can be found at http://www.awpf.state.az.us/

Most grants require matching funds in dollars or in-kind services. In-kind services may include volunteer labor, access to equipment and facilities, and a reduction on fee schedules / rates for subcontracted tasks. Grant matching and cost share strategies allow for creative management of limited financial resources to fund a project.

Education and Outreach

An information/education component is an important aspect of the Stakeholder-group local watershed-based plan that will be used to enhance public understanding of the project and encourage early and continued participation in selecting, designing and implementing management measures.

The Verde Watershed has a number of Stakeholder-group local watershed partnerships, including the Yavapai County Water Advisory Committee (WAC), a coalition of communities and watershed groups that are dedicated to developing a management plan for the sustainable use of the regional water supply. Although the primary focus of the WAC is water supply, most of the watershed groups in the region are represented, and the WAC acts as a forum for discussion of watershed-wide concerns, including water quality.

The Stewards of Public Lands [www.verdeconnections.com] is a stakeholder group promoting wild-cat dump clean-up. Because of their riparian area and wash cleanup activities, the Stewards were recognized by Governor Napolitano's as a Rural Development Success Story in August of 2005

The Verde Watershed Association [www.vwa.org] has become an established stakeholder group that meets on a regular basis to plan water quality improvement projects and strategize funding opportunities. Education outreach is a regular part of their monthly meetings with their agenda usually including reports on the status of grant-funded projects.

The Verde Watershed Association has initiated the establishment of a Verde River basin Partnership with the Yavapai County WAC and other watershed groups across the area following on Congressional legislation known as the "Northern Arizona Land Exchange and Verde River Basin Partnership Act of 2005". Title II of the law authorizes the appropriation of whatever amounts are necessary over the next four years for the U.S. Department of Agriculture and the Department of the Interior to conduct (in partnership with state and local entities) water resources studies of the Verde River Basin in Arizona.
Other successful outreach and public education activities in the watershed include sponsoring a Partnership booth at the County Fair. Working with other Cooperative Extension programs, such as Project WET (Water Education for Teachers, K-12 classroom education), the Partnership booth provided displays, posters and fact sheets on important water topics in addition to individual water quality improvement projects.

The NEMO program offers each watershed partnership the opportunity to post information, fact sheets and status reports on the NEMO web site, and to announce important events on the NEMO calendar (www.ArizonaNEMO.org). In addition, a partnership can obtain guidance and technical support in designing an outreach program through the University of Arizona Cooperative Extension.

Implementation Schedules & Milestones

Necessary to the watershed planning process is a schedule for project selection, design, funding, implementation, reporting, operation and maintenance, and project closure. In the Verde Watershed, 10-digit HUC subwatershed areas have been prioritized in this plan for potential water quality improvement projects, but other locations across the watershed may hold greater interest by the stakeholders for project implementation. Private land owners, or partnerships of stakeholders, may propose discreet projects to respond to immediate water quality concerns, such as stream bank erosion exacerbated by a recent flooding event.

After project selection, implementation may be dependent on the availability of funds, and because of this most watershed partnerships find themselves planning around grant cycles. Table 8-2 depicts the planning process, and suggests that the stakeholder group may want to revisit the listing and ranking of proposed projects on a regular basis, giving the group the opportunity to address changing conditions.

As shown in the table, a 'short' one-year project actually may take as many as three years from conception, to implementation, and ultimate project closure. With the number of grants currently available in Arizona for water quality improvement projects, the watershed partnership may find themselves in a continual cycle of grant writing and project reporting, overlapping and managing several aspects of several projects simultaneously.

Table 8-2: Example Watershed Project Planning Schedule.

Watershed Project Planning Steps	Year				
	1	2	3	4	5
Stakeholder-Group 319 Plan Development	X				
Identify and rank priority projects	X				
Grant Cycle Year 1: Select Project(s)	X				
Project(s) Design, Mobilization, and Implementation	X	X			
Project(s) Reporting and Outreach		X			
Project(s) Operation and Maintenance, Closure		X	X		
Grant Cycle Year 2: Select Project(s)		X			
Project(s) Design, Mobilization, and Implementation		X	X		
Project(s) Reporting and Outreach			X		
Project(s) Operation and Maintenance, Closure			X	X	
Revisit Plan, Identify and re-rank priority projects			X		
Grant Cycle Year 3: Select Project(s)			X		
Project(s) Design, Mobilization, and Implementation			X	X	
Project(s) Reporting and Outreach				X	
Project(s) Operation and Maintenance, Closure				X	X

Most funding agencies operate on a reimbursement basis and will require reporting of project progress and reimbursement on a percent completion basis. In addition, the individual project schedule should be tied to important measurable milestones which should include both project implementation milestones and pollutant load reduction milestones. Implementation milestones may include interim tasks, such as shown in Table 8-3, and can be tied to grant funding-source reporting requirements.

Based on funding availability, the activities outlined in Table 8-3 could be broken down into three separate projects based on location (Stream Channel, Stream Bank or Flood Plain), or organized into activity-based projects (Wildcat Dump Cleanup, Engineered Culverts, etc).

Table 8-3: Example Project Schedule

Management Measures and Implementation Schedule Streambank Stabilization and Estimated Load Reduction					
			Water Quality Milestone Target Load Reduction: 100% Hazardous Materials 75% Sediment Load		
Milestone	**Date**	**Implementation Milestone**	**Area 1 Stream Channel**	**Area 2 Stream Bank**	**Area 3 Flood Plain**
Task 1: Contract Administration	04/01/05 Thru 09/31/06	Contract signed Quarterly reports Final report			
Task 2: Wildcat Dump Clean-up	04/01/05 Thru 07/05/05	Select & Advertise Clean-up date Schedule Containers and removal	Remove hazardous materials from stream channel 100% hazardous material removal	Remove tires and vehicle bodies from streambank 100% hazardous material removal	
Task 3: Engineering Design	04/01/05 Thru 08/15/05	Conceptual design, select final design based on 75% load reduction		Gabions, culverts, calculate estimated load reduction	Re-contour, regrade, berms, water bars, gully plugs: calculate estimated load reduction.
Task 4: Permits	04/01/05 Thru 09/01/05	Confirm permit requirements and apply for necessary permits	US Army Corps of Engineers may require permits to conduct projects within the stream channel	Local government ordinances as well as the US Army Corps and State Historical Preservation permits may be needed.	In addition to local and State permits, the presence of listed or Endangered Species will require special permitting and reporting.
Task 5: Monitoring	07/05/05 thru 10/31/06	Establish photo points and water quality sample locations	Turbidity sampling, baseline and quarterly, compare to anticipated 75% Sediment load reduction	Photo points, baseline and quarterly, Calculate Sediment load reduction	Photo points, baseline and quarterly, Calculate Sediment load reduction
Task 6: Revegetation	08/15/05 thru 09/15/05	Survey and select appropriate vegetation			Willows, native grasses, cotton wood, mulch
Task 7: Mobilization	09/01/05 thru 10/31/05	Purchase, delivery and installation of engineered structures and revegetation material		Install gabions, resized culverts / professional and volunteer labor	Regrade, plant vegetation with protective wire screens around trees / install gully plugs and water bars, volunteer labor

Milestone	Date	Implementation Milestone	Water Quality Milestone Target Load Reduction: 100% Hazardous Materials 75% Sediment Load		
			Area 1 Stream Channel	**Area 2 Stream Bank**	**Area 3 Flood Plain**
Task 8: Outreach	**04/01/05 thru 10/31/06**	**Publication of news articles, posters, monthly reports during stakeholder-group local watershed meetings**			
Task 9: Operation and Maintenance	**09/01/05 thru 10/31/06**	**Documentation of routine operation and maintenance in project quarterly reports during contract period, continued internal record keeping after contract / project closure**		**Maintenance and routine repair of engineered structures**	**Maintenance / irrigation of new plantings until established, removal of weeds and invasive species**

<u>Evaluation</u>

The evaluation section of a watershed plan will provide a set of criteria that can be used to determine whether progress towards individual project goals is being achieved and/or the effectiveness of implementation is meeting expectations. These criteria will help define the course of action as milestones and monitoring activities are being reviewed.

The estimate of the load reductions expected for each of the management measures or best management practices to be implemented is an excellent criterion against which progress can be measured. Prior to project implementation, baselines should be established to track water quality improvements, and standard measurement protocols should be established so as to assure measurement methodology does not change during the life of the project.

To evaluate the example project outlined in Table 8-3, the following key evaluation attributes must be met:

- Schedule and timeliness: Grant applications, invoices and quarterly reports must be submitted to the funding source when due or risk cancellation of contracts. If permits are not obtained prior to project mobilization, the project crew may be subject to penalties or fines.

- Compliance with standards: Engineered designs must meet the standards of the Engineering Board of Licensing; water quality analytical work must be in compliance with State of Arizona

Laboratory Certification. Excellent evaluation criteria would include engineer-stamped 'as-built' construction diagrams and documentation of laboratory certification, for example. Methods for estimating load reduction must be consistent with established methodology, and the means by which load reductions are calculated throughout the life of the plan must be maintained.

- Consistency of measurement: The plan should identify what is being measured, the units of measurement, and the standard protocol for obtaining measurements. For example, turbidity can be measured in 'Nephlometric Units' or more qualitatively with a Siche disk. Water volume can be measured as Acre/feet, gallons, or cubic feet. Failure to train project staff to perform field activities consistently and to use comparable units of measure can result in project failure.

- Documentation and reporting: Field note books, spread sheets, and data reporting methodology must remain consistent throughout the project. Photo point locations must be permanently marked so as to assure changes identified over the life of the project are comparable. If the frequency of data collection changes or the methodology of reporting changes in the midst of the project, the project and overall plan looses credibility.

The project is a near success if the reports are on time, the engineered structures do not fail, data are reported accurately, and an independent person reviewing your project a year after project closure understands what was accomplished. The project is a full success if water quality improvement and load reductions have been made.

The criteria for determining whether the overall watershed plan needs to be revised are an appropriate function of the evaluation section as well. For example, successful implementation of a culvert redesign may reduce the urgency of a stream bank stabilization project downstream from the culvert, allowing for reprioritization of projects.

It is necessary to evaluate the progress of the overall watershed plan to determine effectiveness, project suitability, or the need to revise goals, BMPs or management measures. The criteria used to determine whether there has been success, failure or progress will also determine if objectives, strategies or plan activities need to be revised, as well as the watershed-based plan itself.

<u>Monitoring</u>

Monitoring of watershed management activities is intrinsically linked to the evaluation performed within the watershed because both track effectiveness. While monitoring evaluates the effectiveness of implementation measures over time, the criteria used to judge success/failure/progress is part of the Evaluation process.

Watershed monitoring will include the water quality data reported in Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Verde Watershed Assessment (ADEQ, 2005), but the overall stakeholder group watershed plan will identify additional data collection activities that are tied to stakeholder concerns and goals.

For the Verde Watershed, the East Verde River (Ellison Creek – American Gulch), Grande Wash (headwaters – Ashbrook Wash), Granite Creek (headwaters – Willow Creek) Oak Creek (at Slide Rock State Park), Verde River (Bartlett Dam – Camp Creek) and Watson Lake are identified as vulnerable to water quality impairment due to metals, organics and nutrients, and selenium. Monitoring of stream reaches for these constituents require standard water sample collection methodology and sample analysis by a certified laboratory. If routine monitoring of these reaches is to be conducted, sample collection and analysis must be consistent with data collection by the ADEQ to support the (305) b Assessment Report.

Following the example of the project outlined in Table 8-3, other water quality and watershed health constituents to be monitored include:

- Turbidity. Measuring stream turbidity before, during and after project implementation will allow for quantification of load reduction.

- Stream flow and volume, presence or absence of flow in a wash following precipitation. Monitoring of these attributes is important especially after stream channel hydromodification.

- Presence / absence of waste material. This can be monitored with photo-points.

- Riparian health, based on diversity of vegetation and wildlife. Monitoring can include photo-points, wildlife surveys and plant mapping.

The monitoring section will determine if the partnership's watershed strategies/management plan is successful, and/or the need to revise implementation strategies, milestones or schedule. It is necessary to evaluate the progress of the plan to determine effectiveness, unsuitability, or need to revise goals or BMPs.

Water quality monitoring for chemical constituents that may expose the sampler to hazardous conditions will require appropriate health and safety training and the development of a Quality Assurance Project Plan (QAPP). Monitoring for metals derived from abandoned mine sites, pollutants due to organics, nutrients derived from land use, and selenium will require specialized sample collection and preservation techniques, in addition to laboratory analysis. Monitoring for sediment load reduction may be implemented in the field without extensive protocol development.

Resources to design a project monitoring program can be found at the EPA water quality and assessment web site: www.epa.gov/owow/monitoring/ as well as through the Master Watershed

Steward Program available through the local county office of University of Arizona Cooperative Extension. In addition, ADEQ will provide assistance in reviewing a QAPP and monitoring program.

Conclusions

This watershed-based plan ranked or classified all twenty-two 10-digit HUC subwatersheds within the Verde Watershed for vulnerability to water quality degradation from nonpoint source pollutants (Section 6 and Table 8-1). This ranking was based on Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, for the Verde Watershed (ADEQ, 2005).

In addition to the subwatershed classifications, this plan contains information on the natural resources and socio-economic characteristics of the watershed (Sections 2 through 5). Based on the results of the Classification in Section 6, example best management practices and water quality improvement projects to reduce nonpoint source pollutants are also provided (Section 7).

The subwatershed rankings were determined for the four major constituent groups (metals, sediment, organics and selenium) using fuzzy logic (see Section 6 for more information on this methodology and the classification procedure). The final results are summarized in this section and are shown in Table 8-1. In addition, technical and financial assistance to implement the stakeholder-group local watershed-based plans are outlined in this section.

Of the 22 subwatersheds included in this assessment, the four watersheds with the highest risk of water quality degradation are:

1. West Clear Creek Subwatershed, for metals pollution;

2. Oak Creek Subwatershed, for sediment pollution;

3. Granite Creek – Upper Verde River Subwatershed, for pollutants due to organics and nutrients derived from land use; and,

4. Granite Creek – Upper Verde River, and Cherry Creek – Upper Verde River Subwatersheds, for selenium due to agricultural practices.

This NEMO Watershed-Based Plan is consistent with EPA guidelines for CWA Section 319 Nonpoint Source Grant funding. The nine planning elements required to be eligible for 319 grant funding are discussed, including education and outreach, project scheduling and implementation, project evaluation, and monitoring.

Some basic elements are common to almost all forms of planning: data gathering, data analysis, project identification, implementation and monitoring. It is expected that local stakeholder groups and communities will identify specific projects important to their partnership, and will rely on the NEMO Plan in developing their own plans.

References:

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Michigan Department of Environmental Quality (Michigan DEQ). 1999. Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual. Surface Water Quality Division, Nonpoint Source Unit. http://www.deq.state.mi.us/documents/deq-swq-nps-POLCNTRL.pdf

Northern Arizona University (NAU). November 8, 2000. The Oak Creek Canyon *Escherichia coli* Genotyping Project. Submitted to Arizona Department of Environmental Quality, Nonpoint Source Unit, Phoenix, Arizona.

San Joaquin Valley Drainage Implementation Program. February 1999. Drainage Water Treatment Final Report. Drainage Water Treatment Technical Committee. Sacramento, California. http://wwwdpla.water.ca.gov/agriculture/drainage

Table 1: Water Quality Data and Assessment Status, Verde Watershed.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Aubrey Valley Subwatershed HUC 1506020101 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Upper Big Chino Wash Subwatershed HUC 1506020102 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Ash Fork Draw – Jumbo Tank Subwatershed HUC 1506020103 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Upper Partridge Creek Subwatershed HUC 1506020104 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Lower Partridge Creek Subwatershed HUC 1506020105 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Middle Big Chino Wash Subwatershed HUC 1506020106 **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Williamson Valley Wash Subwatershed HUC 1506020107 **Classification:** • Moderate risk for metals; • Low risk for sediment; • High risk for organics; and • Moderate risk for selenium.		
Granite Basin Lake 15060202-0580 Three Sites: VRGBL-A	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; selenium (2); boron; cadmium (t) (d 2); chromium (t) (d 2); copper (t) (d 2); lead (t) (d 2); manganese (t); mercury (t) (d 2); selenium (t); silver (t) (d 2); zinc (t) (d 2); nickel (t) (d 2); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td>VRGBL-B
VRGBL-BR</td><td>Status</td><td>Parameters exceeding standards: pH (2/6) assessed “Inconclusive”; and ammonia (1/6) assessed as “Inconclusive”.

Subwatershed risk classification:
Moderate risk for metals because of limited data;
Low risk for sediment;
High risk for organics due to pH and ammonia exceedances; and
Moderate risk for selenium because of limited data.</td></tr>
<tr><td colspan="3">Lower Big Chino Wash Subwatershed
HUC 1506020108
Classification:
Moderate risk for metals;
Moderate risk for sediment;
Moderate risk for organics; and
Moderate risk for selenium.</td></tr>
<tr><td rowspan="2">Apache Creek, from headwaters to Walnut Creek
15060201-019</td><td>Sampling</td><td>No current monitoring data.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none. Added to the planning list in 2002 due to missing core parameters.

Subwatershed risk classifications:
Moderate risk for all constituent groups because of missing data.</td></tr>
<tr><td colspan="3">Granite Creek – Upper Verde River Subwatershed
HUC 1506020201
Classification:
High risk for metals;
Moderate risk for sediment;
Extreme risk for organics; and
Moderate risk for selenium.</td></tr>
<tr><td rowspan="2">Granite Creek, from headwaters to Willow Creek
15060202-059A

Two Sites:
VRGRA021.70
VRGRA021.46</td><td>Sampling</td><td>E. coli; temperature (1); pH; dissolved oxygen; total dissolved solids; suspended sediment concentration (2); fluoride; arsenic; barium; beryllium; antimony; boron; cadmium (d); chromium (d); copper (d); lead (d); manganese (t); mercury (t); silver (d); zinc (d); nickel (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: Mercury (1/2) assessed as “Inconclusive”; E. coli (2/4) assessed as “Inconclusive”; and dissolved oxygen (4/6) assessed as “Impaired”.

Subwatershed risk classification:
High risk for metals due to mercury exceedance;
Moderate risk for sediment because of limited data;
Extreme risk for organics due to dissolved oxygen impairment; Low risk for other constituents; and
Moderate risk for selenium because of limited data.</td></tr>
<tr><td>Watson Lake
15060202-1590

Five Sites:
VRWAT-A
VRWAT-BR</td><td>Sampling</td><td>E. coli (1); pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic (2); barium (2); beryllium (2); antimony; boron; cadmium (t 1) (d 2); chromium (t 2) (d 2); copper (t 2) (d 2); lead (t 2) (d 2); manganese (t 2); mercury (t); selenium (t); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate; chlorine; and hardness.</td></tr>
</table>

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
VRWAT-BR VRWAT-DAM VRWAT-SO	Status	Parameters exceeding standards: dissolved oxygen (1/5) assessed as “Impaired”; pH (2/5) assessed as “Impaired”; and nitrogen (t) (2/5) assessed as “Inconclusive”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of limited data; • Extreme risk for organics due to dissolved oxygen and pH impairment; and high nitrogen exceedances; and • Low risk for selenium.
Sullivan Lake 15060202-3370	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from Granite Creek to Hell Canyon. 15060202-052 One Site: VRVER095.73 Note: This reach flows through two subwatershed HUCs: 1506020201 1506020204	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); cadmium (t 1) (d 1); mercury (t 1) (d 1); selenium (t 1) (d1); copper (t 1) (d 1); nitrogen as ammonia (1); n-kjeldahl (1); and nitrite/nitrate (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Hell Canyon Subwatershed **HUC 1506020202** **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Sycamore Creek Subwatershed **HUC 1506020203** **Classification:** • High risk for metals; • High risk for sediment; • Extreme risk for organics; and • Moderate risk for selenium.		
Whitehorse Lake 15060202-1630 Three Sites: VRWHH-A	Sampling	*E. coli* (2); pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; boron; cadmium (t) (d 1); chromium (t) (d 1); copper (t) (d 1); lead (t) (d 1); manganese (t); mercury (t); selenium (t); silver (t) (d 1); zinc (t) (d 1); nickel (t) (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.

Reach **Sites**	**Results**	**Available Water Quality Data and Assessment Status**[1,2,3]
VRWHH-B VRWHH-BR	Status	Parameters exceeding standards: nickel (t) (1/11) assessed as "Attaining"; turbidity (9/9) assessed as "Inconclusive"; dissolved oxygen (4/14) assessed as "Impaired"; ammonia (2/13) assessed as "Inconclusive"; and pH (2/16 high, 1/16 low) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals because of limited data and nickel exceedance; • High risk for sediment because turbidity exceedances; • Extreme risk for organics due to dissolved oxygen impairment; and • Moderate risk for selenium because of limited data.
Perkins Tank 15060202-1080 Two Sites: VRPER-A VRPER-MID	Sampling	pH (2); dissolved oxygen (2); total dissolved solids (2); fluoride (1); arsenic (1); barium (1); beryllium (1); antimony (1); selenium (1); boron (1); chromium (t 2); manganese (t 2); selenium (t 2); zinc (t 1); nitrogen as ammonia (2); n-kjeldahl (2); phosphorus (2); sulfate (1); and chlorine (1).
	Status	Parameters exceeding standards: turbidity (1/1) assessed as "Inconclusive"; and dissolved oxygen (2/2) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals because of limited data; • High risk for sediment due to turbidity exceedance; • High risk for organics due to dissolved oxygen exceedances; Moderate risk for other constituents; and • Moderate risk for selenium because of limited data.
Scholz Lake 15060202-1350 One Site: VRSCH-A	Sampling	*E. coli* (1); pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; boron; cadmium (t) (d 1); chromium (t) (d 1); copper (t) (d 1); lead (t) (d 1); manganese (t); mercury (t) (d 1); selenium (t) (d 1); silver (t) (d 1); zinc (t) (d 1); nickel (t) (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: lead (d) (1/1) assessed as "Inconclusive"; turbidity (1/3) assessed as "Inconclusive"; dissolved oxygen (1/3) assessed as "Inconclusive"; and nitrogen (2/4) assessed as "Inconclusive". Subwatershed risk classification: • High risk for metals due to lead exceedance; • High risk for sediment due to turbidity exceedance; • High risk for organics due to dissolved oxygen and nitrogen exceedances; Low risk for other constituents and • Moderate risk for selenium because of limited data.
Sycamore Creek, from Cedar Creek to the Verde River 15060202-026 One Site: VRSYW001.4	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); turbidity (1); cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
J D Dam Lake 15060202-0700 Three Sites: VRJDD-A	Sampling	*E. coli* (1); pH (1); dissolved oxygen; total dissolved solids (1); fluoride; boron; arsenic; barium; beryllium; cadmium (t) (d 2); chromium (t) (d); copper (t) (d 2); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; phosphorus; sulfate (1); and chlorine (1).

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
VRJDD-BR VRJDD-M	Status	Parameters exceeding standards: pH (1/5) assessed as “Inconclusive”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of limited data; • High risk for organics due to pH exceedances; Low risk for other constituents and • Low risk for selenium.
Grindstone Wash-Upper Verde River Subwatershed HUC 1506020204 Classification: • High risk for metals; • Moderate risk for sediment; • Moderate risk for organics; and • Moderate risk for selenium.		
Verde River, from Granite Creek to Hell Canyon. 15060202-052 One Site: VRVER095.73 Note: This reach flows through two subwatershed HUCs: 1506020201 1506020204	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); cadmium (t 1) (d 1); mercury (t 1) (d 1); selenium (t 1) (d1); copper (t 1) (d 1); nitrogen as ammonia (1); n-kjeldahl (1); and nitrite/nitrate (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from Hell Canyon to unnamed reach 15060202-065. 15060202-038 One Site: VRVER095.54	Sampling	temperature; pH; dissolved oxygen (2); total dissolved solids (1); turbidity (2); fluoride (2),arsenic; barium; beryllium; antimony; thallium; boron (2); cadmium (t 2) (d 2); chromium (t 2) (d 2); copper (t 2) (d 2); lead (t 2) (d 2); manganese (t 2); mercury (t 2) (d 2); selenium (t 2) (d 2); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia (2); n-kjeldahl (2); nitrite/nitrate (2); and phosphorus (2).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from unnamed reach 15060202-065 to Railroad Draw. 15060202-037	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Two Sites: VRVER095.74 VRVER095.65	Status	Parameters exceeding standards: mercury (t) (1/17) assessed as "Attaining"; arsenic (1/17) assessed as "Attaining"; turbidity (3/17) assessed as "Attaining"; dissolved oxygen (1/16) assessed as "Attaining"; and *E. coli* (1/15) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals due to arsenic and mercury exceedances; • Moderate risk for sediment because turbidity exceedances; • Moderate risk for organics due to dissolved oxygen and *E. coli* exceedances; Low for other constituents; and • Low risk for selenium.
Verde River, from Sycamore Creek to Oak Creek. 15060202-025 Eleven Sites: VRVER091.61 VRVER087.70 VRVER086.92 VRVER086.81 VRVER086.62 VRVER085.61 VRVER085.60 VRVER085.49 VRVER084.38 VRVER84.38 VRVER084.42 Note: This reach flows through two subwatershed HUCs: 1506020204 1506020207	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); uranium; nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and sulfate.
	Status	Parameters exceeding standards: mercury (1/1) assessed as "Inconclusive"; and lead (2/63) assessed as "Attaining"; turbidity (1/25) assessed as "Attaining"; and *E coli* (1/25) assessed as "Inconclusive". Subwatershed risk classification: • High risk for metals due to mercury exceedance; • Moderate risk for sediment because turbidity exceedance; • Moderate risk for organics due to *E. coli* exceedance; Low risk for other constituents; and • Low risk for selenium.
Oak Creek Subwatershed HUC 1506020205 Classification: • Moderate risk for metals; • High risk for sediment; • Extreme risk for organics; and • Moderate risk for selenium.		
Oak Creek, at Slide Rock State Park only 15060202-018B	Sampling	*E. coli*; pH; dissolved oxygen (1); total dissolved solids (1); turbidity (1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); phosphorus (1); sulfate (1); and total suspended solids (1).

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Seven Sites: VROAK020.03 VROAK020.00A VROAK020.00B VROAK020.00C VROAK020.00D VROAK020.00E VROAK019.97	Status	Parameters exceeding standards: *E. coli* (269/3408) assessed as "Impaired". Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of limited data; • Extreme risk for organics due to *E. coli* exceedances; Moderate risk for other constituents because of limited data; and • Moderate risk for selenium because of limited data.
Oak Creek, headwaters To West Fork Oak Creek. 15060202-019 Three Sites: VROAK025.3 VROAK025.2 VROAK023.21	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate; hardness; and total suspended solids (2).
	Status	Parameters exceeding standards: turbidity (2/8) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals because of limited data; • High risk for sediment because of turbidity exceedances; • Low risk for organics and other constituents; and • Moderate risk for selenium because of limited data.
Oak Creek, Below Slide Rock State Park to Dry Creek 15060202-018C Eight Sites: VROAK018.3 VROAK018.1 VROAK016.57 VROAK014.54 VROAK013.11 VROAK011.4 VROAK010.29 VROAK009.33	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration (2); fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate (2); and total suspended solids (2).
	Status	Parameters exceeding standards: beryllium (1/29) assessed as "Attaining"; manganese (t) (1/29) assessed as "Attaining"; turbidity (2/37) assessed as "Attaining"; nitrogen (1/37) assessed as "Attaining"; and phosphorus (1/37) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals due to beryllium and manganese exceedances; • Moderate risk for sediment because of turbidity exceedances; • Moderate risk for organics due to nitrogen and phosphorus exceedances; Low risk for other constituents and • Low risk for selenium.
Oak Creek, from Dry Creek to Spring Creek 15060202-017 Two Sites: VROAK006.4 VROAK005.91	Sampling	pH; dissolved oxygen (1); total dissolved solids (1); turbidity; fluoride (1); arsenic (2); barium (2); beryllium (2); antimony (2); selenium (2); thallium (2); boron (1); cadmium (t 1) (d 1); copper (t 1) (d 1); lead (t 1) (d 1); manganese (t 1); mercury (t 1); selenium (t 2); silver (t 1) (d 1); zinc (t 1) (d 1); nickel (t 1) (d 1); nitrogen as ammonia (2); n-kjeldahl (2); nitrite/nitrate (2); phosphorus (2); sulfate (1); and total suspended solids (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Oak Creek, from Spring Creek to the Verde River. 15060202-016 Two Sites: VROAK004.9 VROAK000.1	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); turbidity (1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); phosphorus (1); sulfate (1); and total suspended solids (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Oak Creek, West Fork, from headwaters to Oak Creek. 15060202-020 One Site: VRWOK000.64	Sampling	temperature; pH (2); dissolved oxygen (1); total dissolved solids (1); turbidity (2); cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); phosphorus (1); and sulfate (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Spring Creek, from Coffee Creek to Oak Creek. 15060202-022 One Site: VRSPN001.36	Sampling	PH (1); turbidity (1); cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Pumphouse Wash, from headwaters to Oak Creek 15060202-442 Four Sites: VRPMW008.4 VRPMW007.5 VRPMW002.7	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids (1); turbidity; cadmium (d 1); copper (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate; and total suspended solids.
	Status	Parameters exceeding standards: turbidity (2/10) assessed as “Attaining”; and phosphorus (1/10) assessed as “Attaining”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of turbidity exceedances; • Moderate risk for organics due to phosphorus exceedances; Low risk for other constituents; and • Moderate risk for selenium because of limited data.
Munds Creek, from headwaters to Oak Creek. 15060202-415 Five Sites: VRMUN004.3 VRMUN004.1 VRMUN003.5 VRMUN003.4 VRMUN000.1	Sampling	*E. coli*; temperature (1); pH; dissolved oxygen; total dissolved solids; turbidity; nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and sulfate.
	Status	Parameters exceeding standards: turbidity (2/14) assessed as “Attaining”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Moderate risk for sediment because of turbidity exceedances; • Low risk for organics and other constituents; and • Moderate risk for selenium because of limited data.

<table>
<tr><th>Reach
Sites</th><th>Results</th><th>Available Water Quality Data and Assessment Status[1,2,3]</th></tr>
<tr><td colspan="3">Beaver Creek Subwatershed
HUC 1506020206
Classification:
High risk for metals;
High risk for sediment;
Extreme risk for organics; and
Moderate risk for selenium.</td></tr>
<tr><td rowspan="2">Stoneman Lake
15060202-1490

Eight Sites:
VRSTN-A
VRSTN-B
VRSTN-MIDBW
VRSTN-1
VRSTN-1E
VRSTN-1EE
VRSTN-1S
VRSTN-MID</td><td>Sampling</td><td>pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony (1); boron; cadmium (t); chromium (t); copper (t); lead (t); manganese (t); mercury (t); selenium (t); silver (t); zinc (t); nickel (t); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; hardness (2); and total suspended solids (2).</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: arsenic (2/8) assessed as “Inconclusive”; dissolved oxygen (1/12) assessed as “Attaining”; and pH (6/10) assessed as Impaired”.

Subwatershed risk classification:
High risk for metals because arsenic exceedances;
Low risk for sediment;
Extreme risk for organics due to pH impairment; Low risk for other constituents; and
Low risk for selenium.</td></tr>
<tr><td rowspan="2">Wet Beaver Creek, from Long Canyon to Rarick Canyon.
15060202-004

Four Sites:
VRWBV006.79
VRWBV005.06
VRBEV004.95
VRWBV003.18</td><td>Sampling</td><td>pH; dissolved oxygen; total dissolved solids; turbidity; fluoride (1); cadmium (d); chromium (d); copper (t) (d); lead (t) (d); selenium (d); zinc (d); nitrite/nitrate; phosphorus; and hardness (1).</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: dissolved oxygen (2/7) assessed as “Inconclusive” (the low dissolved oxygen levels were found to be naturally occurring and were not considered a problem).

Subwatershed risk classification:
Moderate risk for metals because of limited data;
Low risk for sediment;
High risk for organics due to oxygen exceedances ; Low risk for other constituents; and
Low risk for selenium.</td></tr>
<tr><td rowspan="2">Wet Beaver Creek, from Rarick Canyon to Dry Beaver Creek.
15060202-003

One Site:
VRWBV003.16</td><td>Sampling</td><td>PH (1); dissolved oxygen (1); total dissolved solids (1); fluoride (1); barium (1); beryllium (1); antimony (1); uranium (1); nitrite/nitrate (1); and phosphorus (1).</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Subwatershed risk classifications:
Moderate risk for all constituent groups because of missing data.</td></tr>
<tr><td>Beaver Creek, from Dry Beaver to Verde River.
15060202-002

Seven Sites:
VRBEV003.27</td><td>Sampling</td><td>E. coli (1); pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d 1); chromium (t) (d 1); copper (t 1) (d); lead (t 1) (d); manganese (t) mercury (t 1) (d); selenium (t) (d); silver (t) (d); zinc (t) (d 1); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate; and total suspended solids.</td></tr>
</table>

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
VRBEV003.18 VRBEV002.62 VRBEV002.44 VRBEV002.02 VRBEV001.28 VRBEV000.62	Status	Parameters exceeding standards: turbidity standard (5/26) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals because of limited data; • High risk for sediment because of turbidity exceedances; • Moderate risk for organics because of limited data; Low risk for other constituents; and • Low risk for selenium.
Cherry Creek – Upper Verde River Subwatershed HUC 1506020207 Classification: • High risk for metals; • Extreme risk for sediment; • Extreme risk for organics; and • Moderate risk for selenium.		
Peck's Lake 15060202-1060 Three Sites: VRPEC-A VRPEC-AA VRPEC-F	Sampling	pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium (1); boron; cadmium (t) (d 2); chromium (t) (d 2); copper (t) (d 2); lead (t) (d 2); manganese (t); mercury (t) (d 2); selenium (t); silver (t) (d 2); zinc (t) (d 2); nickel (t) (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: dissolved oxygen (2/7) assessed as "Impaired". Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Extreme risk for organics due to dissolved oxygen impairment; Low risk for other constituents; and • Low risk for selenium.
Verde River, from Oak Creek to Beaver Creek. 15060202-015 Three Sites: VRVER078.8 VRVER078.76 VRVER075.14	Sampling	pH; dissolved oxygen (2); total dissolved solids (1); turbidity; fluoride (2),arsenic; barium; beryllium; antimony; thallium; boron (2); cadmium (t 2) (d 2); chromium (t 2) (d 2); copper (t 2) (d 2); lead (t 2) (d 2); manganese (t 2); mercury (t) (d 1); selenium (t 1); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate (1); hardness (1); and total suspended solids (1).
	Status	Parameters exceeding standards: none Subwatershed risk classification: • Moderate risk for metals because of limited data; • Extreme risk for sediment because impaired by turbidity. EPA approved sediment TMDL in 2002; • Moderate risk for organics because of limited data; and • Moderate risk for selenium because of limited data.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Verde River, from Beaver Creek to HUC Boundary 15060202-001	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none Subwatershed risk classification: • Moderate risk for metals because of limited data; • Extreme risk for sediment because impaired by turbidity. EPA approved sediment TMDL in 2002; • Moderate risk for organics because of limited data; and • Moderate risk for selenium because of limited data.
Bitter Creek from, Jerome WWTP to 2.5 miles below. 15060202-066B	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Bitter Creek, from unnamed tributary of headwaters to Bitter Creek. 15060202-868	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from Sycamore Creek to Oak Creek. 15060202-025 Eleven Sites: VRVER091.61 VRVER087.70 VRVER086.92 VRVER086.81 VRVER086.62 VRVER085.61 VRVER085.60 VRVER085.49 VRVER084.38 VRVER84.38 VRVER084.42 Note: This reach flows through two subwatershed HUCs: 1506020204 1506020207	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); uranium; nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and sulfate.
	Status	Parameters exceeding standards: mercury (1/1) assessed as “Inconclusive”; and lead (2/63) assessed as “Attaining”; turbidity (1/25) assessed as “Attaining”; and *E coli* (1/25) assessed as “Inconclusive”. Subwatershed risk classification: • High risk for metals due to mercury exceedance; • Moderate risk for sediment because turbidity exceedance; • Moderate risk for organics due to *E. coli* exceedance; and • Low risk for selenium.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
West Clear Creek Subwatershed **HUC 1506020301** **Classification:** • Moderate risk for metals; • Low risk for sediment; • Low risk for organics; and • Moderate risk for selenium.		
West Clear Creek, from Meadow Canyon to the Verde River. 15060203-026B Three Sites: VRWCL006.09 VRWCL005.79 VRWCL002.91	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; total suspended solids; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t 2) (d); chromium (t 2) (d 2); copper (t 2) (d); lead (t 2) (d 2); manganese (t); mercury (t 2) (d); selenium (t 1) (d); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and total suspended solids (2).
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • Low risk for organics and other constituents; and • Moderate risk for selenium because of limited data.
East Verde River Subwatershed **HUC 1506020302** **Classification:** • High risk for metals; • High risk for sediment; • Moderate risk for organics; and • Extreme risk for selenium.		
East Verde River, from Ellison Creek to American Gulch. 15060203-022B One Site: VREVR012.28	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t); chromium (t); copper (t); lead (t); manganese (t); mercury (t); selenium (t); silver (t); zinc (t); nickel (t); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and total suspended solids.
	Status	Parameters exceeding standards: lead (1/18) assessed as “Attaining”; mercury (1/18) assessed as “Attaining”; turbidity (3/16) assessed as “Attaining”; nitrogen (1/18) assessed as “Attaining”; and selenium (2/2) assessed as “Impaired”. Subwatershed risk classification: • Moderate risk for metals due to lead and mercury exceedances; • Moderate risk for sediment due to turbidity exceedances; • Moderate risk for organics due to nitrogen exceedance; Low risk for other constituents and • Extreme risk for selenium due to impairment.
East Verde River, from headwaters to Ellison Cree 15060203-022A One Site: VREVR015.97	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids (2); turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d - lab reporting limit too high); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
	Status	Parameters exceeding standards: turbidity (2/2) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals because of limited data; • High risk for sediment due to turbidity exceedances; • Low risk for organics and other constituents; and • Low risk for selenium.
Ellison Creek, from headwaters to East Verde River. 15060203-459	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Green Valley Lake AZL 15060203-0015	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Pine Creek, from headwat to unnamed tributary. 15060203-049A	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Pine Creek, from unnamed tributary to East Verde River. 15060203-049B	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Webber Creek, from headwaters to East Verde River. 15060203-058	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
East Verde River, from American Gulch to Verde River. 15060203-022C One Site: VREVR001.42	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: boron (4/20) assessed as "Inconclusive". Subwatershed risk classification: • High risk for metals due to boron exceedances; • Low risk for sediment; • Low risk for organics and other constituents; and • Low risk for selenium.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Fossil Creek – Lower Verde River Subwatershed **HUC 1506020303** **Classification:** • Moderate risk for metals; • Extreme risk for sediment; • High risk for organics; and • High risk for selenium.		
Verde River, from West Clear Creek to Fossil Creek. 15060203-025 Two Sites: VRVER064.80 VRVER064.68	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and total suspended solids (2).
	Status	Parameters exceeding standards: turbidity (6/17) assessed as "Impaired"; *E. coli* (1/16) assessed as "Attaining"; and selenium (1/1) assessed as "Inconclusive". Subwatershed risk classification: • Low risk for metals; • Extreme risk for sediment because impaired by turbidity. EPA approved sediment TMDL in 2002;Moderate risk for organics due to *E. coli* exceedance; Low risk for other constitutes; and • High risk for selenium due to exceedances.
Fossil Creek, from headwaters to Verde River. 15060203-024 One Site: VRFOS005.67	Sampling	*E. coli* (2); pH; dissolved oxygen (2); total dissolved solids (2); turbidity (2); fluoride (2); arsenic (2); barium (2); beryllium (2); antimony (2); selenium (2); thallium (2); boron (2); cadmium (t 2) (d 2); chromium (t 2) (d 2); copper (t 2) (d 1); lead (t 2) (d 2); manganese (t 2); mercury (t 2); selenium (t 2); silver (t 2) (d 2); zinc (t 2) (d 2); nickel (t 2) (d 2); nitrogen as ammonia (2); n-kjeldahl (2); nitrite/nitrate (2); and phosphorus (2).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Stehr Lake 15060203-1480	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from HUC border 15060203 to West Clear Creek. 15060203-027 Two Sites:	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; suspended sediment concentration; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t 1) (d 1); chromium (t) (d 1); copper (t) (d 1); lead (t) (d 1); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d 1); zinc (t 1) (d 1); nickel (t 1) (d 1); uranium; nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
VRVER066.74 VRVER066.64	Status	Parameters exceeding standards: *E. coli* (1/5) assessed as “Inconclusive”. Subwatershed risk classification: • Moderate risk for metals because of limited data; • Low risk for sediment; • High risk for organics due to *E. coli* exceedances; Low risk for other constituents; and • Low risk for selenium.
Tangle Creek – Lower Verde River Subwatershed HUC 1506020304 **Classification:** • Moderate risk for metals; • High risk for sediment; • Moderate risk for organics; and • Moderate risk for selenium.		
Roundtree Canyon Creek, from headwaters to Tangle Creek. 15060203-853 One Site: VRROU001.79	Sampling	pH (1); turbidity (1); cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Sycamore Creek, from headwaters to Verde River. 15060203-055 One Site: VRSYH000.16	Sampling	pH (1); turbidity (1); cadmium (d 1); copper (d 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Wet Bottom Creek, from headwaters to Verde River. 15060203-020	Sampling	No current monitoring data
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River, from Tangle Creek to Istar Flat. 15060203-018 Three Sites: VRVER036.68 VRVER036.48 VRVER032.74 Note: This reach flows through two subwatershed HUCs: 1506020304 1506020305	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and total suspended solids.
	Status	Parameters exceeding standards: copper (d) (1/58) assessed as “Attaining”; turbidity (5/24) assessed as “Inconclusive”; and *E. coli* (1/24) assessed as “Inconclusive”. Subwatershed risk classification: • Moderate risk for metals due to copper exceedance; • High risk for sediment due to turbidity exceedances; • Moderate risk for organics due to *E. coli* exceedance; Low risk for other constituents and • Low risk for selenium.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Lower Verde River – Horseshoe and Bartlett Reservoir Subwatershed **HUC 1506020305** **Classification:** • Moderate risk for metals; • High risk for sediment; • Moderate risk for organics; and • Moderate risk for selenium.		
Horseshoe Reservoir 15060203-0620 Four Sites: VRHSR-A VRHSR-B VRHSR-C VRHSR-East Spill Tower	Sampling	pH; dissolved oxygen; total dissolved solids; turbidity; arsenic (1); chromium (d 1); manganese (t); zinc (t); nitrogen as ammonia; n-kjeldahl; phosphorus; sulfate; and chlorine.
	Status	Parameters exceeding standards: turbidity (4/18) assessed as "Inconclusive"; and pH (1/16) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals due to lack of samples; • High risk for sediment due to turbidity exceedances; • Moderate risk for organics due to pH exceedances; Low risk for other constituents; and • Moderate risk for selenium because of lack of data.
Bartlett Lake 15060203-0110 Ten Sites: VRBAR-A (deepest) VRBAR-B (mid lake) VRBAR-C VRBAR-NTU1 through NTU5 VRBAR-MAR1 VRBAR-SW VRBAR-DAM SITE VRBAR-MID LAKE VRBAR- BARTLETT FLATS VRBAR-A	Sampling	*E. coli* (1); pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; boron; cadmium (t) (d 2); chromium (t) (d 2); copper (t) (d 2); lead (t) (d 2); manganese (t); mercury (t) (d); selenium (t) (d 2); silver (t) (d 2); zinc (t) (d 2); nickel (t) (d 2); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; sulfate; and chlorine.
	Status	Parameters exceeding standards: pH (1/60) assessed as "Attaining". Subwatershed risk classification: • Moderate risk for metals due to lack of data; • Low risk for sediment; • Moderate risk for organics due to pH exceedance; Low risk for other constituents; and • Low risk for selenium.
Verde River, from Tangle Creek to Istar Flat. 15060203-018 Three Sites: VRVER036.68 VRVER036.48 VRVER032.74 Note: This reach flows through two subwatershed HUCs: 1506020304 1506020305	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; phosphorus; and total suspended solids.
	Status	Parameters exceeding standards: copper (d) (1/58) assessed as "Attaining"; turbidity (5/24) assessed as "Inconclusive"; and *E. coli* (1/24) assessed as "Inconclusive". Subwatershed risk classification: • Moderate risk for metals due to copper exceedances; • High risk for sediment due to turbidity exceedances; • Moderate risk for organics due to *E. coli* exceedance; Low risk for other constituents; and • Low risk for selenium.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Verde River, from Horseshoe Dam to Alder Creek. 15060203-008 Four Sites: VRVER030.17 VRVER028.85 VRVER028.70 VRVER027.54	Sampling	*E. coli* (1); temperature; pH; dissolved oxygen; total dissolved solids (2); turbidity (1); fluoride (1); arsenic; barium (2); beryllium (2); antimony (1); selenium (1); thallium (1); boron (1); cadmium (t) (d 1); chromium (t) (d 1); copper (t) (d 1); lead (t) (d 1); manganese (t); mercury (t 1) (d 1); selenium (t 1); silver (t) (d 1); zinc (t) (d 1); nickel (t 1) (d 1); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate (1); phosphorus; sulfate; hardness (2); and total suspended solids (2).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Mesquite Wash Subwatershed **HUC 1506020306** **No Data Collected** **Classification:** • Moderate risk for all constituent groups due to lack of monitoring data.		
Camp Creek – Lower Verde River Subwatershed **HUC 1506020307** **Classification:** • Extreme risk for metals; • Moderate risk for sediment; • Extreme risk for organics; and • Extreme risk for selenium.		
Verde River (Bartlett Dam – Camp Creek) 15060203-004 Three Sites: VRVER018.51 VRVER018.13 VRVER017.55	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; turbidity; fluoride; arsenic; barium; beryllium; antimony; thallium; boron; cadmium (t) (d); chromium (t) (d); copper (t) (d); lead (t) (d); manganese (t); mercury (t) (d); selenium (t) (d); silver (t) (d); zinc (t) (d); nickel (t) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: copper (4/80) assessed as "Impaired"; and selenium (4/23) assessed as "Impaired". Subwatershed risk classification: • Extreme risk for metals due to copper impairment; • Low risk for sediment; • Low risk for organics; and • Extreme risk for selenium due to impairment.
Grande Wash (headwaters – Ashbrook Wash) 15060203-991 One Site: VRGRW000.30	Sampling	*E. coli* (2); pH; dissolved oxygen (2); total dissolved solids; suspended sediment concentration (2); fluoride (2),arsenic; barium; beryllium; antimony (2); selenium (2); thallium (1); boron (2); cadmium (t 1) (d); chromium (t 1) (d); copper (t 1) (d); lead (t 1) (d); manganese (t); mercury (t 1); selenium (t 1); silver (t 1) (d); zinc (t 1) (d); nickel (t 1) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: *E. coli* exceedances (2/2) assessed as "Impaired". Subwatershed risk classification: • Moderate risk for metals because of lack of data; • Moderate risk for sediment because of lack of data; • Extreme risk for organics due to *E. coli* impairment; Moderate risk for other constituents; and • Moderate risk for selenium because of lack of data.

Reach Sites	Results	Available Water Quality Data and Assessment Status[1,2,3]
Camp Creek (headwaters – Verde River 15060203-031 One Site: VRCMP009.30	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); turbidity (1); cadmium (d 1); copper (d 1); lead (t 1); mercury (d 1); selenium (d 1); nitrogen as ammonia (1); n-kjeldahl (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Colony Wash (headwaters – Fort McDowell Indian Reservation) 15060203-998 One Site: VRCLW001.43	Sampling	pH (1); dissolved oxygen (1); total dissolved solids (1); fluoride (1); arsenic (1); barium (1); beryllium (1); antimony (1); boron (1); cadmium (d 1); chromium (d 1); copper (d 1); lead (d 1); manganese (t 1); mercury (d 1); selenium (d 1); silver (d 1); zinc (d 1); nickel (d 1); nitrogen as ammonia (1); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Fountain Lake 15060203-0003 One Site: VRFHL	Sampling	pH; total dissolved solids (1); fluoride (1),arsenic (1); barium (1); beryllium (1); antimony (1); selenium (1); boron (1); cadmium (d 1); chromium (d 1); copper (d 1); lead (d 1); manganese (t 1); mercury (d 1); silver (d 1); zinc (d 1); nickel (d 1); nitrogen as ammonia (2); n-kjeldahl (1); nitrite/nitrate (1); and phosphorus (1).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River (Sycamore Creek – Salt River) 15060203-001 Two Sites: VRVER003.18 VRVER000.18	Sampling	temperature (2); pH (2); dissolved oxygen (2); total dissolved solids (2); turbidity (1); nitrogen as ammonia (2); n-kjeldahl (2); phosphorus (2); sulfate (2); and total suspended solids (2).
	Status	Parameters exceeding standards: none. Subwatershed risk classifications: • Moderate risk for all constituent groups because of missing data.
Verde River (Camp Creek – Sycamore Creek) 15060203-003 One Site: VRVER011.34	Sampling	*E. coli*; pH; dissolved oxygen; total dissolved solids; suspended sediment concentration; fluoride; arsenic; barium; beryllium; antimony; thallium (1); boron; cadmium (t 1) (d); chromium (t 1) (d); copper (t 1) (d); lead (t 1) (d); manganese (t); mercury (t 1) (d); selenium (t 1) (d); silver (t 1) (d); zinc (t1) (d); nickel (t 1) (d); nitrogen as ammonia; n-kjeldahl; nitrite/nitrate; and phosphorus.
	Status	Parameters exceeding standards: none. Subwatershed risk classification: • Moderate risk for metals because of lack of data; • Low risk for sediment; • Low risk for organics; and • Moderate risk for selenium because of lack of data.

[1] All water quality constituents had a minimum of three samples unless otherwise indicated by numbers in parenthesis. For example, arsenic (2) indicates two samples have been taken for arsenic on this reach.

[2] The number of samples that exceed a standard are described by a ratio. For example, the statement "Exceedances reported for E. coli (1/2)," indicates that one from two samples has exceeded standards for E. coli.

[3] The acronyms used for the water quality parameters are defined below:

(t) = (t) metal or metalloid (before filtration)
(d) = dissolved fraction of the metal or metalloid (after filtration)
cadmium (d): Filtered water sample analyzed for dissolved cadmium.
cadmium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) cadmium content.
chromium (d): Filtered water sample analyzed for dissolved chromium.
chromium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) chromium content.
copper (d): Filtered water sample analyzed for dissolved copper.
copper (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) copper content.
dissolved oxygen: dissolved Oxygen
E. coli: Escherichia coli bacteria
lead (d): Filtered water sample analyzed for dissolved lead.
lead (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) lead content.
manganese (d): Filtered water sample analyzed for dissolved manganese.
manganese (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) manganese content.
mercury (d): Filtered water sample analyzed for dissolved mercury.
mercury (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) mercury content.
nickel (d): Filtered water sample analyzed for dissolved nickel.
nickel (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) nickel content.
nitrate/nitrite: Water sample analyzed for Nitrite/Nitrate content.
n-kjeldahl: Water sample analyzed by the Kjeldahl nitrogen analytical method which determines the nitrogen content of organic and inorganic substances by a process of sample acid digestion, distillation, and titration.
pH: Water sample analyzed for levels of acidity or alkalinity.
selenium (d): Filtered water sample analyzed for dissolved selenium.
selenium (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) selenium content.
silver (d): Filtered water sample analyzed for dissolved silver.
silver (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) silver content.
suspended sediment concentration: Suspended Sediment Concentration
temperature: Sample temperature
total dissolved solids: total dissolved solids
total solids: (t) Solids
total suspended solids: (t) Suspended Solids
turbidity: Measurement of suspended matter in water sample.
zinc (d): Filtered water sample analyzed for dissolved zinc.
zinc (t): Unfiltered water sample and sediment/particulates suspended in the water sample analyzed for (t) zinc content.

Appendix B: Suggested References
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Appendix C: Revised Universal Soil Loss Equation (RUSLE) Modeling

The Revised Universal Soil Loss Equation (RUSLE) was used to model erosion potential. RUSLE computes average annual erosion from field slopes as (Renard, 1997):

$$A = R*K*L*S*C*P$$

Where:

A = computed average annual soil loss in tons/acre/year.
R = rainfall-runoff erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover-management factor
P = Conservation Practice

The modeling was conducted in the ArcInfo Grid environment using Van Remortel's (2004) Soil & Landform Metrics program. This is a series of Arc Macro Language (AML) programs and C++ executables that are run sequentially to prepare the data and run the RUSLE model. A 30-meter cell size was used to correspond to the requirements of the program.

All of the required input spatial data layers were converted to the projection required by the program (USGS Albers NAD83) and placed in the appropriate directories. The input data layers include:

- USGS Digital Elevation Model (DEM). The DEM was modified by multiplying it by 100 and converting it to an integer grid as prescribed by the program.

- Master watershed boundary grid (created from USGS DEM).

- National Land Cover Dataset (NLCD) land cover grid.

- Land mask grid for open waters, such as oceans or bays, derived from the NLCD land cover data. No oceans or bays are present in this watershed, so no cells were masked.

The first component AML of the program sets up the 'master' soil and landform spatial datasets for the study area. This includes extracting the STATSGO soil map and attributes as well as the R, C, and P factors, from datasets that come with the program. The R-factor is rainfall-runoff erosivity, or the potential of rainfall-runoff to cause erosion. The C-factor considers the type of cover or land management on the land surface. The P-factor looks at conservation practices, such as conservation tillage.

Additionally, a stream network is delineated from the DEM using a user specified threshold for contributing area. A threshold of 500 30x30 meter cells was specified as the contributing area for stream delineation. This number was chosen based on consultation with the program author. The AML also created the K factor grid. The K factor considers how susceptible a soil type is to erosion.

The second component AML sets up additional directory structures for any defined subwatersheds. In this use of the model the entire Upper Gila watershed was done as a single unit.

The third component AML iteratively computes a set of soil parameters derived from the National Resource Conservation Service's State Soil Geographic (STATSGO) Dataset.

The fourth component AML calculates the LS factor according to the RUSLE criteria using DEM-based elevation and flow path. The L and S factors take into account hill slope length and hill slope steepness.

The fifth component AML runs RUSLE and outputs R, K, LS, C, P factor grids and an A value grid that contains the modeled estimate of erosion in tons/acre/year for each cell.

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National Elevation Dataset 30-Meter Digital Elevation Models (DEMs). April 8, 2003. http://gisdata.usgs.net/NED/default.asp

**Note: Dates for each data set refer to when data was downloaded from the website. Metadata (information about how and when the GIS data were created) is available from the website in most cases. Metadata includes the original source of the data, when it was created, its geographic projection and scale, the name(s) of the contact person and/or organization, and general description of the data.*

Appendix D: Automated Geospatial Watershed Assessment Tool – AGWA

The Automated Geospatial Watershed Assessment (AGWA) tool is a multipurpose hydrologic analysis system for use by watershed, water resource, land use, and biological resource managers and scientists in performing watershed- and basin-scale studies (Burns et al., 2004). It was developed by the U.S.D.A. Agricultural Research Service's Southwest Watershed Research Center. AGWA is an extension for the Environmental Systems Research Institute's (ESRI) ArcView versions 3.x, a widely used and relatively inexpensive geographic information system (GIS) software package.

AGWA provides the functionality to conduct all phases of a watershed assessment for two widely used watershed hydrologic models: the Soil and Water Assessment Tool (SWAT); and the KINematic Runoff and EROSion model, KINEROS2.

The watershed assessment for the Upper Gila Watershed was performed with the Soil and Water Assessment Tool. SWAT (Arnold et al., 1994) was developed by the USDA Agricultural Research Service (ARS) to predict the effect of alternative land management decisions on water, sediment and chemical yields with reasonable accuracy for ungaged rural watersheds. It is a distributed, lumped-parameter model that will evaluate large, complex watersheds with varying soils, land use and management conditions over long periods of time (> 1 year). SWAT is a continuous-time model, i.e. a long-term yield model, using daily average input values, and is not designed to simulate detailed, single-event flood routing. Major components of the model include: hydrology, weather generator, sedimentation, soil temperature, crop growth, nutrients, pesticides, groundwater and lateral flow, and agricultural management. The Curve Number method is used to compute rainfall excess, and flow is routed through the channels using a variable storage coefficient method developed by Williams (1969). Additional information and the latest model updates for SWAT can be found at http://www.brc.tamus.edu/swat/.

Data used in AGWA include Digital Elevation Models (DEMs), land cover grids, soil data and precipitation data.

For this study data were obtained from the following sources:

- DEM: United States Geological Survey National Elevation Dataset, 30-Meter Digital Elevation Models (DEMs). April 8, 2003. http://gisdata.usgs.net/NED/default.asp

- Soils: USDA Natural Resource Conservation Service, STATSGO Soils. April 17, 2003. http://www.ncgc.nrcs.usda.gov/branch/ssb/products/statsgo/

- Land cover: United States Geological Survey. July 21, 2003. http://landcover.usgs.gov/natllandcover.asp

- Precipitation Data: Cooperative Summary of the Day TD3200: Includes daily weather data from the Western United States and the Pacific Islands. Version 1.0. August 2002. National Oceanic and Atmospheric Administration/National Climatic Data Center, Asheville, North Carolina.

The AGWA Tools menu is designed to reflect the order of tasks necessary to conduct a watershed assessment, which is broken out into five major steps, as shown in Figure 1 and listed below:

1. Watershed delineation and discretization;
2. Land cover and soils parameterization;
3. Writing the precipitation file for model input;
4. Writing the input parameter file and running the chosen model; and
5. Viewing the results.

When following these steps, the user first creates a watershed outline, which is a grid based on the accumulated flow to the designated outlet (pour point) of the study area. The user then specifies the contributing area for the establishment of stream channels and subwatersheds (model elements) as required by the model of choice.

From this point, the tasks are specific to the model that will be used, which in this case is SWAT. If internal runoff gages for model validation or ponds/reservoirs are present in the discretization, they can be used to further subdivide the watershed.

The application of AGWA is dependent on the presence of both land cover and soil GIS coverages. The watershed is intersected with these data, and parameters necessary for the hydrologic model runs are determined through a series of look-up tables. The hydrologic parameters are added to the watershed polygon and stream channel tables.

For SWAT, the user must provide daily rainfall values for rainfall gages within and near the watershed. If multiple gages are present, AGWA will build a Thiessen polygon map and create an area-weighted rainfall file. Precipitation files for model input are written from uniform (single gage) rainfall or distributed (multiple gage) rainfall data.

In this modeling process, the precipitation file was created for a 10-year period (1990-2000) based on data from the National Climatic Data Center. In each study watershed multiple gages were selected based on the adequacy of the data for this time period. The precipitation data file for model input was created from distributed rainfall data.

After all necessary input data have been prepared, the watershed has been subdivided into model elements, hydrologic parameters have been determined for each element, and rainfall files have been prepared, the user can run the hydrologic model of choice. SWAT was used in this application.

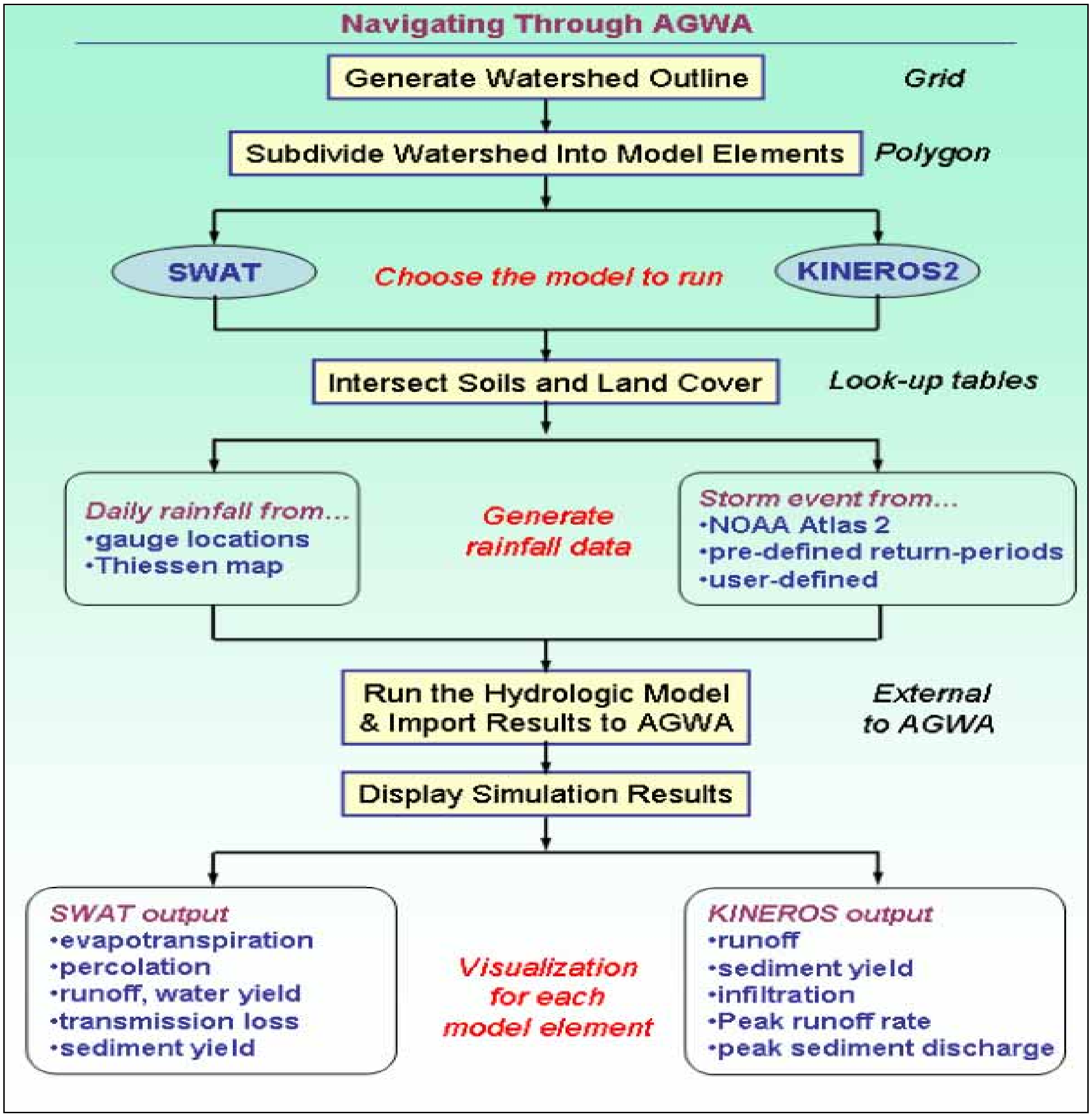

Figure D-1: Flow chart showing the general framework for using KINEROS2 and SWAT in AGWA.

After the model has run to completion, AGWA will automatically import the model results and add them to the polygon and stream map tables for display. A separate module within AGWA controls the visualization of model results. The user can toggle between viewing the total depth or accumulated volume of runoff, erosion, and infiltration output for both upland and channel elements. This enables problem areas to be identified visually so that limited resources can be focused for maximum effectiveness. Model results can also be overlaid with other digital data layers to further prioritize management activities.

Output variables available in AGWA/SWAT are:

- Channel Discharge (m^3/day);
- Evapotranspiration (ET) (mm);
- Percolation (mm);
- Surface Runoff (mm);
- Transmission loss (mm);
- Water yield (mm);
- Sediment yield (t/ha); and
- Precipitation (mm).

It is important to note that AGWA is designed to evaluate relative change and can only provide qualitative estimates of runoff and erosion. It cannot provide reliable quantitative estimates of runoff and erosion without careful calibration. It is also subject to the assumptions and limitations of its component models, and should always be applied with these in mind.

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