NEMO Watershed Based Plan

Agua Fria Watershed

ADEQ
Arizona Department of Environmental Quality

The University of Arizona
Tucson Arizona

Arizona Cooperative Extension
The University of Arizona • College of Agriculture and Life Sciences

Water Resources Research Center

Acknowledgements

Arizona NEMO acknowledges the University of Arizona Cooperative Extension Service, Arizona Department of Environmental Quality (ADEQ) Water Quality Division, the Water Resources Research Center, and the University of Arizona Advanced Resource Technology Lab (ART) for their technical support in producing the Watershed Based Plans.

Funding provided by the U.S. Environmental Protection Agency under the Clean Water Act and the Arizona Department of Environmental Quality's Water Quality Protection Division. Additional financial support is provided by the University of Arizona, Technology and Research Initiative Fund (TRIF), Water Sustainability Program through the Water Resources Research Center.

The NEMO website is www.ArizonaNEMO.org.

Written and prepared by:
Lainie R. Levick, Mickey Reed, Elisabeth vanderLeeuw, D. Phillip Guertin and Kristine Uhlman
University of Arizona
Tucson, Arizona
October 2006

Table of Contents

List of Figures

List of Tables

Appendices

Section 1: Introduction

Background: Nonpoint Source Pollution and NEMO

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 degradation of our water resources.

Water quality problems may originate from both "point" and "nonpoint" sources. The Clean Water Act (CWA) defines "point source" pollution as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged" (33 U.S.C. § 1362(14)). Point source discharge is regulated through provisions in the CWA.

Although nonpoint source pollution is not defined under the CWA, it is widely understood to be the type of pollution that arises from many dispersed activities over large areas, and is not traceable to any single discrete source. Nonpoint source pollution may originate 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 and ground water. In contrast to point source pollution, nonpoint source pollution is addressed primarily through non-regulatory means under the CWA. Nonpoint source pollution is the leading cause of water quality degradation across the United States, and is the water quality issue that NEMO, the Nonpoint Education for Municipal Officials program, and this watershed based plan will address.

Nationally, NEMO 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) and the University of Arizona (U of A) Water Resources Research Center, the Arizona Cooperative Extension at the U of A has initiated the Arizona NEMO program. Arizona NEMO attempts to adapt 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), and education on water conservation and riparian water quality restoration. Arizona NEMO maintains a website, http://www.ArizonaNEMO.org that contains these watershed based plans, Best Management Practices fact sheets, and other educational materials.

Watershed-Based Plans

Watershed-based plans are holistic documents 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 present proactive measures that can be applied to protect water bodies.

In watersheds with developed or drafted Total Maximum Daily Load (TMDL) studies for specific waterbodies, the watershed-based plan must be designed to achieve the load reductions identified in the TMDL. The CWA requires each state to perform a TMDL on waterbodies that are identified as impaired due to exceedances of state surface water quality standards. As point sources and nonpoint sources of pollution are determined through TMDL analysis, subsequent load reductions are assigned to each source as necessary for the purposes of improving water quality to meet state standards.

In collaboration with the local 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. 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.

The first component of the planning process is to characterize the watershed by summarizing all readily available natural resource information and other data for that 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 detailed planning documents. That document may cover a subwatershed area within the NEMO Watershed-based Plan, or include the entire watershed area. In addition, stakeholder-group local watershed-based plans will incorporate local knowledge and concerns gleaned from stakeholder involvement and will 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.

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. This NEMO watershed-based plan addresses each of these elements (except for Element 2: Expected Load Reductions); however, the watershed group must determine the final watershed plan and actions.

- 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.

<u>Purpose and Scope</u>

This watershed-based plan includes a watershed characterization and a watershed classification for the Agua Fria Watershed. The watershed characterization (Sections 2 through 5) will include the entire Agua Fria Watershed, while the classification (Sections 6 through 8) will address only the Upper Agua Fria Watershed (above Lake Pleasant). This is because the lower portions of the watershed have been heavily impacted by urbanization and agricultural development (including diversion canals) which have altered the topography and hydrology. Therefore, these areas cannot be modeled with the same methodology as the upper watershed, and will be modeled separately in a future report.

The Agua Fria Watershed is located in the central portion of the state of Arizona, southeast of the city of Prescott, and north of Phoenix, as shown in Figure 1-1. The light green portion of the watershed will be classified in this plan.

The watershed characterization in Sections 2 through 5 includes physical, biological, and social/economic data in a geographic information system (GIS) database format, as both mapped and tabulated data, that has been collected from available existing and published data sources. No new field data were collected for this plan. This characterization represents an inventory of natural resources and environmental conditions that affect primarily surface water quality. It provides educational outreach material to stakeholders and watershed partnerships.

The watershed classification identifies water quality problems by incorporating water quality data reported in *The Status of Water Quality in Arizona – 2004: Arizona's Integrated 305(b) Assessment and 303(d) Listing Report* (ADEQ, 2004), 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 identifying and mapping important resources, and ranking 10-digit HUC (hydrologic unit codes) subwatersheds (discussed later in this section) based on the likelihood of nonpoint source pollutant contribution to stream water quality degradation.

In addition to the watershed characterization and classification, this plan includes general discussions of recommended nonpoint source Best Management Practices (BMP) that may be implemented to achieve pollutant load reductions and other watershed goals. It provides methods and tools to identify problem sources and locations for implementation of BMPs to mitigate nonpoint source pollution.

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. 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.

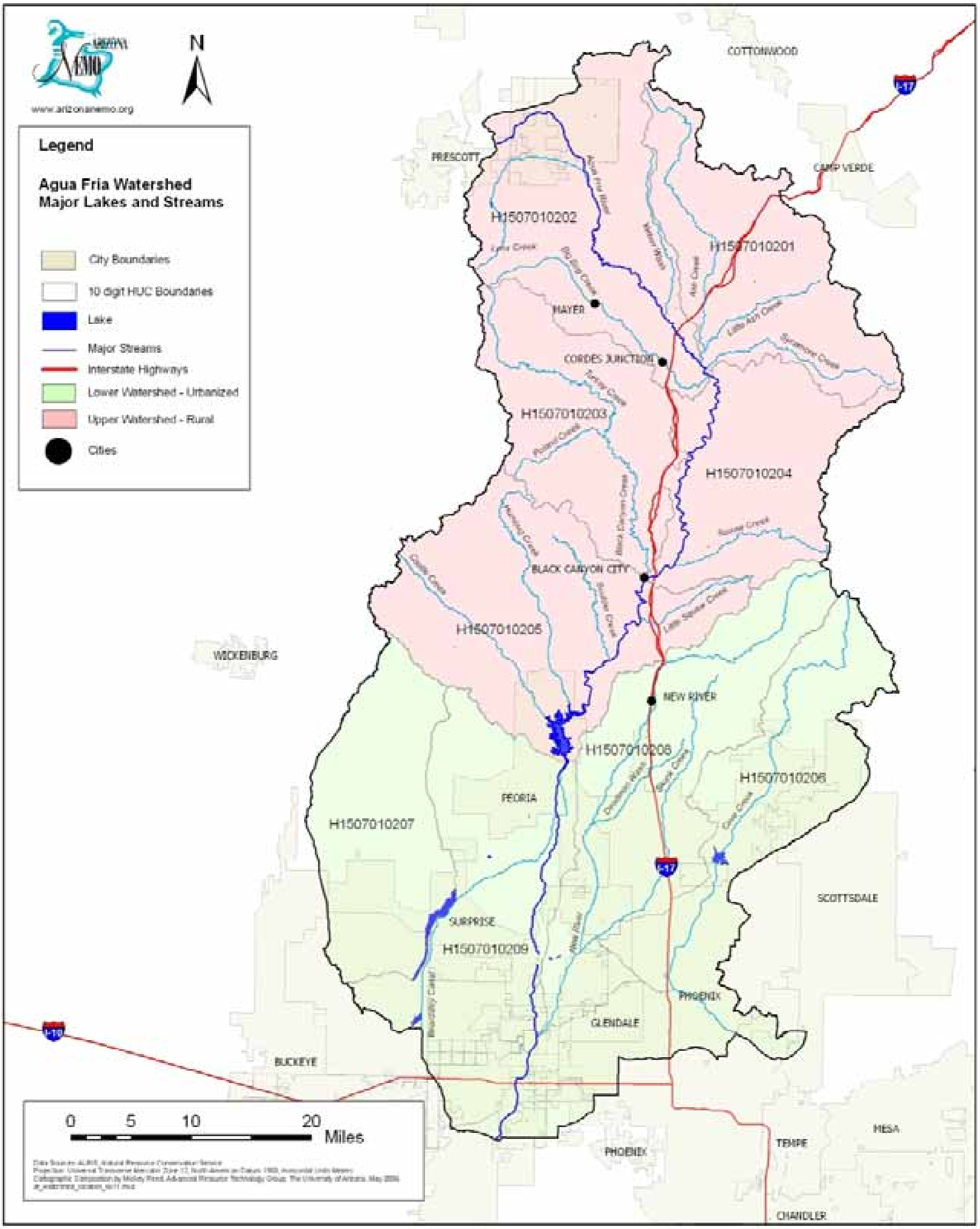


Figure 1-1: Agua Fria Watershed Location Map

Methods

The methods used to develop this watershed-based plan include GIS analysis and hydrologic modeling to classify and characterize the subwatersheds, and fuzzy logic to rank them.

GIS and Hydrologic Modeling

GIS and hydrologic modeling were the major tools used to develop this watershed-based plan. In a GIS, two types of information represent geographic features: locational and descriptive data. Locational (spatial) data are stored using a vector (line) or a raster (grid) 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 or cells, each of which is limited and defined by an equal amount of the earth's surface. These cells may be triangular or hexagonal, although the square is the most common. Corresponding descriptive (attribute) data for each geographic feature are stored in a set of tables. The spatial and descriptive data are linked in the GIS so that both sets of information are always available.

Planning and assessment in land and water resource management requires spatial modeling tools to incorporate complex watershed-scale attributes into the assessment process. Modeling tools applied to the Upper Agua Fria Watershed include 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 on runoff and sediment load in a 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 SEDMOD model (Van Remortel et al., 2004), which uses the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), was applied in this plan to estimate soil erosion and sediment delivery from different land use types. This procedure involves a series of automated Arc Macro Language (AML) scripts and two supported programs that run an ESRI ArcGIS 8.x Workstation platform.

The watershed classification within this plan 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, 2004). In addition, impacts due to mine sites (erosion and metals pollution) and grazing (erosion and pollutant nutrients) are simulated.

The Agua Fria Watershed is defined and mapped by the U.S. Geological Survey using the eight-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).

The Agua Fria is an eight-digit HUC watershed located within the Middle Gila River six-digit HUC watershed. Within the Agua Fria, smaller subwatershed areas are delineated using the ten-digit cataloging HUC. These ten-digit HUCs were used for the characterizations, classifications and GIS modeling.

The following nine HUC units and subwatershed names are used to clarify locations in this plan. Only the first five HUC units will be modeled in the GIS and classified.

H150701 Middle Gila Watershed

H15070102 Agua Fria Watershed

- 1507010201 - Ash Creek & Sycamore Creek
- 1507010202 - Big Bug Creek – Agua Fria River
- 1507010203 - Black Canyon Creek
- 1507010204 - Bishop Creek
- 1507010205 - Agua Fria River – Lake Pleasant
- 1507010206 - Cave Creek – Arizona Canal Division Channel
- 1507010207 - Trilby Wash – Trilby Wash Basin
- 1507010208 - New River
- 1507010209 - Agua Fria River below Lake Pleasant

Fuzzy Logic

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 set theory that handles vagueness or uncertainty, and has been described 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. Fuzzy logic allows for an object to be a partial member of a set.

For example, classical set theory might place a man into either the tall or short class, 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 would not be considered 'not-tall'. This is unacceptable, for example, for describing or quantifying 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, creating a discrete data set. A continuous data set would 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.

A benefit of using a fuzzy membership function is that it can be based on published data, expert opinions, stakeholder values or institutional policy, and can be created in a data-poor environment. Another benefit 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.

The general approach used in this plan 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 this watershed classification, the goal is to identify critical subwatersheds in which BMPs should be implemented to reduce nonpoint source pollution.

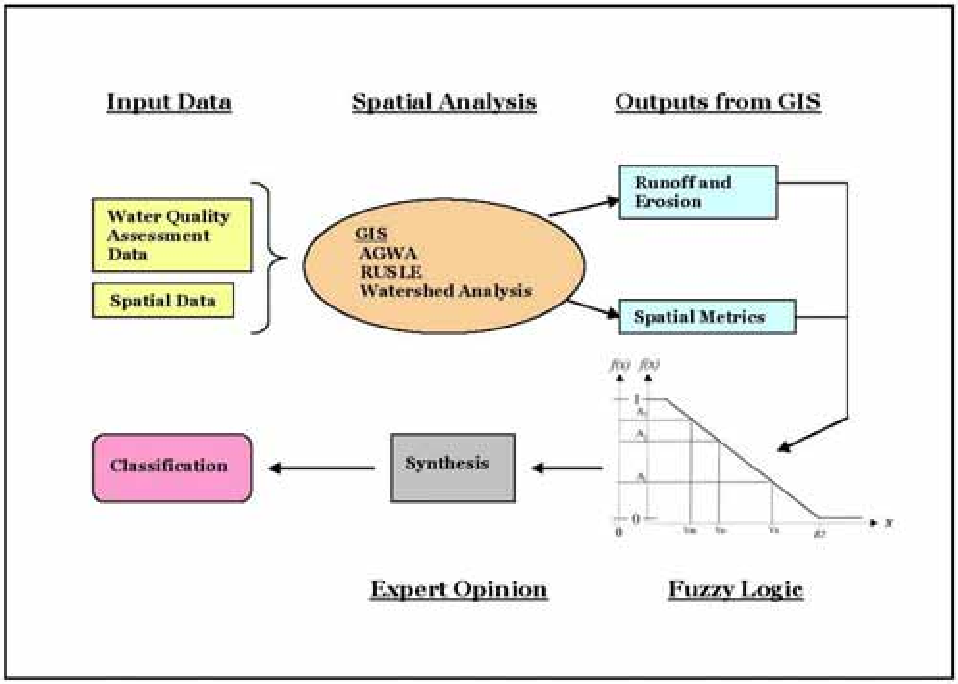


Figure 1-2: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.

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

1. Define the goal of this watershed classification: Classify water quality impairment due to dissolved total metals from mining activity;

2. Assemble GIS data and other observational data;

3. Define watershed characteristics through:

    a. Water quality data provided in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004);

    b. GIS mapping analysis; and

    c. Modeling and simulation of erosion vulnerability and potential for stream impairment (i.e. from soils at mine sites and proximity to abandoned mine sites).

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

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

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004), 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 final 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 exceedances in a constituent group and there are sufficient data to make a classification.

Classifications were conducted at the 10-digit HUC subwatershed scale, for just the Upper Agua Fria Watershed, resulting in the ranking of the five subwatershed areas.

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. These sections will address the entire Agua Fria Watershed (all nine 10-digit HUCs).

The 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, the Watershed Plan is presented in Section 8, and a summary of EPA's 9 Key Elements is provided in Section 9. These sections will address only the Upper Agua Fria Watershed (five 10-digit HUCs).

The full tabulation of the ADEQ water quality data and assessment status is provided in Appendix A. Suggested technical references of studies completed across the Agua Fria Watershed are included in Appendix B, a description of RUSLE is in Appendix C, and a description of AGWA is in Appendix D.

References:

Arizona Department of Environmental Quality, ADEQ. 2004. 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.

Arnold, J.G., J. R. Williams, R. Srinivasan, K.W. King, and R. H. Griggs. 1994. SWAT - Soil & Water Assessment Tool. USDA, Agricultural Research Service, Grassland, Soil and Water Research Laboratory, Temple, Texas.

Burns, I.S., S. Scott, L. Levick, M. Hernandez, D.C. Goodrich, S.N. Miller, D.J. Semmens, and W.G. Kepner. 2004. Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual *Version 1.4*, from http://www.tucson.ars.ag.gov/agwa/

Guertin, D.P., Fiedler, R.H., S.N. Miller, and D.C. Goodrich. 2000. Fuzzy logic for watershed assessment. Proceedings of the ASCE Conference on Science and Technology for the New Millennium: Watershed Management 2000, Fort Collins, CO, June 21-24, 2000.

Miller, S.N., W.G. Kepner, M.H. Mehaffrey, M. Hernandez, R.C. Miller, D.C. Goodrich, K.K. Devonald, D.T. Heggem, and W.P. Miller. 2002. Integrating Landscape Assessment and Hydrologic Modeling for Land Cover Change Analysis, in Journal of the American Water Resources Association, Vol. 38, No. 4, August. P. 915- 929.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), U. S. Department of Agriculture, Agriculture Handbook No. 703. 404 pp.

Reynolds, K.M. 2001. Fuzzy logic knowledge bases in integrated landscape assessment: Examples and possibilities. General Technical Report PNW-GTR-521. USDA Forest Service Pacific Northwest Research Station. 24 pp.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294. 63p.

Van Remortel, R., D. Heggem, and A. Pitchford. 2004. SEDMOD, Version 1.1 of Soil & Landform Metrics: Programs and U.S. Geodatasets (CD). U.S. Environmental Protection Agency, Environmental Sciences Division, Landscape Ecology Branch, Las Vegas, NV.

Section 2: Physical Features

The Agua Fria Watershed in Arizona is defined as the area drained by the Agua Fria River to the confluence with the Gila River west of the Phoenix metropolitan area near Avondale. The watershed is located in the central part of the state, from the western part of Phoenix, north to the Prescott area, as shown in Figure 2-1.

The Agua Fria National Monument encompasses two mesas and the canyon of the Agua Fria River. Elevations range from 2,150 feet above sea level along the Agua Fria Canyon to about 4,600 feet in the northern hills. This expansive mosaic of semi-desert area, cut by ribbons of valuable riparian forest, offers one of the most significant systems of prehistoric sites in the American Southwest. In addition to the rich record of human history, the monument contains outstanding biological resources. The diversity of vegetative communities, pristine riparian habitat, topographical features, and relative availability of water provide habitat for a wide array of sensitive species and other wildlife (http://www.blm.gov/az/aguafria/bkgda.htm).

Watershed Size

The Agua Fria Watershed covers approximately 2,784 square miles, representing about 2.4% of the state of Arizona. The watershed has a maximum approximate width of 46 miles east-west, and a maximum length of 90 miles north-south.

All watersheds in the U.S. were originally delineated by the U.S. Geological Survey into 8-digit HUC cataloging units, and were later subdivided into 10 or 11-digit HUC subwatersheds by the NRCS (http://cain.nbii.gov/calwater/calhist.html). Each drainage area has a unique hydrologic unit code number, or HUC, and a name based on the primary surface water feature within the HUC. The Agua Fria is an 8-digit HUC, and the subwatershed areas for this watershed-based plan were delineated on the basis of the 10-digit HUC. The classifications and GIS modeling were conducted on the ten-digit HUC subwatershed areas.

The subwatersheds 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.

Table 2-1: Agua Fria Watershed HUCs and Subwatershed Areas.

Subwatershed Name and HUC Designation	Area (square miles)
Ash Creek and Sycamore Creek H1507010201	**261**
Big Bug Creek-Agua Fria River H1507010202	**324**
Black Canyon Creek H1507010203	**244**
Bishop Creek H1507010204	**236**
Agua Fria River-Lake Pleasant H1507010205	**372**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**288**
Trilby Wash-Trilby Wash Basin H1507010207	**242**
New River H1507010208	**353**
Agua Fria River below Lake Pleasant H1507010209	**464**
Agua Fria Watershed	***2,784***

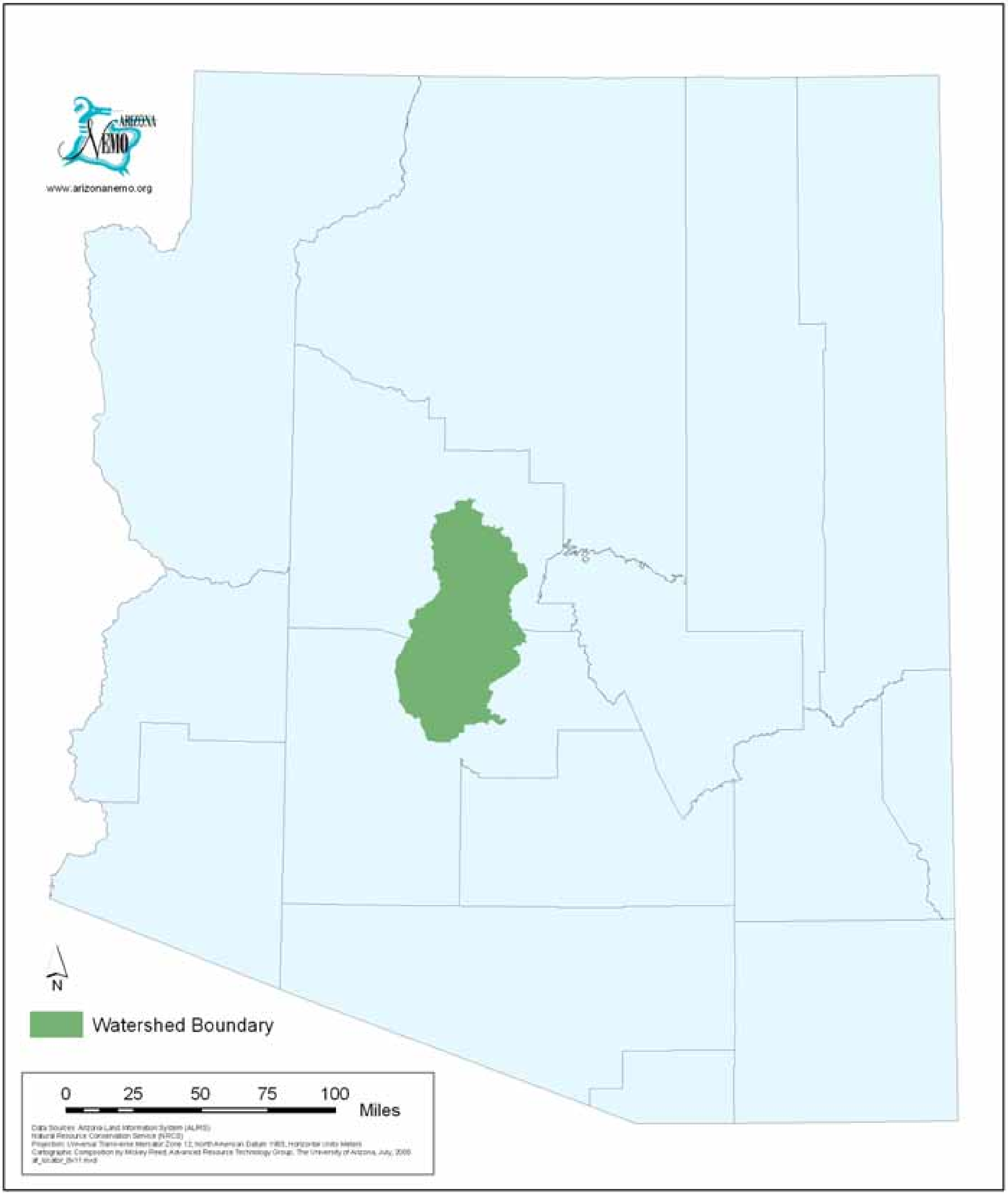


Figure 2-1: Agua Fria Watershed Location

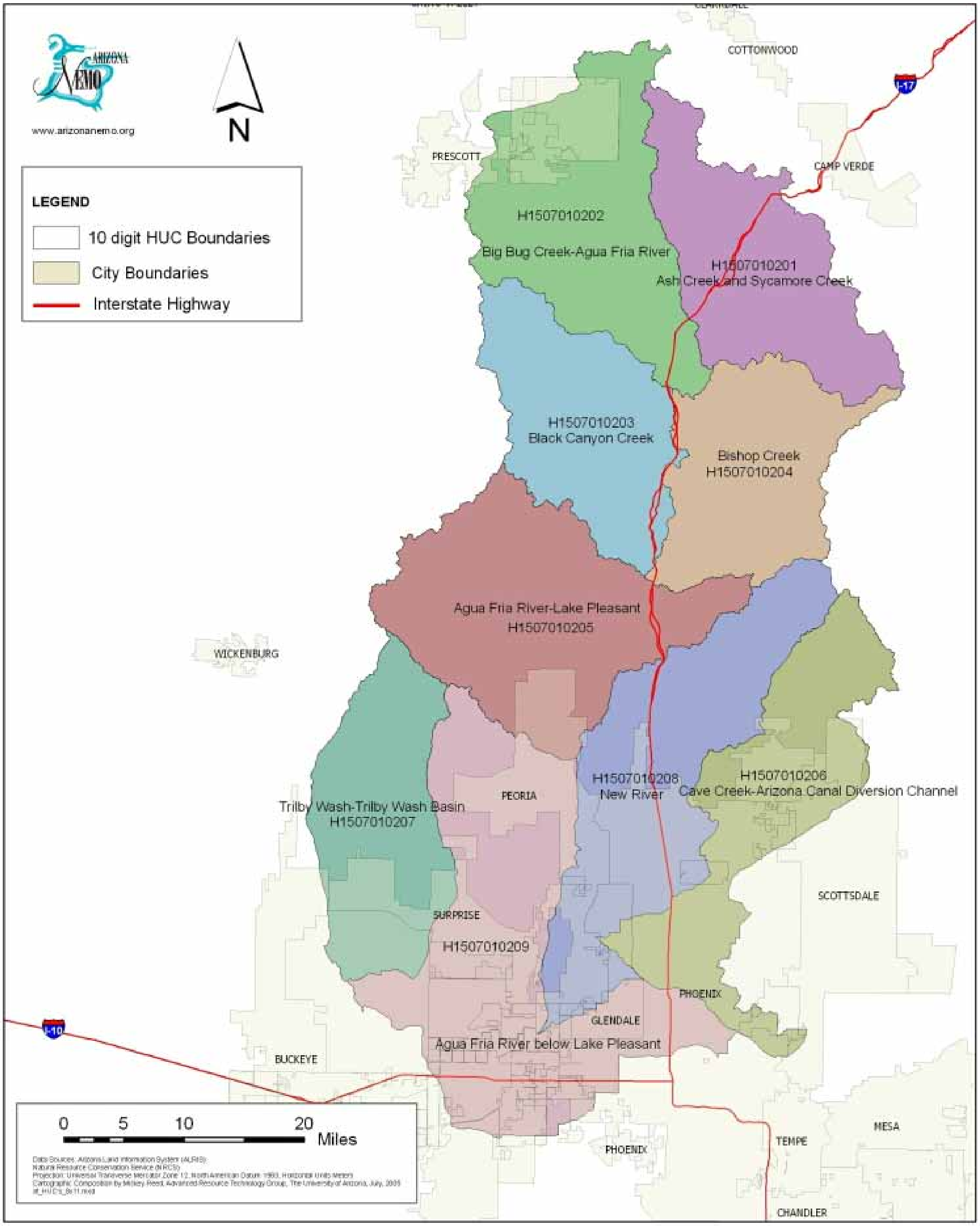


Figure 2-2: Agua Fria Watershed Subwatershed Names and HUCs (see Table 2-2 for subwatershed names).

The Prescott Active Management Area (AMA) is located in the far northwest portion of the watershed. An AMA is managed by the State to provide long-term management and conservation of ground water resources. The Prescott AMA is over 485 square miles, although only a small portion is within the Agua Fria Watershed. The mission of this AMA is to achieve safe-yield through the promotion of conservation and the development and utilization of renewable water sources.

The AMA consists of two sub-basins: the Little Chino and the Upper Agua Fria. Lynx Creek and other smaller ephemeral streams drain the Upper Agua Fria sub-basin into the Agua Fria River (ADWR, 2007).

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.

The land surface elevation of the Agua Fria Watershed ranges between 1,028 and 7,979 feet above sea level.
The tallest feature in the watershed is Mt. Union at 7,979 feet. The lowest point in the watershed is at the outlet of the Agua Fria River, at the very southern tip of the watershed where the Agua Fria joins with the Gila River west of the Phoenix metropolitan area near Avondale. Mean elevation for the whole Agua Fria Watershed is 3,084 feet (Table 2-2). The Agua Fria River below Lake Pleasant subwatershed (HUC 1507010209) is lower than the rest of the watershed with a mean elevation of 1,352 feet, almost 2,000 feet lower than the mean for the entire watershed (Figure 2-3).

Approximately 42.6% of the Agua Fria Watershed has a slope greater than 15%, while 39.1% of the watershed has a slope less than 5%. The Agua Fria River below Lake Pleasant subwatershed is flatter than the watershed mean with only 11.6% of its area over 15% slope, and 80.1% less than 5% slope. The Black Canyon Creek and Agua Fria – Lake Pleasant subwatersheds are the steepest, with 74.7% and 77.9% of the area greater than 15% slope, respectively (Table 2-3 and Figure 2-4).

Table 2-2: Agua Fria Watershed Elevation Range.

Subwatershed Name	Min (feet)	Max (feet)	Mean (feet)
Ash Creek and Sycamore Creek H1507010201	**3,503**	**7,095**	**4,805**
Big Bug Creek-Agua Fria River H1507010202	**3,455**	**7,890**	**5,045**
Black Canyon Creek H1507010203	**1,960**	**7,979**	**4,412**
Bishop Creek H1507010204	**1,960**	**6,812**	**3,960**
Agua Fria River-Lake Pleasant H1507010205	**1,434**	**7,206**	**3,057**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**1,205**	**5,394**	**2,377**
Trilby Wash-Trilby Wash Basin H1507010207	**1,331**	**4,329**	**1,957**
New River H1507010208	**1,028**	**5,866**	**2,164**
Agua Fria River below Lake Pleasant H1507010209	**902**	**4,085**	**1,352**
Agua Fria Watershed	***1,028***	***7,979***	***3,084***

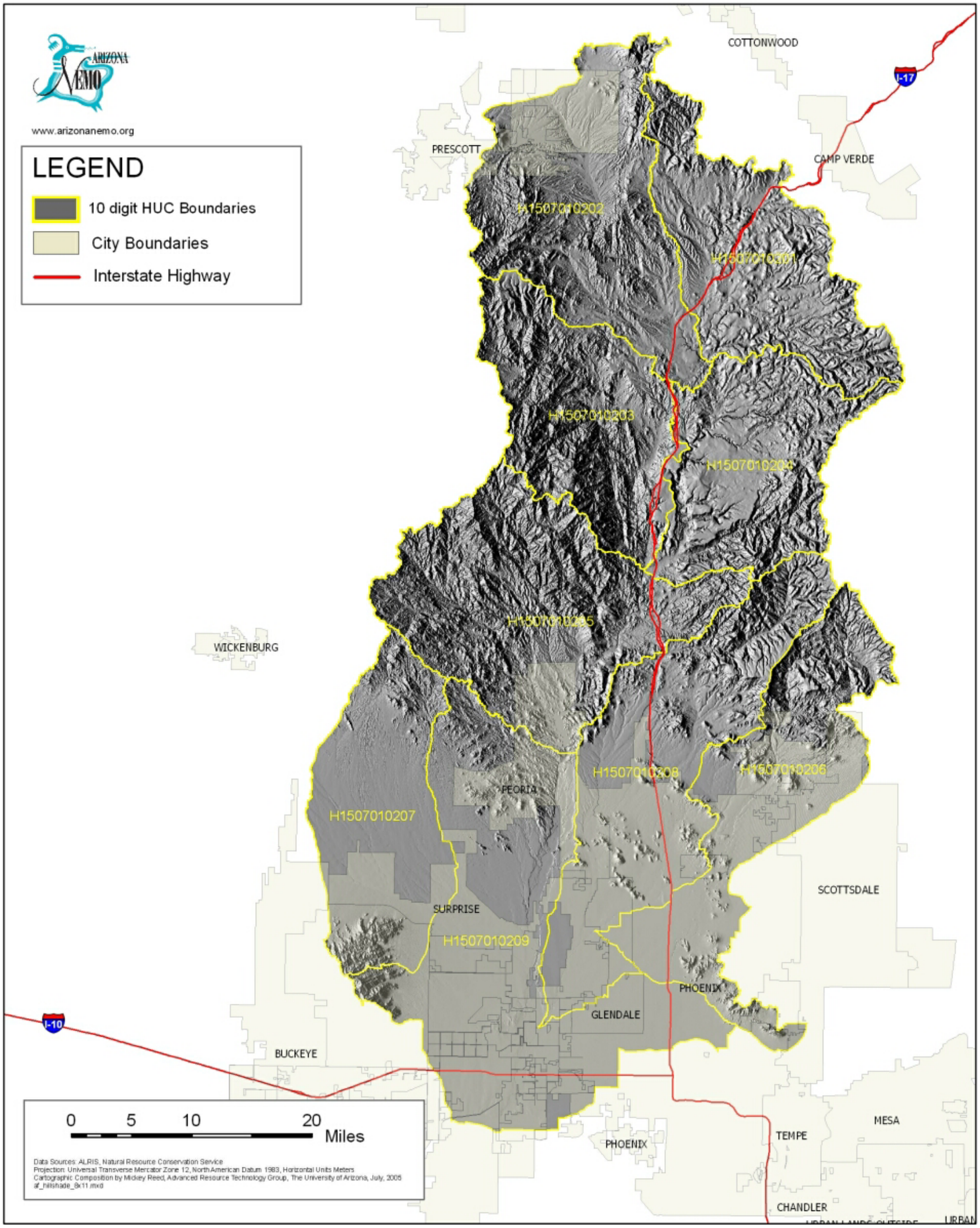


Figure 2-3: Agua Fria Watershed Topography (see Table 2-2 for subwatershed names).

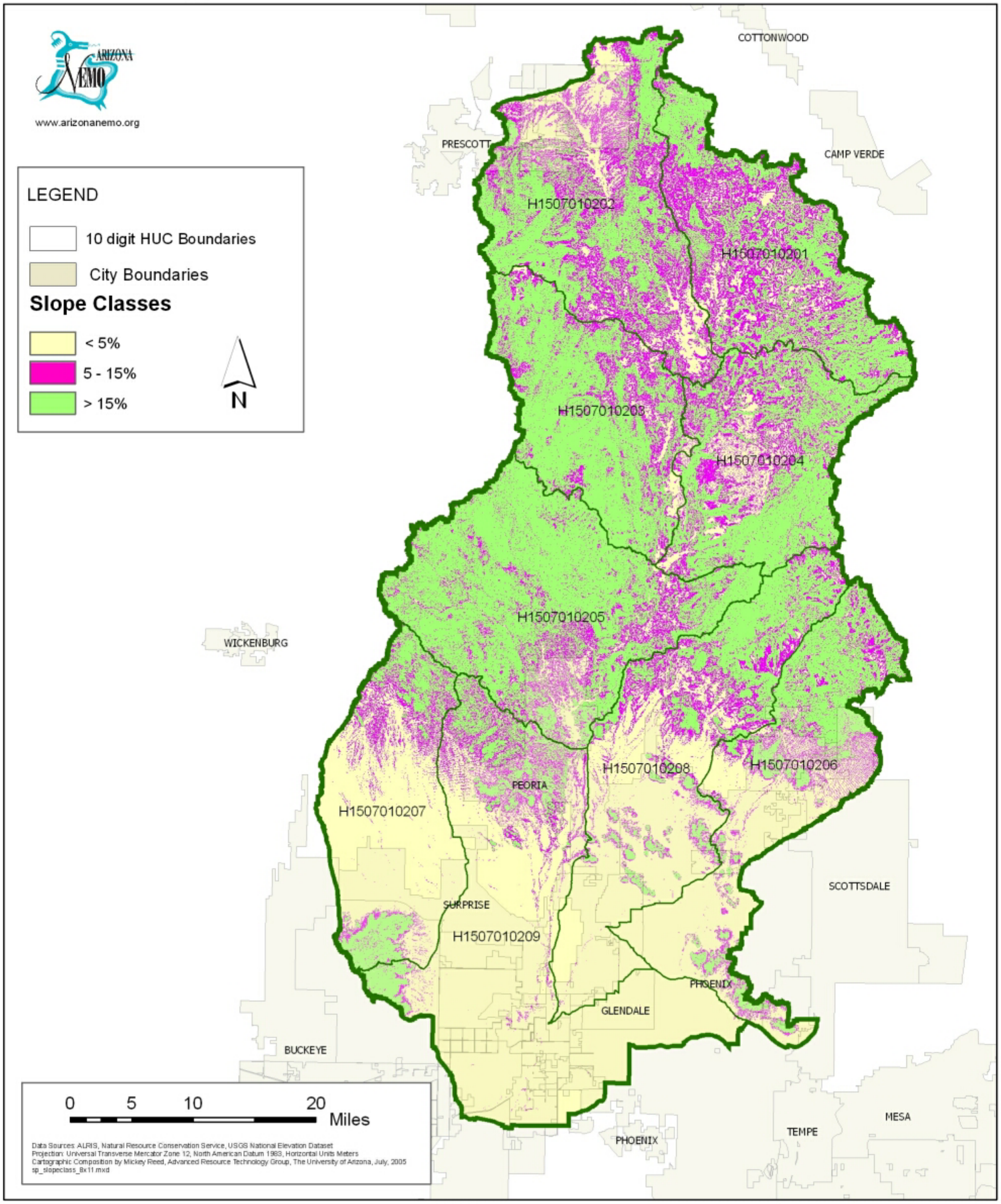


Figure 2-4: Agua Fria Watershed Slope Classes (see Table 2-2 for subwatershed names).

Table 2-3: Agua Fria Watershed Slope Classes.

Subwatershed Name	Area (sq. mi.)	Percent Slope		
		0-5%	5-15%	>15%
Ash Creek and Sycamore Creek H1507010201	**261**	**15.1**	**34.2**	**50.7**
Big Bug Creek-Agua Fria River H1507010202	**324**	**22.3**	**31.1**	**46.6**
Black Canyon Creek H1507010203	**244**	**7.4**	**17.9**	**74.7**
Bishop Creek H1507010204	**236**	**18.1**	**24.2**	**57.7**
Agua Fria River-Lake Pleasant H1507010205	**372**	**6.2**	**15.9**	**77.9**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**288**	**51.0**	**14.7**	**34.2**
Trilby Wash-Trilby Wash Basin H1507010207	**242**	**71.1**	**10.9**	**18.0**
New River H1507010208	**353**	**56.9**	**15.3**	**27.8**
Agua Fria River below Lake Pleasant H1507010209	**464**	**80.1**	**8.3**	**11.6**
Agua Fria Watershed	***2,784***	***39.1***	***18.4***	***42.6***

Water Resources

Lakes and Reservoirs

There are 27 mapped lakes and other water features in the Agua Fria Watershed. Trilby Wash Basin and Lake Pleasant are by far the largest surface waters with areas of 2,068 and 2,042 acres respectively. The next largest water body is Cave Creek Reservoir which covers 677 acres. Table 2-4 lists the major surface water bodies and their associated areas. Figure 2-5 shows the major lakes and streams. Table 2-5 lists the major streams and their lengths.

Stream Types

The Agua Fria Watershed contains a total of 3,377 miles of streams. There are three different stream types: perennial, intermittent and ephemeral.

- Perennial streams have surface water that flows continuously throughout the year.
- Intermittent streams are streams or reaches that flow 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.
- Ephemeral streams are at all times above the elevation of the ground water table, has no base flow, and flows only in direct response to precipitation.

Most 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).

Approximately 90.3% (3,048 miles) of the streams in the Agua Fria Watershed are intermittent or ephemeral. Only 9.6% (323 miles) of streams are perennial. Table 2-6 shows the percent perennial and intermittent/ephemeral streams in the Agua Fria Watershed. Figure 2-6 shows the stream types for the major streams in the watershed.

Table 2-4: Agua Fria Watershed Major Lakes and Reservoirs.

Lake Name (if known)	Subwatershed	Surface Area (acre)	Elevation (feet above mean sea level)	Dam Name (if known)
Trilby Wash Basin	Trilby Wash-Trilby Wash Basin	2,068	1,348	McMicken Dam
Lake Pleasant	Agua Fria River-Lake Pleasant	2,042	1,570	Carl Pleasant Dam
Cave Creek Reservoir	Cave Creek-AZ Canal Diversion Channel	677	1,642	Cave Creek Dam
not known	Agua Fria River below Lake Pleasant	261	1,202	not known
Lower Lake	Agua Fria River below Lake Pleasant	78	1,438	Camp Dyer Diversion Dam
Lynx Lake	Big Bug Creek-Agua Fria River	49	5,532	Lynx Lake Dam
Dawn Lake	New River	36	1,160	not known
Viewpoint Lake	New River	32	1159	not known
Bonita, Lake	Agua Fria River below Lake Pleasant	29	1,409	not known
not known	Agua Fria River below Lake Pleasant	15	1,046	not known
Caterpillar Tank	Agua Fria River below Lake Pleasant	12	1,535	not known
not known	Cave Creek-AZ Canal Diversion Channel	10	1,261	not known
not known	Cave Creek-AZ Canal Diversion Channel	9	1,266	not known
not known	Big Bug Creek – Agua Fria River	9	5,096	not known
Layton Tank	Agua Fria River-Lake Pleasant	8	2,786	not known
not known	New River	7	1,235	not known
Mesa Reservoir	Big Bug Creek-Agua Fria River	6	5,108	Mesa Reservoir Dam
not known	Agua Fria River below Lake Pleasant	6	1,061	not known
not known	Agua Fria River below Lake Pleasant	6	958	not known
not known	Agua Fria River below Lake Pleasant	6	943	not known
Hooker Tank	Ash Creek and Sycamore Creek	5	4,231	not known
not known	Agua Fria River below Lake Pleasant	5	1,227	not known
Cedar Tank	Black Canyon Creek	5	4,769	not known
not known	Big Bug Creek-Agua Fria River	4	3,868	not known
not known	Agua Fria River below Lake Pleasant	4	1,008	not known
Double Tank	Bishop Creek	3	3,727	not known
not known	Bishop Creek	3	3,454	not known

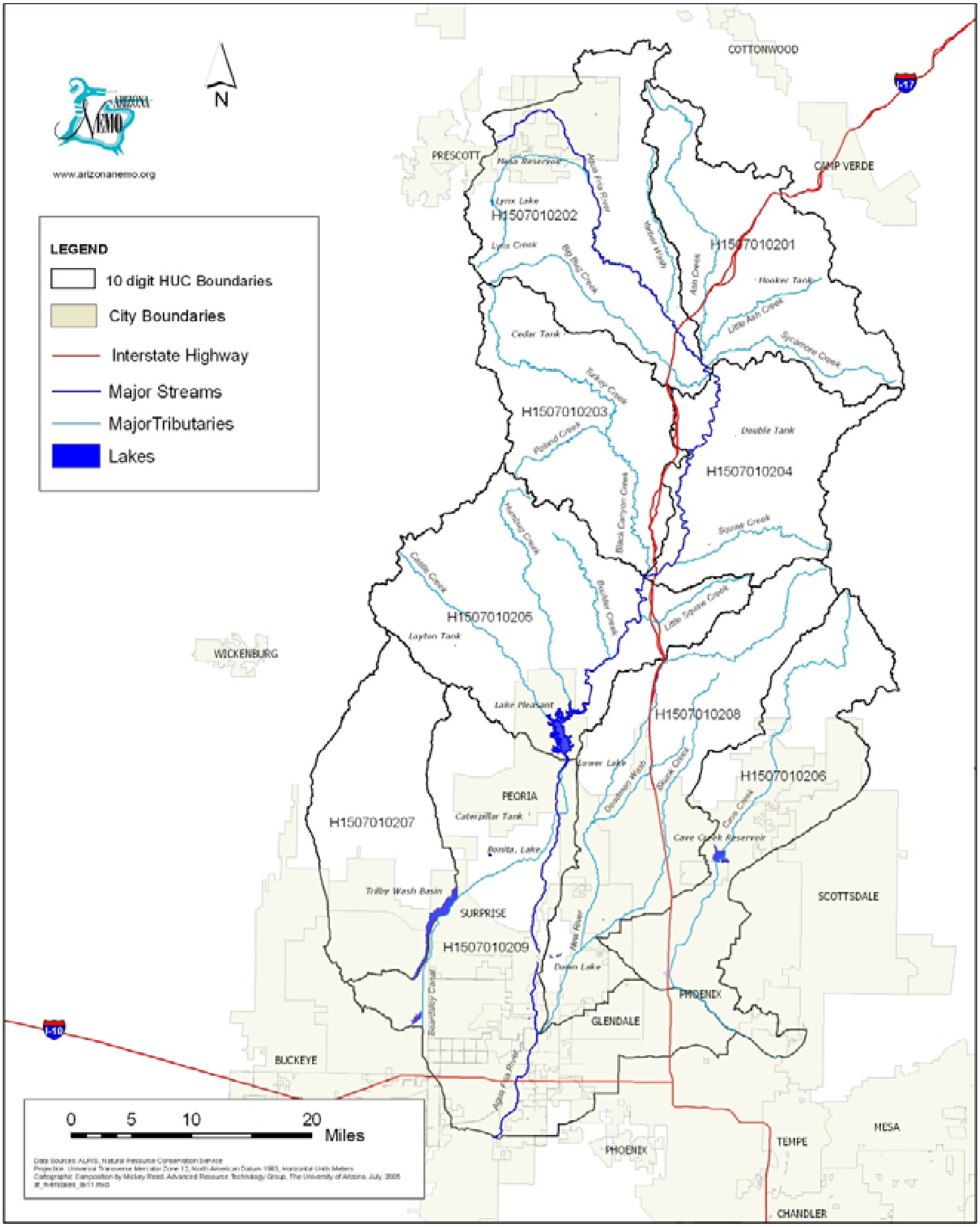


Figure 2-5: Agua Fria Watershed Major Lakes and Streams (see Table 2-2 for subwatershed names).

Table 2-5: Agua Fria Watershed Major Streams and Lengths.

Stream Name	Subwatershed	Stream Length (miles)
Agua Fria River	Agua Fria River below Lake Pleasant; Agua Fria River-Lake Pleasant; Ash Creek and Sycamore Creek; Big Bug Creek-Agua Fria River; Bishop Creek	172.8
Arizona Canal	Agua Fria River below Lake Pleasant; Cave Creek-Arizona Canal Diversion Channel	15.1
Ash Creek	Ash Creek and Sycamore Creek	34.2
Beardsley Canal	Agua Fria River below Lake Pleasant	32.1
Big Bug Creek	Big Bug Creek-Agua Fria River	29.0
Black Canyon Creek	Black Canyon Creek	19.1
Boulder Creek	Agua Fria River-Lake Pleasant	17.0
Castle Creek	Agua Fria River-Lake Pleasant	21.6
Cave Creek	Cave Creek-Arizona Canal Diversion Channel	45.5
Deadman Wash	New River	12.3
Humbug Creek	Agua Fria River-Lake Pleasant	27.5
Little Ash Creek	Ash Creek and Sycamore Creek	5.2
Little Squaw Creek	Agua Fria River-Lake Pleasant	12.3
Lynx Creek	Big Bug Creek-Agua Fria River	21.5
New River	New River	59.1
Poland Creek	Black Canyon Creek	11.3
Skunk Creek	Bishop Creek	30.4
Squaw Creek	Bishop Creek	17.9
Sycamore Creek	Ash Creek and Sycamore Creek	22.5
Turkey Creek	Black Canyon Creek	30.2
Yarber Wash	Big Bug Creek-Agua Fria River	16.8
Yellow Jacket Creek	Ash Creek and Sycamore Creek	8.4

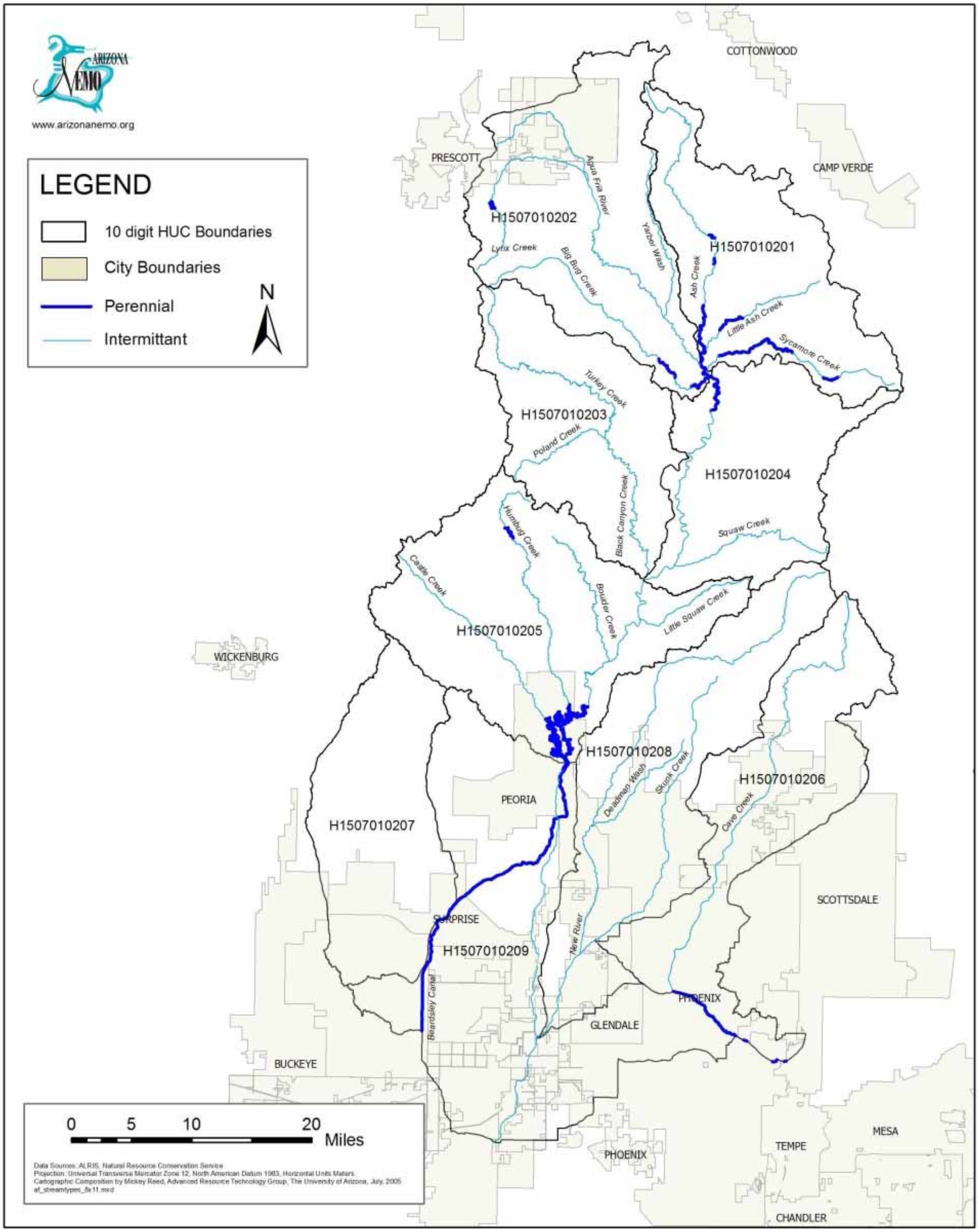


Figure 2-6: Agua Fria Watershed Stream Types for Major Streams (see Table 2-2 for subwatershed names).

Table 2-6: Agua Fria Watershed Stream Types and Length for All Streams.

Stream Type	Stream Length (miles)	Percent of Total Stream Length
Intermittent	**3,048**	**90.3%**
Perennial	**323**	**9.6%**
Ephemeral	**6**	**<1%**
Total Length	***3,377***	***100%***

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 network for the Agua Fria 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 Agua Fria Watershed is 10.15 feet/acre. The Agua Fria River – Lake Pleasant subwatershed has the highest drainage density at 11.75 feet/acre. The Agua Fria River below Lake Pleasant subwatershed has the lowest drainage density at 8.6 feet/acre.

Annual Stream Flow

Annual stream flows for twenty one gages were obtained for the Agua Fria 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 the Agua Fria River at Waddell Dam had the highest measured annual mean stream flow with 320.87 cubic feet per second (cfs); however those data are very old (1915 to 1918). More recent data show that the Agua Fria River near Rock Springs had the greatest annual mean stream flow with 78.89 cfs in 1995, for the period from 1966 through 2004.

Figures 2-9 through 2-14 show hydrographs for three selected U.S. Geological Survey stream gages, for mean daily flow and for a five-year moving average mean annual flow. These graphs show the variability in streamflow over time and space in this watershed.

For example, Figure 2-9 shows that at the Agua Fria River at Avondale there were series of years where there was little or no flow, but the five year moving average (Figure 2-10) shows an increasing trend in stream flow. This gage is located west of Phoenix, near the confluence with the Gila River.

Figure 2-13 shows that the mean daily stream flow at the Agua Fria River near Mayer has less variation than at Avondale, but also shows an increasing trend for the five year moving average. This gage is near the headwaters of the Agua Fria River.

Table 2-7: Agua Fria Watershed Stream Density.

Subwatershed Name	Area (acres)	Stream Length (feet)	Stream Density (feet / acre)
Ash Creek and Sycamore Creek H1507010201	**166,753**	**1,870,879**	**11.22**
Big Bug Creek-Agua Fria River H1507010202	**207,451**	**2,326,083**	**11.21**
Black Canyon Creek H1507010203	**156,207**	**1,643,817**	**10.52**
Bishop Creek H1507010204	**151,326**	**1,738,604**	**11.49**
Agua Fria River-Lake Pleasant H1507010205	**237,961**	**2,795,808**	**11.75**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**184,619**	**1,692,224**	**9.17**
Trilby Wash-Trilby Wash Basin H1507010207	**154,998**	**1,347,118**	**8.69**
New River H1507010208	**226,035**	**2,125,263**	**9.40**
Agua Fria River below Lake Pleasant H1507010209	**297,159**	**2,554,781**	**8.60**
Agua Fria Watershed	***1,782,510***	***18,094,576***	***10.15***

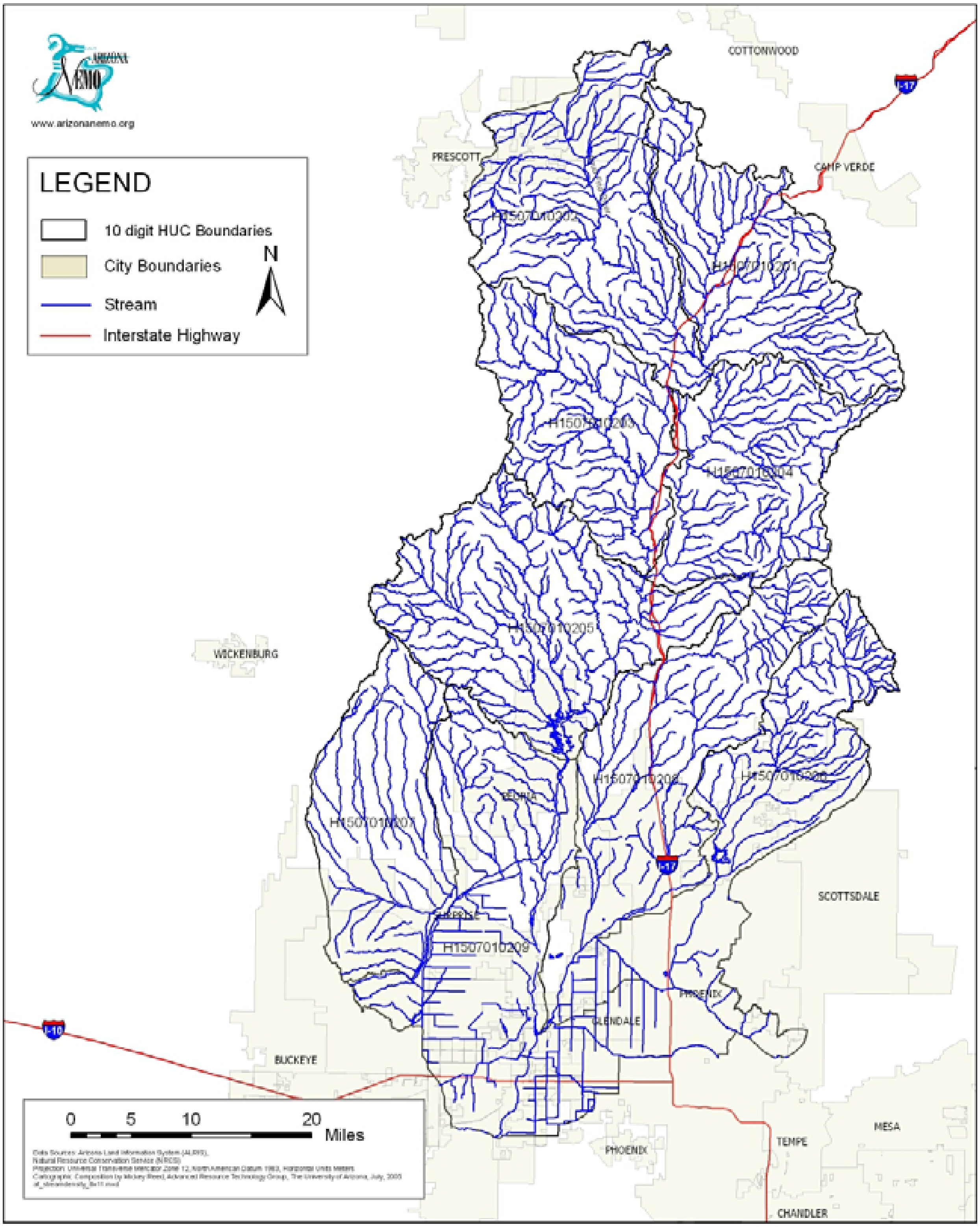


Figure 2-7: Agua Fria Watershed Stream Density (see Table 2-2 for subwatershed names).

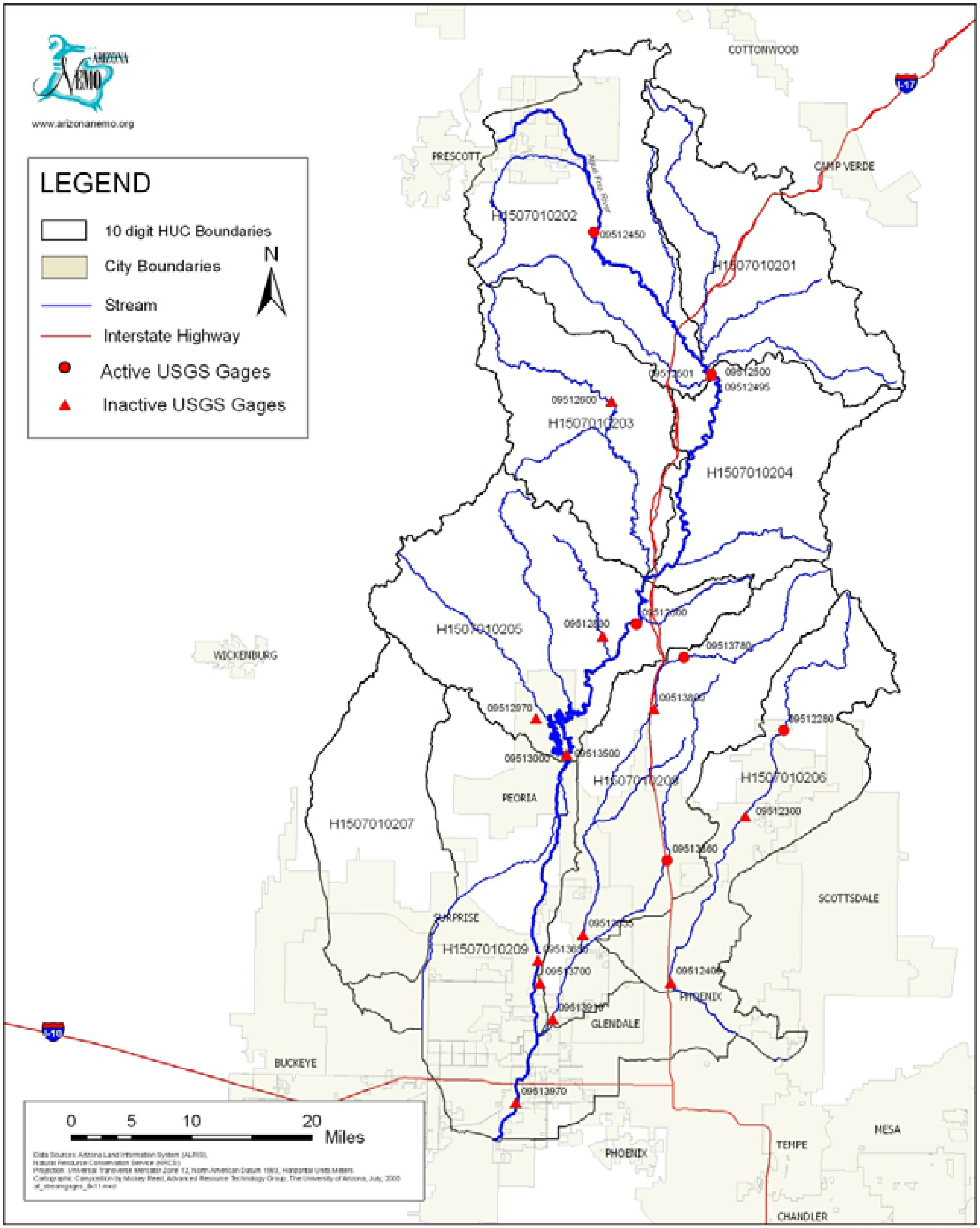


Figure 2-8: Agua Fria Watershed USGS Stream Gages (see Table 2-2 for subwatershed names).

Table 2-8: Agua Fria Watershed USGS Stream Gages and Annual Mean Stream Flow.

USGS Gage ID	Site Name	Begin Date	End Date	Annual Mean Stream Flow (cfs)
9512450	Agua Fria River near Humboldt	1/1/2001	12/30/2004	3.89
9512495	Perry Canal near Mayer	1/1/1941	12/30/1958	0.45
9512500	Agua Fria River Near Mayer	1/1/1940	12/30/2004	22.25
9512501	Sycamore Dam Site Total *	1/1/1941	12/30/1959	24.09
9512501	Sycamore Dam Site Total *	1/1/1978	12/30/1980	85.3
9512600	Turkey Creek near Cleator	1/1/1980	12/30/1991	11.26
9512800	Agua Fria River near Rock Springs	1/1/1971	12/30/2004	78.89
9512830	Boulder Creek near Rock Springs	1/1/1984	12/30/1992	3.25
9512970	Cottonwood Creek near Waddell Dam	1/1/1984	12/30/1992	0.35
9513000	Agua Fria River at Waddell Dam	1/1/1915	12/30/1918	320.87
9513650	Agua Fria River at El Mirage	1/1/1994	12/30/1997	0.085
9513700	Agua Fria River Trib at Youngtown	1/1/1962	12/30/1967	0.016
9513780	New River near Rock Springs	1/1/1966	12/30/2004	12.06
9513800	New River at New River	1/1/1961	12/30/1981	13.96
9513835	New River at Bell Road, Near Peoria *	1/1/1968	12/30/1983	11.31
9513835	New River at Bell Road, Near Peoria *	1/1/1991	12/30/1992	7.78
9513860	Skunk Creek, near Phoenix	1/1/1968	12/30/2004	1.48
9513910	New River near Glendale *	1/1/1965	12/30/1969	11.19
9513910	New River near Glendale *	1/1/1991	12/30/1997	32.41
9513970	Agua Fria River at Avondale	1/1/1968	12/30/1981	35.25

* discontinuous years of data

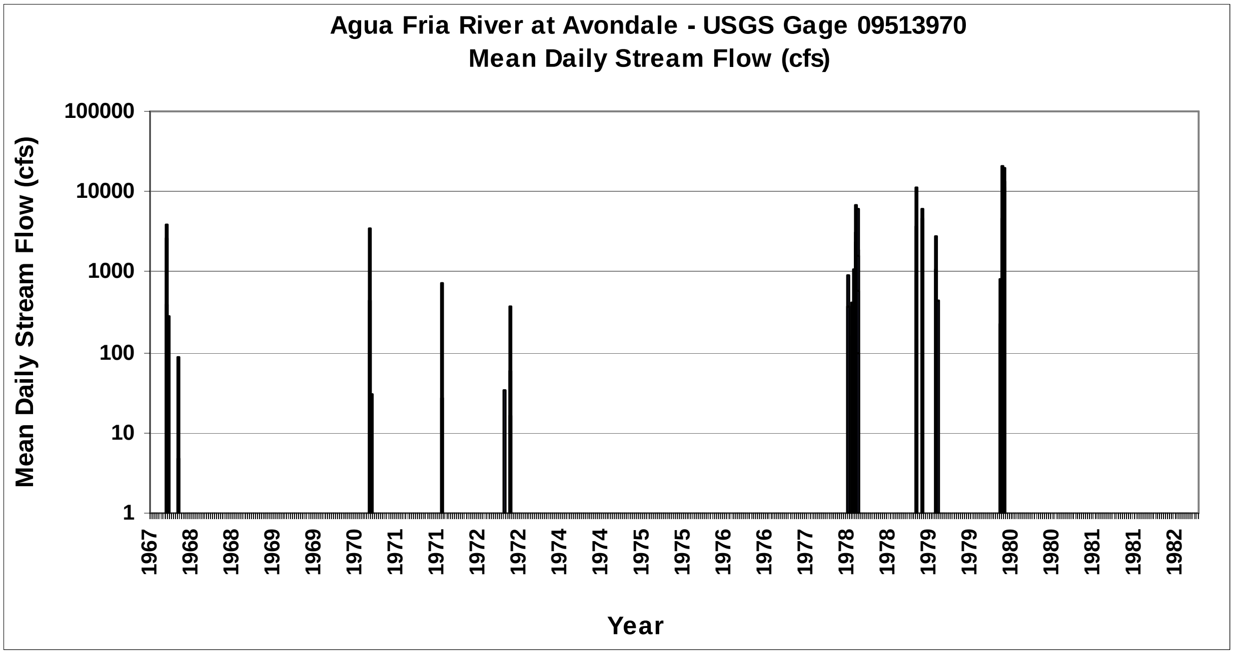


Figure 2-9: Agua Fria River at Avondale USGS Gage 09513970, Mean Daily Stream Flow (cfs) Hydrograph.

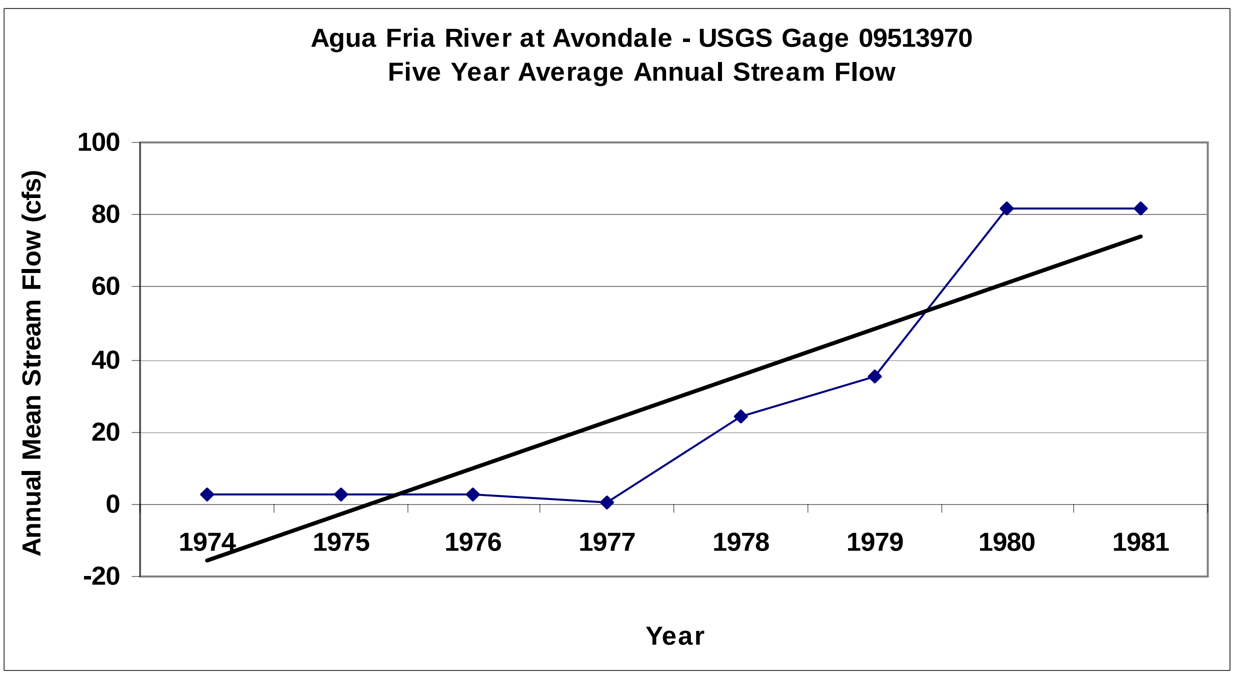


Figure 2-10: Agua Fria River at Avondale USGS Gage 09513970, Five Year Moving Average Annual Stream Flow (cfs) Hydrograph.

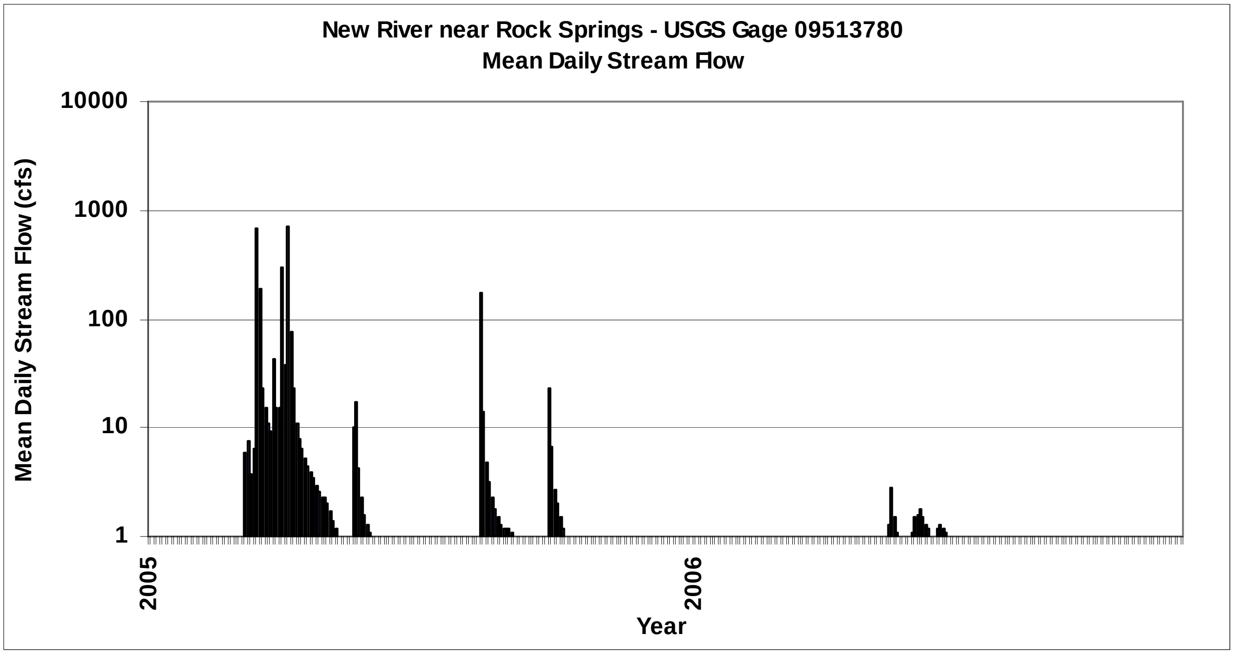


Figure 2-11: New River near Rock Springs USGS Gage 09513780, Mean Daily Stream Flow (cfs) Hydrograph.

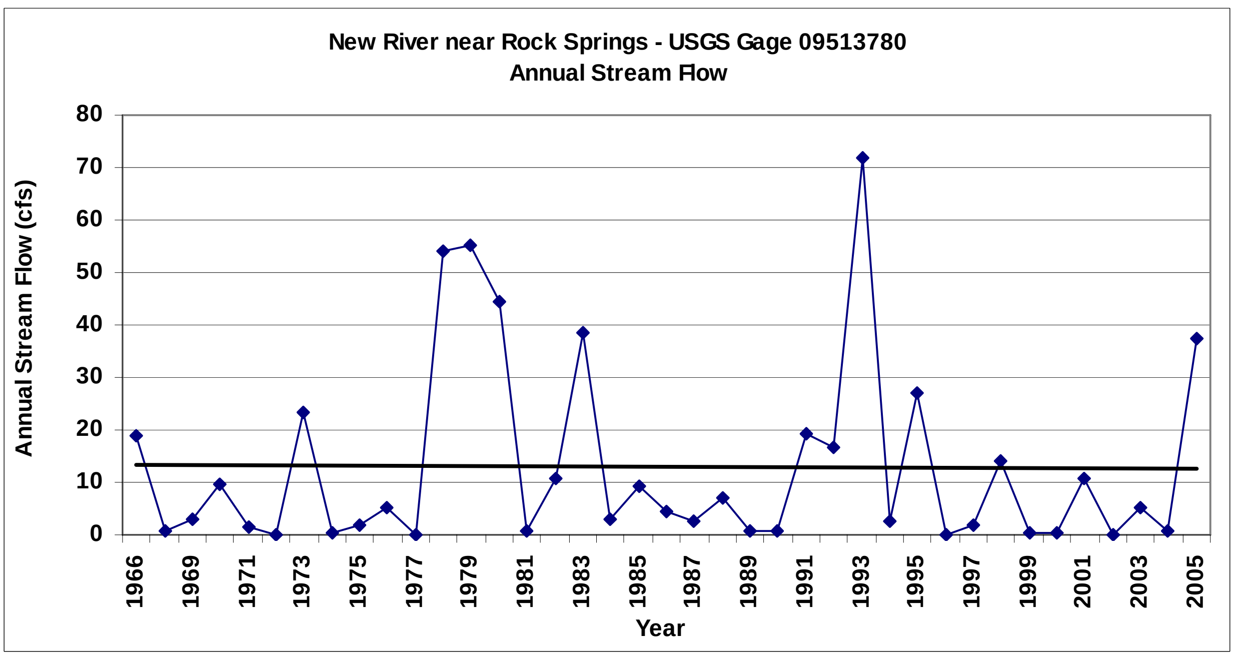


Figure 2-12: New River near Rock Springs USGS Gage 09513780, Five Year Moving Average Annual Stream Flow (cfs) Hydrograph.

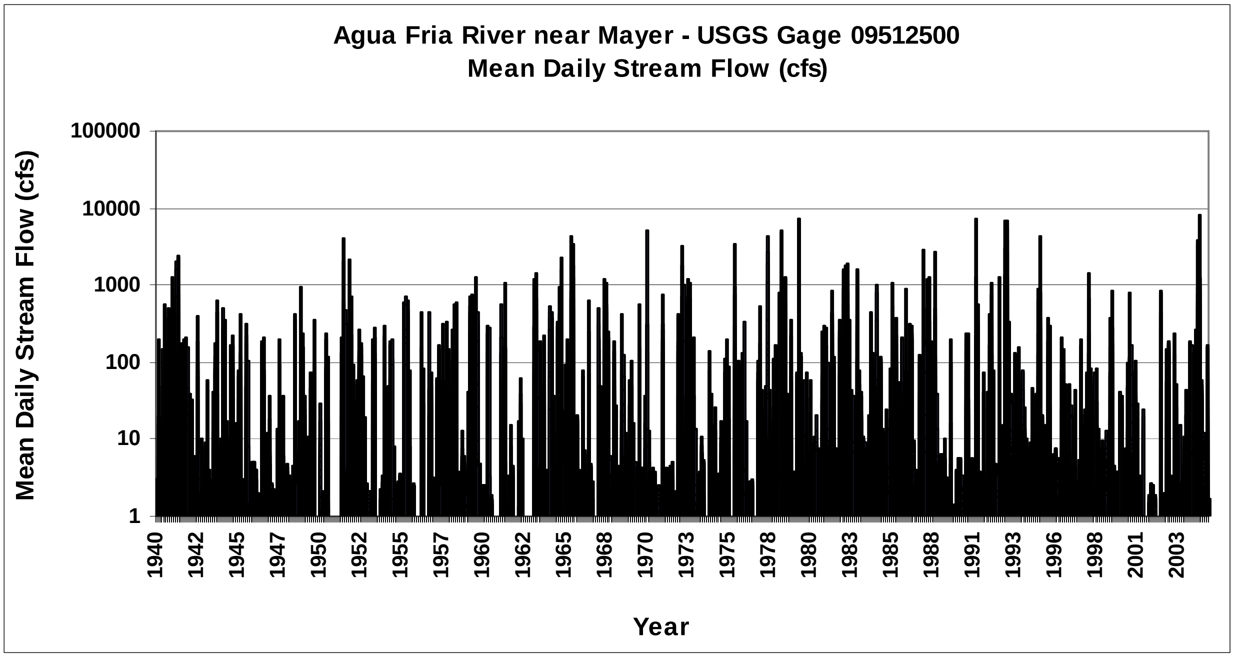


Figure 2-13: Agua Fria River near Mayer USGS Gage 09512500, Mean Daily Stream Flow (cfs) Hydrograph.

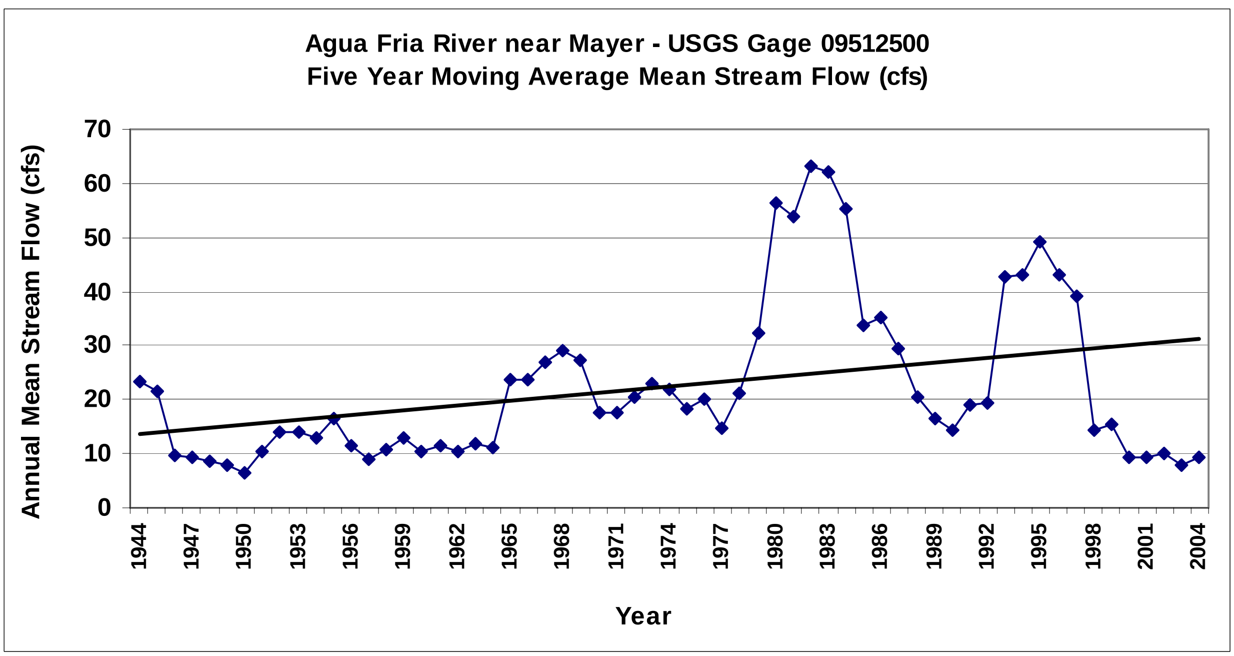


Figure 2-14: Agua Fria River near Mayer USGS Gage 09512500, Five Year Moving Average Mean Stream Flow (cfs) Hydrograph.

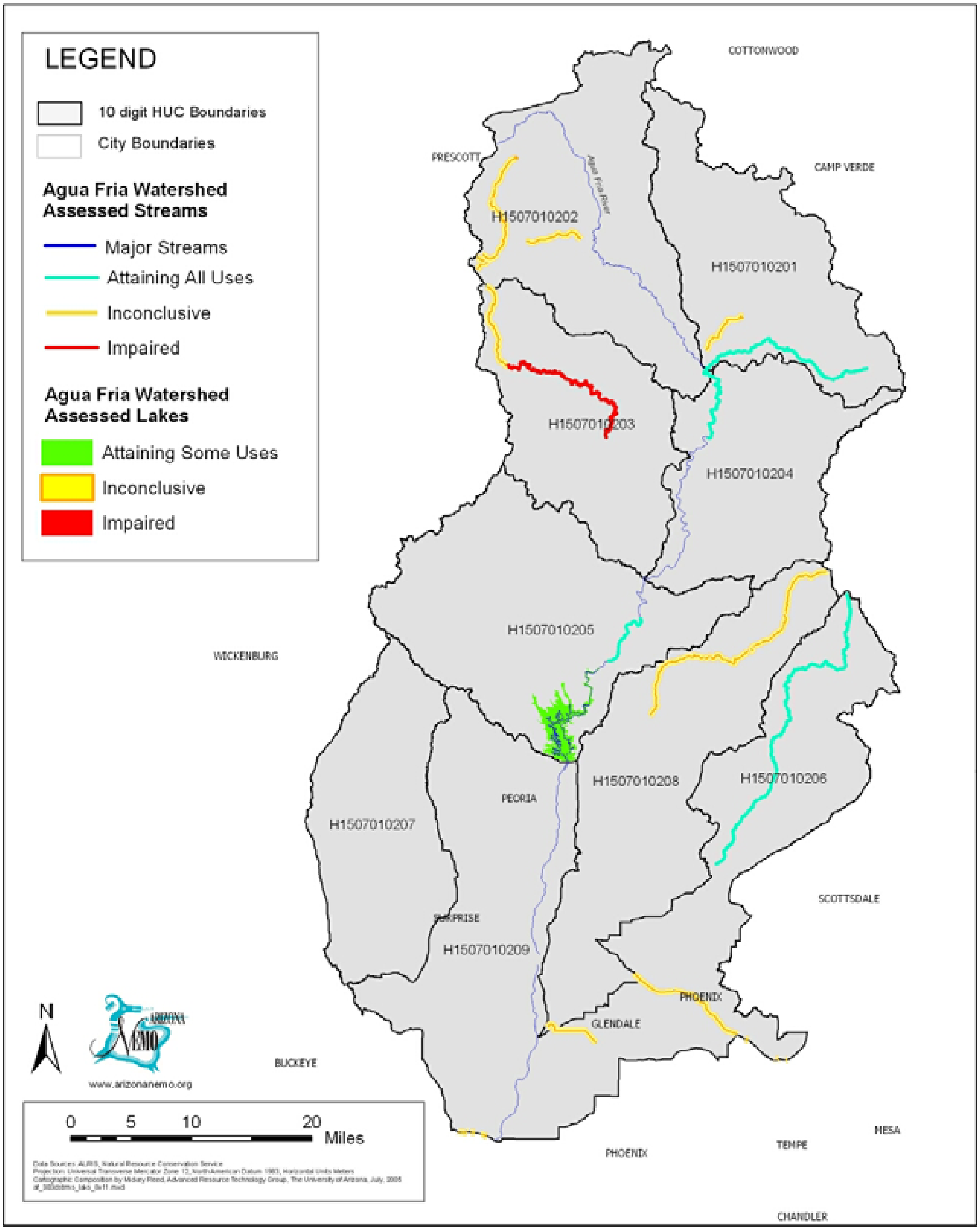


Figure 2-15: Agua Fria Watershed 303(d) Streams and Lakes (see Table 2-2 for subwatershed names)

Water Quality

The Agua Fria Watershed has one stream reach and one lake assessed as impaired in Arizona's 303(d) List of Impaired Waters:

- Turkey Creek, from an unnamed tributary at (latitude/longitude) 34 19 28 / 112 21 28 to Poland Creek, dissolved cadmium copper, lead and zinc ((15070102-036B)

- Cortez Park Lake, dissolved oxygen and pH (15060106B-0410)

Two other lakes, Lake Pleasant and Lynx Lake, are assessed as "attaining some uses" (Figure 2-17). Four reaches are listed as "attaining all uses", and are therefore not considered environmentally degraded:

- The Agua Fria River from Sycamore Creek to Big Bug Creek (15070102-023)
- Sycamore Creek from Tank Canyon to the Agua Fria River (15070102-024B)
- Cave Creek from the headwaters to Cave Creek Dam (15060106B-026A)
- The Agua Fria River from Little Squaw Creek to Cottonwood Creek (15070102-017)

The remaining reaches and lakes are listed as "inconclusive" due to insufficient monitoring data. An explanation of the 303(d) listing process is found in Section 1, Introduction, and a tabulation of the water quality attributes can be found in Section 6, Watershed Assessment. The constituents analyzed for each stream and lake are listed in Appendix A, Table 1.

Geology

The Agua Fria Watershed straddles the margin of the Basin and Range and the Transition Zone, two of the three geologic provinces found in the state of Arizona. It is characterized by a narrow, rugged valley rising up from the desert floor of the Phoenix Basin, steadily gaining in elevation as the watershed extends up and over a lava plateau and to the edge of the southern boundary of the Verde Watershed. The geology of the watershed is complex, varying widely in age, lithology, and structure (Figure 2-16).

The Agua Fria National Monument (AFNM) is located in the transition zone of central Arizona, between the Colorado Plateau Province to the Northeast and the Basin and Range Province to the Southwest. It is situated between the New River Mountains (Moore Gulch shear zone) to the East and the Bradshaw Mountains (Shylock shear zone) to the West. Just north of the monument is the Estler basalt volcanic center (Estler peak area) and south is the Black Canyon Dispositional Basin (Chalk Canyon & Hickey Formations) (from http://www.geocities.com/afnmus/Geology.html).

The Precambrian rocks consist primarily of granite that weathers to rounded boulders and knobs, and flaky, silvery schist. Flat-lying layers of whitish limestone, siltstone, and water-laid volcanic ash are found in Tertiary-age lake sediments, and Quaternary and Tertiary lava flows cap the higher mesas. Near Cordes Junction loosely consolidated Tertiary stream and lake deposits are capped with basalt, and a lava plateau forms the drainage divide between Turkey Creek (an Agua Fria tributary) and the Verde Watershed to the west (Chronic, 1983).

The Agua Fria Valley is an erosional basin bounded by the Verde fault on northeast margin and formed by drainage off of the more resistant Quaternary basalt unconformally lying on the deeply eroded Precambrian schist of the Bradshaw Mountains. The overall vertical displacement of the mile-wide multiple faults in the Verde Fault zone is estimated at approximately 6,000 feet. Continued subsidence along this zone eventually caused both the Verde River to the north and west, and the Agua Fria to stop flowing, forming a series of ancient lakes and deposition of lake sediments.

Damming of the Agua Fria also occurred due to multiple lava flows which originated from a source to the northeast. The mountains and ridges that border the watershed are composed of resistant Precambrian schist which form mountain pediments jutting through alluvial gravel veneer in the southern portion of the watershed; basalt-capped mesas to the east; and the granite and schist of the Bradshaw Mountains to the west. The central portion of the valley consists of Quaternary and Tertiary stream deposits of sand, silt and gravel with stream-rounded pebbles; and Quaternary and Tertiary lava flows, commonly lying on soil zones baked by the heat of the flowing lava.

Sunset Point Rest Area on Interstate Route 17 looks down on Black Canyon, named for the dark metamorphic rocks of about 1.7 million years old. The Bradshaw Mountains are walled with the same rock but had been intruded with a larger mass of granite in Precambrian time.

Along the edge of the Mogollon Rim (the physiographic boundary of the Colorado Plateau Highlands), lava flows cascaded from the plateau surface, draining and forming poorly drained, nearly flat-lying mesas in the eastern margin of the Agua Fria. The rim lava flows have been age dated to approximately 6 to 8 million years old, during the Tertiary period, but more recent flows have been dated in the Agua Fria to within Quaternary time (approximately 10,000 years before present).

Figure 2-16 shows the geology of the Agua Fria Watershed. Table 2-9 lists the geologic units by subwatershed, and Table 2-10 lists the percentage of each rock type.

Alluvial Aquifers

Much of the younger Quaternary stream alluvium consists of unconsolidated sand, gravel, and silt deposited within narrow and shallow stripes of the present stream channels as floodplain alluvium and channel fill, however portions of the Aqua Fria flows over bedrock (Figure 2-17). Coarse cobbles of Precambrian metamorphic rocks line the bed of the New River, a tributary of the Agua Fria in the lower, more urbanized portion of the watershed.

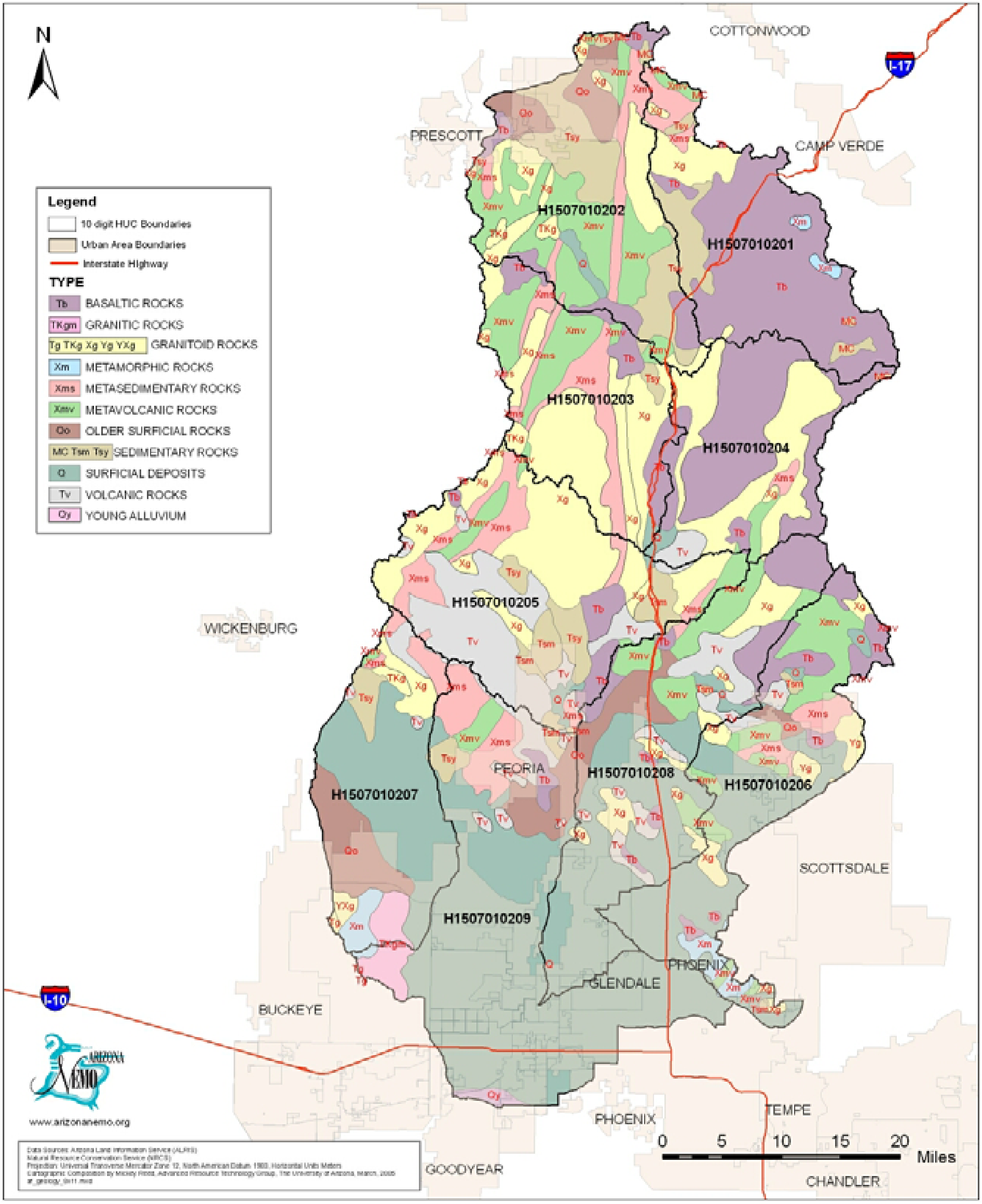


Figure 2-16: Agua Fria Watershed Geology (see Table 2-2 for subwatershed names).

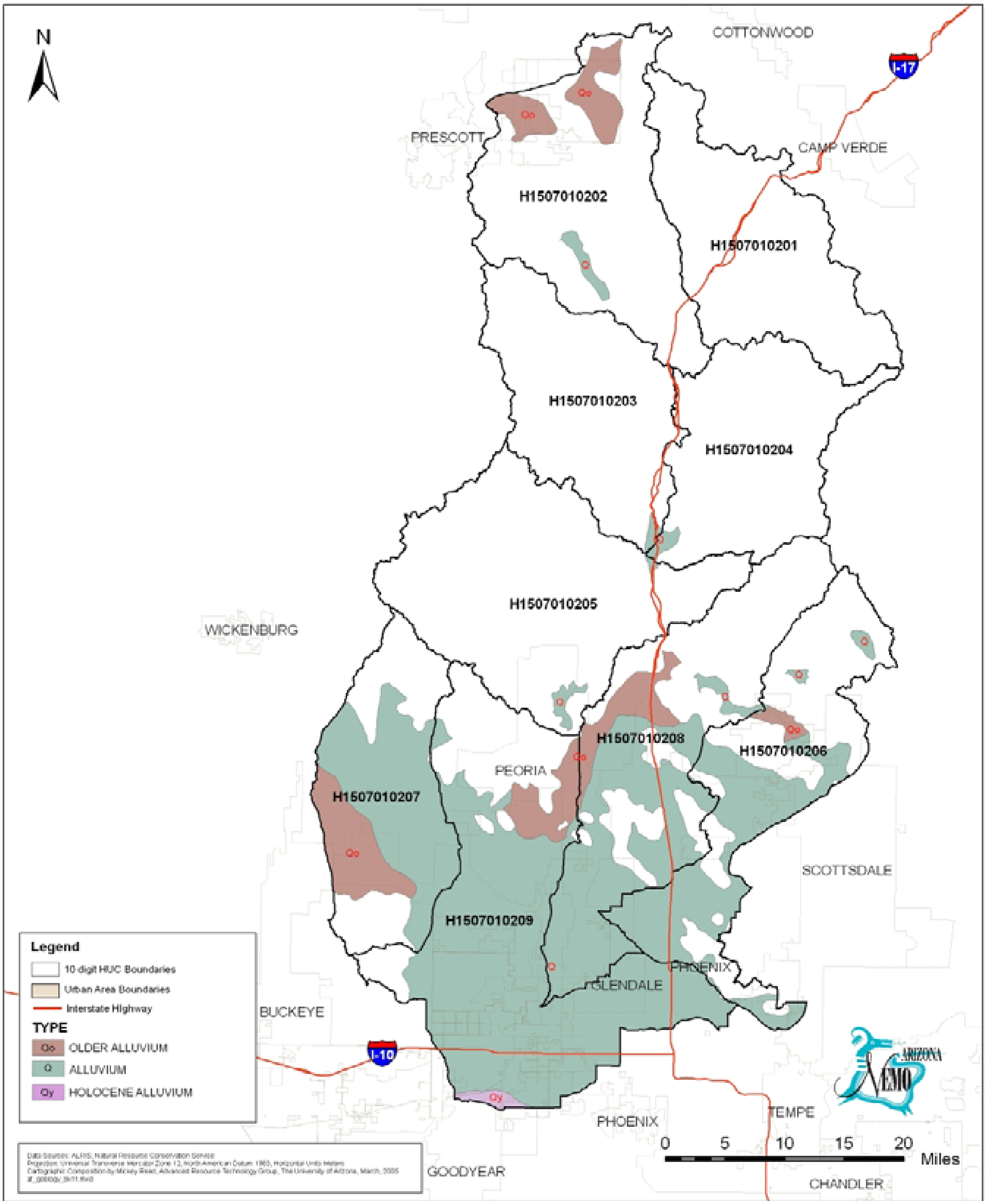


Figure 2-17. Agua Fria Watershed Alluvial Geology (see Table 2-2 for subwatershed names).

Table 2-9: Agua Fria Watershed Geology (part 1 of 2).

Geologic Unit	Geologic Code	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
SEDIMENTARY ROCKS (Mississippian to Cambrian)	**MC**	**1.84%**	**0.57%**	**-**	**0.24%**	**-**
SURFICIAL DEPOSITS (Holocene to middle Pleistocene)	**Q**	**-**	**1.86%**	**1%**	**1.51%**	**1.16%**
OLDER SURFICIAL DEPOSITS (middle Pleistocene to latest Pliocene)	**Qo**	**-**	**10.70%**	**-**	**-**	**0.01%**
YOUNG ALLUVIUM (Holocene to latest Pleistocene)	**Qy**	**-**	**-**	**-**	**-**	**-**
BASALTIC ROCKS (late to middle Miocene; 8 to 16 Ma.)	**Tb**	**69.94%**	**8.58%**	**12.52%**	**54.36%**	**4.92%**
GRANITOID ROCKS (early Miocene to Oligocene; 18 to 38 Ma.)	**Tg**	**-**	**-**	**-**	**-**	**-**
GRANITOID ROCKS (early Tertiary to late Cretaceous; 55-85 Ma.)	**TKg**	**-**	**1.55%**	**1.58%**	**-**	**0.07%**
GRANITIC ROCKS (early Tertiary to late Cretaceous; 45-75 Ma.)	**TKgm**	**-**	**-**	**-**	**-**	**-**
SEDIMENTARY ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tsm**	**-**	**-**	**-**	**-**	**6.03%**
SEDIMENTARY ROCKS (Pliocene to middle Miocene)	**Tsy**	**9.99%**	**21.93%**	**1.89%**	**-**	**4.13%**
VOLCANIC ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tv**	**-**	**-**	**-**	**3.71%**	**22.61%**
GRANITOID ROCKS (early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Xg**	**9.71%**	**15.46%**	**45.36%**	**36.04%**	**27.35%**
METAMORPHIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xm**	**1.66%**	**-**	**-**	**-**	**-**
METASEDIMENTARY ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xms**	**5.41%**	**8.43%**	**18.41%**	**1.53%**	**9.71%**
METAVOLCANIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xmv**	**1.46%**	**30.91%**	**19.28%**	**2.61%**	**4.08%**
GRANITOID ROCKS (middle Proterozoic; 1400 Ma.)	**Yg**	**-**	**-**	**-**	**-**	**-**
GRANITOID ROCKS (middle or early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Yxg**	**-**	**-**	**-**	**-**	**-**
Area (square miles)		***260.55***	***324.74***	***244.07***	***236.45***	***371.81***

Table 2-9: Agua Fria Watershed Geology (part 2 of 2).

Geologic Unit	Geologic Code	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
SEDIMENTARY ROCKS (Mississippian to Cambrian)	**MC**	-	-	-	-	***0.26%***
SURFICIAL DEPOSITS (Holocene to middle Pleistocene)	**Q**	**43.70%**	**50.05%**	**43.97%**	**71.68%**	***27.03%***
OLDER SURFICIAL DEPOSITS (middle Pleistocene to latest Pliocene)	**Qo**	**1.86%**	**18.06%**	**7.85%**	**5.55%**	***4.93%***
YOUNG ALLUVIUM (Holocene to latest Pleistocene)	**Qy**	-	-	-	**1.22%**	***0.20%***
BASALTIC ROCKS (late to mid Miocene; 8 to 16 Ma.)	**Tb**	**12.77%**	-	**12.76%**	**1.50%**	***17.26%***
GRANITOID ROCKS (early Miocene to Oligocene; 18 to 38 Ma.)	**Tg**	-	**0.53%**	-	**0.02%**	***0.05%***
GRANITOID ROCKS (early Tertiary to late Cretaceous; 55-85 Ma.)	**TKg**	-	**1.52%**	-	-	***0.46%***
GRANITIC ROCKS (early Tertiary to late Cretaceous; 45-75 Ma.)	**TKgm**	-	**4.88%**	-	**2.83%**	***0.90%***
SEDIMENTARY ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tsm**	**0.89%**	-	**0.47%**	**0.62%**	***1.26%***
SEDIMENTARY ROCKS (Pliocene to middle Miocene)	**Tsy**	-	**4.57%**	-	**1.79%**	***5.04%***
VOLCANIC ROCKS (middle Miocene to Oligocene; 15 to 38 Ma.)	**Tv**	**2.33%**	**3.56%**	**11.04%**	**4.21%**	***6.74%***
GRANITOID ROCKS (early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Xg**	**5.01%**	**5.42%**	**9.93%**	**0.12%**	***16.57%***
METAMORPHIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xm**	**4.05%**	**4.52%**	-	**0.34%**	***1.02%***
METASEDIMENTARY ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xms**	**5.71%**	**4.67%**	**0.33%**	**8.22%**	***7.26%***
METAVOLCANIC ROCKS (early Proterozoic; 1650 to 1800 Ma.)	**Xmv**	**19.12%**	**0.49%**	**13.65%**	**1.88%**	***10.39%***
GRANITOID ROCKS (middle Proterozoic; 1400 Ma.)	**Yg**	**4.56%**	-	-	-	***0.47%***
GRANITOID ROCKS (middle or early Proterozoic; 1400 Ma. or 1650 to 1750 Ma.)	**Yxg**	-	**1.72%**	-	-	***0.15%***
Area (square miles)		***288.47%***	***242.18%***	***353.18***	***464.31***	***2785.17***

Table 2-10: Agua Fria Watershed Rock Types, percent by Subwatershed (part 1 of 2).

Rock Type	Geologic Code	Ash Creek & Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Volcanic Rocks	**V**	**69.94%**	**8.58%**	**12.52%**	**58.07%**	**27.53%**
Sedimentary Rocks	**S**	**11.83%**	**22.50%**	**1.89%**	**0.24%**	**10.16%**
Alluvium	**A**		**12.56%**	**1%**	**1.51%**	**1.17%**
Granitoid Rocks	**G**	**9.71%**	**17.01%**	**46.94%**	**36.04%**	**27.42%**
Metamorphic Rocks	**M**	**8.53%**	**39.34%**	**37.69%**	**4.14%**	**13.79%**
Area (sq. miles)		***260.55***	***324.74***	***244.07***	***236.45***	***371.81***

Table 2-10: Agua Fria Watershed Rock Types, percent by Subwatershed (part 2 of 2).

Rock Type	Geologic Code	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
Volcanic Rocks	**V**	**15.10%**	**3.56%**	**23.80%**	**5.71%**	***24.00%***
Sedimentary Rocks	**S**	**0.89%**	**4.57%**	**0.47%**	**2.41%**	***6.56%***
Alluvium	**A**	**45.56%**	**68.11%**	**51.82%**	**78.45%**	***32.16%***
Granitoid Rocks	**G**	**9.57%**	**14.07%**	**9.93%**	**2.97%**	***18.60%***
Metamorphic Rocks	**M**	**28.88%**	**9.68%**	**13.98%**	**10.44%**	***18.67%***
Area (sq. miles)		***288.47%***	***242.18%***	***353.18***	***464.31***	***2,785.17***

Soils

Based on the soil characteristics for the Agua Fria Watershed two types of maps were created: a soil texture map (Figure 2-18) and a soil erodibility factor map (Figure 2-19). Soil erodibility is generated from the soil texture characteristics.

There are 15 different soil textures in the Agua Fria Watershed (Table 2-11). Very gravelly clay loam is the most common soil texture, covering 20.66% of the watershed. Clay loam and loam are the next most common soil textures, covering 12.74% and 12.50% respectively.

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. It has been revised to reflect updates in the calculations, and additional analysis of the research data, and is now referred to as the Revised Universal Soil Loss Equation, or RUSLE.

Within the RUSLE equation, the Soil Erodibility Factor (K) represents the rate of soil loss per rainfall erosion index unit. Soil erodibility can be thought of as the ease with which soil is detached by splash during rainfall or by surface flow or both. It is estimated in the units of mass per unit area, or tons per acre per year, 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 Ash Creek and Sycamore Creek subwatershed and the Agua Fria River below Lake Pleasant subwatershed had the highest weighted mean Soil Erodibility Factors, with K = 0.191 and 0.206 respectively. The Agua Fria River-Lake Pleasant subwatershed had the lowest weighted mean K at 0.055. The weighted mean K for the whole Agua Fria Watershed is 0.139.

Table 2-11: Agua Fria Watershed Soil Texture – Percent by Subwatershed (part 1 of 2).

Soil Texture	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Clay loam	**62.94**	**10.85**	**3.72**	**52.93**	**-**
Cobbly loam	**1.17**	**1.08**	**2.26**	**-**	**-**
Extremely gravelly loam	**-**	**-**	**-**	**-**	**-**
Extremely stony coarse sandy loam	**-**	**-**	**-**	**-**	**9.69**
Flaggy silt loam	**-**	**-**	**-**	**-**	**-**
Gravelly loam	**20.60**	**28.22**	**7.74**	**1.70**	**1.69**
Gravelly sandy loam	**-**	**-**	**-**	**-**	**0.02**
Loam	**8.36**	**43.83**	**-**	**3.22**	**-**
Sandy Loam	**-**	**-**	**5.99**	**-**	**0.63**
Silt loam	**-**	**-**	**-**	**-**	**-**
Very flaggy silt loam	**-**	**0.90**	**42.73**	**0.12**	**16.23**
Very gravelly clay loam	**-**	**-**	**9.56**	**42.09**	**55.88**
Very gravelly loam	**-**	**-**	**-**	**-**	**0.05**
Very gravelly sandy loam	**-**	**-**	**-**	**-**	**-**
Unweathered bedrock	**7.00**	**15.17**	**28.03**	**-**	**15.85**

Table 2-11: Agua Fria Watershed Soil Texture – Percent by Subwatershed (part 2 of 2).

Soil Texture	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
Clay loam	**2.35**	**-**	**4.14**	**-**	***12.74***
Cobbly loam	**-**	**-**	**-**	**-**	***0.43***
Extremely gravelly loam	**-**	**37.62**	**-**	**3.11**	***3.79***
Extremely stony coarse sandy loam	**6.54**	**7.30**	**7.03**	**8.75**	***4.95***
Flaggy silt loam	**1.62**	**2.19**	**-**	**25.28**	***4.57***
Gravelly loam	**-**	**-**	**-**	**-**	***6.26***
Gravelly sandy loam	**1.13**	**30.05**	**-**	**11.41**	***4.63***
Loam	**30.66**	**-**	**10.10**	**11.35**	***12.50***
Sandy Loam	**11.31**	**-**	**26.90**	**25.26**	***9.40***
Silt loam	**-**	**-**	**-**	**6.24**	***1.04***
Very flaggy silt loam	**9.47**	**-**	**0.16**	**-**	***7.03***
Very gravelly clay loam	**27.48**	**18.40**	**25.65**	**6.57**	***20.66***
Very gravelly loam	**9.49**	**-**	**26.07**	**2.08**	***4.64***
Very gravelly sandy loam	**-**	**4.47**	**-**	**-**	***0.39***
Unweathered bedrock	**-**	**-**	**-**	**-**	***6.99***

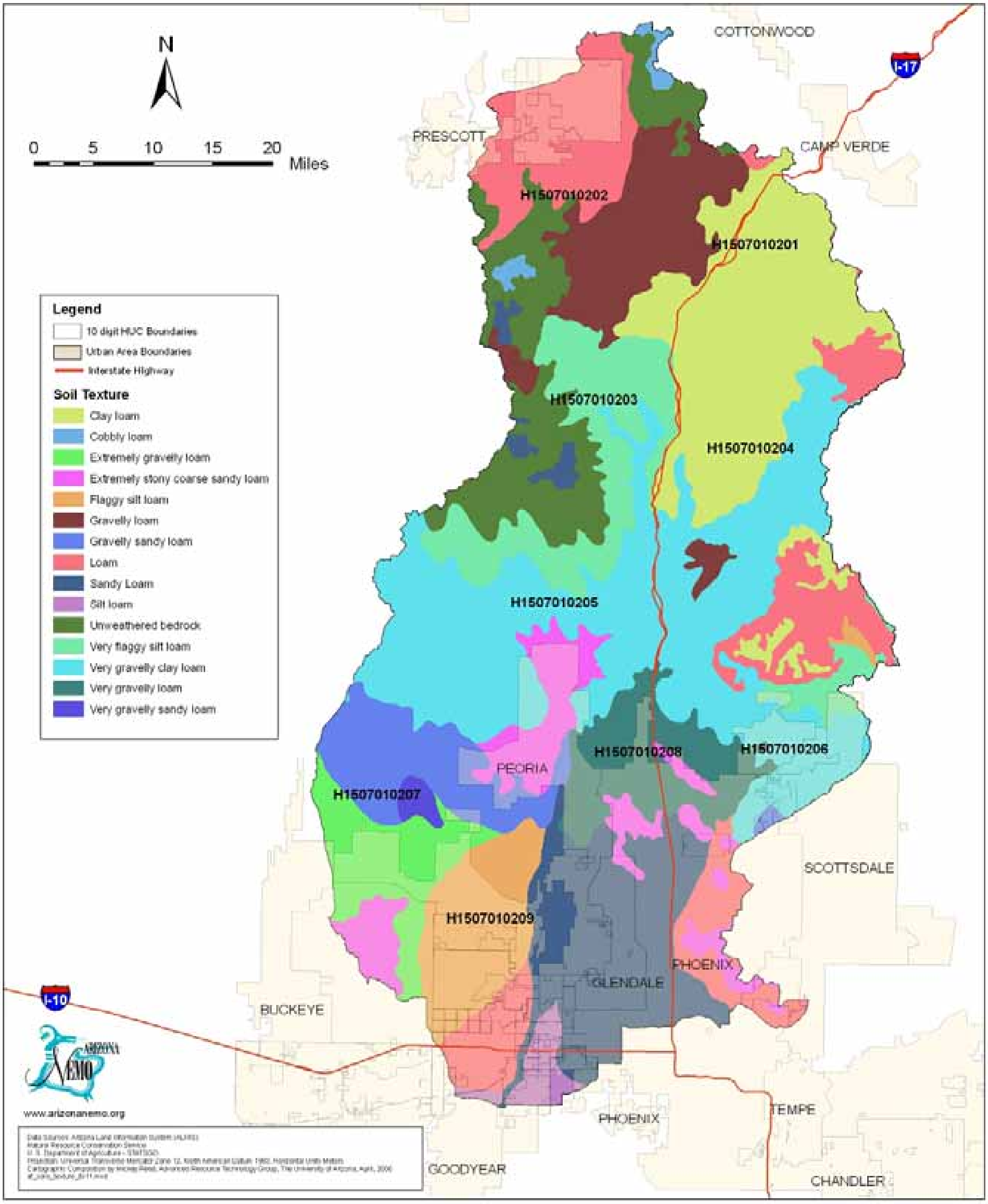


Figure 2-18: Agua Fria Watershed Soil Texture (see Table 2-2 for subwatershed names)

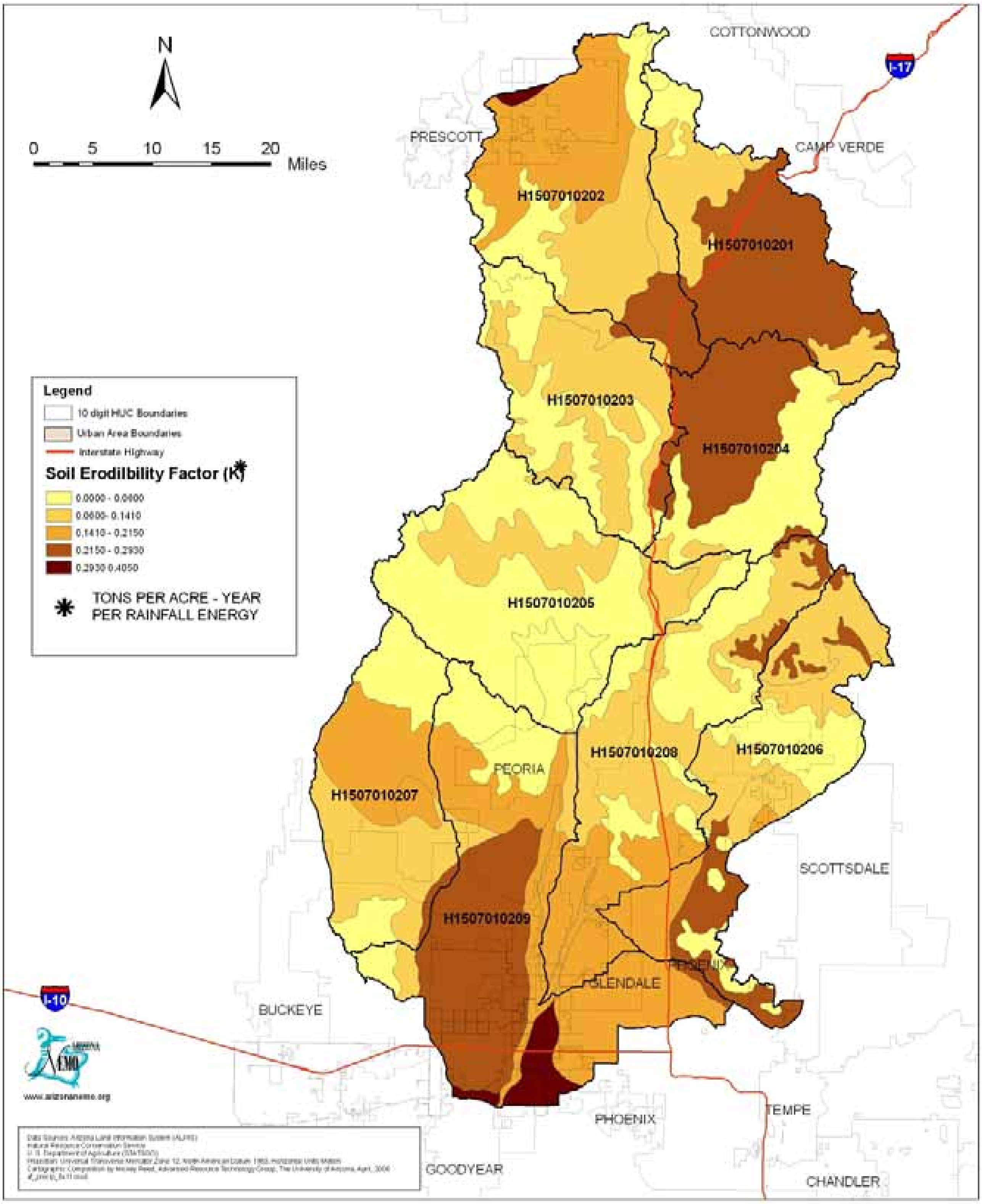


Figure 2-19: Agua Fria Watershed Soil Erodibility Factor (see Table 2-2 for subwatershed names).

Table 2-12: Agua Fria Watershed Soil Erodibility Factor K.

Subwatershed Name	Min K	Max K	Weighted Average
Ash Creek and Sycamore Creek H1507010201	**0.030**	**0.254**	**0.191**
Big Bug Creek-Agua Fria River H1507010202	**0.030**	**0.310**	**0.157**
Black Canyon Creek H1507010203	**0.030**	**0.140**	**0.072**
Bishop Creek H1507010204	**0.060**	**0.254**	**0.155**
Agua Fria River-Lake Pleasant H1507010205	**0.013**	**0.209**	**0.055**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**0.013**	**0.254**	**0.132**
Trilby Wash-Trilby Wash Basin H1507010207	**0.013**	**0.264**	**0.135**
New River H1507010208	**0.013**	**0.254**	**0.133**
Agua Fria River below Lake Pleasant H1507010209	**0.013**	**0.405**	**0.206**
Agua Fria Watershed	***0.013***	***0.405***	***0.139***

Climate

Precipitation

For the 30 years (1961-1990) of precipitation data used in this report, the average annual precipitation for the Agua Fria Watershed is 15.14 inches. The Black Canyon Creek subwatershed receives the most rainfall with 19.76 inches of rain in an average year, while the Agua Fria River below Lake Pleasant subwatershed typically receives only 9.83 inches. The valley floor surrounding the Agua Fria main channel receives less rain than the surrounding mountains. Figure 2-20 shows the distribution of precipitation over the watershed, and Table 2-13 shows the average annual precipitation in inches per year.

Table 2-13: Agua Fria Watershed Average Annual Precipitation (in/yr)

Subwatershed Name	Min (in/yr)	Max (in/yr)	Weighted Average
Ash Creek and Sycamore Creek H1507010201	**15.00**	**25.00**	**18.41**
Big Bug Creek-Agua Fria River H1507010202	**15.00**	**27.00**	**18.81**
Black Canyon Creek H1507010203	**13.00**	**31.00**	**19.76**
Bishop Creek H1507010204	**13.00**	**23.00**	**17.43**
Agua Fria River-Lake Pleasant H1507010205	**11.00**	**31.00**	**16.58**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**9.00**	**23.00**	**14.03**
Trilby Wash-Trilby Wash Basin H1507010207	**9.00**	**17.00**	**12.06**
New River H1507010208	**9.00**	**25.00**	**13.15**
Agua Fria River below Lake Pleasant H1507010209	**7.00**	**17.00**	**9.83**
Agua Fria Watershed	***7.00***	***31.00***	***15.14***

Temperature

Forty weather stations in the Agua Fria Watershed are shown in Figure 2-21. Thirteen of these locations were used for watershed modeling (Table 2-14) because of consistency and duration of the data.

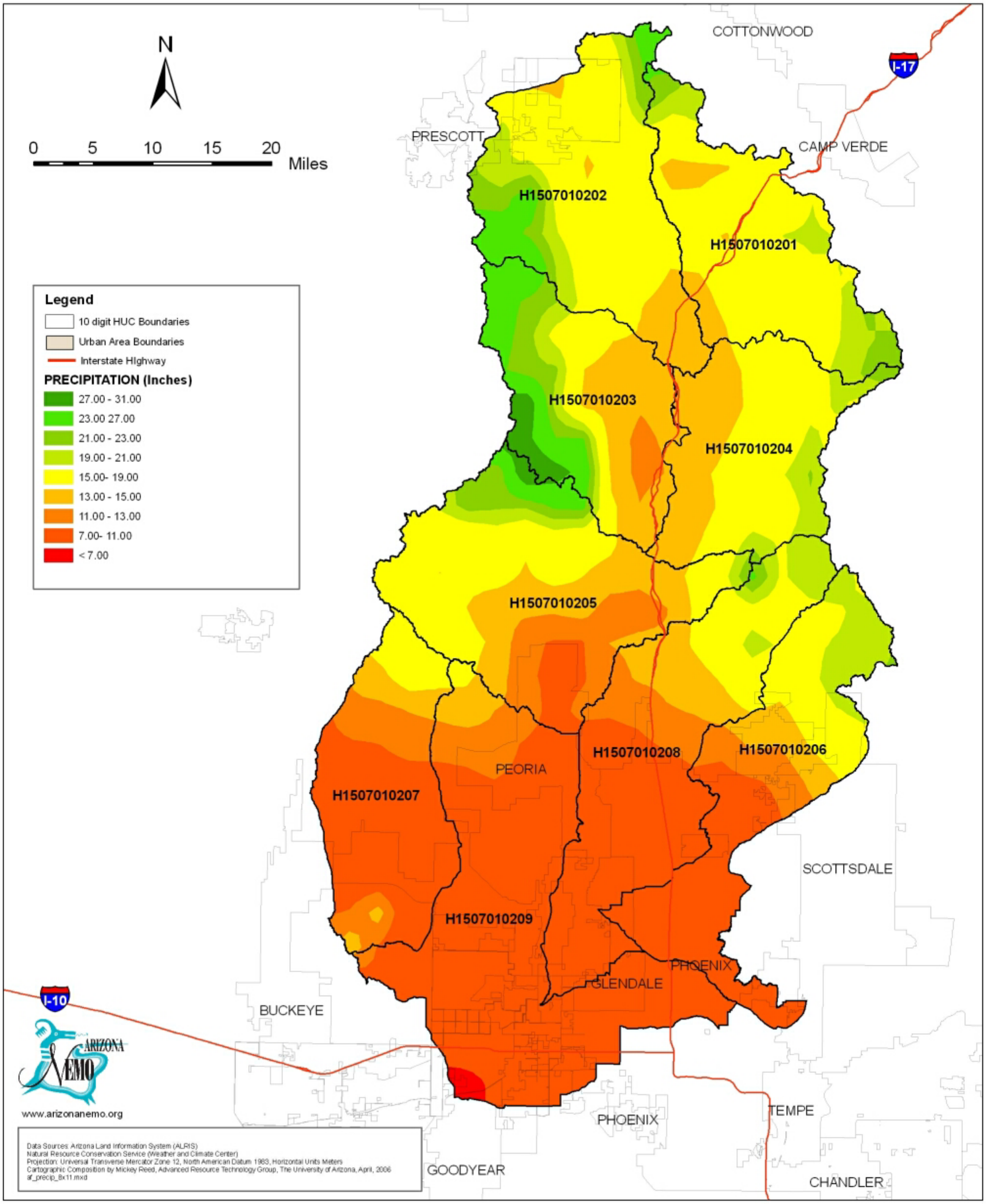


Figure 2-20: Agua Fria Watershed Average Annual Precipitation (inches/year) (see Table 2-2 for subwatershed names).

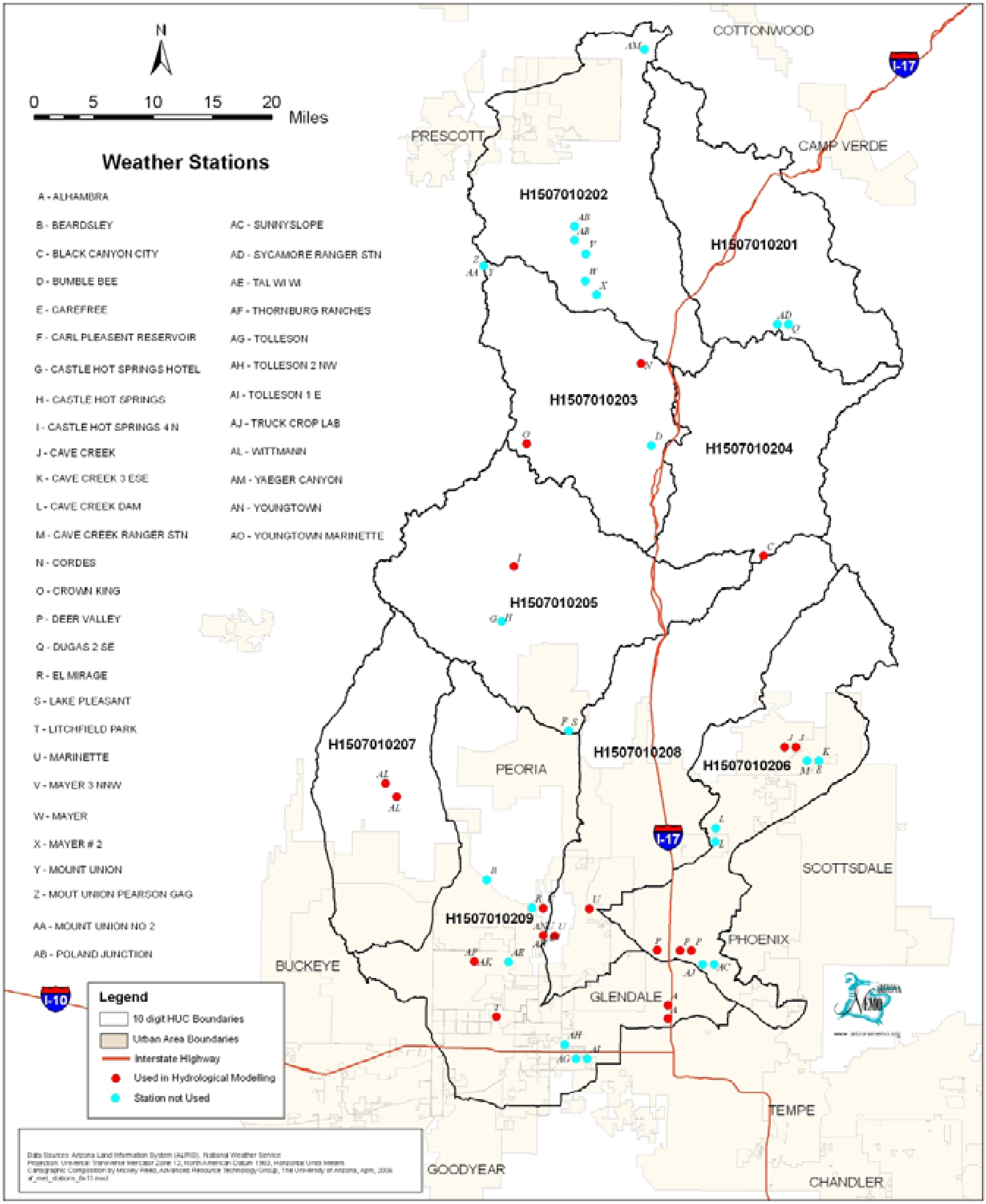


Figure 2-21: Agua Fria Watershed Weather Stations (see Table 2-2 for subwatershed names).

Table 2-14: Summary of Temperature Data for 13 Temperature Gages with Sufficient Data.

ID	Gage	Average Annual Max. Temperature (F)	Average Annual Min Temperature (F)	Average Annual Temperature (F)
A	Alhambra	86.1	53	69.55
C	Black Canyon City	83.6	55.9	69.75
E	Carefree	82	56.6	69.3
I	Castle Hot Springs 4 N	83.6	56	69.8
J	Cave Creek	83.1	53.4	68.25
N	Cordes	75.7	46.9	61.3
O	Crown King	67.9	39	53.45
P	Deer Valley	85.2	54.2	69.7
T	Litchfield Park	87.3	53.6	70.45
U	Marinette	86.9	52.9	69.9
AF	Thornburg Ranches	84.8	50.5	67.65
AL	Wittmann	84.2	54.4	69.3
AN	Youngtown	86.6	57	71.8

For the 30 years (1961 – 1990) of temperature data, the average annual temperature for the Agua Fria Watershed is 65.1° Fahrenheit (Table 2-15). The Agua Fria River below Lake Pleasant subwatershed has the highest annual average temperature (73.6°). Table 2-15 shows the annual average temperatures for each subwatershed and Figure 2-22 is a map of the temperature ranges.

Table 2-15: Agua Fria Watershed Average Annual Temperature (°F).

Subwatershed	Avg Annual Temp (°F)
Ash Creek and Sycamore Creek H1507010201	57.8
Big Bug Creek-Agua Fria River H1507010202	56.3
Black Canyon Creek H1507010203	58.3
Bishop Creek H1507010204	61.3
Agua Fria River-Lake Pleasant H1507010205	65.4
Cave Creek-Arizona Canal Diversion Channel H1507010206	68.6
Trilby Wash-Trilby Wash Basin H1507010207	68.0
New River H1507010208	69.6
Agua Fria River below Lake Pleasant H1507010209	73.6
Agua Fria Watershed	*65.1*

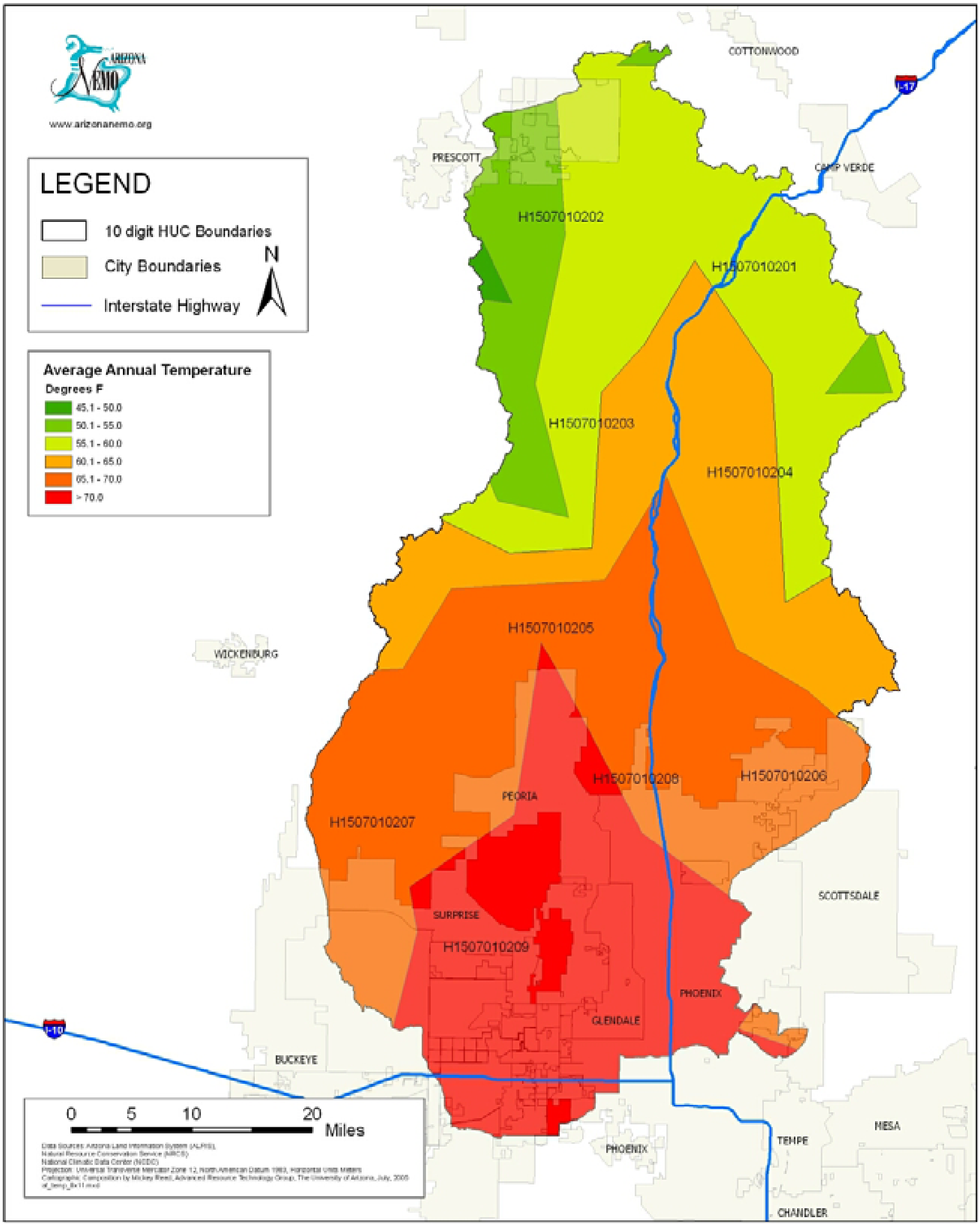


Figure 2-22: Agua Fria Watershed Average Annual Temperature (°F) (see Table 2-2 for subwatershed names).

References:

Arizona Department of Water Resources (ADWR). Prescott Active Management Area. www.azwater.gov/WaterManagement_2005/Content/AMAs/PrescottAMA/default.htm
Website accessed March 1, 2007.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology; Chapter 4 - Getting to know your stream. John Wiley & Sons, New York, New York.

USDA. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook No. 703. USDA Washington D.C.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting Rainfall-Erosion Losses. Agricultural Handbook No. 537. USDA SEA Washington, D.C.

Woodhouse, B., M.E. Flynn, J.T.C. Parker, and J.P. Hoffmann. 2002. Investigation of the Geology and Hydrology of the Upper and Middle Agua Fria River Watershed of Central Arizona: A Project of the Arizona Rural Watershed Initiative: U.S. Geological Survey Fact-Sheet 059-02, 4p.

Data Sources:*

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/index.html
Arizona State Boundary map. June 12, 2003.
Geology map. February 7, 2003.
Lakes and Reservoirs map. February 7, 2003.
Streams map. October, 10, 2002.

Chronic, Halka. 1983. Roadside Geology of Arizona. Mountain Press Publishing Company, Montana.

U.S. Department of Agriculture, Natural Resources Conservation Service, http://www.ncgc.nrcs.usda.gov/products/datasets/climate/data/
PRISM Precipitation Map. February 26, 2003.

U.S. Department of Agriculture, Natural Resources Conservation Service, http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/
State Soil Geographic Database (STATSGO) Soils map. April 17, 2003.

USDA. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook No. 703. USDA Washington D.C.

U.S. Department of the Interior, U.S. Geological Survey, National Elevation Dataset (NED), http://edc.usgs.gov/geodata/
30-Meter Digital Elevation Models (DEMs). April 8, 2003.

University of Arizona, Arizona Electronic Atlas. http://atlas.library.arizona.edu/atlas/index.jsp?theme=NaturalResources.Temperature map. February 13, 2003.

Western Regional Climate Center (WRCC). http://www.wrcc.dri.edu/summary/climsmaz.html, (1971-2000). Temperature data. July 15, 2004.

**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

Ecoregions

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. This classification system was applied to the Agua Fria Watershed, based on subwatersheds, which are identified using the USGS eight digit Hydrologic Unit Codes (HUC).

In Bailey's classification system, there are four *Domains*: polar, humid temperate, humid tropical and dry. The first three are differentiated based on humidity and thermal characteristics. The fourth, the dry domain, is defined on the basis of moisture alone. 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 Agua Fria Watershed in the dry domain, with 39.69% in the Tropical/Subtropical Desert Division, and 60.31% in the Tropical/Subtropical Steppe Division. For the provinces, 60.31% is in the Colorado Plateau Semi-Desert Province, and 39.69% is in the American Semi-Desert and Desert Province, corresponding respectively to the Tonto Transition, and the Sonoran Mohave Desert Sections. Figures 3-1, 3-2 and 3-3, and Tables 3-1, 3-2 and 3-3 show these divisions.

The following descriptions are from Bailey's Ecosystem Classification (Bailey, 1995). The Dry Domain describes a dry climate where annual losses of water through evaporation at the earth's surface exceed annual water gain from precipitation. Due to the resulting water deficiency, no permanent streams originate in dry climate zones. Dry climates occupy one-fourth or more of the earth's land surface.

The two Divisions present in the Agua Fria Watershed are the Tropical/Subtropical Desert Division and the Tropical/Subtropical Steppe Division.

The Tropical/Subtropical Desert Division occurs in the southern portion of the watershed (Figure 3-1). It is characterized by extreme aridity, extremely high air and soil temperatures, with extreme variations between day and night temperatures. Annual precipitation can be less than 8 in (200 mm) in many places. The dry-desert vegetation, a class of xerophytic plants, is widely dispersed and provides negligible ground cover.

A dominant pedogenic process is salinization, which produces areas of salt crust where only salt-loving (halophytic) plants can survive. Calcification is conspicuous on well-drained uplands, where encrustations and deposits of calcium carbonate (caliche) are common. Humus is lacking and soils 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 Tropical/Subtropical Steppe Division occurs in the northern portion of the watershed (Figure 3-1). This is a hot, semiarid climate where potential evaporation exceeds precipitation, and where all months have temperatures above 32ºF.

Steppes are typically grasslands with short grasses and other herbs, and with locally developed shrubland and woodland. Pinyon-juniper woodland occurs on the Colorado Plateau, while to the east, in Texas, the grasslands grade into savanna woodland or semi deserts composed of xerophytic shrubs, cactus or trees, and the climate becomes semiarid-subtropical. These areas are able to support limited grazing, but generally require supplemental irrigation for crop cultivation. Soils are commonly Mollisols and Aridisols, containing some humus.

Bailey's Ecoregion classification defines two Provinces in the Agua Fria Watershed: the Colorado Plateau Semi-Desert Province, and the American Semi-Desert and Desert Province, corresponding respectively to the Tonto Transition, and the Sonoran Mohave Desert Sections.

The Colorado Plateau Semi-Desert Province and Tonto Transition Section is found in the northern portion of the watershed (Figures 3-2 and 3-3). The area is characterized as tablelands with moderate to considerable relief, and generally high elevations which keep the temperatures cooler than in other parts of Arizona. Precipitation averages about 20 inches (510 mm) per year, with some areas receiving less than 10 inches (260 mm). Summer rains are thunderstorms, with gentler rains during the winter.

The American Semi-Desert and Desert Province and Sonoran Mohave Desert Section (Figures 3-2 and 3-3) occur in the southern portion of the watershed, and are characterized by extensive plains, most gently undulating, from which isolated mountains and buttes rise abruptly. Summers are long and hot, with convective thunderstorms. Winters are moderate, with gentle, widespread rains. Washes generally flow only after rains.

Vegetation consists of cactus and shrubs such as the creosote bush, and Mesquite trees. Some places have a near-woodland appearance, due to the treelike saguaro cactus, prickly pear cactus, ocotillo, creosote bush, and smoke tree.

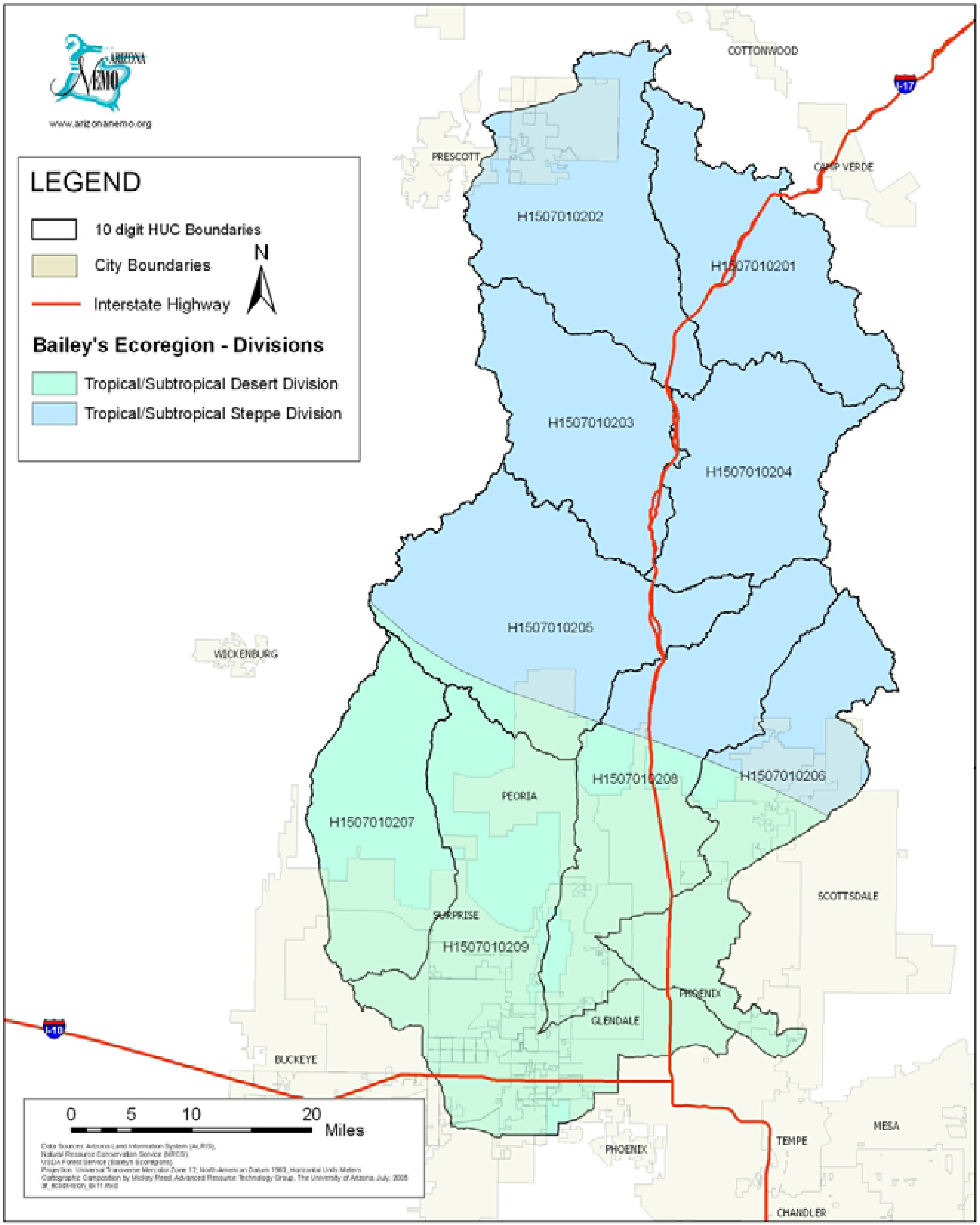


Figure 3-1: Agua Fria Watershed Ecoregions – Divisions (See Table 3-1 for subwatershed names).

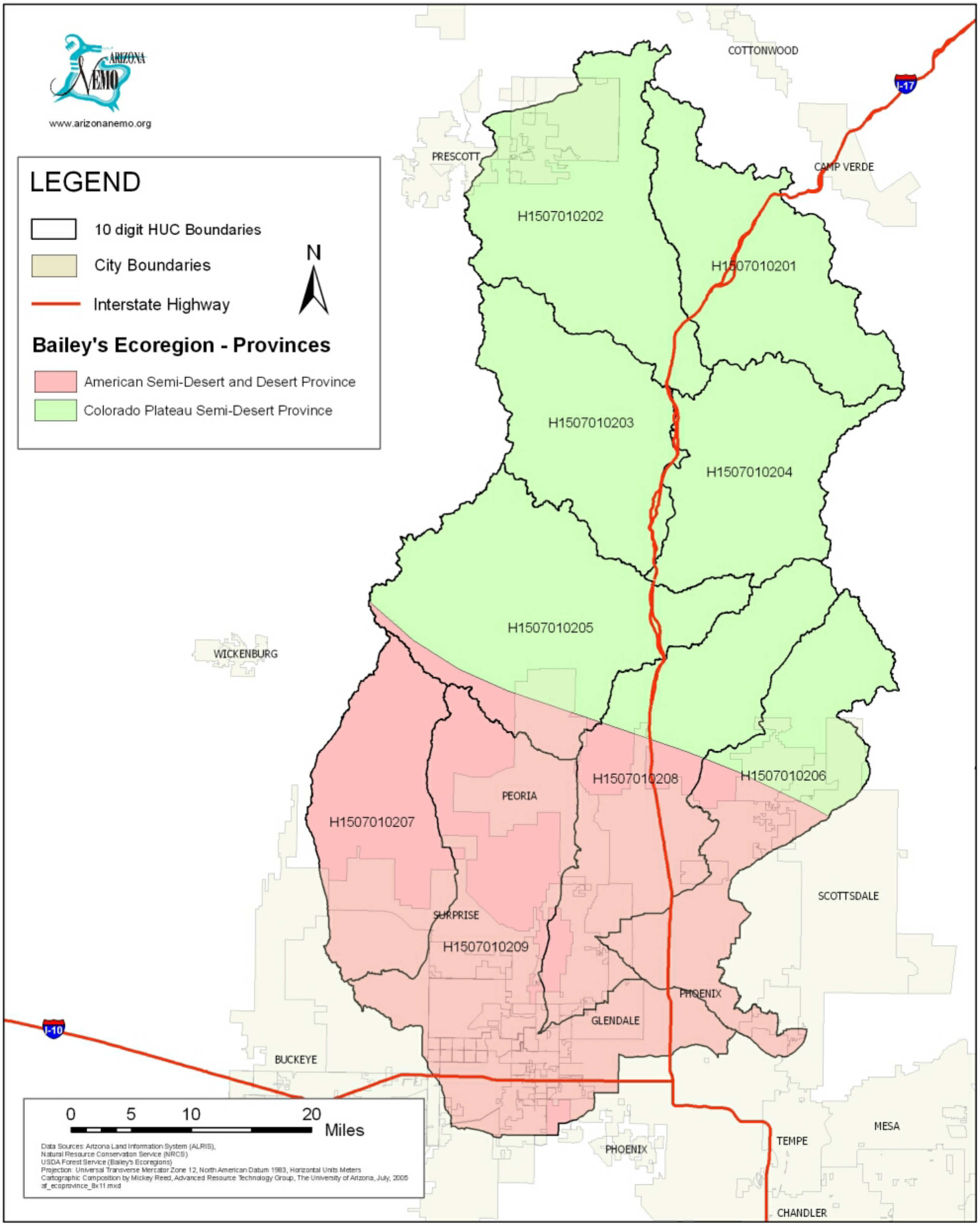


Figure 3-2: Agua Fria Watershed Ecoregions – Provinces (See Table 3-1 for subwatershed names).

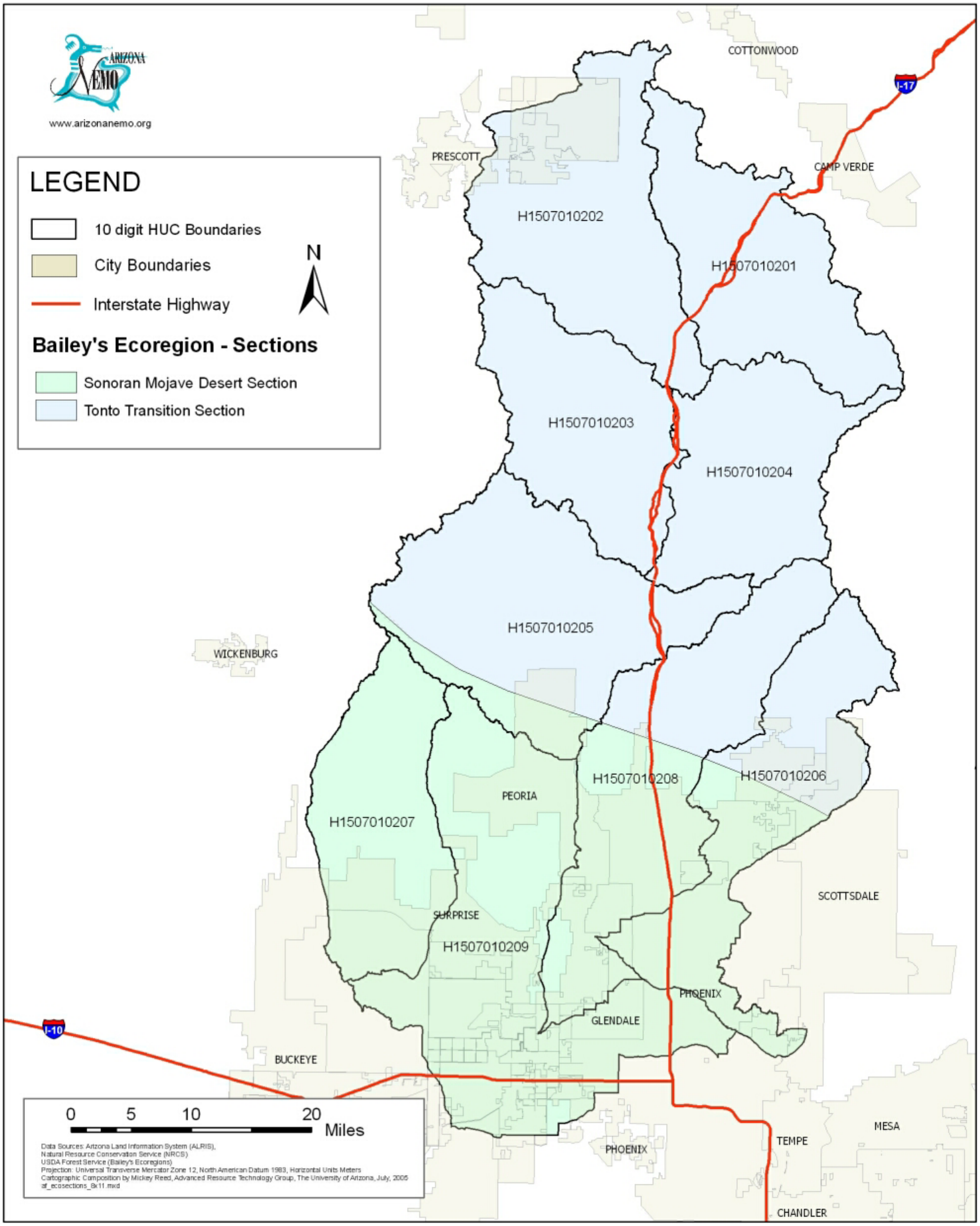


Figure 3-3: Agua Fria Watershed Ecoregions – Sections (*See Table 3-1 for subwatershed names*).

Table 3-1: Agua Fria Watershed Ecoregions - Divisions.

Subwatershed	Tropical/Subtropical Desert Division		Tropical/Subtropical Steppe Division		*Agua Fria Area (sq. miles)*
	percent	area (sq. miles)	percent	area (sq. miles)	
Ash Creek and Sycamore Creek H1507010201	**0%**	**0**	**100%**	**260.55**	***260.55***
Big Bug Creek-Agua Fria River H1507010202	**0%**	**0**	**100%**	**324.14**	***324.14***
Black Canyon Creek H1507010203	**0%**	**0**	**100%**	**244.07**	***244.07***
Bishop Creek H1507010204	**0%**	**0**	**100%**	**236.45**	***236.45***
Agua Fria River-Lake Pleasant H1507010205	**12%**	**44.62**	**88%**	**327.19**	***371.81***
Cave Creek-Arizona Canal Diversion Channel H1507010206	**52%**	**150.00**	**48%**	**138.47**	***288.47***
Trilby Wash-Trilby Wash Basin H1507010207	**100%**	**242.18**	**0%**	**0**	***242.18***
New River H1507010208	**58%**	**204.84**	**42%**	**148.34**	***353.18***
Agua Fria River below Lake Pleasant H1507010209	**100%**	**464.31**	**0%**	**0**	***464.31***
Agua Fria Watershed	***39.69***	***1105.43***	***60.31***	***1679.73***	***2785.16***

Table 3-2: Agua Fria Watershed Ecoregions - Provinces.

Subwatershed	American Semi-Desert and Desert Province		Colorado Plateau Semi-Desert Province		*Area (sq. miles)*
	percent	area (sq. miles)	percent	area (sq. miles)	
Ash Creek and Sycamore Creek H1507010201	**0%**	**0**	**100%**	**260.55**	***260.55***
Big Bug Creek-Agua Fria River H1507010202	**0%**	**0**	**100%**	**324.14**	***324.14***
Black Canyon Creek H1507010203	**0%**	**0**	**100%**	**244.07**	***244.07***
Bishop Creek H1507010204	**0%**	**0**	**100%**	**236.45**	***236.45***
Agua Fria River-Lake Pleasant H1507010205	**12%**	**44.62**	**88%**	**327.19**	***371.81***
Cave Creek-Arizona Canal Diversion Channel H1507010206	**52%**	**150.00**	**48%**	**138.47**	***288.47***
Trilby Wash-Trilby Wash Basin H1507010207	**100%**	**242.18**	**0%**	**0**	***242.18***
New River H1507010208	**58%**	**204.84**	**42%**	**148.34**	***353.18***
Agua Fria River below Lake Pleasant H1507010209	**100%**	**464.31**	**0%**	**0**	***464.31***
Agua Fria Watershed	***39.69***	***1105.43***	***60.31***	***1679.73***	***2785.16***

Table 3-3: Agua Fria Watershed Ecoregions - Sections.

Subwatersheds	Sonoran Mojave Desert Section		Tonto Transition Section		Area (sq. miles)
	percent	area (sq. miles)	percent	area (sq. miles)	
Ash Creek and Sycamore Creek H1507010201	**0%**	**0**	**100%**	**260.55**	**260.55**
Big Bug Creek-Agua Fria River H1507010202	**0%**	**0**	**100%**	**324.14**	**324.14**
Black Canyon Creek H1507010203	**0%**	**0**	**100%**	**244.07**	**244.07**
Bishop Creek H1507010204	**0%**	**0**	**100%**	**236.45**	**236.45**
Agua Fria River-Lake Pleasant H1507010205	**12%**	**44.62**	**88%**	**327.19**	**371.81**
Cave Creek-Arizona Canal Diversion Channel H1507010206	**52%**	**150.00**	**48%**	**138.47**	**288.47**
Trilby Wash-Trilby Wash Basin H1507010207	**100%**	**242.18**	**0%**	**0**	**242.18**
New River H1507010208	**58%**	**204.84**	**42%**	**148.34**	**353.18**
Agua Fria River below Lake Pleasant H1507010209	**100%**	**464.31**	**0%**	**0.00**	**464.31**
Agua Fria Watershed	**39.69**	**1105.43**	**60.31**	**1679.73**	**2785.16**

Vegetation

Two different vegetation maps were created for the Agua Fria watershed, one based on biotic (vegetation) communities and the other based on land cover.

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 (Figure 3-4). Under this classification there are seven different biotic communities in the Agua Fria Watershed. The primary community type over the entire watershed is Arizona Upland Sonoran Desert Scrub (36.83%), with Interior Chaparral and Lower Colorado River Sonoran Desertscrub comprising 22.74% and 22.46% respectively. Table 3-4 shows the percentage of each biotic community in each subwatershed.

The second vegetation map was created from the Southwest Regional Gap Analysis Project land cover map (Lowry et. al, 2005). According to this map, 26 different land cover types are found within the watershed, including vegetation communities, developed land, open water, and agriculture (Table 3-5). The most common land cover type over the entire watershed is Sonoran Paloverde Mixed Cacti Desert Scrub encompassing 21.59% of the watershed. The next most common types are Developed, Medium-High Intensity (14.18%), Mogollon Chaparral (12.94%), and Sonora-Mojave Creosote bush – White Bursage Desert Scrub (10.65%). Figure 3-5 is a map of the Southwest Regional GAP Land Cover for the Agua Fria Watershed.

Table 3-4: Agua Fria Watershed Brown, Lowe and Pace Biotic Communities, Percent by Subwatershed (part 1 of 2).

Biotic Community	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
AZ Upland Sonoran Desertscrub	-	-	17.43	23.62	73.14
Interior Chaparral	27.60	42.42	48.12	30.81	26.53
Petran Montane Conifer Forest	0.17	5.12	10.42	0.14	0.34
Semi-desert Grassland	54.19	25.34	24.04	40.90	-
Plains & Great Basin Grassland	-	25.76	-	-	-
Great Basin Conifer Woodland	18.05	1.36	-	4.53	-
Lower Colorado River Sonoran Desertscrub	-	-	-	-	-
Area (square miles)	*260.55*	*324.14*	*244.07*	*236.45*	*371.81*

Table 3-4: Agua Fria Watershed Brown, Lowe and Pace Biotic Communities, Percent by Subwatershed (part 2 of 2).

Biotic Community	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
AZ Upland Sonoran Desertscrub	48.40	64.90	60.88	24.31	*36.83*
Interior Chaparral	21.37	0.18	15.24	-	*22.74*
Petran Montane Conifer Forest	-	-	-	-	*1.63*
Semi-desert Grassland	-	-	-	-	*14.02*
Plains & Great Basin Grassland	-	-	-	-	*3.09*
Great Basin Conifer Woodland	0.24	-	-	-	*2.32*
Lower Colorado River Sonoran Desertscrub	29.99	34.92	23.87	75.69	*22.46*
Area (square miles)	*288.47*	*242.19*	*353.18*	*464.31*	*2785.17*

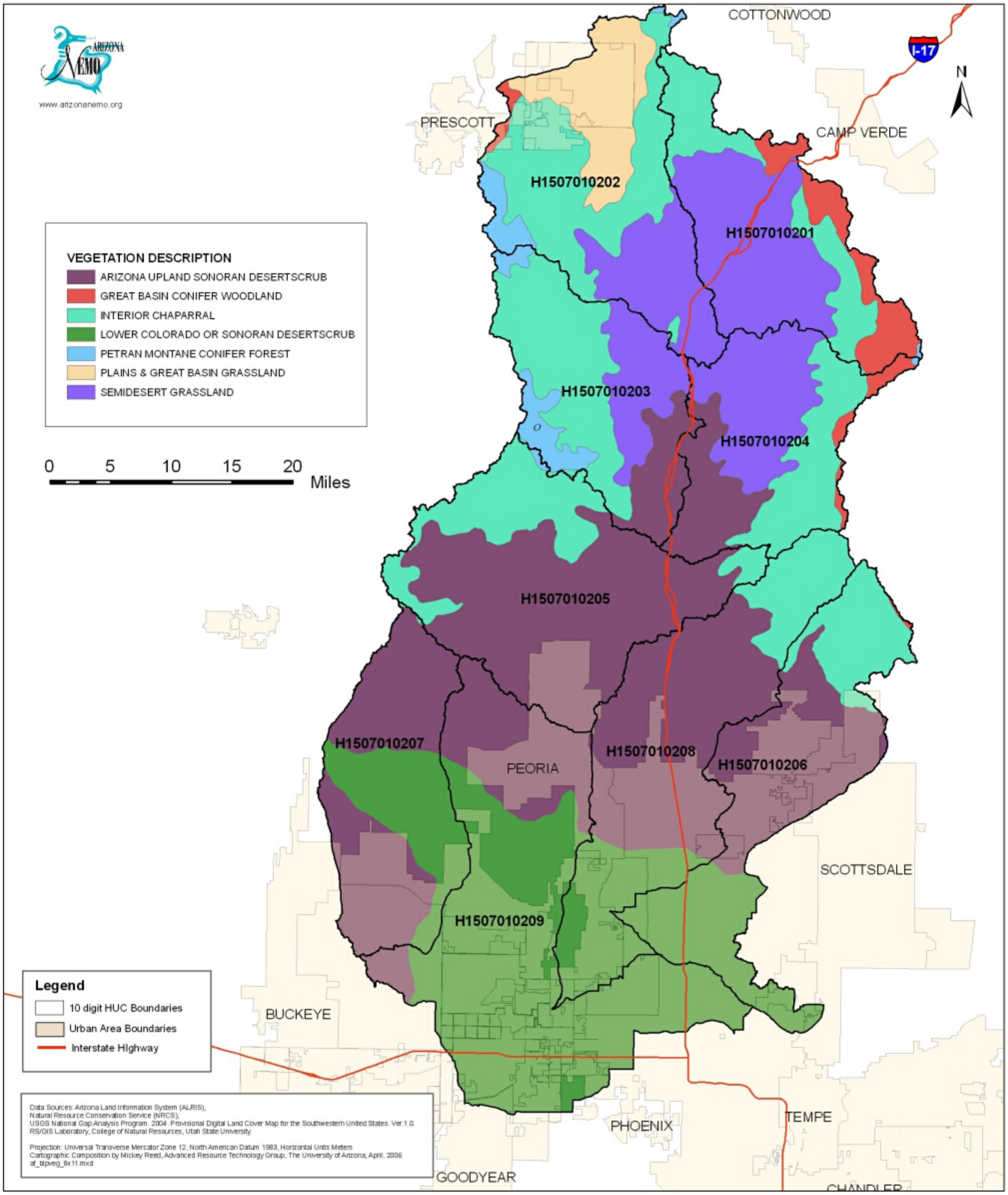


Figure 3-4: Agua Fria Watershed Brown, Lowe and Pace Biotic Communities (See Table 3-1 for subwatershed names).

Table 3-5: Agua Fria Watershed Southwest Regional GAP Analysis Project Land Cover, Percent of Subwatershed (Part 1 of 2).

Land Cover	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204
Agriculture	**0.10**	**0.30**	**-**	**-**
Apacherian-Chihuahuan Mesquite Upland Scrub	**10.44**	**7.68**	**21.81**	**25.86**
Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe	**12.33**	**15.42**	**2.44**	**15.91**
Barren Lands, Non-specific	**-**	**-**	**-**	**-**
Chihuahuan Creosote bush, Mixed Desert and Thorn Scrub	**0.04**	**0.05**	**0.04**	**0.05**
Colorado Plateau Mixed Bedrock Canyon and Tableland	**0.08**	**0.22**	**0.20**	**0.12**
Developed, Medium - High Intensity	**0.58**	**9.29**	**0.62**	**1.50**
Developed, Open Space - Low Intensity	**-**	**0.22**	**-**	**-**
Invasive Southwest Riparian Woodland and Shrubland	**-**	**-**	**0.01**	**0.01**
Madrean Encinal	**-**	**0.04**	**0.06**	**-**
Madrean Juniper Savanna	**2.60**	**0.45**	**0.31**	**1.42**
Madrean Pine-Oak Forest and Woodland	**3.20**	**5.65**	**11.28**	**2.06**
Madrean Pinyon-Juniper Woodland	**39.84**	**24.63**	**7.27**	**17.33**
Mogollon Chaparral	**26.33**	**27.04**	**31.27**	**22.76**
North American Warm Desert Lower Montane Riparian Woodland and Shrubland	**0.70**	**0.28**	**0.10**	**0.67**
North American Warm Desert Riparian Mesquite Bosque	**-**	**-**	**0.07**	**0.05**
North American Warm Desert Riparian Woodland and Shrubland	**-**	**-**	**0.35**	**0.44**
North American Warm Desert Wash	**0.04**	**0.02**	**0.01**	**0.01**
Open Water	**-**	**0.03**	**-**	**-**
Recently Burned	**-**	**-**	**0.25**	**-**
Recently Mined or Quarried	**-**	**-**	**-**	**-**
Rocky Mountain Ponderosa Pine Woodland	**3.38**	**8.47**	**6.29**	**0.42**
Sonora-Mojave Creosote bush-White Bursage Desert Scrub	**0.03**	**0.04**	**0.02**	**0.08**
Sonora-Mojave Mixed Salt Desert Scrub	**-**	**-**	**-**	**-**
Sonoran Mid-Elevation Desert Scrub	**0.22**	**0.07**	**0.68**	**0.77**
Sonoran Paloverde-Mixed Cacti Desert Scrub	**0.09**	**0.08**	**16.93**	**10.54**
Area (square miles)	***260.55***	***324.14***	***244.07***	***236.45***

Table 3-5: Agua Fria Watershed Southwest Regional GAP Analysis Project Land Cover, Percent of Subwatershed (Part 2 of 2).

Land Cover	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
Agriculture	-	-	1.08	21.83	*4.41*
Apacherian-Chihuahuan Mesquite Upland Scrub	8.52	0.11	5.35	0.01	*8.71*
Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe	0.22	-	0.42	-	*5.30*
Barren Lands, Non-specific	0.02	0.26	0.07	0.01	*0.04*
Chihuahuan Creosote bush, Mixed Desert and Thorn Scrub	0.03	-	-	-	*0.02*
Colorado Plateau Mixed Bedrock Canyon and Tableland	-	-	0.02	-	*0.07*
Developed, Medium - High Intensity	30.36	0.58	21.84	30.04	*14.18*
Developed, Open Space - Low Intensity	12.81	1.62	5.10	3.53	*3.15*
Invasive Southwest Riparian Woodland and Shrubland	0.01	-	0.02	0.03	*0.01*
Madrean Encinal	-	-	-	-	*0.01*
Madrean Juniper Savanna	0.44	-	0.38	-	*0.64*
Madrean Pine-Oak Forest and Woodland	1.21	-	0.63	-	*2.69*
Madrean Pinyon-Juniper Woodland	8.65	0.16	7.06	0.02	*12.11*
Mogollon Chaparral	4.11	0.47	3.63	0.01	*12.94*
North American Warm Desert Lower Montane Riparian Woodland and Shrubland	0.38	-	0.29	-	*0.28*
North American Warm Desert Riparian Mesquite Bosque	0.06	0.25	0.08	0.01	*0.06*
North American Warm Desert Riparian Woodland and Shrubland	0.32	0.04	0.05	0.04	*0.14*
North American Warm Desert Wash	-	-	-	-	*0.01*
Open Water	0.03	-	0.08	0.08	*0.03*
Recently Burned	-	-	-	-	*0.03*
Recently Mined or Quarried	-	-	-	0.11	*0.02*
Rocky Mountain Ponderosa Pine Woodland	-	-	-	-	*2.18*
Sonora-Mojave Creosote bush-White Bursage Desert Scrub	4.91	44.79	15.68	16.93	*10.65*
Sonora-Mojave Mixed Salt Desert Scrub	0.05	0.20	0.08	0.29	*0.09*
Sonoran Mid-Elevation Desert Scrub	0.64	3.10	0.22	0.25	*0.64*
Sonoran Paloverde-Mixed Cacti Desert Scrub	27.25	48.43	37.92	26.81	*21.59*
Area (square miles)	*288.47*	*242.19*	*353.18*	*464.31*	*2785.17*

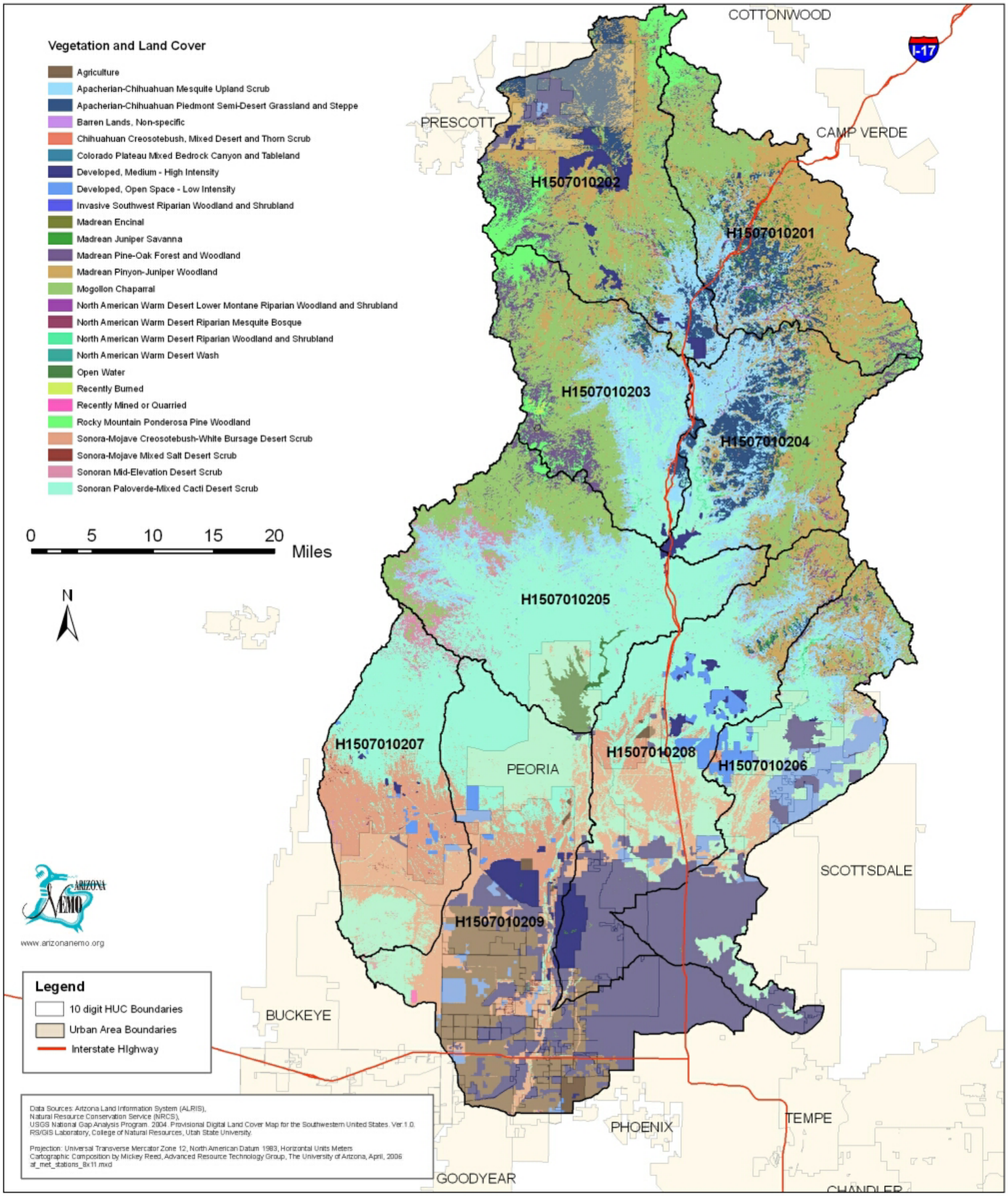


Figure 3-5: Agua Fria Watershed Southwest Regional Gap Analysis Project Land Cover (See Table 3-1 for subwatershed names).

Habitats (Riparian and Wetland Areas)

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 (July 1994). This map was used to identify riparian areas in the Agua Fria Watershed (Figure 3-6).

Seven of the ten different types of riparian areas occur within this watershed (Table 3-6). Riparian areas encompass approximately 1,715 acres (2.7 square miles) or 0.04% of the entire watershed. Mixed Broadleaf comprises about 1,025 acres (1.6 square miles, or 59.8%) of the riparian areas, and Strand (the area alongside the stream channel) comprises about 337.9 acres (0.53 square miles, or 19.7%).

The Ash Creek and Sycamore Creek subwatershed has the greatest amount of riparian vegetation with about 577 acres (0.90 square miles). The Bishop Creek and Agua Fria – Lake Pleasant subwatersheds also have large amounts of riparian vegetation with 421 acres (0.66 square miles) and 328 acres (0.51 square miles) respectively. The Trilby Wash-Trilby Wash Basin and New River subwatersheds have no riparian vegetation associated with perennial waters. Table 3-6 contains the list of riparian vegetation types and areas for each subwatershed.

Major Land Resource Areas (MLRAs)

Major Land Resource Areas, or MLRA's, are ecosystem divisions in Arizona. There are four different MLRA's in the Agua Fria Watershed (Figure 3-7): Arizona and New Mexico Mountains, Central Arizona Basin and Range, Colorado and Green River Plateaus, and Sonoran Basin and Range (Table 3-7).

The Central Arizona Basin and Range MLRA has the largest representation with 58.16% (1,619.85 square miles) of the watershed. Arizona and New Mexico Mountains is the next largest with 37.58% of the entire watershed (1,046.67 square miles). Trilby Wash – Trilby Wash Basin is entirely within the Central Arizona Basin and Range MLRA (Cassady, 2000).

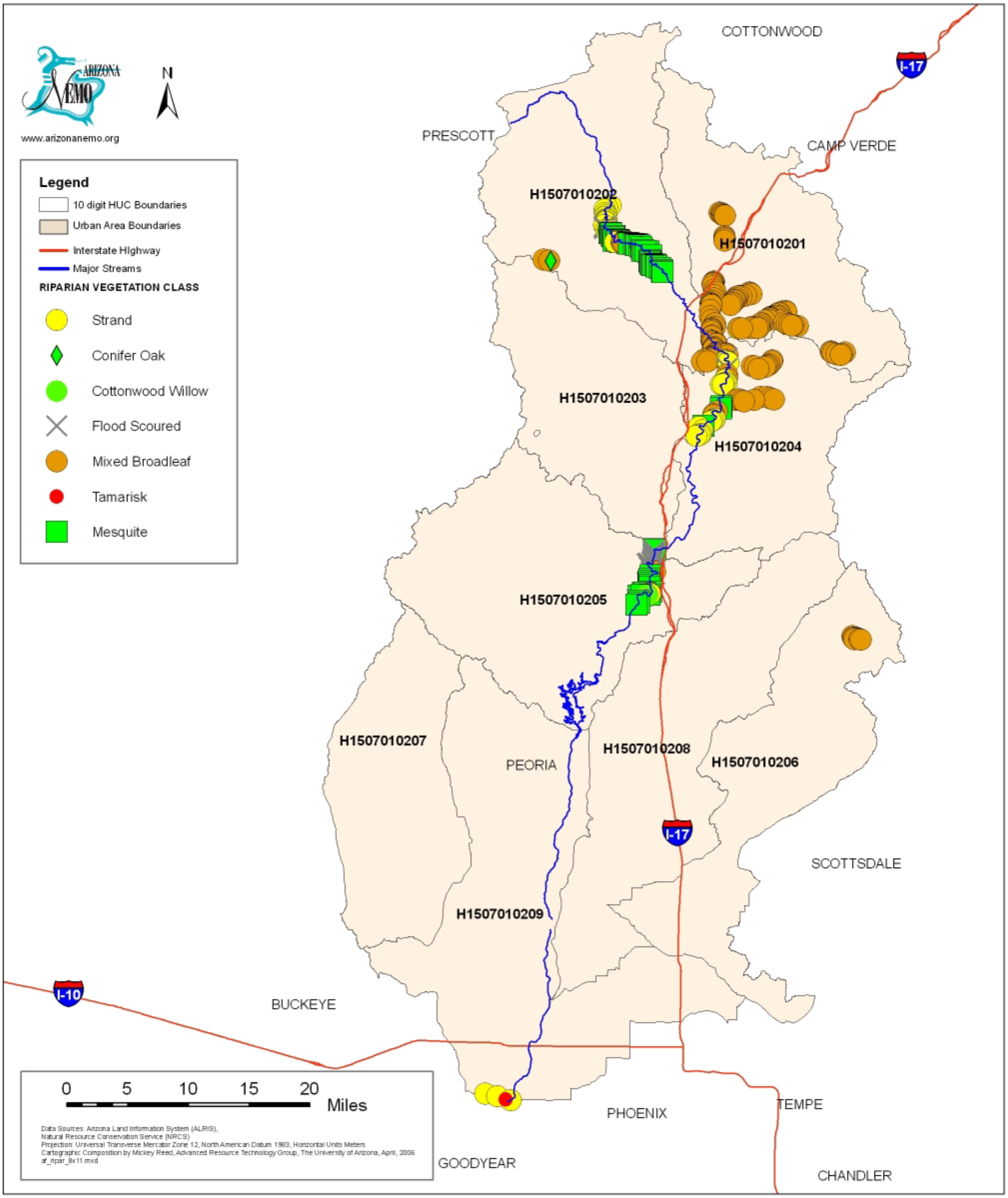


Figure 3-6: Agua Fria Watershed Riparian and Wetland Areas (See Table 3-1 for subwatershed names).

Table 3-6: Agua Fria Watershed Riparian and Wetland Areas (acres) by Subwatershed (Part 1 of 2).

Riparian Vegetation Community	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Conifer Oak	-	1.78	-	-	-
Cottonwood Willow	-	-	-	-	2.16
Flood Scoured	-	2.58	-	9.94	148.03
Mesquite	-	93.85	0.26	6.99	83.43
Mixed Broadleaf	545.52	82.34	-	355.79	17.76
Strand	31.63	55.29	-	48.10	86.30
Tamarisk	-	-	-	-	-
Total Area (acres)	*577.15*	*235.85*	*0.26*	*420.84*	*337.67*

Table 3-6: Agua Fria Watershed Riparian and Wetland Areas (acres) by Subwatershed (Part 2 of 2).

Riparian Vegetation Community	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
Conifer Oak	-	-	-	-	*1.78*
Cottonwood Willow	1.13	-	-	-	*3.29*
Flood Scoured	-	-	-	-	*160.56*
Mesquite	-	-	-	-	*184.53*
Mixed Broadleaf	24.11	-	-	-	*1025.53*
Strand	-	-	-	116.60	*337.93*
Tamarisk	-	-	-	1.07	*1.07*
Total Area (acres)	*25.24*	*0.00*	*0.00*	*117.67*	*1714.68*

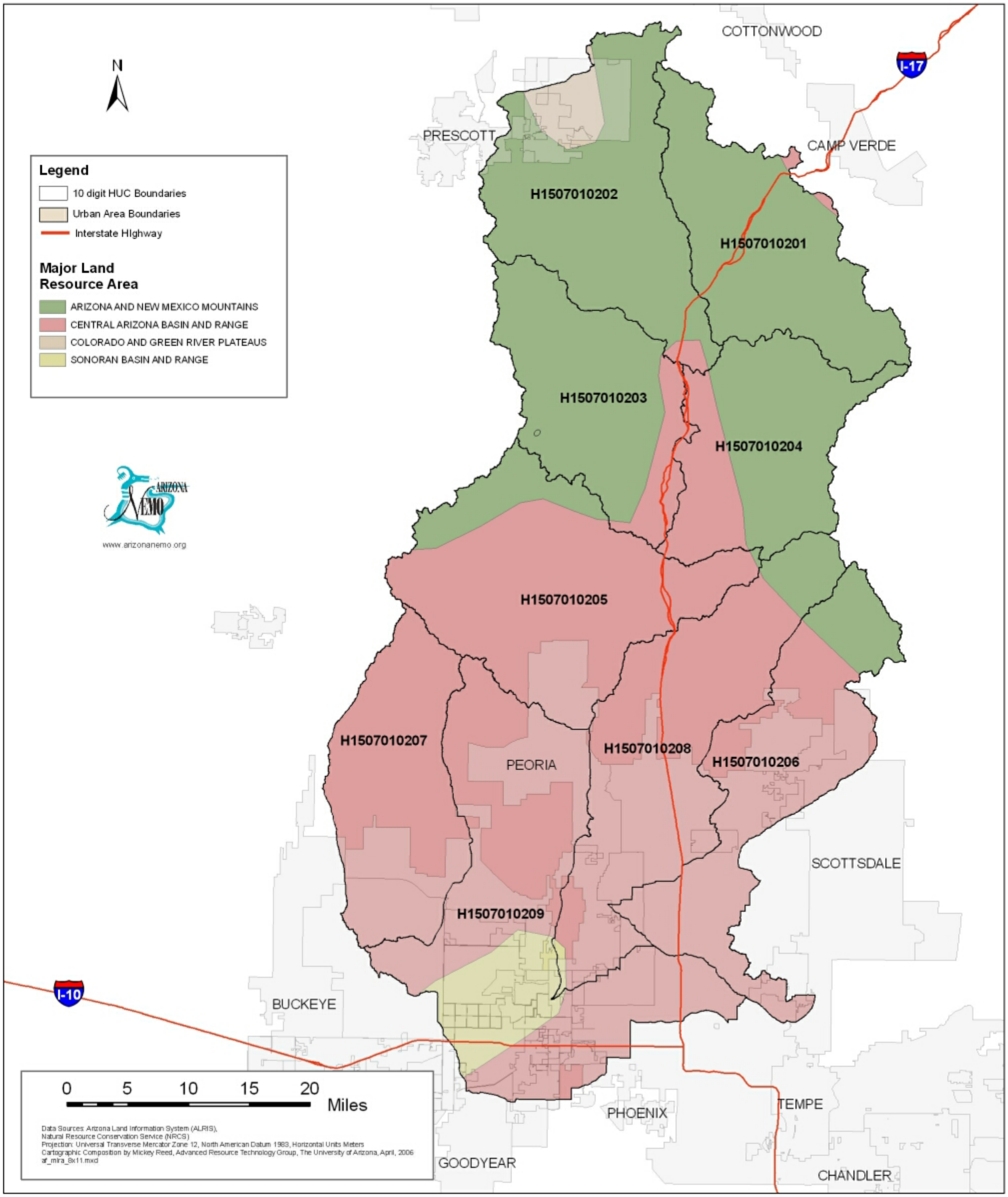


Figure 3-7: Agua Fria Watershed Major Land Resource Areas (See Table 3-1 for subwatershed names).

Table 3-7: Agua Fria Watershed - Major Land Resource Areas (percent per Subwatershed).

Subwatershed	Major Land Resource Areas, Area (percent per subwatershed)				*Agua Fria Watershed area (square miles)*
	Arizona and New Mexico Mountains	**Central Arizona Basin and Range**	**Colorado and Green River Plateaus**	**Sonoran Basin and Range**	
Ash Creek and Sycamore Creek H1507010201	**98.68**	**1.32**	**-**	**-**	***260.55***
Big Bug Creek-Agua Fria River H1507010202	**88.27**	**2.10**	**9.63**	**-**	***324.14***
Black Canyon Creek H1507010203	**83.50**	**16.50**	**-**	**-**	***244.07***
Bishop Creek H1507010204	**70.67**	**29.33**	**-**	**-**	***236.45***
Agua Fria River-Lake Pleasant H1507010205	**15.05**	**84.95**	**-**	**-**	***371.81***
Cave Creek-Arizona Canal Diversion Channel H1507010206	**15.15**	**84.85**	**-**	**-**	***288.47***
Trilby Wash-Trilby Wash Basin H1507010207	**-**	**100.00**	**-**	**-**	***242.19***
New River H1507010208	**9.29**	**89.84**	**-**	**0.87**	***353.18***
Agua Fria River below Lake Pleasant H1507010209	**-**	**81.86**	**-**	**18.14**	***464.31***
Agua Fria Watershed (percent)	***37.58***	***58.16***	***1.13***	***3.13***	***2785.17***

References:

Bailey, R.G. 1976. "Ecoregions of the United States" map, Aug. 17, 2001, unnumbered publication. Intermountain Region, USDA Forest Service, Ogden, Utah. http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html

Bailey, R.G. 1995. Description of the Ecoregions of the United States, Aug. 17, 2001. U.S. Forest Service, USDA. http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html

Brown, D.E., C.H. Lowe, and C.P. Pace. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest, J. Arizona-Nevada Acad. Sci., 14 (Suppl. 1), 1–16, 1979

Cassady, Stephen. 2000. Arizona's Major Land Resource Areas. Proceedings, Arizona Ecological site Symposium, August 17-19, 2000.

Lowry, J. H, Jr., R. D. Ramsey, K. Boykin, D. Bradford, P. Comer, S. Falzarano, W. Kepner, J. Kirby, L. Langs, J. Prior-Magee, G. Manis, L. O'Brien, T. Sajwaj, K. A. Thomas, W. Rieth, S. Schrader, D. Schrupp, K. Schulz, B. Thompson, C. Velasquez, C. Wallace, E. Waller and B. Wolk. 2005. *Southwest Regional Gap Analysis Project: Final Report on Land Cover Mapping Methods*, RS/GIS Laboratory, Utah State University, Logan, Utah. http://fws-nmcfwru.nmsu.edu/swregap/

Data Sources:*

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/alrishome.html
Habitats (Riparian & Wetland Areas). June 12, 2003.

Interior Columbian Basin Ecosystem Management Project.
http://www.icbemp.gov/spatial/phys/
Bailey's Ecoregions - Divisions map. June 12, 2003.
Bailey's Ecoregions - Provinces map. June 12, 2003.
Bailey's Ecoregions - Sections map. June 12, 2003

Southern Arizona Data Services Program, University of Arizona. Published by the USGS Sonoran Desert Field Station, University of Arizona.
http://sdrsnet.srnr.arizona.edu/index.php
Brown, Lowe and Pace Biotic Communities map. June 12, 2003. This dataset was digitized by the Arizona Game and Fish Department, Habitat Branch from the August 1980 David E. Brown & Charles H. Lowe 1:1,000,000 scale, 'Biotic Communities of the Southwest'.

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.

U.S. Geological Survey National Gap Analysis Program. 2004. Provisional Digital Land Cover Map for the Southwestern United States. Version 1.0. RS/GIS Laboratory, College of Natural Resources, Utah State University. http://earth.gis.usu.edu/swgap/landcover.html Southwest Regional Gap Analysis Project Land Cover map, 2005.

**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 hold jurisdiction over the land in a given watershed helps a watershed partnership understand the significance of each stakeholder's influence on the watershed. The Agua Fria Watershed is located in two counties: Yavapai and Maricopa, as shown in Figure 4-1. The area is nearly equally split between the two counties, with 48.92% in Maricopa County, and 51.08% in Yavapai County (Table 4-1).

Several of the subwatersheds are located 100% in Yavapai County. Table 4-1 lists the percentage of each subwatershed in each county.

Council of Governments (COGs)

Two Councils of Governments (COGs) are present in the Agua Fria Watershed, the Maricopa Association of Governments (MAG), and the Northern Arizona Council of Governments (NACOG) (Figure 4-2). These two COGs match up with the counties described above. The MAG represents 48.92% of the watershed, or the Maricopa County portion, and the NACOG represents the Yavapai County portion, or 51.08%.

Table 4-1: Agua Fria Watershed Percent of Subwatershed by County.

Subwatershed and HUC	Area (sq. mi.)	Maricopa	Yavapai
Ash Creek and Sycamore Creek - H1507010201	**260.55**	**-**	**100**
Big Bug Creek-Agua Fria River - H1507010202	**324.14**	**-**	**100**
Black Canyon Creek - H1507010203	**244.07**	**-**	**100**
Bishop Creek - H1507010204	**236.45**	**-**	**100**
Agua Fria River-Lake Pleasant - H1507010205	**371.81**	**16.48**	**83.52**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**288.47**	**97.75**	**2.25**
Trilby Wash-Trilby Wash Basin - H1507010207	**242.18**	**95.10**	**4.93**
New River - H1507010208	**353.18**	**92.52**	**7.47**
Agua Fria River below Lake Pleasant - H1507010209	**464.31**	**99.54**	**0.46**
Total Agua Fria Watershed	***2785.16***	***48.92***	***51.08***

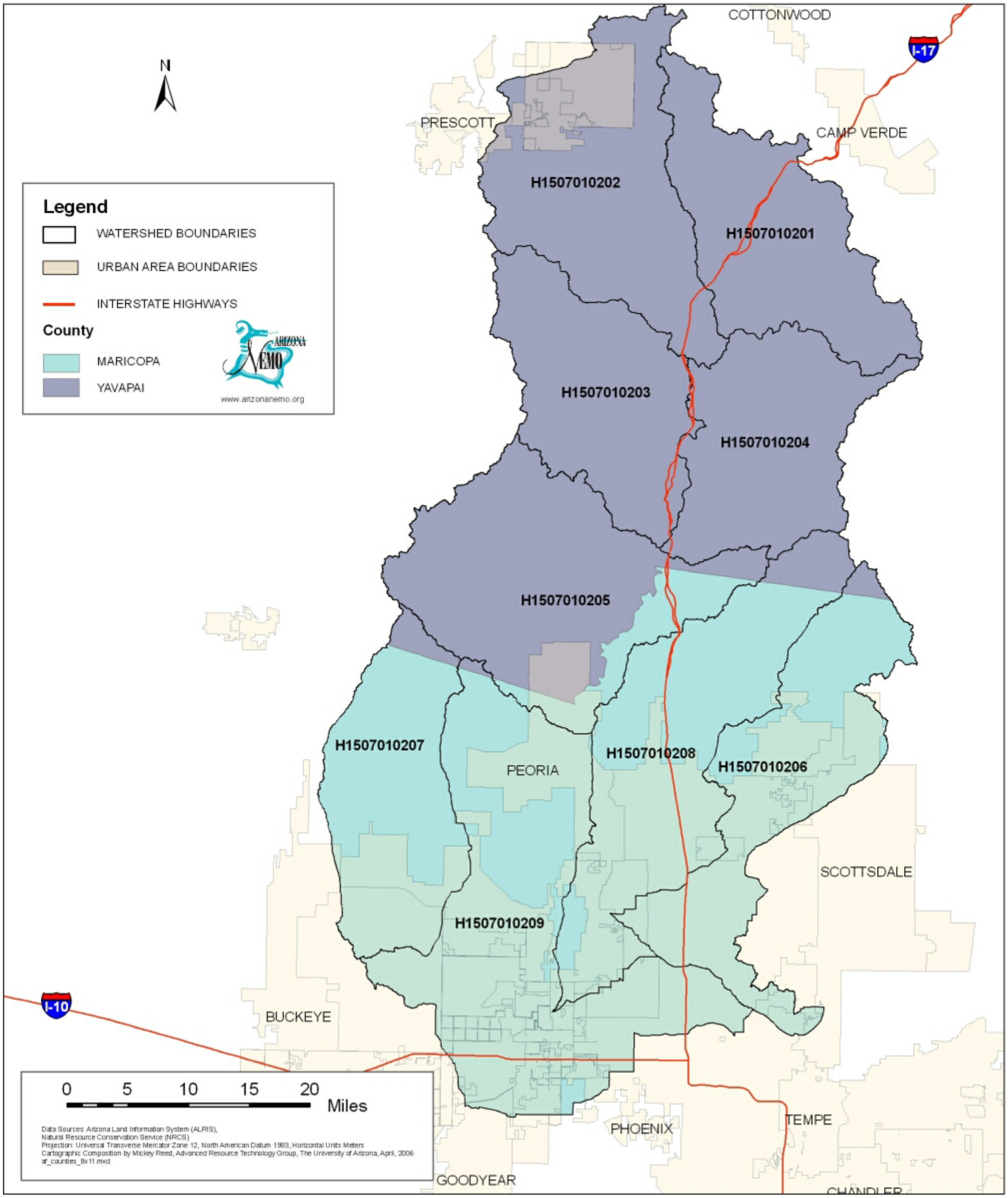


Figure 4-1: Agua Fria Watershed Counties.
Note: See Table 4-1 for subwatershed names.

Table 4-2: Agua Fria Watershed Councils of Governments, Percent by Subwatershed.

Subwatershed Name and HUC	Councils Of Governments	
	MAG[1]	NACOG[2]
Ash Creek and Sycamore Creek - H1507010201	**-**	**100**
Big Bug Creek-Agua Fria River - H1507010202	**-**	**100**
Black Canyon Creek - H1507010203	**-**	**100**
Bishop Creek - H1507010204	**-**	**100**
Agua Fria River-Lake Pleasant - H1507010205	**16.48**	**83.52**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**97.75**	**2.25**
Trilby Wash-Trilby Wash Basin - H1507010207	**95.10**	**4.93**
New River - H1507010208	**92.52**	**7.47**
Agua Fria River below Lake Pleasant - H1507010209	**99.54**	**0.46**
Total Agua Fria Watershed	***48.92***	***51.08***

1 Maricopa Association of Governments
2 Northern Arizona Council of Governments

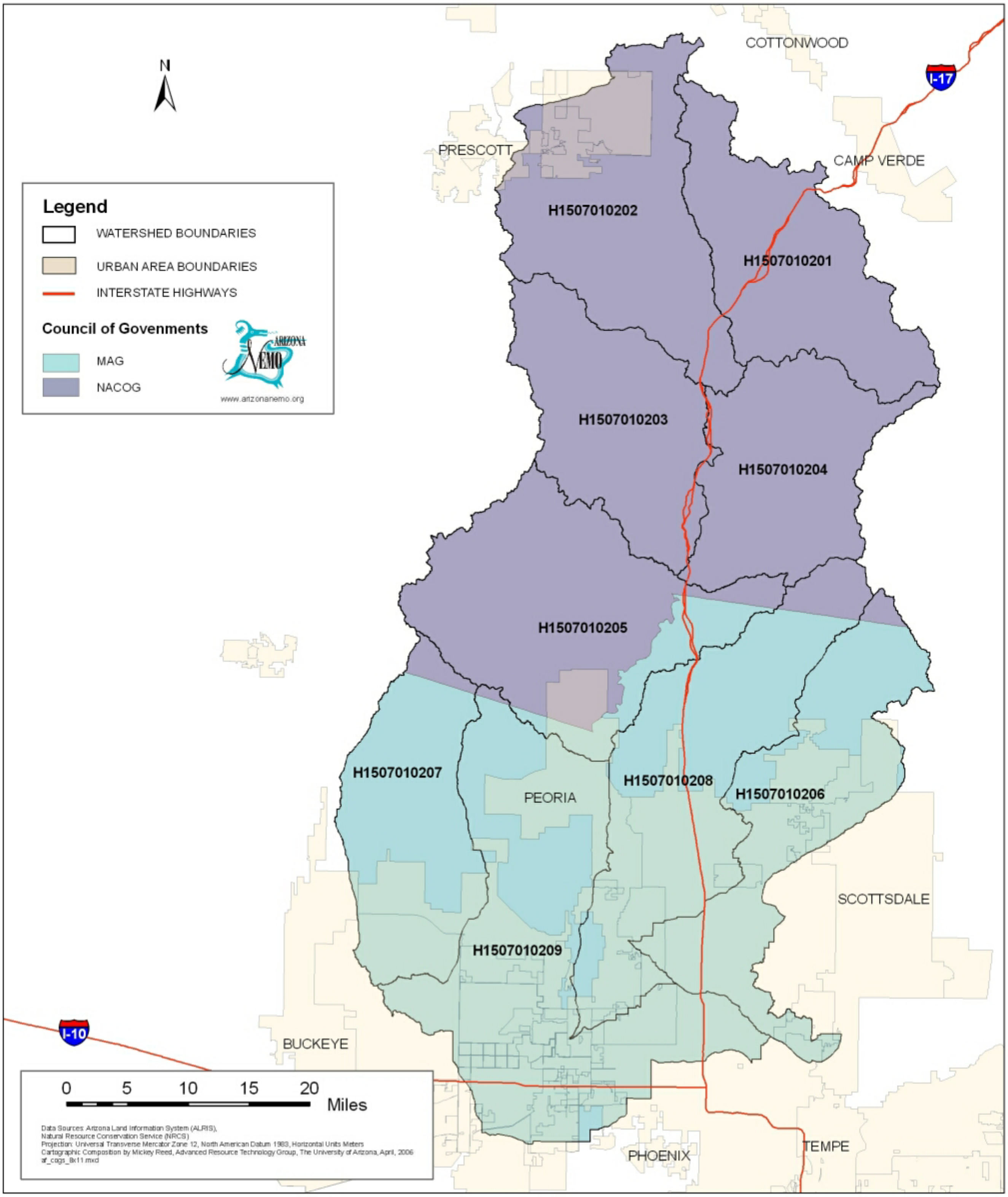


Figure 4-2: Agua Fria Watershed Council of Governments.

Urban Areas

The U.S. Census Bureau categorizes various types of population centers based on population figures and density. Densely settled territory that contains 50,000 or more people is defined as an urban area (www.census.gov/geo/www/geo_defn.html). Based on that definition and Census Bureau data, there are four major urban areas that lie partially within the Agua Fria Watershed: Glendale, Peoria, Phoenix and Scottsdale (Figure 4-3). Each of these urban areas lies partially within the Agua Fria Watershed. Phoenix has the largest area with 154,313.66 acres (241 square miles), most of which lies within the Cave Creek-Arizona Canal Diversion Channel subwatershed. Table 4-3 tabulates these areas.

A population density map was created using 2000 census block population data. Areas with a population density greater than 1,000 persons per square mile were determined (Figure 4-4). This classification yielded seven urban areas (Table 4-4): Avondale, Glendale, Litchfield Park, Phoenix, Scottsdale, Tolleson and Youngtown. Glendale had the greatest density with 3,943 persons per square mile.

Table 4-3: Agua Fria Watershed Urban Areas (acres).

	Urban Area (acres)			
Sub-watershed Name	**Glendale**	**Peoria**	**Phoenix**	**Scottsdale**
Ash Creek and Sycamore Creek - H1507010201	**0**	**0**	**0**	**0**
Big Bug Creek-Agua Fria River - H1507010202	**0**	**0**	**0**	**0**
Black Canyon Creek - H1507010203	**0**	**0**	**0**	**0**
Bishop Creek - H1507010204	**0**	**0**	**0**	**0**
Agua Fria River-Lake Pleasant - H1507010205	**0**	**22,126.22**	**0**	**0**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**3,630.08**	**37.44**	**67,027.95**	**19,351.68**
Trilby Wash-Trilby Wash Basin - H1507010207	**0**	**0**	**0**	**0**
New River - H1507010208	**13,491.34**	**30,290.14**	**49,342.89**	**0**
Agua Fria River below Lake Pleasant - H1507010209	**18,394.78**	**37,966.0**	**37,942.82**	**0**
Total Agua Fria Watershed	***35,516.2***	***90,419.8***	***154,313.66***	***19,351.68***

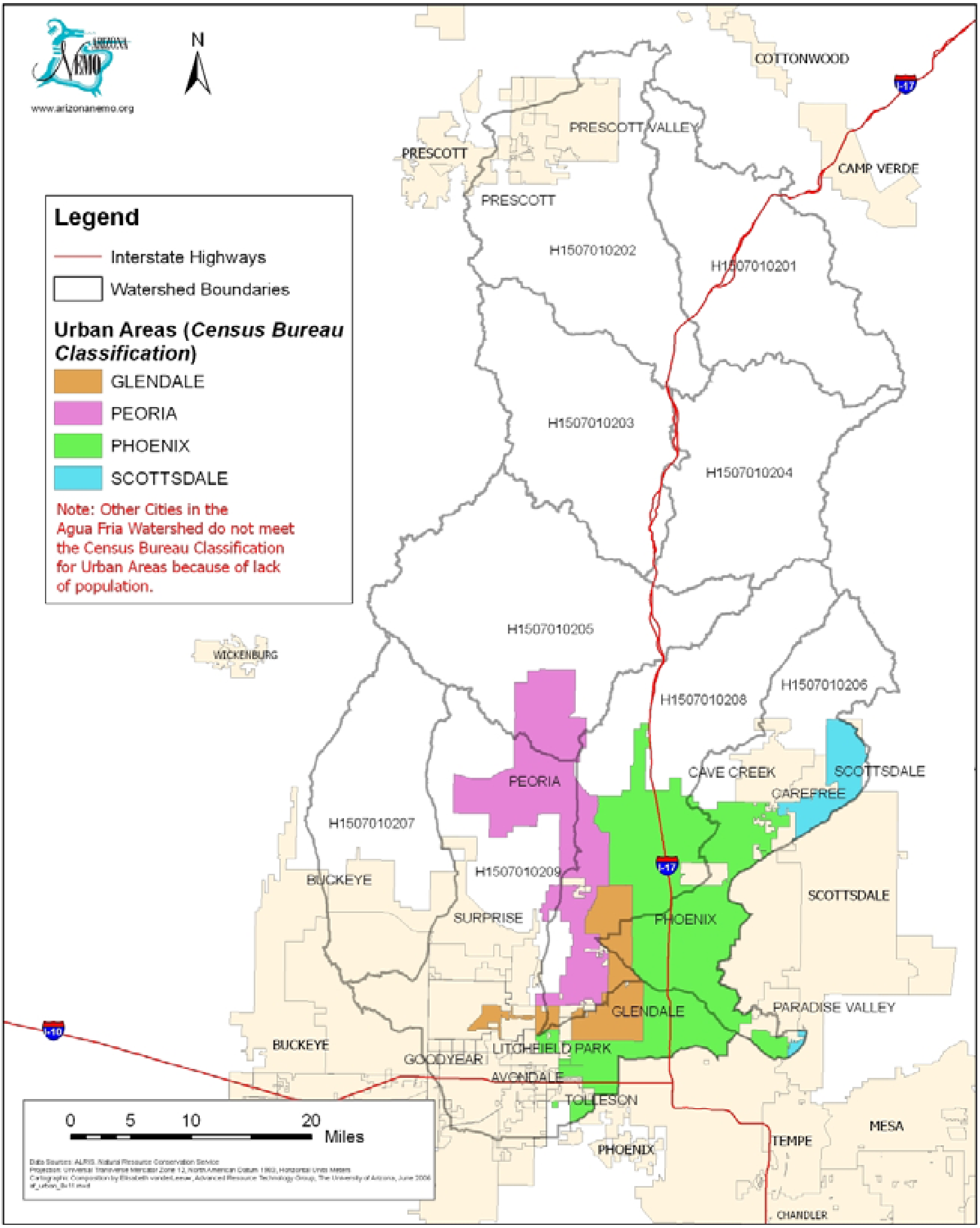


Figure 4-3: Agua Fria Watershed Urbanized Areas (Census Bureau Classification).

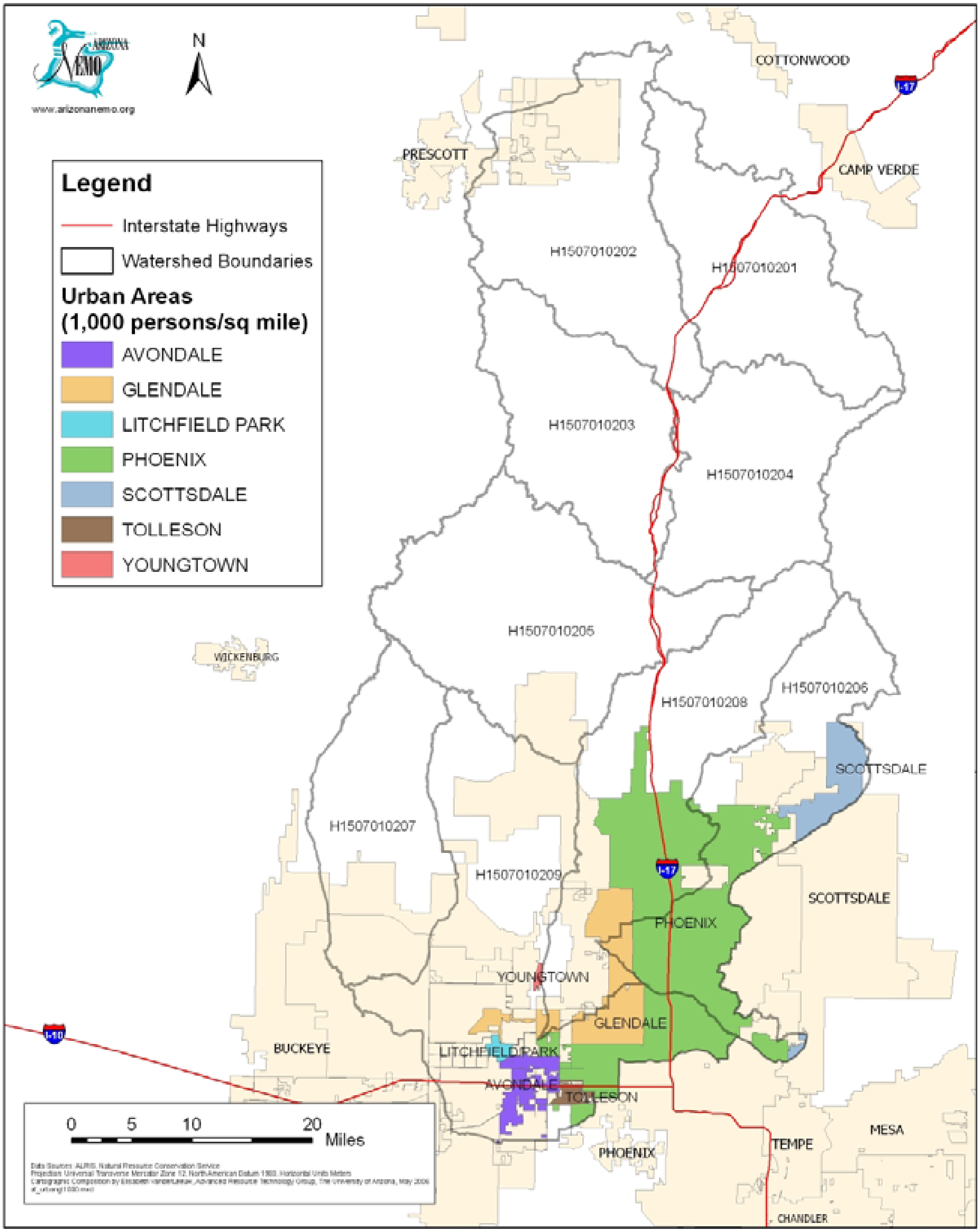


Figure 4-4: Agua Fria Watershed Urban Areas based on 2000 Population Density Greater than 1,000 persons/square mile.

Table 4-4: Agua Fria Watershed Urban Areas Based on 2000 Population Density (1,000 persons/square mile).

Urban Areas	Population 2000	Area (square miles)	Urban Area Density persons / sq. mi.
Avondale	**35,883**	**26**	**1,355**
Glendale	**218,812**	**55**	**3,943**
Litchfield Park	**3,810**	**3**	**1,219**
Phoenix	**1,321,045**	**462**	**2,857**
Scottsdale	**202,705**	**184**	**1,102**
Tolleson	**4,974**	**5**	**1,074**
Youngtown	**3,010**	**1**	**2,571**
Total Urban Areas (acre)	***1,790,239***	***737***	***2,428***

* population data obtained from 2000 census data, size of city from www.city-data.com

Population

Census Population Densities in 1990

Census block statistics for 1990 were compiled from a CD prepared by Geo-Lytics (Geo-Lytics, 1998). These data were linked with census block data and used to create a density map (Figure 4-5), through a normalization process using a grid of 7 km squares. This process involves calculating density per census block and intersecting it with the grid, which is then used to calculate the number of people and thus density per grid square.

Table 4-5 shows the tabulated minimum, maximum and mean number of persons per square mile in 1990 for each subwatershed. In 1990, the mean population density for the entire watershed was 304.86 persons per square mile. The Agua Fria below Lake Pleasant subwatershed had the highest population density with an average of 901.14 persons per square mile, and a maximum of 7178.86. The Ash Creek and Sycamore Creek subwatershed had an average of only 1.71 persons per square mile.

Table 4-5: Agua Fria Watershed 1990 Population Density (persons/square mile).

Sub-watershed Name	Area (sq. miles)	Min	Max	Mean
Ash Creek and Sycamore Creek - H1507010201	**260.55**	**0**	**46.00**	**1.71**
Big Bug Creek-Agua Fria River - H1507010202	**324.14**	**0**	**1,090.86**	**45.14**
Black Canyon Creek - H1507010203	**244.07**	**0**	**167.43**	**6.29**
Bishop Creek - H1507010204	**236.45**	**0**	**167.43**	**6.57**
Agua Fria River-Lake Pleasant - H1507010205	**371.81**	**0**	**129.43**	**2.00**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**288.47**	**0**	**6,190.29**	**839.43**
Trilby Wash-Trilby Wash Basin - H1507010207	**242.18**	**0**	**137.14**	**12.57**
New River - H1507010208	**353.18**	**0**	**6,190.29**	**488.86**
Agua Fria River below Lake Pleasant - H1507010209	**464.31**	**0**	**7,178.86**	**901.14**
Total Agua Fria Watershed	***2,785.16***	***0***	***7,178.86***	***304.86***

Note: Adjacent watersheds may share a grid square.

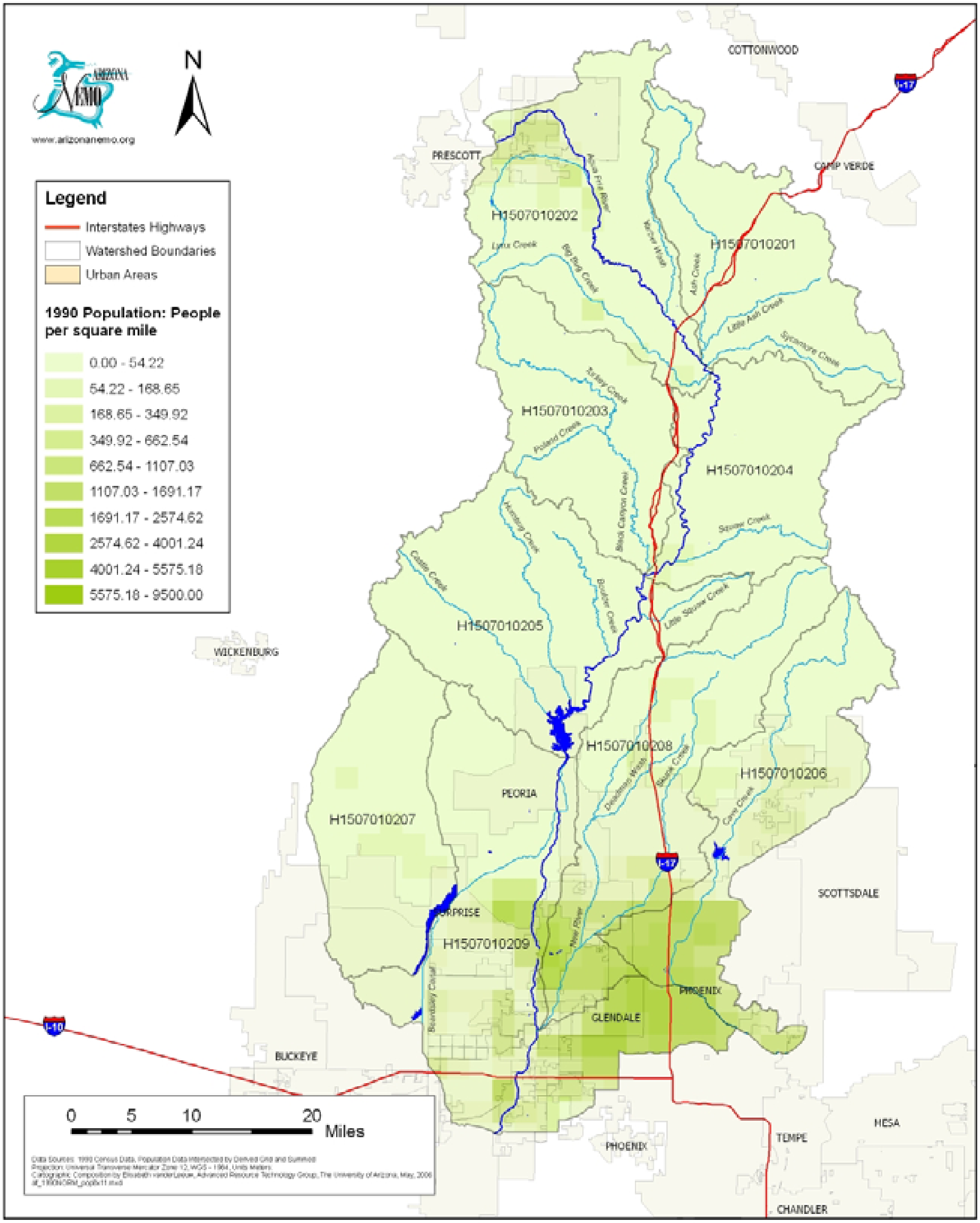


Figure 4-5: Agua Fria Watershed 1990 Population Density, persons/square mile.

Census Population Densities in 2000

The Census Block 2000 statistics data were downloaded from the Environmental Systems Research Institute (ESRI) website (ESRI Data Products, 2003) and are shown in Table 4-6. A population density map (Figure 4-6) was created from these data. The average population density in 2000 was 436.75 persons per acre. The Cave Creek – Arizona Canal Diversion Channel and the Agua Fria River below Lake Pleasant subwatersheds had nearly the same population density with 1,123.38 and 1,235.97 average persons per acre, respectively. The Agua Fria River below Lake Pleasant subwatershed had the highest density of 9,208.12 persons per square mile.

Population Change

The 1990 and 2000 population density maps were used to create a population density change map. The resulting map (Figure 4-7) shows population increase or decrease over the ten year time frame. Overall, population density increased by an average of 131.89 persons per square mile during this ten year time period. Three subwatersheds had similar, large increases in average population: Agua Fria River below Lake Pleasant, New River, and Cave Creek – Arizona Canal Diversion Channel. Table 4-7shows the change in population density from 1990 to 2000 in persons per square mile. The Ash Creek and Sycamore Creek subwatershed experienced a decrease of an average 0.22 persons per square mile.

Table 4-6: Agua Fria Watershed 2000 Population Density (persons/square mile).

Subwatershed Name	Area (sq. mi.)	Min	Max	Mean
Ash Creek and Sycamore Creek - H1507010201	**260.55**	**0**	**16.11**	**1.54**
Big Bug Creek-Agua Fria River - H1507010202	**324.14**	**0**	**2,490.12**	**92.84**
Black Canyon Creek - H1507010203	**244.07**	**0**	**526.09**	**15.92**
Bishop Creek - H1507010204	**236.45**	**0**	**526.09**	**13.03**
Agua Fria River-Lake Pleasant - H1507010205	**371.81**	**0**	**341.16**	**4.93**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**288.47**	**0**	**6,377.48**	**1,123.38**
Trilby Wash-Trilby Wash Basin - H1507010207	**242.18**	**0**	**965.74**	**28.51**
New River - H1507010208	**353.18**	**0**	**6,377.48**	**794.50**
Agua Fria River below Lake Pleasant - H1507010209	**464.31**	**0**	**9,208.12**	**1,235.97**
Total Agua Fria Watershed	***2,785.16***	***0***	***9,208.12***	***436.75***

Note: Adjacent watersheds may share a grid square.

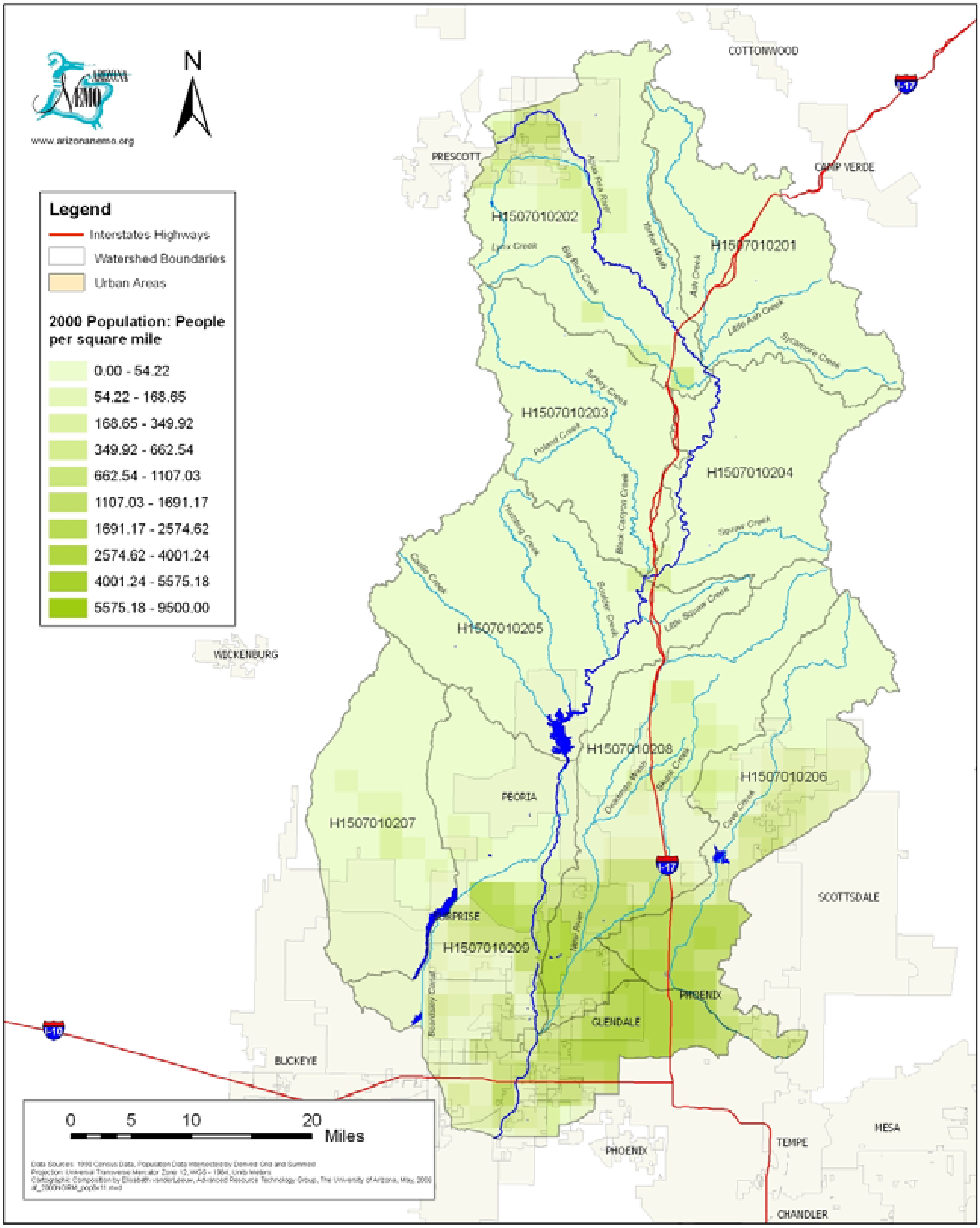


Figure 4-6: Agua Fria Watershed Population Density 2000, persons/square mile.

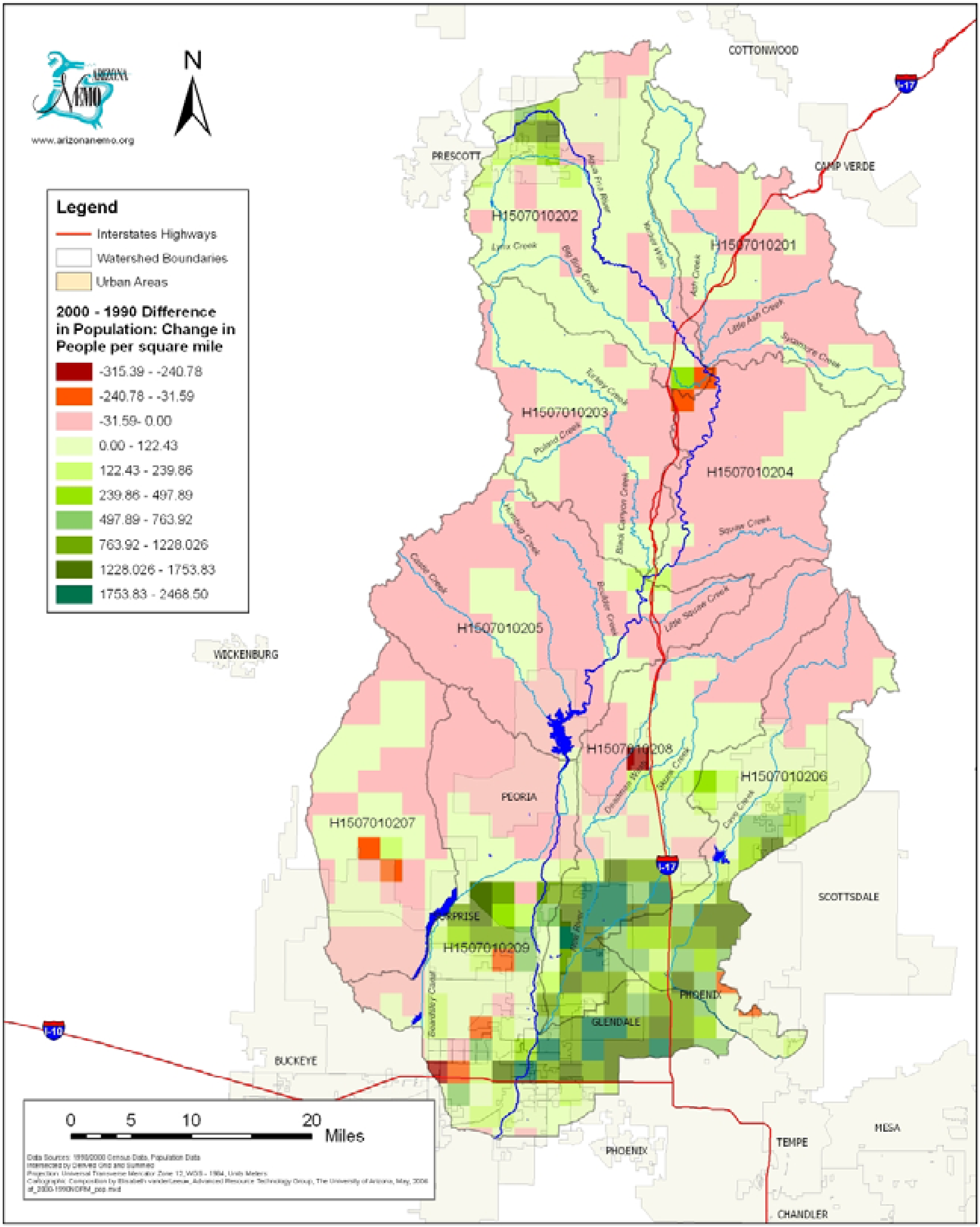


Figure 4-7: Agua Fria Watershed Population Density Change 1990 -2000 (persons/square mile).

Table 4-7: Agua Fria Watershed Population Density Change 1990-2000 (persons/square mile).

Subwatershed Name	Area (sq. mi.)	Min	Max	Mean
Ash Creek and Sycamore Creek - H1507010201	**260.55**	**0**	**-38.07**	**-0.22**
Big Bug Creek-Agua Fria River - H1507010202	**324.14**	**0**	**1,399.05**	**47.69**
Black Canyon Creek - H1507010203	**244.07**	**0**	**358.51**	**9.72**
Bishop Creek - H1507010204	**236.45**	**0**	**358.51**	**6.44**
Agua Fria River-Lake Pleasant - H1507010205	**371.81**	**0**	**211.73**	**3.07**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**288.47**	**0**	**2,468.24**	**283.93**
Trilby Wash-Trilby Wash Basin - H1507010207	**242.18**	**0**	**882.31**	**15.89**
New River - H1507010208	**353.18**	**0**	**2,468.24**	**305.65**
Agua Fria River below Lake Pleasant - H1507010209	**464.31**	**0**	**2,180.42**	**334.69**
Total Agua Fria Watershed	***2,785.16***	***0***	***2,468.24***	***131.89***

Note: Adjacent watersheds may share a grid square.

Roads

Roads are important to consider in a watershed classification because they can impact water quality by increasing runoff and, especially in construction areas or where the roads are unpaved, can increase sediment yield.

The total road length in the Agua Fria Watershed is 648.79 miles (Table 4-8). The predominant road type, based on the Census Classification, is "road" with 352.79 miles, or 54.38% of the total roads length. The Agua Fria River below Lake Pleasant subwatershed has the greatest accumulated length of roads with 179.4 miles, or 27.71% of the total roads length. Table 4-9 lists road types and lengths in each subwatershed. Figure 4-8 shows the road types.

Table 4-8: Agua Fria Watershed Road Types.

Census Classification Code	Road Length (miles)	Percent of Total Length
Road	**352.79**	**54.38**
Interstate	**93.06**	**14.34**
U.S. and State Hwys	**60.27**	**9.29**
County Roads	**17.31**	**2.67**
Unimproved Roads	**125.36**	**19.32**
Total Road Length (miles)	***648.79***	***100.00***

Table 4-9: Agua Fria Watershed Road Types and Lengths by Subwatershed.

Subwatershed Name	Road Length (miles)	Percent of Total Length
Ash Creek and Sycamore Creek - H1507010201	**36.93**	**5.62**
Big Bug Creek-Agua Fria River - H1507010202	**88.88**	**13.52**
Black Canyon Creek - H1507010203	**79.7**	**12.12**
Bishop Creek - H1507010204	**8.71**	**1.32**
Agua Fria River-Lake Pleasant - H1507010205	**40.2**	**6.11**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**95.41**	**14.51**
Trilby Wash-Trilby Wash Basin - H1507010207	**54.06**	**8.22**
New River - H1507010208	**74.2**	**11.29**
Agua Fria River below Lake Pleasant - H1507010209	**179.4**	**27.71**
Total Agua Fria Watershed	***657.49***	***100***

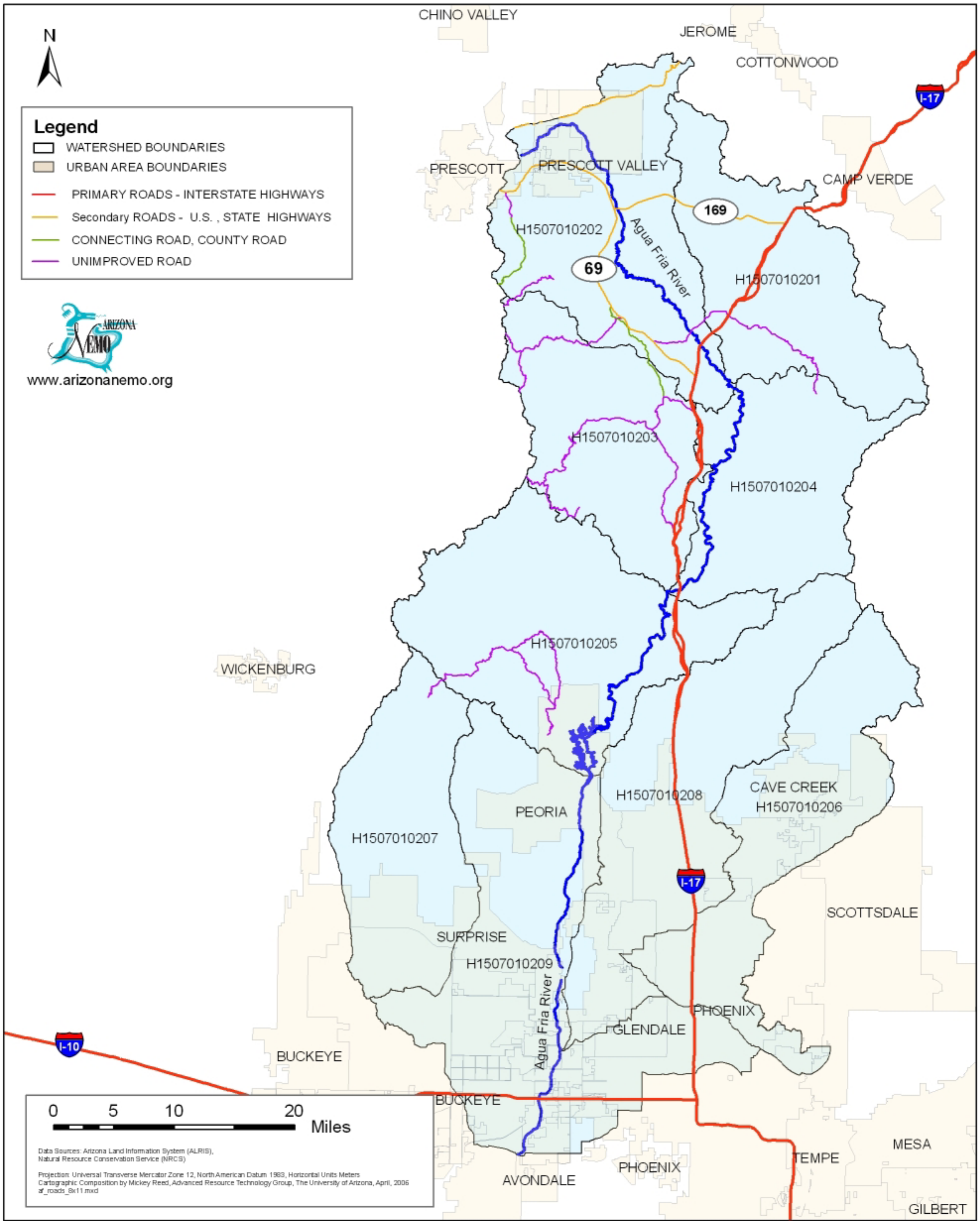


Figure 4-8: Agua Fria Watershed Road Types.

Mines

There are 1,061mineral extraction mines recorded with the Office of the Arizona State Mine Inspector in the Agua Fria Watershed. The Big Bug Creek – Agua Fria River subwatershed has the highest number of mines (293), while the Bishop Creek subwatershed has only 25 mines.

There are eleven different types of mines reported (including "well" and "unknown"), of which 295 (27.8 %) are underground mines (Table 4-10 and Figure 4-9).

Mine activity status is shown in Table 4-11 and Figure 4-10, listing seven different types of mines ranging from active to inactive production, or unknown status. There are 438 (41.3%) mines listed as "unknown". Thirty-three (3.1%) are currently producing, and 60 (5.7%) are "developed deposits".

Table 4-12 and Figure 4-11 show the types of ores being mined in the Agua Fria watershed. There are 386 mines whose ore type is unknown. The most common known ore types are copper, gold, silver, and sand and gravel.

Table 4-10: Agua Fria Watershed Mine Types (part 1 of 2).

Mine Types	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Leach	**-**	**1**	**-**	**-**	**-**
Mineral Locatable	**-**	**-**	**-**	**-**	**5**
Placer	**-**	**22**	**13**	**2**	**15**
Processing Plant	**-**	**1**	**2**	**-**	**2**
Prospect	**9**	**51**	**75**	**8**	**71**
Surface/Underground	**7**	**21**	**19**	**3**	**28**
Surface	**-**	**16**	**5**	**4**	**13**
Underground	**9**	**91**	**91**	**2**	**56**
Underwater	**-**	**-**	**1**	**-**	**1**
Unknown	**9**	**90**	**42**	**6**	**32**
Well	**-**	**-**	**-**	**-**	**-**
Total Mines	***34***	***293***	***248***	***25***	***223***

Table 4-10: Agua Fria Watershed Mine Types (part 2 of 2).

Mine Types	**Cave Creek-Arizona Canal Diversion Channel H1507010206**	**Trilby Wash-Trilby Wash Basin H1507010207**	**New River H1507010208**	**Agua Fria River below Lake Pleasant H1507010209**	***Agua Fria Watershed***
Leach	**-**	**-**	**-**	**-**	***1***
Mineral Locatable	**1**	**-**	**-**	**-**	***6***
Placer	**1**	**2**	**-**	**-**	***55***
Processing Plant	**1**	**-**	**-**	**3**	***9***
Prospect	**4**	**5**	**2**	**3**	***228***
Surface/Underground	**19**	**8**	**2**	**1**	***108***
Surface	**30**	**10**	**21**	**25**	***124***
Underground	**19**	**12**	**4**	**11**	***295***
Underwater	**-**	**-**	**-**	**-**	***2***
Unknown	**20**	**9**	**5**	**20**	***233***
Well	**-**	**-**	**-**	**-**	***0***

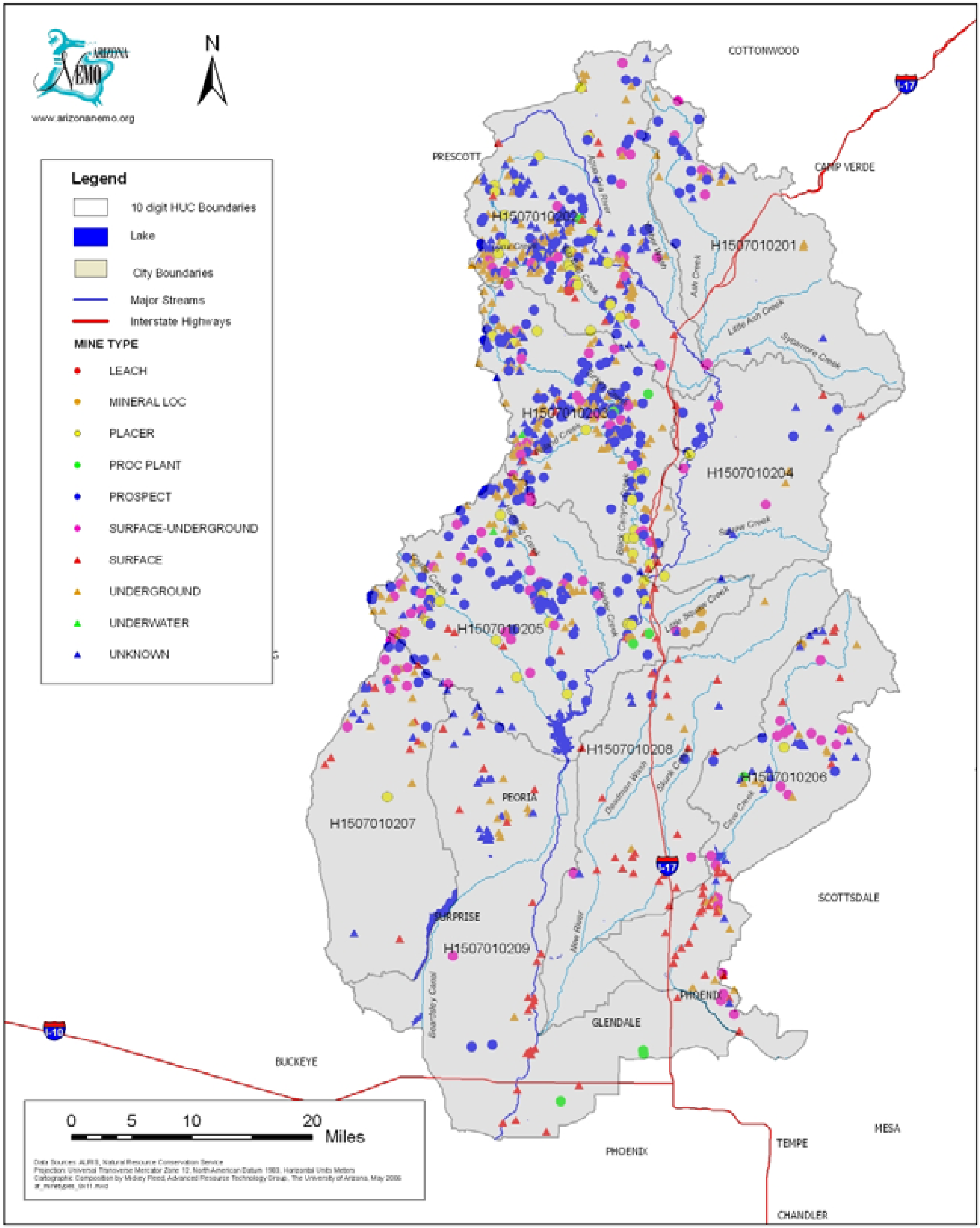


Figure 4-9: Agua Fria Watershed Mine Types.

Table 4-11: Agua Fria Watershed Mines – Status (part 1 of 2).

Mine Status	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Developed Deposit	2	16	12	1	10
Explored Prospect	11	59	83	8	91
Past Producer	6	77	61	5	52
Producer	-	7	5	-	2
Raw Prospect	-	3	4	-	5
Temporary Shutdown	-	2	-	-	3
Unknown	15	129	83	11	60
Total Mines	34	293	248	25	223

Table 4-11: Agua Fria Watershed Mines – Status (part 2 of 2).

Mine Status	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
Developed Deposit	9	7	1	2	*60*
Explored Prospect	9	8	3	1	*273*
Past Producer	12	5	4	7	*229*
Producer	5		1	13	*33*
Raw Prospect	4	3	2	2	*23*
Temporary Shutdown					*5*
Unknown	56	23	23	38	*438*
Total Mines	*95*	*46*	*34*	*63*	*1,061*

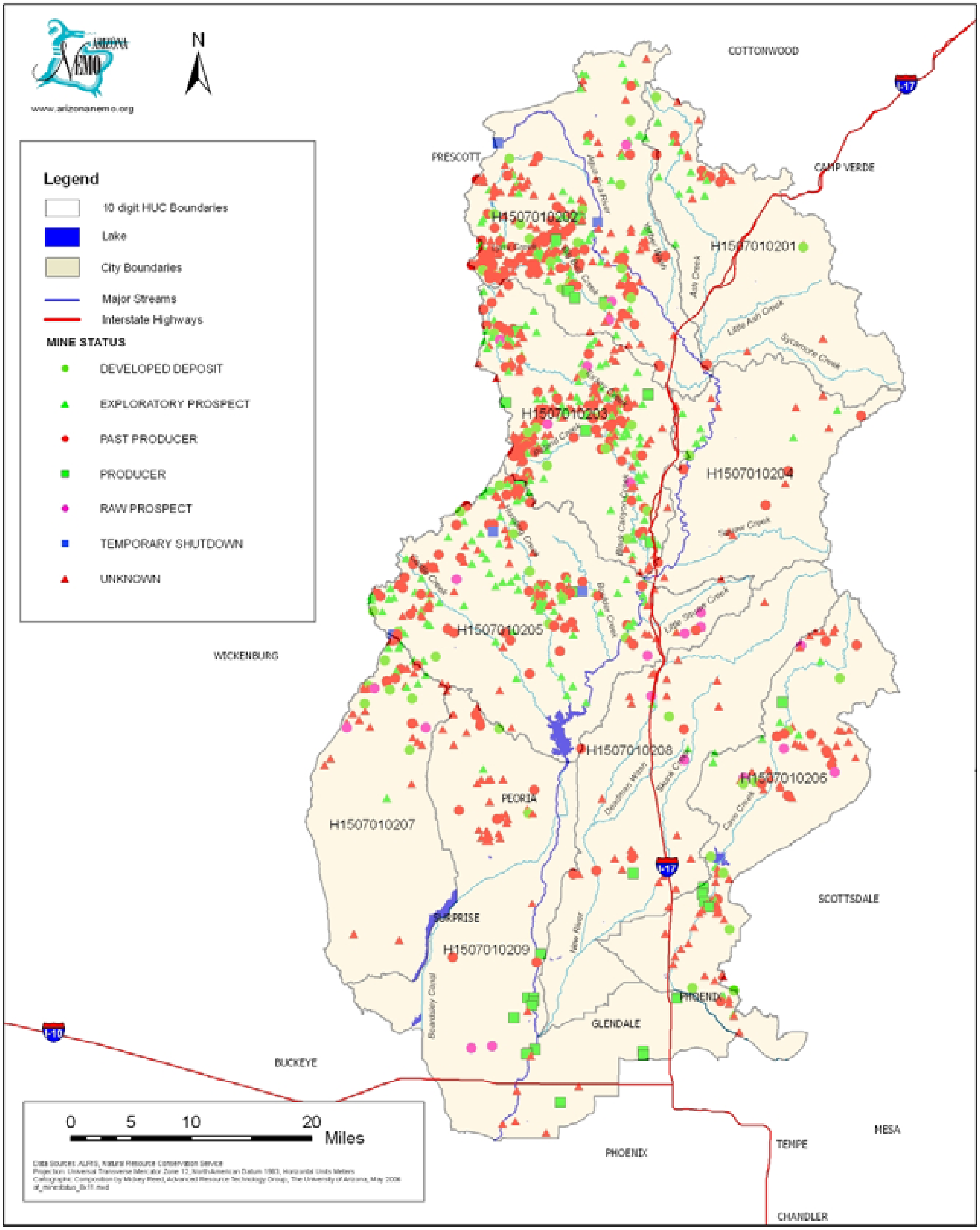


Figure 4-10: Agua Fria Watershed Mines - Status.

Table 4-12: Agua Fria Watershed Mines – Ore Type.

Ore Type	Total Number of Mines	Ore Type	Total Number of Mines
Unknown	**386**	**Sodium**	**3**
Gold	**260**	**Calcium**	**2**
Copper	**125**	**Clay**	**2**
Silver	**81**	**Pumice**	**2**
Sand & Gravel	**55**	**Zinc**	**2**
Lead	**27**	**Aluminum**	**1**
Iron	**19**	**Antimony**	**1**
Tungsten	**19**	**Arsenic**	**1**
Stone	**16**	**Barium**	**1**
Manganese	**14**	**Chlorine**	**1**
Mica	**12**	**Columbium**	**1**
Uranium	**8**	**Diatomite**	**1**
Mercury	**6**	**Geothermal**	**1**
Beryllium	**5**	**Magnesium**	**1**
Feldspar	**3**	**Perlite**	**1**
Gemstone	**3**	**Vermiculite**	**1**

Note: If a mine contains more than one ore, only the major ore is noted.

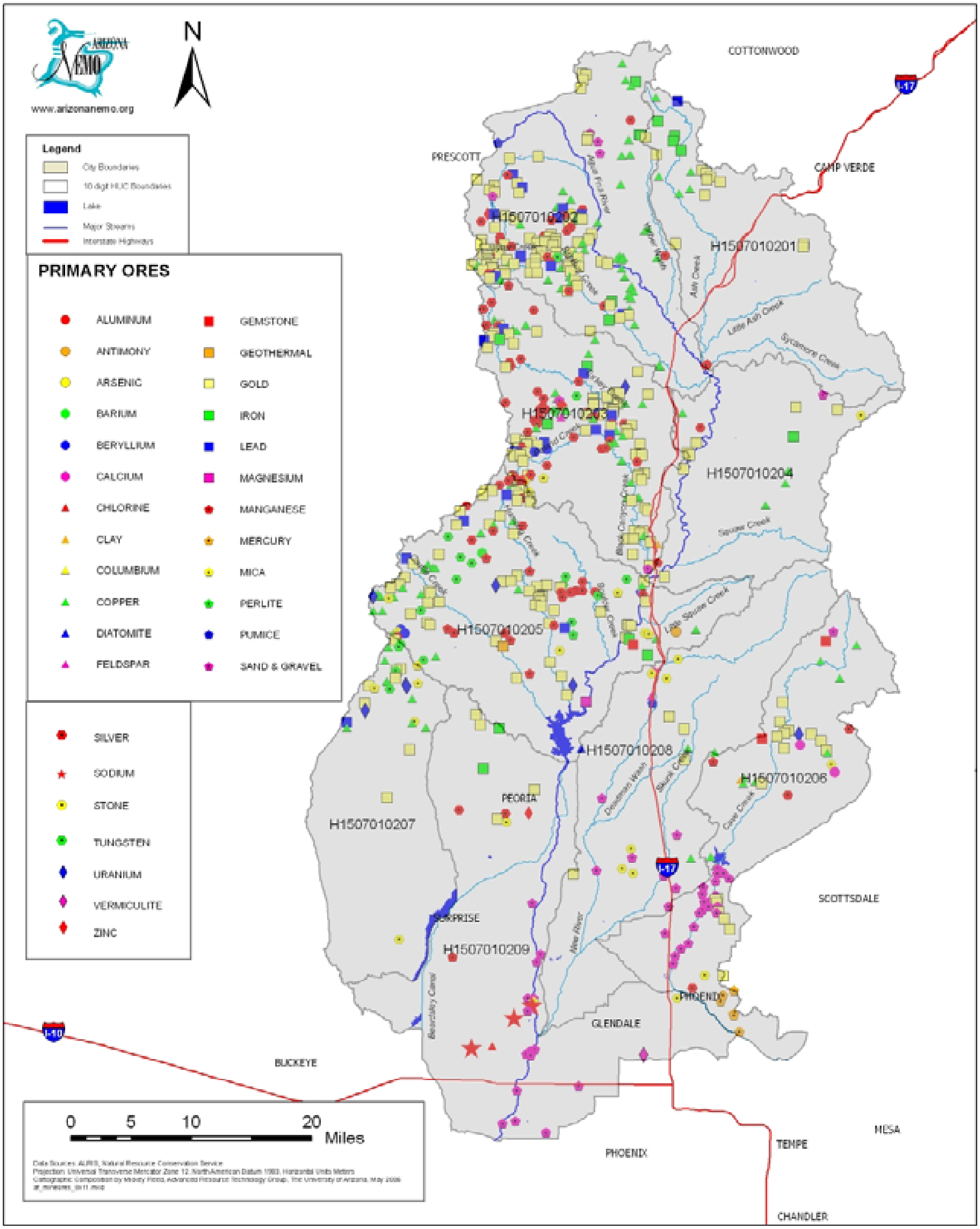


Figure 4-11: Agua Fria Watershed Mines - Primary Ore.

Land Use

The land cover condition during the early 1990's was determined using the National Land Cover Dataset (NLCD). The NLCD classification contains 21 different land cover categories; however, these categories were consolidated into six land cover types (Figure 4-12 and Table 4-13). The six groupings for the land cover categories are:

1. *Agriculture*: Confined feeding operations; Cropland and pasture; Orchards, groves, vineyards, nurseries and ornamental horticulture; Other agricultural land.
2. *Evergreen forest land*: Evergreen forest land (no change in category).
3. *Lakes and Wetlands*: Forested wetland; Lakes; Nonforested wetland.
4. *Rangeland*: Herbaceous rangeland; Mixed rangeland; Shrub and brush rangeland.
5. *Industrial and commercial complexes or Mixed urban built-up land*: Commercial and services; Industrial; Industrial and commercial complexes; Mixed urban or built-up land; Other urban or built-up land; Strip mines quarries and gravel pits; Transportation, communication and utilities.
6. *Residential*: Residential (no change in category).

The most common land cover type is Rangeland which makes up 64.99% of the watershed. Residential land is the next most common type with 19.41% of the total area.

Land Ownership

In the Agua Fria Watershed, there are 8 different land ownership entities (Figure 4-13 and Table 4-14). Private individuals are the largest land owners, representing 33.91% of the watershed. The Forest Service and the State of Arizona (State Trust Lands) are the next most significant land owners with 26.65% and 22.47% of the watershed, respectively.

Special Areas

Preserves:

Preserves listed here are part of the Arizona Preserve Initiative (API). The API was passed by the Arizona State Legislature as HB 2555 and signed into law by the Governor in the spring of 1996. It is designed to encourage the preservation of select parcels of state Trust land in and around urban areas for open space to benefit future generations. The law lays out a process by which Trust land can be leased for up to 50 years or sold for conservation purposes. Leases and sales must both occur at a public auction (http://www.land.state.az.us/programs/operations/api.htm).

Figure 4-14 shows the boundaries of the preserve lands within the Agua Fria Watershed. The State Trust lands within these 441.5 square miles or 282,562.66 acres are eligible for conservation purposes. Table 4-15 show the API areas for each subwatershed.

Wilderness Areas:

There are four different Wilderness Areas within the Agua Fria watershed. Table 4-16 lists each one and the acreage in each subwatershed. Figure 4-15 shows where each wilderness area is located.

There are a total of 41,795.91 acres (65.3 square miles), or approximately 2.3% of the watershed. The largest wilderness area is the Castle Creek Wilderness Area with approximately 23,060 acres of area, all within the Black Canyon Creek subwatershed.

Golf Courses:

There are 26 mapped golf courses within the Agua Fria Watershed, shown as green squares in Figure 4-16. Most are located in the southern part of the watershed, near the Phoenix metropolitan area. Additional golf courses may exist in the Agua Fria watershed that were included in the 2001 GIS data layer used in this analysis (ESRI Data and Maps, 2003).

Table 4-13: Agua Fria Watershed Land Cover (part 1 of 2).

Land Cover	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
Agriculture	**0.05**	**0.82**	**0.06**	**0.02**	**14.33**
Evergreen forest land	**35.54**	**30.54**	**38.48**	**20.60**	**-**
Lakes and Wetland					**-**
Rangeland	**63.34**	**64.73**	**60.25**	**78.14**	**84.37**
Industrial and commercial complexes or Mixed urban built-up land	**1.05**	**1.27**	**1.06**	**0.69**	**0.49**
Residential	**0.01**	**2.31**	**0.12**	**0.45**	**0.03**
Total Area (square miles)	***260.55***	***324.74***	***244.07***	***236.45***	***371.81***

Table 4-13: Agua Fria Watershed Land Cover (part 2 of 2).

Land Cover	**Cave Creek-Arizona Canal Diversion Channel H1507010206**	**Trilby Wash-Trilby Wash Basin H1507010207**	**New River H1507010208**	**Agua Fria River below Lake Pleasant H1507010209**	***Agua Fria Watershed***
Agriculture	**7.71**	**0.52**	**12.19**	**42.25**	***4.04***
Evergreen forest land	**1.64**	**-**	**6.18**	**-**	***10.78***
Lakes and Wetland	**0.09**	**-**	**0.03**	**0.00**	***0.01***
Rangeland	**32.69**	**98.72**	**72.64**	**46.23**	***64.99***
Industrial and commercial complexes or Mixed urban built-up land	**1.49**	**0.00**	**0.62**	**1.82**	***0.37***
Residential	**53.87**	**0.24**	**7.24**	**6.26**	***19.41***
Total Area (square miles)	***288.47***	***242.18***	***353.18***	***464.31***	***2785.17***

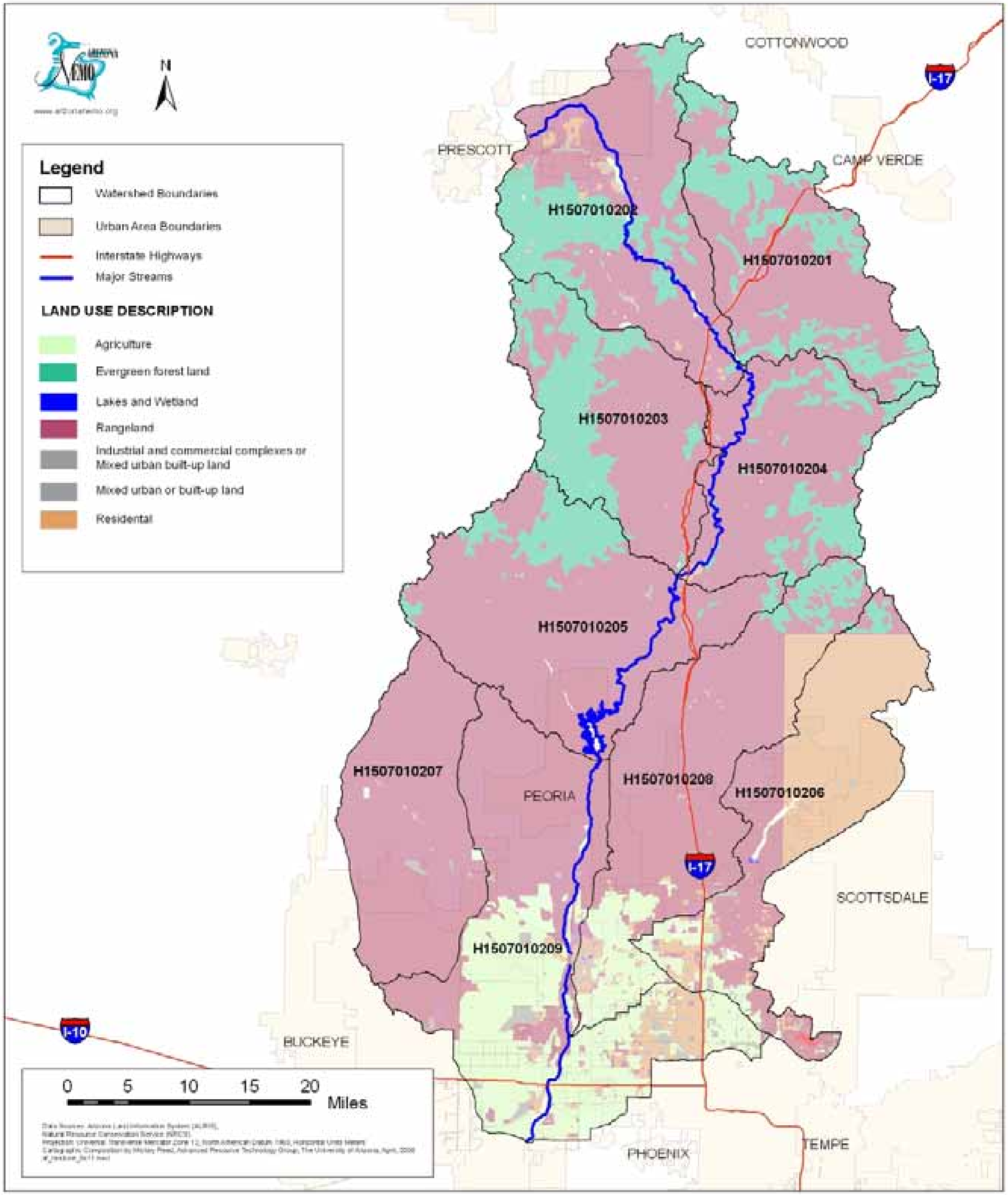


Figure 4-12: Agua Fria Watershed Land Cover.

Table 4-14: Agua Fria Watershed Land Ownership (Percent of each Subwatershed) (part 1 of 2).

Land Owner	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
BLM	**1.83%**	**11.35%**	**25.43%**	**8.65%**	**37.68%**
Military	**-**	**-**	**-**	**-**	**-**
Private	**4.74**	**37.47%**	**3.96%**	**3.67%**	**16.15%**
State Parks and Recreation Areas	**-**	**-**	**-**	**-**	**3.20%**
State Trust	**4.86**	**23.90%**	**6.01%**	**32.55%**	**29.65%**
State Wildlife & Management Areas	**-**	**-**	**-**	**-**	**-**
USFS	**85.90%**	**27.29**	**49.91%**	**52.29%**	**8.64%**
USFS & BLM Wilderness Areas	**2.67%**	**-**	**14.69%**	**2.85%**	**4.69%**
Area (square miles)	***260.56***	***324.13***	***243.99***	***236.47***	***371.79***

Table 4-14: Agua Fria Watershed Land Ownership (Percent of each Subwatershed) (part 2 of 2).

Land Owner	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
BLM	**1.45%**	**8.32%**	**3.08%**	**9.17%**	***12.28%***
Military	**-**	**0.14%**	**-**	**0.72%**	***0.13%***
Private	**58.46%**	**36.38%**	**39.05%**	**72.74%**	***33.91%***
State Parks and Recreation Areas	**2.39%**	**10.95%**	**0.47%**	**2.06%**	***2.03%***
State Trust	**13.15%**	**44.21%**	**33.65%**	**15.10%**	***22.47%***
State Wildlife & Management Areas	**0.01%**	**-**	**0.67%**	**-**	***0.09%***
US Forest Service	**24.54%**	**-**	**23.08%**	**-**	***26.65%***
USFS & BLM Wilderness Areas	**-**	**-**	**-**	**0.21%**	***2.44%***
Area (square miles)	***288.47***	***242.20***	***353.16***	***464.25***	***2,785.02***

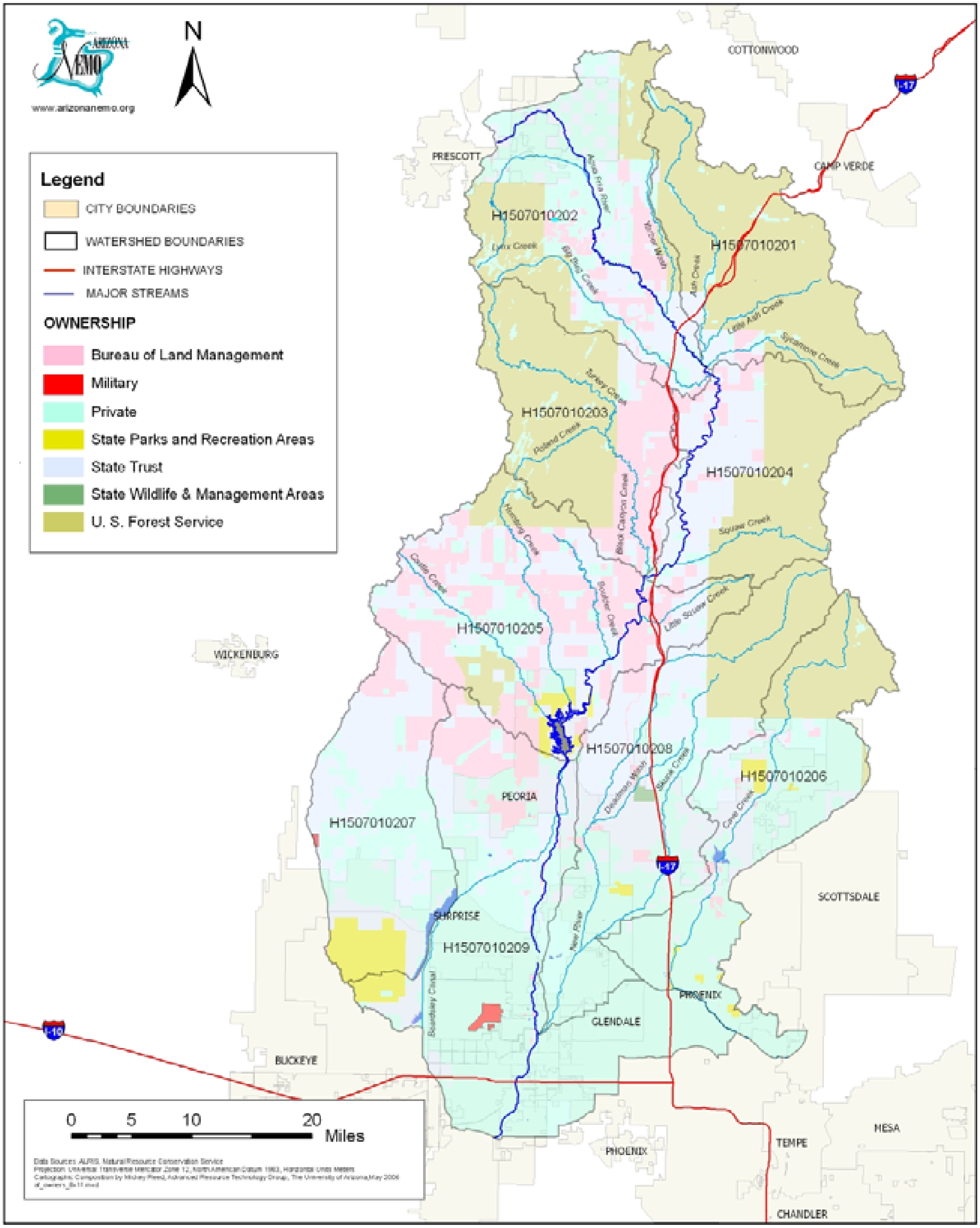


Figure 4-13: Agua Fria Watershed Land Ownership.

Table 4-15: Agua Fria Watershed Areas of Arizona Preserve Initiative Lands.

Subwatershed Name	Subwatershed Area (square miles)	Preserve Areas (square miles)	Preserve Areas (acre)	percent of subwatershed
Ash Creek and Sycamore Creek - H1507010201	**260.55**	**3.57**	**2,281.97**	**1.4**
Big Bug Creek-Agua Fria River - H1507010202	**324.14**	**151.77**	**97,130.41**	**46.8**
Black Canyon Creek - H1507010203	**244.07**	**0.00**	**0**	**0.0**
Bishop Creek - H1507010204	**236.45**	**0.00**	**0**	**0.0**
Agua Fria River-Lake Pleasant - H1507010205	**371.81**	**88.60**	**56,707.03**	**23.8**
Cave Creek-Arizona Canal Diversion Channel - H1507010206	**288.47**	**235.71**	**150,854.58**	**81.7**
Trilby Wash-Trilby Wash Basin - H1507010207	**242.18**	**121.64**	**77,847.44**	**50.2**
New River - H1507010208	**353.18**	**236.01**	**151,046.02**	**66.8**
Agua Fria River below Lake Pleasant - H1507010209	**464.31**	**0.00**	**0**	**0.0**
Total Agua Fria Watershed	***2,785.16***	***441.50***	***282,562.66***	**15.9**

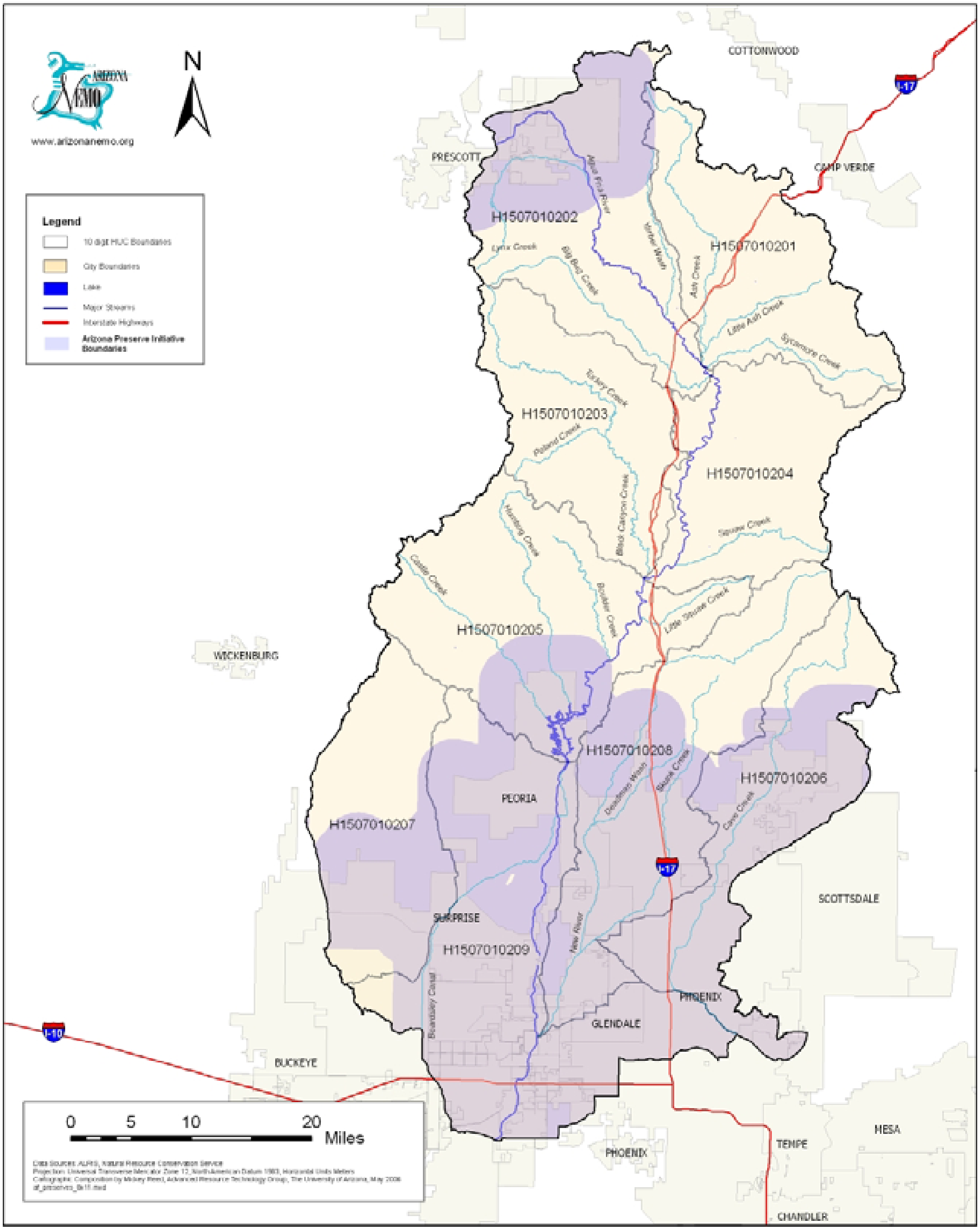


Figure 4-14: Agua Fria Watershed Arizona Preserve Initiative Areas.

Table 4-16: Agua Fria Watershed Wilderness Areas (acres) (part 1 of 2).

Wilderness Area	**Ash Creek and Sycamore Creek H1507010201**	**Big Bug Creek-Agua Fria River H1507010202**	**Black Canyon Creek H1507010203**	**Bishop Creek H1507010204**	**Agua Fria River-Lake Pleasant H1507010205**
Cedarbench	**160.44**	**-**	**-**	**-**	**-**
Pine Mtn.	**4,295.09**	**-**	**-**	**4,309.40**	**-**
Castle Creek	**-**	**-**	**23,060.05**	**-**	**-**
Hells Canyon	**-**	**-**	**-**	**-**	**9,347.28**
Total Wilderness Area (acre)	***4,455.53***	***0.00***	***23,060.05***	***4,309.40***	***9,347.28***

Table 4-16: Agua Fria Watershed Wilderness Areas (acres) (part 2 of 2).

Wilderness Area	**Cave Creek-Arizona Canal Diversion Channel H1507010206**	**Trilby Wash-Trilby Wash Basin H1507010207**	**New River H1507010208**	**Agua Fria River below Lake Pleasant H1507010209**	***Agua Fria Watershed***
Cedarbench	**-**	**-**	**-**	**-**	***160.44***
Pine Mtn.	**-**	**-**	**-**	**-**	***8604.49***
Castle Creek	**-**	**-**	**-**	**-**	***23,060.05***
Hells Canyon	**-**	**-**	**-**	**623.65**	***9,970.93***
Total Wilderness Area (acre)	***0.00***	***0.00***	***0.00***	***623.65***	***41,795.91***

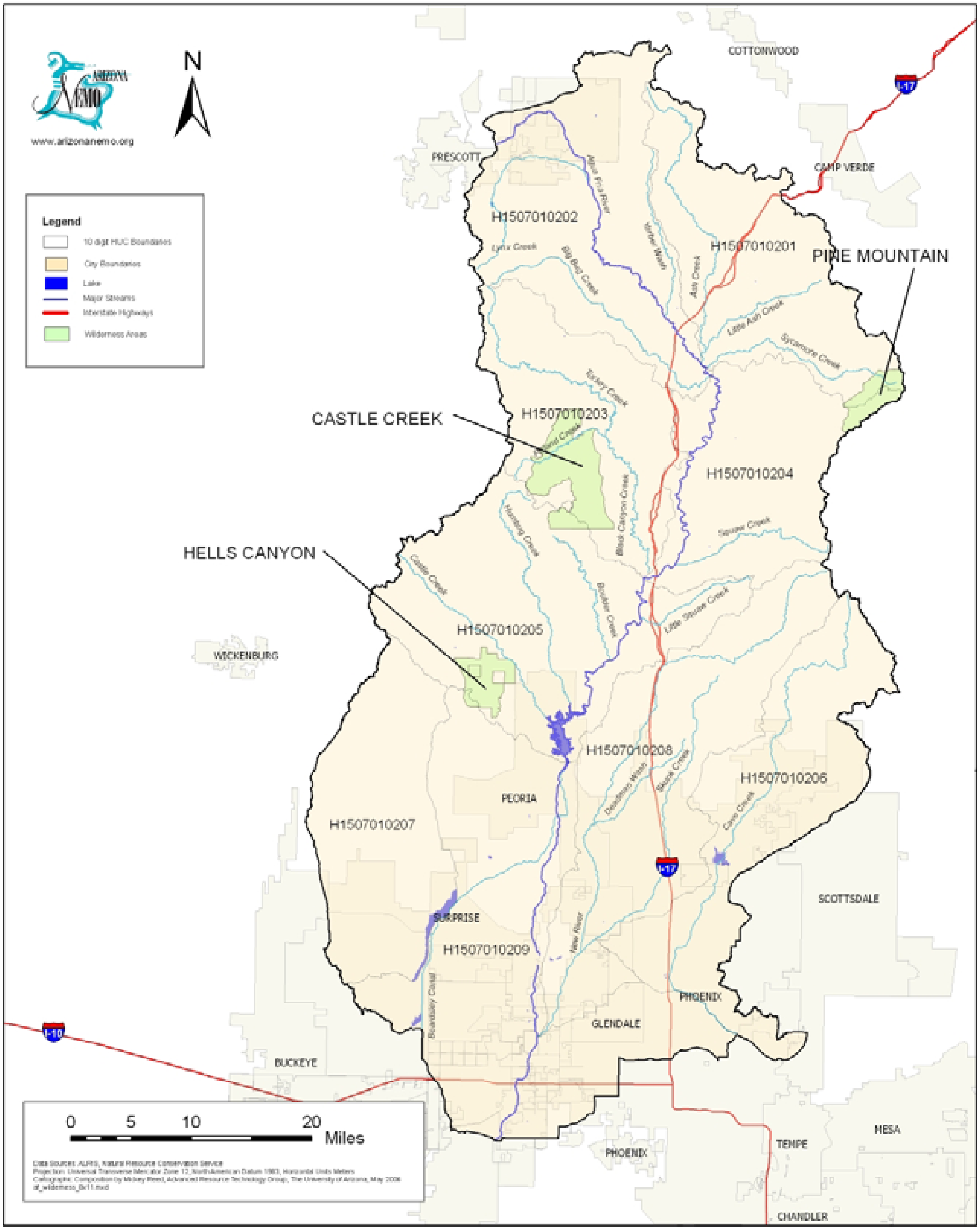


Figure 4-15: Agua Fria Watershed Wilderness Areas.

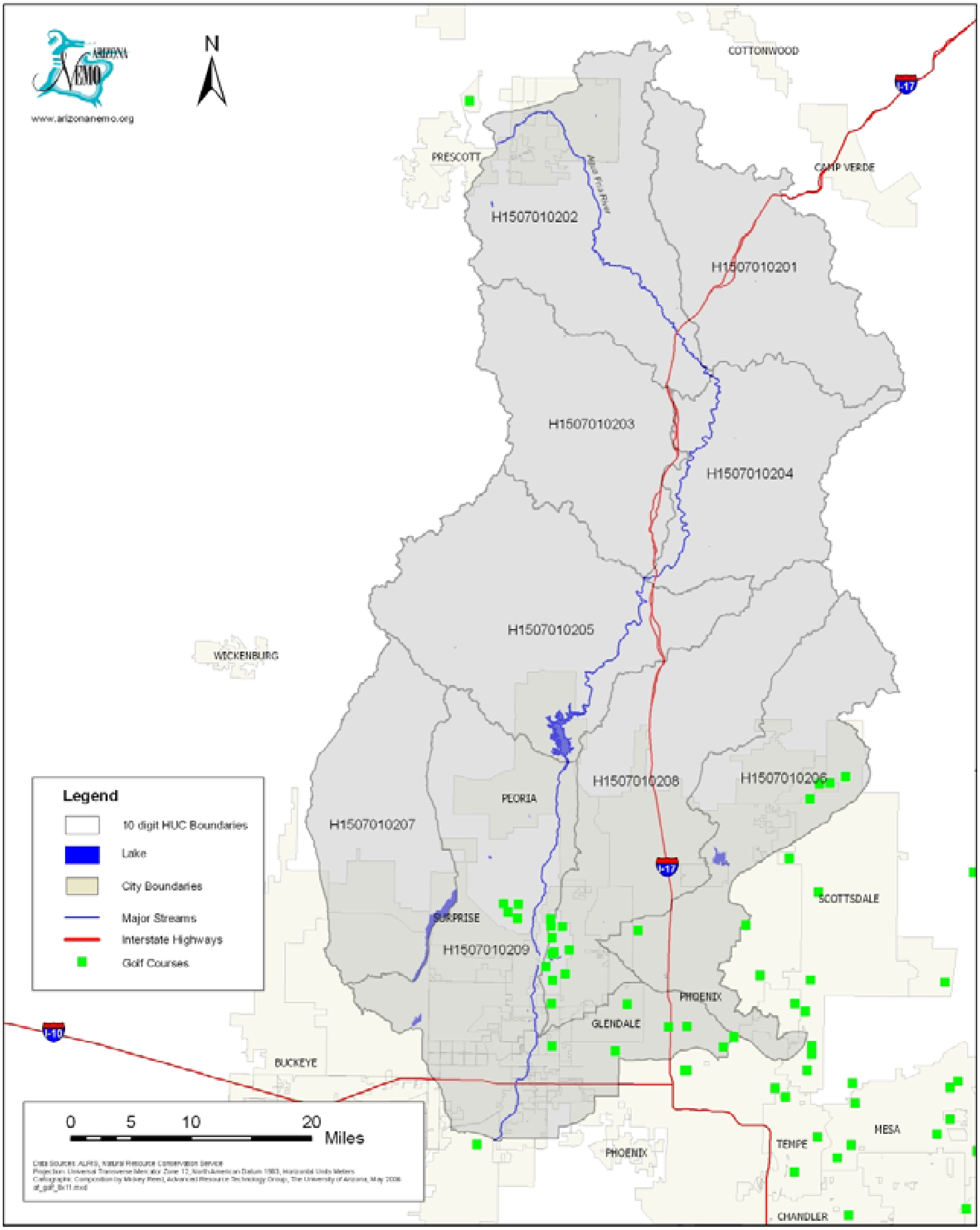


Figure 4-16: Agua Fria Watershed Golf Courses.

References:

GeoLytics, Inc. 1998. Census 1990. Census CD + Maps. Release 3.0.

Data Sources:*

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), http://www.land.state.az.us/alris/index.html
County Governments. June 6, 2003.
Council of Governments. June 6, 2003
Land ownership. February 7, 2002.
Mines. February 7, 2002.
Preserve Areas. July 31, 2003.
Wilderness Areas. June 9, 2003.

ESRI Data Products, http://arcdata.esri.com/data/tiger2000/tiger_download.cfm
Census 2000. October 17, 2003.

ESRI Data and Maps. 2001. 7 CD set: CD 3, no.85913.
Golf Courses. 2003

Southern Arizona Data Services Program, University of Arizona. Published by the U.S. Geological Survey, Sonoran Desert Field Station, University of Arizona. http://sdrsnet.srnr.arizona.edu/index.php
Roads. February 17, 2003.

U.S. Census Bureau. http://www.census.gov/geo/www/cob/ua2000.html
Urban Areas 2000. July 22, 2003.

U.S. Department of the Interior, U.S. Geological Survey, http://landcover.usgs.gov/natllandcover.asp
Land use. 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 Agua Fria Watershed has extensive and important natural resources, with national, regional and local significance. The watershed contains critical riparian habitat for the Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004). The watershed also contains important recreational resources including extensive wilderness areas with hiking, bird watching and fishing.

As a result of our analysis, three Natural Resource Areas (NRAs) have been identified for protection based on the combination of natural resource values. Factors that were considered in delineating these areas include: legal status (unique waters, critical habitat for threatened and endangered species, national monument areas and wilderness), the presence of perennial waters and riparian areas, the presence of state parks and forests, recreational resources and local values.

The NRAs have been categorized within the 10-digit HUC subwatershed area where they are located. Several 10-digit contiguous HUCs have been combined to form a unique NRA based on criteria such as State Parks, Forests, Wilderness areas and endangered species they have in common. The significance of each area is discussed in the following paragraphs. The three identified Natural Resource Areas consist of the following groupings of 10-digit HUCS:

1. *Upper Agua Fria River NRA*: Big Bug Creek-Agua Fria River, Ash Creek and Sycamore Creek, Black Canyon Creek, Bishop Creek.

2. *Agua Fria River-Lake Pleasant NRA:* Agua Fria River-Lake Pleasant.

3. *Lower Agua Fria River NRA*: New River, Cave Creek, Trilby Wash-Trilby Wash Basin, Agua Fria River Below Lake Pleasant.

<u>Upper Agua Fria River NRA</u>

The Upper Agua Fria River NRA includes four 10-digit HUC subwatersheds: Big Bug Creek-Agua Fria River, Ash Creek and Sycamore Creek, Bishop Creek, and Black Canyon Creek. This NRA contains the Agua Fria National Monument, extensive riparian vegetation along the Agua Fria River and its tributaries, important perennial streams, two wilderness areas, critical wildlife habitat and national forests.

The following description of the Agua Fria National Monument is from the BLM website (http://www.blm.gov/az/aguafria/bkgda.htm). The Agua Fria National Monument is located approximately forty miles north of central Phoenix. The 71,100 acres of federal land managed by the Bureau of Land Management contains elevations which range from 2,150 feet above sea level along the Agua Fria Canyon to about 4,600 feet in the northern hills.

The monument contains one of the most significant systems of late prehistoric sites in the American Southwest. Its ancient ruins offer insights into the lives of those who long ago inhabited this part of the desert southwest. Between A.D. 1250 and 1450, the area's pueblo communities were populated by up to several thousand people. At least 450 prehistoric sites are known to exist within the monument area and there are likely many more. The monument also contains historic sites representing early Anglo-American history through the nineteenth century, including remnants of Basque sheep camps, historic mining features, and military activities.

In the last few decades, the area has received increased recognition as an outstanding archaeological resource. The area contains most of a National Register of Historic Places District. Originally designated in 1975, the District was expanded in 1996 to encompass approximately 50,000 acres managed by the BLM and the Tonto National Forest. It is one of the largest prehistoric districts listed on the National Register of Historic Places. The area also contains all of the Perry Mesa Area of Critical Environmental Concern (ACEC), designated in 1987 to protect its cultural resource values.

In addition to its rich record of human history, the monument contains outstanding biological resources. The diversity of vegetative communities, pristine riparian habitat, topographical features, and relative availability of water provide habitat for a wide array of sensitive species and other wildlife, including the pronghorn antelope, lowland leopard frog, the desert tortoise, and four species of native fish.

The Larry Canyon ACEC, which was designated in 1987 to protect a rare, pristine riparian deciduous forest within a desert ecosystem, is included in the Monument lands. The area included in the monument is relatively isolated and rugged. Currently, the federal lands in the area are used primarily for scientific study, primitive recreation, and livestock grazing (http://www.blm.gov/az/aguafria/bkgda.htm , 2006).

The Upper Agua Fria River NRA contains six perennial waterways: The Agua Fria River, Ash Creek, Big Bug Creek, Black Canyon Creek, Sycamore Creek and Silver Creek (Arizona Department of Water Resources, 2006). All but one of these waterways are at least partially located within the Agua Fria National Monument.

The Upper Agua Fria River NRA contains two wilderness areas managed by the U.S. Forest Service: the Castle Creek Wilderness Area, and the Pine Mountain Wilderness Area.

In addition, there are two Wilderness Study Areas in the Agua Fria National Monument, recommended by the Arizona Wilderness Coalition: Perry Mesa for its endangered semi-desert grassland ecosystem and pronghorn antelope habitat, and the Agua Fria River Canyon. Both areas are important for their numerous archeological sites. Protection of the Perry Mesa archeological resources was one of the major reasons for the creation of the Agua Fria National Monument.

The 25,215 acre Castle Creek Wilderness area, designated in 1984, is located in the Prescott National Forest on the eastern slopes of the Bradshaw Mountains. It is characterized by extremely rugged topography with prominent granite peaks overlooking the Agua Fria River. Elevations range from 2,800 feet to 7,000 feet (Wilderness Institute, Univ. of Montana College of Forestry and Conservation, 2006, http://www.wilderness.net/index.cfm?fuse=NWPS&sec=wildView&WID=104).

The Pine Mountain Wilderness was designated in 1972, and includes 20,061 acres. Pine Mountain, its highest point, provides a view of Horseshoe Lake to the south, the Mogollon Rim to the East, the Verde Valley to the north and the Bradshaw Mountains to the west. Elevations vary from 4,600 ft to 6,814 feet.

The western section lies within the Prescott National Forest and is characterized by an island of virgin ponderosa pine surrounded by woodland, chaparral, and open grassland. The eastern section on the Tonto NF includes steep and rough chaparral covered slopes leading down to the Verde River (Wilderness Institute, University of Montana College of Forestry and Conservation, 2006, http://www.wilderness.net/index.cfm?fuse=NWPS&sec=wildView&wname=Pine%20Mountain).

The Upper Agua Fria River NRA contains the entire Mexican spotted owl habitat that occurs in the Agua Fria watershed. The Mexican spotted owl was listed as threatened on April 14, 1993, and a recovery plan was approved in December 1995. The distributional pattern of the Mexican spotted owl is more disjunct than that of the other subspecies (Noon and McKelvey 1992).

The Mexican spotted owl appears to use a wider range of habitat types than the other subspecies. These unique aspects of the ecology of this owl require unique approaches for management. Habitat management plans may need to consider not only areas occupied by owls but also intervening areas, even where such areas are very different in habitat structure from areas typically occupied by spotted owls. (U.S. Fish & Wildlife Service)

The NRA also contains portions of desert tortoise habitat. The desert tortoise is listed as a wildlife of special concern by Arizona Game and Fish.

The Upper Agua Fria River NRA is roughly 50% forest (Prescott National Forest and portions of the Tonto National Forest). The Prescott National Forest is located about 70 miles northwest of Phoenix, Arizona, contains approximately 1,237,000 acres, and is composed of two distinct divisions. The western portion of the Agua Fria watershed includes the Bradshaw and Santa Maria mountain ranges. Recreational opportunities include hiking, backpacking, horseback riding, or trail bike riding on the extensive trail systems.

The General Crook Trail, a National Historic Study Trail, is located on the

Prescott National Forest. Portions of the Tonto National Forest occur in the Upper Agua Fria NRA. This nearly 3 million acre forest includes Saguaro cactus-studded desert through pine-forested mountains. Elevations range from 1,300 to 7,900 feet.

According to the Tonto National Forest website, one of the primary purposes for establishing the forest in 1905 was to protect its watersheds around reservoirs. The forest produces an average of 350,000 acre-feet of water each year. Six major reservoirs on the forest have the combined capacity to store more than 2 million acre-feet of water. Management efforts are directed at protecting both water quality, and watershed and riparian area conditions. (http://www.fs.fed.us/r3/tonto/about/history.shtml)

Agua Fria River - Lake Pleasant NRA

The Agua Fria River – Lake Pleasant NRA includes just the Agua Fria River – Lake Pleasant 10-digit HUC. This NRA contains Lake Pleasant and the Lake Pleasant Recreational Area, extensive riparian vegetation along the Agua Fria River, the Hells Canyon Wilderness area, and much of the desert tortoise habitat for the Agua Fria watershed.

Lake Pleasant is an artificial reservoir located in the Lake Pleasant Regional Park, and is managed by the Maricopa County Parks and Recreation Department. The park covers a total of over 23,000 acres of mountainous desert landscape, including the lake. The 10,000 acre lake was created by the Waddell Dam, which was finished in 1928 and filled by the Agua Fria River, capturing a large watershed throughout Yavapai County.

Completed in 1993, the New Waddell Dam tripled the surface area of the lake, submerging the old dam beneath its waters. Although still fed by the Agua Fria River, the CAP aqueduct is the primary source of water for the reservoir. Lake Pleasant is used as a major watersports recreation center as well as serving as an important storage reservoir for the rapidly growing region. (http://en.wikipedia.org/wiki/Lake_Pleasant_Regional_Park)

The reservoir has 114 miles of shoreline for family recreation uses. A number of boat docks make the lake a popular destination for waterskiing, jetskiing, sailing and other watersports. Sport fishing is very popular and numerous species inhabit the lake including white bass, largemouth bass, striped bass, channel catfish, and black crappie. Other recreational opportunities include mountain biking, camping, and hiking. (http://www.recreation.gov/detail.cfm?ID=6)

The 9,900-acre Hells Canyon Wilderness, managed by the Bureau of Land Management, lies 25 miles northwest of Phoenix in Maricopa and Yavapai counties. It consists of a scenic portion of the Hieroglyphic Mountain Range, including Garfias Mountain at 3,381 feet and Hellgate Mountain at 3,339 feet. Most of the wilderness is covered by Sonoran desert shrub vegetation: Saguaro, Palo

Verde, barrel cactus, ocotillo, and desert grasses. Recreational opportunities include climbing, hiking and sightseeing (http://www.wilderness.net/index.cfm?fuse=NWPS&sec=wildView&wid=238).

The desert tortoise generally occupies Sonoran Desert habitat, along rocky slopes and bajadas, ranging from 508 feet to 5,250 feet in elevation. Although the desert tortoise is not listed as threatened or endangered, Arizona law prohibits removing these creatures from the wild or taking them across state lines. Desert tortoise are threatened by habitat fragmentation, illegal capture, invasion of exotic species, road kill, and predation. (Arizona Game & Fish website, 2006, http://www.gf.state.az.us/w_c/desert_tortoise.shtml0).

Lower Agua Fria River NRA

The Lower Agua Fria River NRA contains four 10-digit HUC subwatersheds: New River, Cave Creek, Trilby Wash Trilby Wash Basin and Agua Fria River-Below Lake Pleasant. The northeastern portion of the NRA includes the Tonto National Forest and an important riparian zone located along the perennial Seven Springs Wash. The southern portion of the NRA contains various parks, basins, reservoirs and several canals. The cities of Cave Creek, Carefree, Peoria, Surprise, Goodyear, Avondale, Litchfield Park, El Mirage, Youngtown, Glendale, Paradise Valley, Tolleson and a good portion of the Phoenix metropolitan area are located here.

White Tank Mountain Regional Park and Cave Creek Regional Park are located in the Lower Agua Fria River NRA. White Tank Mountain Regional Park is nearly 30,000 acres, which makes this the largest regional park in Maricopa County. Most of the park is made up of the rugged and beautiful White Tank Mountains on the Valleys west side. The range, deeply serrated with ridges and canyons, rises sharply from its base to peak at over 4,000 feet. Infrequent heavy rains cause flash floodwaters to plunge through the canyons and pour onto the plain. These torrential flows, pouring down chutes and dropping off ledges, have scoured out a series of depressions, or tanks, in the white granite rock below, thus giving the mountains their name (http://www.maricopa.gov/parks/white%5Ftank/).

Cave Creek Regional Park is located just north of Phoenix. This 2,922-acre park sits in the upper Sonoran Desert. Ranging in elevation from 2,000 feet to 3,060, this desert oasis provides many majestic views (http://www.maricopa.gov/parks/cave_creek/).

Other parks in the Lower Agua Fria NRA which provide hikers and other recreationists with plenty of space and scenic views are: Adobe Dam Regional Park, Thunderbird Park, Phoenix Mountain Preserve, and Lookout Mountain Preserve.

The Lower Agua Fria contains portions of the Tonto National Forest. The Tonto National Forest spreads over a spectacular 2.9 million acres of pine and cactus country just northwest of Phoenix, Arizona. To

the north along the Rim country, cool, pine-covered slopes and clear trout-stocked streams attract thousands from the cities when summer temperatures soar (http://www.recreation.gov/detail.cfm?ID=1096).
Seven Springs Wash and recreation area is also an important riparian and archeological area, containing many petroglyphs and trails.

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, from http://www.azdeq.gov/environ/water/assessment/2004.html.

Arizona Department of Water Resources. 2006. Perennial Streams, http://www.water.az.gov/dwr/content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/CentralHighlands/aguafria_watershed.pdf

U.S. Fish & Wildlife Service. 2004. Mexican Spotted Owl, http://www.fws.gov/ifw2es/Documents/R2ES/MSO_Recovery_Plan.pdf

Section 6: Watershed Classification

As noted in earlier sections of this plan, the watershed classification was conducted on the five subwatersheds that comprise the Upper Agua Fria Watershed, above Lake Pleasant. The lower four subwatersheds, which have been heavily impacted by urbanization and agriculture, will be classified in a future plan.

In this watershed classification, each 10-digit subwatershed in the Upper Agua Fria 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.

<u>Methods</u>

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.

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: 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;

2. Assemble GIS data and other observational data;

3. Define watershed characteristics through:

   a. Water quality assessment data provided by Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004);

   b. GIS mapping analysis; and

   c. Modeling / simulation of erosion vulnerability and potential for stream impairment (in this case, from soils in mine site areas and proximity of mines sites to riparian areas).

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

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

GIS and Hydrologic Modeling

GIS and hydrologic modeling were the major tools used to develop this watershed-based plan. Planning and assessment in land and water resource management require spatial modeling tools so as to incorporate complex watershed-scale attributes into the

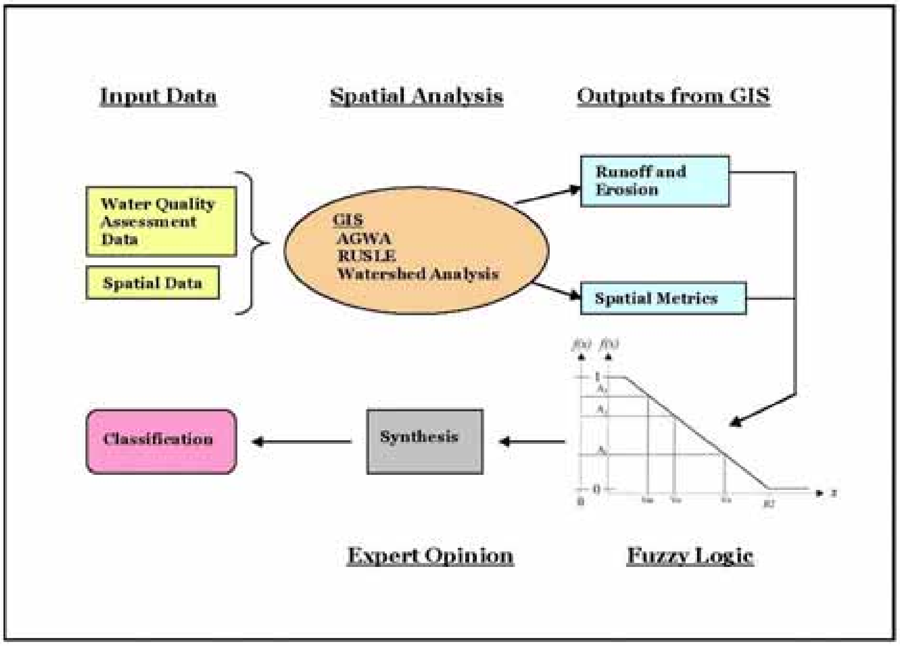


Figure 6-1: Transformation of Input Data via a GIS, Fuzzy Logic Approach, and Synthesis of Results into a Watershed Classification.

assessment process. Modeling tools applied to the Agua Fria Watershed include AGWA, SWAT, and SEDMOD/RUSLE, as described below and in Appendices C and D.

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 on runoff and sediment load in a 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 SEDMOD model (Van Remortel et al., 2004), which uses the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), was used to estimate soil erosion and sediment delivery from different land use types.

The watershed classification within this plan 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, 2004). In addition, impacts due to mine sites (e.g. erosion and metals pollution) and grazing (e.g. erosion and pollutant nutrients) are simulated.

Fuzzy Logic

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 set theory that handles vagueness or uncertainty, and has been described 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. Fuzzy logic allows for an object to be a partial member of a set, and converts the range in values between different data factors to the same scale (0.0 -1.0) using fuzzy membership functions. Fuzzy membership functions can be discrete or continuous depending on the input characteristics.

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

This classification was conducted at the 10-digit HUC subwatershed scale. Because of the extensive agricultural development and diversion channels in the southern portion of the Agua Fria Watershed, the topography south of Lake Pleasant has been severely altered. Therefore, this watershed based plan will address the five watersheds north of Lake Pleasant separately from the subwatersheds to the south. HUC subwatersheds 1507010201 through 1507010205 are north of the lake and will be analyzed together. The remaining four subwatersheds will be analyzed in a future plan based on AGWA watershed delineations. Table 6-1 lists the 10-digit HUC numerical identifications and subwatershed names for all nine subwatersheds in the Agua Fria Watershed. The five subwatersheds addressed in this classification are shaded and in bold.

Table 6-1: HUC 10-Digit Designation and Subwatershed Name.

HUC 10	Subwatershed Name
1507010201	**Ash Creek and Sycamore Creek**
1507010202	**Big Bug Creek-Agua Fria River**
1507010203	**Black Canyon Creek**
1507010204	**Bishop Creek**
1507010205	**Agua Fria River-Lake Pleasant**
1507010206	**Cave Creek-Arizona Canal Diversion Channel**
1507010207	**Trilby Wash-Trilby Wash Basin**
1507010208	**New River**
1507010209	**Agua Fria River below Lake Pleasant**

Classifications were conducted on 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 Upper Agua Fria Watershed are:

- Metals (cadmium, mercury, copper, zinc, lead, arsenic), with cadmium 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 (concerns include *Escherichia coli*, nutrients, high pH factors and dissolved oxygen, 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.

Water Quality Assessment Data

ADEQ's water quality assessment criteria and assessment definitions are found in Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004). These data were used to define the current level of impairment of each HUC-10 subwatershed using fuzzy membership values. The Upper Agua Fria Watershed is part of the larger Middle Gila Watershed. For more information see the ADEQ website: http://www.azdeq.gov/environ/water/assessment/2004.html.

Surface waters assessed as "impaired" and included in the 303(d) List of Impaired Waters 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, 2006). Although all monitored water bodies will be reviewed in this watershed-based plan, only those assessed as impaired will be discussed for best management practices (Section 7 of this Watershed-Based Plan).

Appendix A Table 1 is a summary of the ADEQ water quality monitoring data (ADEQ, 2004) and 10-digit HUC subwatershed classification results for the entire Agua Fria Watershed. The water quality data were used to classify each monitored stream reach or water body based on its relative risk of impairment for the constituent groups. It should be noted that not every 10-digit HUC subwatershed contained a water quality sampling site.

The four levels of risk used to classify each water body are: Extreme, High, Moderate and Low.

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

- High risk - If a surface water body 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 body within the subwatershed was assessed as "inconclusive" or "attaining", but there are still a low number of samples exceeding standards for a constituent group (i.e. less than 10% of samples); 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.

An overall risk classification is assigned to the 10-digit HUC subwatershed based on the worst case risk classification of the water bodies in that subwatershed. Fuzzy membership values (FMV) were assigned to each subwatershed using the criteria in Table 6-2.

The FMVs in Table 6-2 are based on two considerations: 1) Subwatershed relative risk of impairment (described above), and 2) Downstream subwatershed risk of impairment.

The status of downstream surface waters provides a way to evaluate the possibility 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.

Water bodies classified as either extreme (impaired) or low (no exceedances) risk had a higher influence than high or moderate classified water bodies in determining downstream water quality condition because they were less ambiguous than the other levels of risk. For example, if a water body was classified as extreme risk, it was used to define the water quality condition, and the subwatershed was given an FMV of 1.0. Likewise, if a water body along the pathway was classified as low risk, then that water body was used to define the downstream water quality condition (see Table 6-2).

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

Subwatershed Classification	Downstream Subwatershed Classification	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**

<u>Metals</u>

Metals are one of the most significant water quality problems in the Upper Agua Fria Watershed because of the potential toxicity to aquatic life.

Turkey Creek, from an unnamed tributary to Poland Creek, is impaired for arsenic, cadmium, copper, lead and zinc (ADEQ, 2004). Several other reaches exceeded water quality standards for metals; however limited data prevented them from being assessed. In addition, some stream reaches have not been sampled for metals.

The primary sources for metals in the Upper Agua Fria Watershed are probably runoff and erosion from active and abandoned mines since there are a high number of mines in the watershed.

Developed urban areas are also considered to be a nonpoint source for metals pollutants. However, the current population density of the Upper Agua Fria Watershed is moderate and urban areas are therefore not likely a major source of metals. Although "development" was not used as a classification factor at this time, it 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 - Metals

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004) was used to define the current level of impairment for metals for each stream reach. Each subwatershed was then assigned a risk level based on the worst case stream reach. The FMV was assigned based on the location of the subwatershed relative to an impaired water (Table 6-2).

Table 6-2 lists the fuzzy membership values used for different watershed conditions based on watershed location and 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. The justification used to determine the FMV is also included in Table 6-3.

Location of Mining Activities

The type and location of a mine within a watershed and in relation to a riparian zone determines its potential for impact on nearby water quality. Mining generally causes soil disturbance, which results in erosion and sediment yield to streams. In addition, since mines by definition occur in mineralized areas, it is assumed that the eroded soil is also high in metals. More thorough discussions of the geologic conditions and location of mine sites and mine types across the watershed are found in Section 2, Physical Characteristics and Section 4, Social/Economic Characteristics. The spatial data described in those sections were used along with the ADEQ water quality assessment data to classify each subwatershed for susceptibility to erosion and risk for metals pollution using the methodology described below.

The number of mines in a subwatershed and within the riparian zone (< = 250 m from a stream) were determined in the GIS. The results were used to assign an FMV to each subwatershed based on the following criteria.

Number of mines per watershed:

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

Number of mines in riparian zone:

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

Table 6-3: Fuzzy Membership Values (FMV) Assigned to each 10-digit HUC Subwatershed, Based on Water Quality Assessment Results for Metals.

Subwatershed Name	Metals FMV	Justification
Ash Creek and Sycamore Creek H1507010201	**0.6**	**Classified as moderate risk, drains into Big Bug Creek-Agua Fria River that is classified as high risk**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**Classified as high risk, drains into Bishop Creek that is classified as low risk**
Black Canyon Creek H1507010203	**1.0**	**Classified as extreme risk**
Bishop Creek H1507010204	**0.0**	**Classified as low risk**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**Classified as moderate risk, drains into Agua Fria River below Lake Pleasant that is classified as moderate risk**

Table 6-4 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on the number of and location of mines. Because of the numerous mines in the Upper Agua Fria Watershed, the FMVs are 1.0 for all subwatersheds. These values were used in the summary analysis to assess the relative impact of mining on the concentration of dissolved and total metals in the subwatershed.

Table 6-4: FMV for each Subwatershed Based on the Number and Location of Mines.

Subwatershed	FMV # mines /HUC	FMV # mines/ riparian
Ash Creek and Sycamore Creek H1507010201	**1.00**	**1.00**
Big Bug Creek-Agua Fria River H1507010202	**1.00**	**1.00**
Black Canyon Creek H1507010203	**1.00**	**1.00**
Bishop Creek H1507010204	**1.00**	**1.00**
Agua Fria River-Lake Pleasant H1507010205	**1.00**	**1.00**

Potential Contribution of Mines to Sediment Yield

Gross soil erosion in kg/ha/yr was determined for each subwatershed using the SEDMOD model (Van Remortel et al., 2004), which is based on RUSLE (Renard et al., 1997; see Appendix C). Since this watershed based plan assumes that mine sites contribute to erosion and the resulting sediments are high in metals, the potential for erosion from mines to contribute to the risk for metals impairment for a subwatershed was evaluated.

The model results for soil loss (RUSLE "a" value) were imported into the GIS and reclassified into 5 categories. Table 6-5 tabulates the values for soil loss in kg/ha/yr for each subwatershed, and Figure 6-2 shows these results.

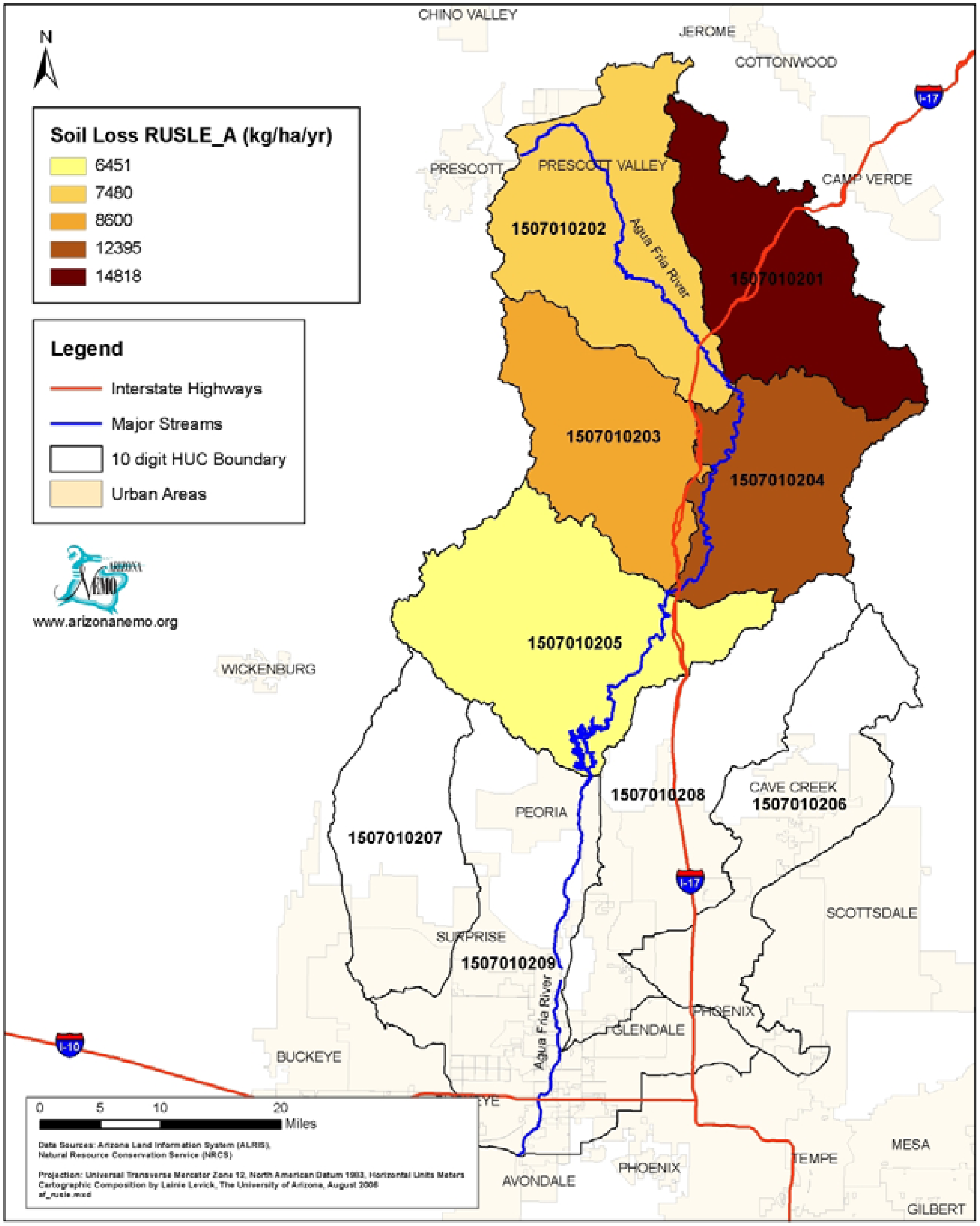


Figure 6-2. RUSLE Soil Loss "A" (kg/ha/yr) by Subwatershed (See Table 6-1 for subwatershed names).

Table 6-5: RUSLE Calculated Soil Loss "A" (kg/ha/yr)

Subwatershed	RUSLE Soil Loss "A" (kg/ha/yr)
Ash Creek and Sycamore Creek H1507010201	**14,818**
Big Bug Creek-Agua Fria River H1507010202	**7,480**
Black Canyon Creek H1507010203	**8,600**
Bishop Creek H1507010204	**12,395**
Agua Fria River-Lake Pleasant H1507010205	**6,451**

Metals Results

Table 6-6 shows the erosion category and fuzzy membership value for each subwatershed. The range of erosion values were classified into five erosion categories, where category 1 represents zero potential for metals contribution (i.e. low sediment yield), and category 5 represents a high potential (i.e. high sediment yield). The fuzzy membership values ranged from 0.0 to 1.0, and were increased by 0.25 for each higher erosion category.

The fuzzy membership values for the number of mines and for the erosion category were used to create a combined fuzzy score for each subwatershed using the weighted combination method.

This method uses a weighting scheme (weighted combination method) which was developed in cooperation with ADEQ. The weights consider 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 this weight was set at 0.1, as opposed to 0.3 for the other conditions.

Table 6-6: Fuzzy Membership Values per Erosion Category.

Subwatershed	Erosion Category	FMV
Ash Creek and Sycamore Creek H1507010201	**5**	**1.00**
Big Bug Creek-Agua Fria River H1507010202	**1**	**0.00**
Black Canyon Creek H1507010203	**2**	**0.25**
Bishop Creek H1507010204	**4**	**0.75**
Agua Fria River-Lake Pleasant H1507010205	**1**	**0.00**

The results are found in Table 6-7, and the weights are listed at the bottom of the table. Each of the assigned weights were multiplied with the FMV, and then added to produce the weighted FMV ranking.

Using the weighted FMV values, the subwatershed areas were classified into 'high' or 'low" risk for impairment due to metals based on natural breaks. Figure 6-3 shows the results of the weighted combination method classified into high and low risk for metals.

Table 6-7: Summary Results for Metals Based on the Fuzzy Logic Approach – Weighted Combination Approach.

Subwatershed	FMV WQA[1]	FMV # Mines / HUC	FMV # Mines / Riparian	FMV Erosion Category	FMV Weighted
Ash Creek and Sycamore Creek H1507010201	**0.6**	**1.0**	**1.0**	**1.00**	**0.88**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**1.0**	**1.0**	**0.00**	**0.61**
Black Canyon Creek H1507010203	**1**	**1.0**	**1.0**	**0.25**	**0.78**
Bishop Creek H1507010204	**0**	**1.0**	**1.0**	**0.75**	**0.63**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**1.0**	**1.0**	**0.00**	**0.55**
Weights	***0.30***	***0.10***	***0.30***	***0.30***	

[1]Water Quality Assessment results, from Table 6-3.

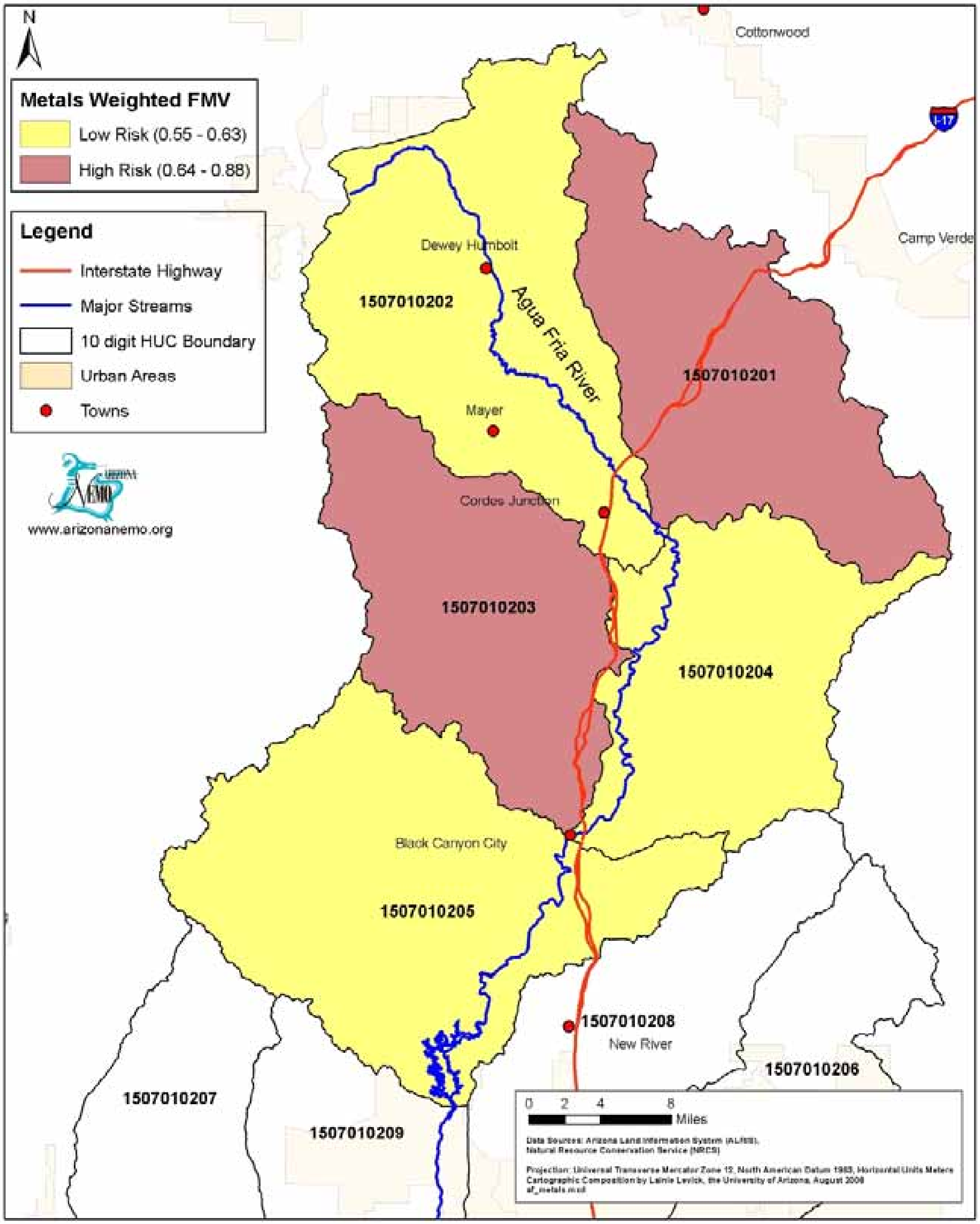


Figure 6-3: Results for the Fuzzy Logic Classification for Metals Based on the Weighted Combination Approach (See Table 6-1 for subwatershed names).

Sediment

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

The factors used for the sediment classification are:

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

Because available water quality data are limited, more weight was placed on subwatershed characteristics and modeling results when performing the classification.

Water Quality Assessment Data - Sediment

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004) was 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 classification results. Table 6-8 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed based on turbidity data.

Table 6-8: Fuzzy Membership Values for Sediment, Assigned to each 10-Digit HUC Subwatershed, Based on Water Quality Assessment Results.

Subwatershed Name	FMV	Justification
Ash Creek and Sycamore Creek H1507010201	**0.6**	**Classified as moderate risk, drains into Big Bug Creek-Agua Fria River that is classified as high risk**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**Classified as high risk, drains into Bishop Creek that is classified as low risk**
Black Canyon Creek H1507010203	**0.3**	**Classified as moderate risk, drains into Bishop Creek that is classified as low risk**
Bishop Creek H1507010204	**0.0**	**Classified as low risk**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**Classified as moderate risk**

Land ownership - Sediment

One of the principal land uses in the Agua Fria 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 71.3% of the total watershed area. The remaining lands where grazing occurs are Arizona State Trust Lands (approximately 12.4%), and privately owned land (approximately 13.9%). 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 plan in place. The fuzzy membership function for the percentage of land in state or private ownership within a 10-digit HUC subwatershed is shown below.

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

Table 6-9 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Upper Agua Fria Watershed based on land ownership.

Table 6-9: Fuzzy Membership Values for Sediment Based on Land Ownership.

Subwatershed	% State + Private	FMV
Ash Creek and Sycamore Creek H1507010201	**6.6**	**0.0**
Big Bug Creek-Agua Fria River H1507010202	**60.1**	**1.0**
Black Canyon Creek H1507010203	**4.7**	**0.0**
Bishop Creek H1507010204	**5.3**	**0.0**
Agua Fria River-Lake Pleasant H1507010205	**38.1**	**1.0**

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 Upper Agua Fria Watershed, human use consists of developed areas as defined by the Southwest Regional GAP land cover data set as residential land use, agriculture, mining and roads (RS/GIS Laboratory, 2004).

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 6-10 contains the fuzzy membership values assigned to each 10-digit HUC subwatershed in the Upper Agua Fria Watershed based on the Human Use Index.

Table 6-10: Fuzzy Membership Values for Sediment Based on the Human Use Index (HUI).

Subwatershed	FMV - HUI Watershed	FMV - HUI Riparian
Ash Creek and Sycamore Creek H1507010201	**0**	**0**
Big Bug Creek-Agua Fria River H1507010202	**0.32**	**0.98**
Black Canyon Creek H1507010203	**0**	**0**
Bishop Creek H1507010204	**0**	**0**
Agua Fria River-Lake Pleasant H1507010205	**0**	**0**

AGWA/SWAT Modeling

Runoff, Erosion and Sediment Yield

AGWA/SWAT was used to evaluate the potential runoff and sediment yield (see Appendix D for a description of AGWA/SWAT) for a subwatershed area. Runoff can be used to evaluate potential sediment yield, which is a measure of the rate of erosion. Both runoff and sediment yield depend on a combination of soil properties, topography, climate and land cover.

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 category. Table 6-11 shows the runoff categories and associated FMV, and Table 6-12 shows the erosion categories and associated FMV.

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

Subwatershed	Runoff Category	FMV
Ash Creek and Sycamore Creek H1507010201	**5**	**1.0**
Big Bug Creek-Agua Fria River H1507010202	**5**	**1.0**
Black Canyon Creek H1507010203	**4**	**0.8**
Bishop Creek H1507010204	**4**	**0.8**
Agua Fria River-Lake Pleasant H1507010205	**3**	**0.6**

Table 6-12: Fuzzy Membership Values and Erosion Categories.

Subwatershed	Erosion Category	FMV
Ash Creek and Sycamore Creek H1507010201	**2**	**0.4**
Big Bug Creek-Agua Fria River H1507010202	**2**	**0.4**
Black Canyon Creek H1507010203	**5**	**1.0**
Bishop Creek H1507010204	**3**	**0.6**
Agua Fria River-Lake Pleasant H1507010205	**2**	**0.4**

Sediment Results

The weighted combination approach was used to create combined fuzzy scores to rank sediment results, as shown in Table 6-13. Figure 6-4 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 6-13.

Table 6-13: Summary Results for Sediment Based on the Fuzzy Logic Approach – Weighted Combination Approach.

Subwatershed Name	FMV WQA[1]	FMV Land Ownership	FMV HU Index / Watershed	FMV HU Index / Riparian	FMV Runoff	FMV Erosion	FMV Weighted
Ash Creek and Sycamore Creek H1507010201	**0.6**	**0**	**0**	**0**	**1.0**	**0.4**	**0.45**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**1.0**	**0.32**	**0.98**	**1.0**	**0.4**	**0.73**
Black Canyon Creek H1507010203	**0.3**	**0**	**0**	**0**	**0.8**	**1.0**	**0.56**
Bishop Creek H1507010204	**0.0**	**0**	**0**	**0**	**0.8**	**0.6**	**0.42**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**1.0**	**0**	**0**	**0.6**	**0.4**	**0.38**
Weights	***0.05***	***0.05***	***0.1***	***0.2***	***0.3***	***0.3***	

[1]WQA = Water Quality Assessment results, Table 6-8

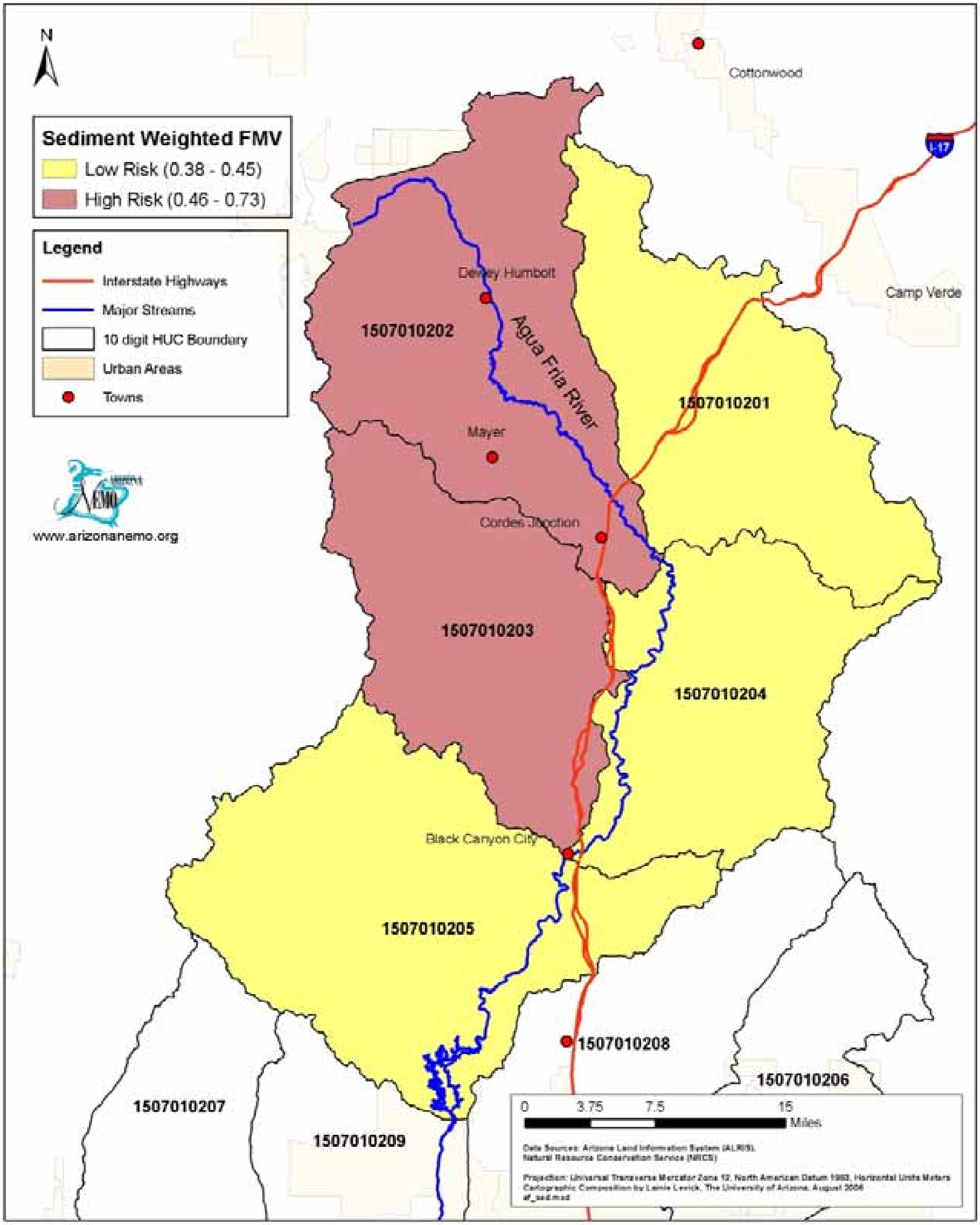


Figure 6-4: Results for the Fuzzy Logic Classification for Sediment Based on the Weighted Combination Approach (See Table 6-1 for subwatershed names).

Organics

Several water quality parameters that have been identified as concerns in the Agua Fria Watershed are related to the introduction of organic material to a water body. Galena Gulch from the headwaters to the Agua Fria River had past cyanide exceedances, and due to limited current data is assessed as “inconclusive”. Several other waterbodies had limited or insufficient data for organics.

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 - Organics

Arizona’s Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004) 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 6-14 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 Agua Fria Watershed, human use consists of developed areas as defined by the Southwest Regional GAP land cover data as residential land use, mining and roads (RS/GIS Laboratory, 2004).

Human activity can introduce organic material to a water body by disposal of organic compounds, waste and sewage. Most of the residential development outside of cities in the Agua Fria 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).

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.

Table 6-14: Fuzzy Membership Values for Organics, Assigned to each 10-digit HUC Subwatershed Based on Water Quality Assessment Results for Organics.

Subwatershed Name	FMV	Justification
Ash Creek and Sycamore Creek H1507010201	**0.6**	**Classified as moderate risk, drains into Big Bug Creek-Agua Fria River subwatershed that is classified as high risk**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**Classified as high risk, drains into Bishop Creek subwatershed that is classified as low risk**
Black Canyon Creek H1507010203	**0.3**	**Classified as moderate risk, drains into Bishop Creek subwatershed that is classified as low risk**
Bishop Creek H1507010204	**0.0**	**Classified as low risk**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**Classified as moderate risk**

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 6-15 contains the fuzzy membership values assigned to each 10- digit HUC subwatershed in the Agua Fria Watershed for organics based on the Human Use Index.

Table 6-15: Fuzzy Membership Values for Organics Based on the Human Use Index.

Subwatershed	FMV HU Index Watershed	FMV HU Index Riparian
Ash Creek and Sycamore Creek H1507010201	**0.00**	**0.16**
Big Bug Creek-Agua Fria River H1507010202	**1.00**	**1.00**
Black Canyon Creek H1507010203	**0.00**	**0.08**
Bishop Creek H1507010204	**0.17**	**0.21**
Agua Fria River-Lake Pleasant H1507010205	**0.00**	**0.03**

Land Use - Organics

The principal land use in the Upper Agua Fria Watershed is livestock grazing. Livestock grazing occurs on most land ownership types, including federal government land (BLM and USFS), Arizona State Trust Land and privately owned land. Therefore, each 10-digit HUC watershed was assigned a fuzzy membership value based on its primary land use relative to livestock grazing.

All subwatersheds were initially assigned a value of 1.0 as most of the land is state, federal or privately owned, and was assumed to be primarily used for livestock grazing.

Nutrients

According to Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004), no waterbodies have exceedances for nutrients. However, there were insufficient monitoring data for many of the waterbodies, resulting in "inconclusive" assessments. Nutrient exceedances can be caused by runoff from residential areas where landscapes are fertilized, or from animal waste where grazing is prevalent.

pH

According to Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004), no waterbodies 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.

Some mine sites may produce acid mine drainage, or low pH conditions, due to the exposure of sulfates to oxygen and water. The acid mine drainage dissolves naturally occurring metals in the soils, increasing the dissolved metal concentrations to sometimes toxic levels. Low pH in aquatic systems can be fatal to many organisms, including fish, or may affect reproduction, causing deformities. In addition, low pH can result in the release of heavy metals, which oxidize and accumulate in the gills of fish, causing asphyxiation (des.nh.gov/wet/Aug04Institute/chemical.pdf).

Organics Results

The weighted combination approach was used to create the combined fuzzy score, and the results are found in Table 6-16, along with the weights used in the classification. Figure 6-5 shows the results of the weighted combination method classified into high and low priority for organics.

Table 6-16: Summary Results for Organics Based on the Fuzzy Logic – Weighted Combination Approach.

Subwatershed	FMV WQA[1]	FMV HUI / subws	FMV HUI / riparian	FMV Owner	FMV Weighted
Ash Creek and Sycamore Creek H1507010201	**0.6**	**0.00**	**0.16**	**1.0**	**0.43**
Big Bug Creek-Agua Fria River H1507010202	**0.7**	**1.00**	**1.00**	**1.0**	**0.91**
Black Canyon Creek H1507010203	**0.3**	**0.00**	**0.08**	**1.0**	**0.31**
Bishop Creek H1507010204	**0.0**	**0.170**	**0.21**	**1.0**	**0.30**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**0.00**	**0.03**	**1.0**	**0.36**
Weights	***0.3***	***0.2***	***0.3***	***0.2***	

[1]WQA = Water Quality Assessment results

Selenium

There were insufficient selenium data to assess most waterbodies, although in locations where monitoring occurred, no exceedances were noted in the ADEQ Water Quality Assessment Report (2004).

High values for selenium may be associated with high values for metals, and are likely to be naturally occurring in highly mineralized soils. 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 agricultural drainage water ("tail water") from seleniferous irrigated soils (Hem, 1970).

Water Quality Assessment Data-Selenium

The ADEQ Water Quality Assessment Report (2004) 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 6-17 contains the fuzzy membership values for selenium for each subwatershed based on the water quality assessment results.

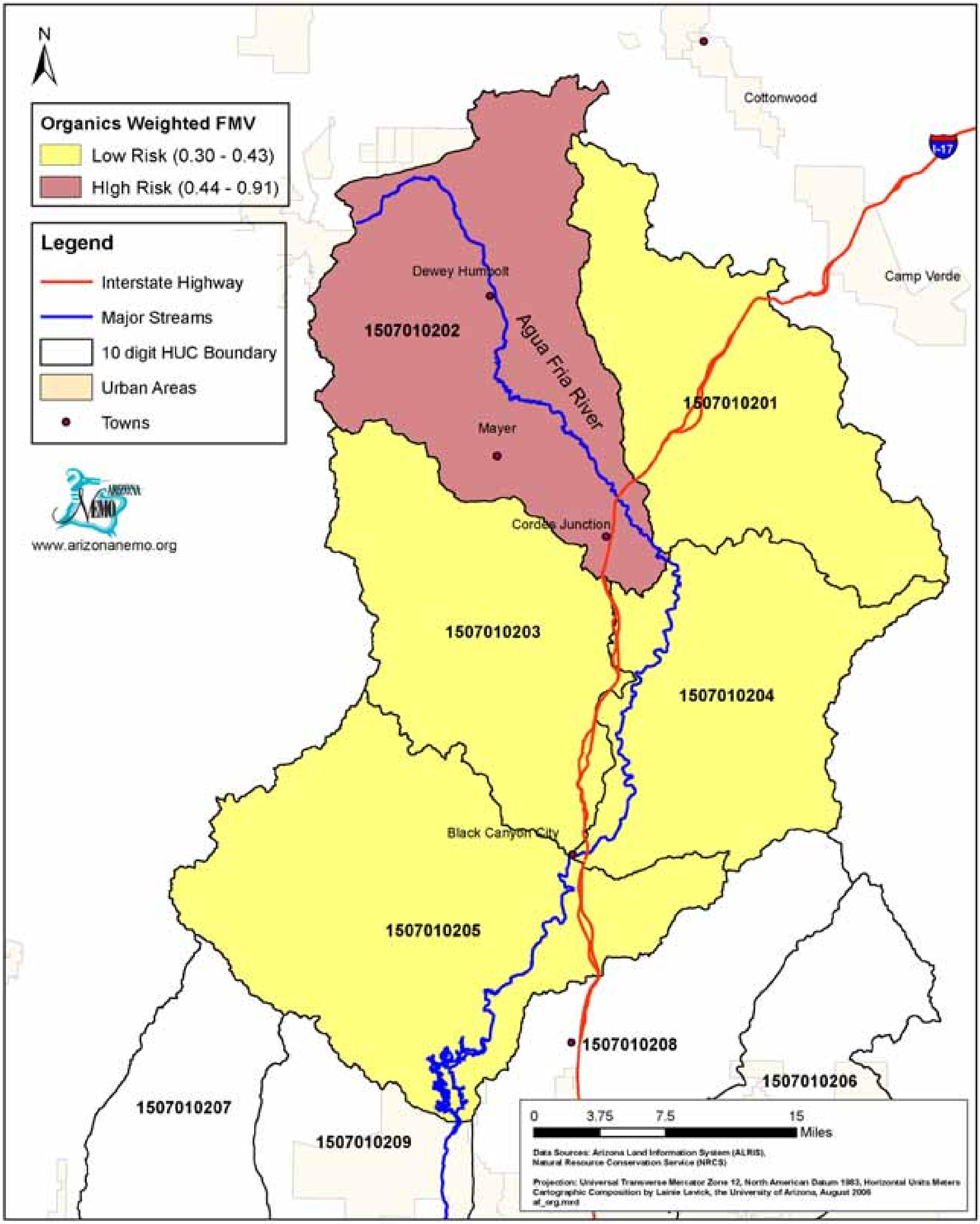


Figure 6-5: Results for the Fuzzy Logic Classification for Organics Based on the Weighted Combination Approach (See Table 6-1 for subwatershed names).

Table 6-17: Fuzzy Membership Values for Selenium Assigned to each 10-digit HUC Subwatershed Based on Water Quality Assessment Results.

Subwatershed Name	FMV	Justification
Ash Creek and Sycamore Creek H1507010201	0.5	Classified as moderate risk, drains into Big Bug Creek-Agua Fria River subwatershed that is classified as moderate risk
Big Bug Creek-Agua Fria River H1507010202	0.3	Classified as moderate risk, drains into Bishop Creek subwatershed that is classified as low risk
Black Canyon Creek H1507010203	0.3	Classified as moderate risk, drains into Bishop Creek subwatershed that is classified as low risk
Bishop Creek H1507010204	0.0	Classified as low risk
Agua Fria River-Lake Pleasant H1507010205	0.5	Classified as moderate risk

Agricultural Lands

The percentage of the agricultural lands in each 10-digit HUC subwatershed was calculated as shown in Table 6-18.

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.

Table 6-18: Percentage of Agricultural Lands in each Subwatershed.

Subwatershed Name	Percentage of Agricultural Land
Ash Creek and Sycamore Creek H1507010201	0.1%
Big Bug Creek-Agua Fria River H1507010202	0.3%
Black Canyon Creek H1507010203	0.0%
Bishop Creek H1507010204	0.0%
Agua Fria River-Lake Pleasant H1507010205	0.0%

Number of Mines per Watershed

Elevated concentrations of selenium in the waters of the Agua Fria 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 6-19.

Table 6-19: 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 6-20 shows the fuzzy membership values for each 10-digit HUC subwatershed based on the number of mines.

Table 6-20: Fuzzy Membership Values for Selenium for each 10-digit HUC Subwatershed Based on the Number of Mines.

Subwatershed Name	Number of mines	FMV for mines/HUC
Ash Creek and Sycamore Creek H1507010201	**34**	**0.66**
Big Bug Creek-Agua Fria River H1507010202	**293**	**1.00**
Black Canyon Creek H1507010203	**248**	**1.00**
Bishop Creek H1507010204	**25**	**0.33**
Agua Fria River-Lake Pleasant H1507010205	**223**	**1.00**

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 6-6). These results are found in Table 6-21, and the weights are listed at the bottom of the table.

Table 6-21: Summary Results for Selenium Based on the Fuzzy Logic - Weighted Combination Approach.

Subwatershed Name	FMV WQA[1]	FMV mines/HUC	FMV Weighted
Ash Creek and Sycamore Creek H1507010201	**0.5**	**0.66**	**0.58**
Big Bug Creek-Agua Fria River H1507010202	**0.3**	**1.00**	**0.65**
Black Canyon Creek H1507010203	**0.3**	**1.00**	**0.65**
Bishop Creek H1507010204	**0.0**	**0.33**	**0.17**
Agua Fria River-Lake Pleasant H1507010205	**0.5**	**1.00**	**0.75**
Weights	**0.5**	**0.5**	

1WQA = Water Quality Assessment results

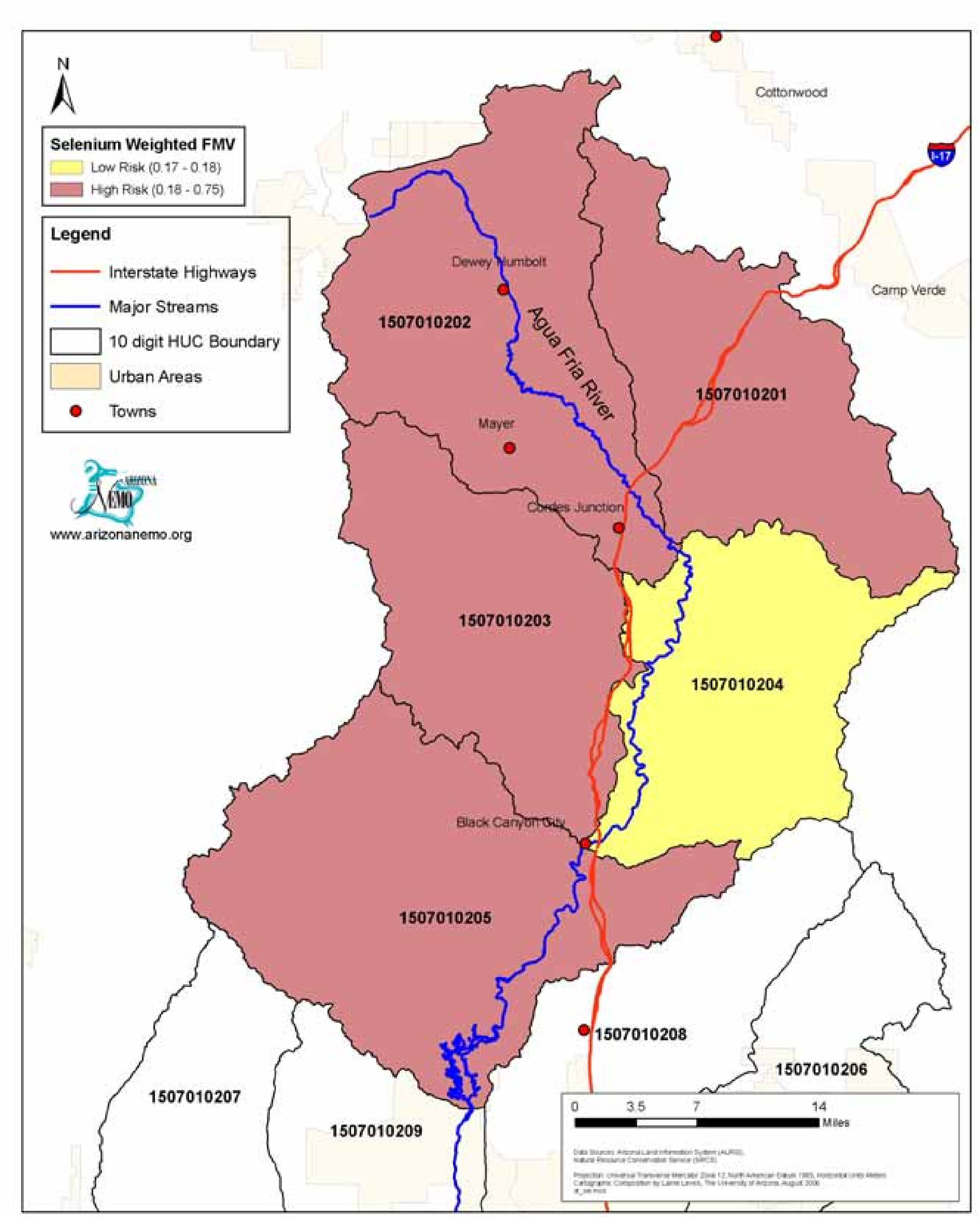


Figure 6-6: Results for the Fuzzy Logic Classification for Selenium Based on the Weighted Combination Approach (See Table 6-1 for subwatershed names).

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, from http://www.azdeq.gov/environ/water/assessment/2004.html.

Arizona Department of Environmental Quality, ADEQ. 2006. TMDL Program, from http://www.azdeq.gov/environ/water/assessment/tmdl.html.

Arnold, J.G., J. R. Williams, R. Srinivasan, K.W. King, and R. H. Griggs. 1994. SWAT - Soil & Water Assessment Tool. USDA, Agricultural Research Service, Grassland, Soil and Water Research Laboratory, Temple, Texas.

Burns, I.S., S. Scott, L. Levick, M. Hernandez, D.C. Goodrich, S.N. Miller, D.J. Semmens, and W.G. Kepner. 2004. Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual *Version 1.4*, from http://www.tucson.ars.ag.gov/agwa/

Guertin, D.P., R.H. Fiedler, S.N. Miller, and D.C. Goodrich. 2000. Fuzzy Logic for Watershed Assessment. Proceedings of the ASCE Conference on Science and Technology for the New Millennium: Watershed Management 2000, Fort Collins, CO, June 21-24, 2000.

Hem, J.D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water, 2nd Edition. U.S. Geological Survey Water-Supply Paper 1473.

Miller, S.N., W.G. Kepner, M.H. Mehaffrey, M. Hernandez, R.C. Miller, D.C. Goodrich, K.K. Devonald, D.T. Heggem, and W.P. Miller. 2002. Integrating Landscape Assessment and Hydrologic Modeling for Land Cover Change Analysis, in Journal of the American Water Resources Association, Vol. 38, No. 4, August. P. 915- 929.

Reynolds, K.M. 2001. Fuzzy Logic Knowledge Bases in Integrated Landscape Assessment: Examples and Possibilities. General Technical Report PNW-GTR-521. USDA Forest Service, Pacific Northwest Research Station. 24 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), U. S. Department of Agriculture, Agriculture Handbook No. 703. 404 pp.

Van Remortel, R., D. Heggem, and A. Pitchford. 2004. SEDMOD, Version 1.1 of Soil & Landform Metrics: Programs and U.S. Geodatasets (CD). U.S. Environmental Protection Agency, Environmental Sciences Division, Landscape Ecology Branch, Las Vegas, NV.

Data Sources:*

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

RS/GIS Laboratory, 2004. Provisional Landcover. http://earth.gis.usu.edu/swgap
Land cover / land use. Sept. 24, 2004.

**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 Agua Fria 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.

The Turkey Creek TMDL Implementation Plan is also summarized within this section. 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.

<u>Management Methods</u>

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 Agua Fria Watershed include the mining industry, new housing developments and increased urbanization, and new road construction. The Big Bug Creek-Agua Fria River subwatershed is 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 Agua Fria 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.

Strategy for Addressing Existing Impairment

The major sources of water quality impairment and environmental damage in the Agua Fria 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.ArizonaNEMO.org.

Metals

The primary nonpoint source of anthropogenic metals in the Agua Fria Watershed is abandoned or inactive 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. Portions of the Agua Fria Watershed have 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 Agua Fria Watershed, including federal, state and private lands, with a majority of the mines located on land administered by the 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 are found in Table 7-1.

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.

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.

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 semi-arid 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.

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.

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.

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.

Removal:

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

Rock Rip-Rap Sediment 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, and Tribal entities).

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

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.

The only subwatershed area prioritized for educational outreach to address metals based on Section 6 analysis is Black Canyon Creek.

Turkey Creek TMDL Implementation Plan:

Turkey Creek is a 30 mile intermittent waterway that drains seasonal precipitation from its headwaters near Mount Union, 7,520 feet above mean sea level, to its confluence with Poland Creek at 2,840 feet. It is delineated within the 10-digit HUC Black Canyon Creek subwatershed.

In 2006, ADEQ completed its draft Turkey Creek TMDL Implementation Plan to meet the State of Arizona's requirements in Arizona Revised Statutes (A.R.S. § 231-4). Turkey Creek first appeared on the 1992 List of Water Quality Limited Waters (303d List) for exceedences of surface water quality standards for arsenic, cadmium, copper, cyanide, lead, mercury and zinc. Since then, it has been listed 5 times, including in 2004, for these and other metals (ADEQ, 2006). Excessive heavy metals negatively impact the aquatic ecosystem and are a detraction from recreation uses.

ADEQ has concluded that historic metal mining within Turkey Creek's watershed has impaired the intermittent waterway for 21 miles from an unnamed tributary to the confluence with Poland Creek. The TMDL addresses cadmium, copper, lead and zinc. The plan defines an action strategy to implement cleanup of the main sources of pollution, which are tailing piles from the Golden Belt, Golden Turkey and French Lily Mines. The tailings piles are located on land managed by the U.S. Forest Service.

Data collected while conducting the TMDL study confirmed the impairment of Turkey Creek due to copper and lead during storm run-off events, and indicated that arsenic, cadmium and zinc do not impair Turkey Creek. Therefore, TMDLs are calculated only for copper and lead (ADEQ, 2006).

A TMDL is comprised of the sum of individual waste load allocations within the receiving water body for point sources, load allocations for nonpoint sources, and natural background levels. 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.

The Turkey Creek TMDL implementation plan makes recommendations for the cleanup of the identified source areas. The Forest Service conducted their own research and hired an engineering consultant to identify and design solutions towards restoring surface water quality located on Forest Service land. Proposed management measures, anticipated load reductions, measurable milestones, and costs of implementation of selected measures are included in the Implementation Plan. The major management measures selected include consolidating and capping the tailings onsite, removal of some of the tailings, and surface control measures (ADEQ, 2006).

Sediment

Erosion and sedimentation are major environment problems in the western United States, including the Agua Fria 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 areas can also mitigate erosion damage.

The primary land uses in the Agua Fria 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 Agua Fria 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 land such as riparian areas 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:

A filter strip along a stream, lake or other waterbody will retard the movement of sediment, and may remove pollutants from runoff before the material enters the body of water. Filter strips will 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.

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.

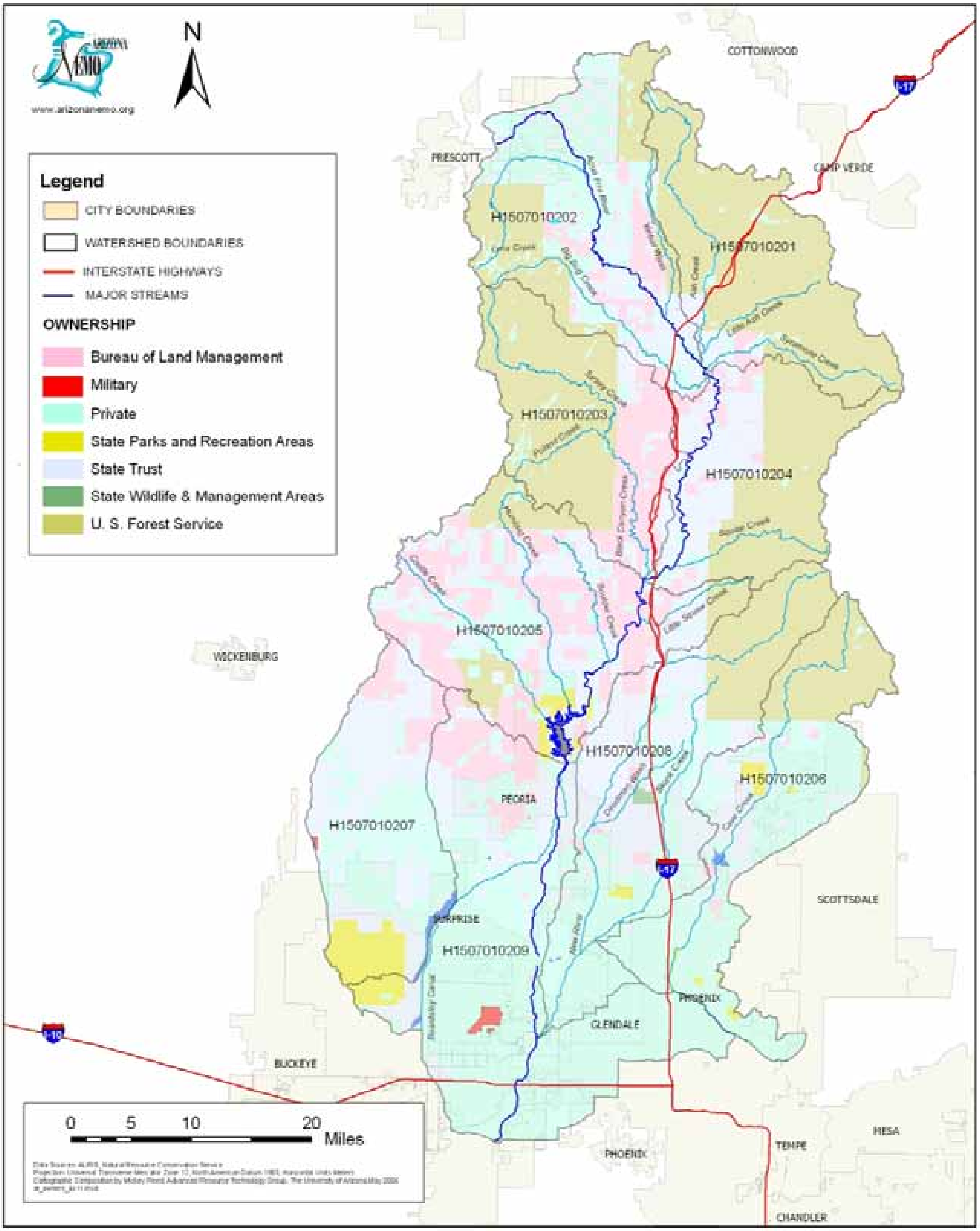


Figure 7-1: Agua Fria Watershed Land Ownership by Subwatershed

Table 7-3: Percentage Land Ownership by Subwatershed (part 1 of 2).

Land Owner	Ash Creek and Sycamore Creek H1507010201	Big Bug Creek-Agua Fria River H1507010202	Black Canyon Creek H1507010203	Bishop Creek H1507010204	Agua Fria River-Lake Pleasant H1507010205
BLM	**1.83%**	**11.35%**	**25.43%**	**8.65%**	**37.68%**
Military	**-**	**-**	**-**	**-**	**-**
Private	**4.74**	**37.47%**	**3.96%**	**3.67%**	**16.15%**
State Parks and Recreation Areas	**-**	**-**	**-**	**-**	**3.20%**
State Trust	**4.86**	**23.90%**	**6.01%**	**32.55%**	**29.65%**
State Wildlife & Management Areas	**-**	**-**	**-**	**-**	**-**
USFS	**85.90%**	**27.29**	**49.91%**	**52.29%**	**8.64%**
USFS & BLM Wilderness Areas	**2.67%**	**-**	**14.69%**	**2.85%**	**4.69%**
Area (square miles)	***260.56***	***324.13***	***243.99***	***236.47***	***371.79***

Table 7-3: Percentage Land Ownership by Subwatershed (part 2 of 2).

Land Owner	Cave Creek-Arizona Canal Diversion Channel H1507010206	Trilby Wash-Trilby Wash Basin H1507010207	New River H1507010208	Agua Fria River below Lake Pleasant H1507010209	*Agua Fria Watershed*
BLM	**1.45%**	**8.32%**	**3.08%**	**9.17%**	***12.28%***
Military	**-**	**0.14%**	**-**	**0.72%**	***0.13%***
Private	**58.46%**	**36.38%**	**39.05%**	**72.74%**	***33.91%***
State Parks and Recreation Areas	**2.39%**	**10.95%**	**0.47%**	**2.06%**	***2.03%***
State Trust	**13.15%**	**44.21%**	**33.65%**	**15.10%**	***22.47%***
State Wildlife & Management Areas	**0.01%**	**-**	**0.67%**	**-**	***0.09%***
US Forest Service	**24.54%**	**-**	**23.08%**	**-**	***26.65%***
USFS & BLM Wilderness Areas	**-**	**-**	**-**	**0.21%**	***2.44%***
Area (square miles)	***288.47***	***242.20***	***353.16***	***464.25***	***2,785.02***

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 cattle watering facilities
(http://www.2gosolar.com/typical_installations.htm)

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 slope 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. This erosion control method is most frequently used at tailings piles or on 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 Big Bug Creek-Agua Fria River, and Black Canyon Creek.

<u>Organics</u>

At several locations within the Agua Fria 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 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.

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.

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.

Filter strip near waterbody (http://jasperswcd.org/practices.htm)

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.

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 condition 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 with more information on permitting septic systems is: http://www.azdeq.gov/environ/water/permits/wastewater.html.

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, the only subwatershed area prioritized for educational outreach to address organics is the Big Bug Creek-Agua Fria River.

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, wheel line 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 wheel line is $805 per acre.

Education:

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

Agriculture represents a very small portion of the land use in the Agua Fria Watershed. Based on the results of the selenium classification and ranking in Section 6, the subwatershed areas that are prioritized for educational outreach to address selenium are Big Bug Creek-Agua Fria River, Ash Creek and Sycamore Creek, Black Canyon Creek and Agua Fria River-Lake Pleasant.

Strategy for Channel and Riparian Protection and Restoration

Riparian areas are one of the most critical resources in the Agua Fria 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 Bureau of Land Management and the 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 three natural resource areas, including the extensive riparian forests and perennial streams of the Upper Agua Fria River NRA, Agua Fria River-Lake Pleasant NRA, and the Lower Agua Fria River NRA.

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 addresses 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* (bank stabilization, filter strips and livestock fencing)
- *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 mine reclamation, septic systems, stormwater management and water conservation, will be considered. Development of an "Adopt a Stream" Program will also be considered.

References

Arizona Department of Environmental Quality, ADEQ. 2006. Turkey Creek (from a tributary at 34º19'28"/112º21'28" to Poland Creek) Total Maximum Daily Loads for Copper and Lead and Cadmium and Zinc De-Lists. http://www.azdeq.gov/environ/water/assessment/download/turkey.pdf

Arizona Department of Environmental Quality, ADEQ. 2004. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Agua Fria 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 8-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 Upper Agua Fria Watershed. This methodology ranked five 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 the five 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**
Ash Creek and Sycamore Creek H1507010201	**0.88**	**0.45**	**0.43**	**0.58**
Big Bug Creek – Agua Fria River H1507010202	**0.61**	**0.69**	**0.82**	**0.65**
Black Canyon Creek H1507010203	**0.78**	**0.56**	**0.31**	**0.65**
Bishop Creek H1507010204	**0.63**	**0.42**	**0.30**	**0.17**
Agua Fria River – Lake Pleasant H1507010205	**0.55**	**0.33**	**0.31**	**0.75**

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. Ash Creek and Sycamore Creek Subwatershed, for metals pollution;

2. Big Bug Creek – Agua Fria River Subwatershed, for sediment pollution and for pollutants due to organics and nutrients derived from land use; and,

3. Agua Fria River – Lake Pleasant Subwatershed, 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. Ash Creek and Sycamore 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 Ash Creek and Sycamore Creek Subwatershed of the Agua Fria River ranked as the most critical area in the Agua Fria Watershed impacted by metals related to abandoned mine sites (i.e. highest fuzzy membership value for metals). 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 (87.5%). State Trust and the Bureau of Land Management are responsible for the remainder of the watershed. Projects implemented on 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. Big Bug Creek – Agua Fria River Subwatershed Example Project

Pollutant Type and Source: sediment pollution due to overgrazing, also organic pollutants, specifically *E. coli,* assumed to originate from wildlife or cattle watering in the stream channel, although the exact source is unknown.

The Big Bug Creek – Agua Fria River subwatershed of the Agua Fria River ranked as the most critical area impacted by land use activities, and for purposes of outlining an example project it will be assumed that grazing within the riparian area has exacerbated erosion and introduced fecal matter into the stream. The land owners within this subwatershed (Table 7-5) include the U.S. Bureau of Land Management (11.34%), private lands (37.47%), State Trust lands (23.9%) and Military (27.28%). 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: Prior to initiating a project to address bacteria pollution, it may benefit the watershed partnership to determine the source of bacterial contamination. Implementation of DNA fingerprinting technology will identify the actual sources of bacteria and clarify how best to target an implementation plan and project.

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).

The results of a study funded from Section 319 Nonpoint Source Grant funds for Oak Creek Canyon within the Verde Watershed to the east of the Agua Fria found that most of the fecal pollution came from natural animal populations 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.

In Big Bug Creek, pathogens and sediment are assumed to most likely originate from grazing practices because rangeland livestock grazing is the primary land use in the Big Bug Creek and the Agua Fria River Watershed. Load reductions can be calculated and documented for sediment and feedlot runoff using Michigan DEQ (1999) methodology (see the NEMO BMP Manual).

Management Measures: Implementing grazing management practices to improve or maintain riparian health will help reduce excess surface runoff and accelerated erosion. 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. Tables 7-2 and 7-3 present load reduction potential, required maintenance, and anticipated costs associated with each project option. 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 the installation of an alternative water source may necessitate project design by a licensed engineer.

3. Agua Fria River – Lake Pleasant Subwatershed Example Project

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

The Agua Fria River – Lake Pleasant subwatershed of the Agua Fria River ranked as the most critical area impacted by agricultural land use practices that exacerbate the concentration of naturally occurring selenium (i.e. Table 8-1, highest fuzzy membership values for Selenium).

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 Agua Fria River – Lake Pleasant subwatershed (Table 7-3) are primarily Bureau of Land Management (37.68%), State Trust Lands (29.65%), and Private (16.15%), although the U.S. Forest Service and State Parks also hold property in the watershed. Agriculture and rangeland are the most common land use in this subwatershed. 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 Upper Agua Fria Watershed Partnership 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. Arizona NEMO hosts a webpage for the group at www.ArizonaNEMO.org/index.php?page=upperaguafria.

Other successful outreach and public education activities in the watershed include sponsoring a Partnership booth at the Yavapai 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 Agua Fria 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

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
Management Measures and Implementation Schedule Streambank Stabilization and Estimated Load Reduction					
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**

Evaluation

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.

Monitoring

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, Agua Fria 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 Agua Fria Watershed, Ash Creek and Sycamore Creek, Big Bug Creek – Agua Fria River, and the Agua Fria River – Lake Pleasant subwatersheds 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 five, non-urban 10-digit HUC subwatersheds within the Agua Fria 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 Agua Fria 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 five subwatersheds included in this assessment, the three watersheds with the highest risk of water quality degradation are:

1. Ash Creek and Sycamore Creek Subwatershed, for metals pollution;

2. Big Bug Creek – Agua Fria River Subwatershed, for sediment pollution and for pollutants due to organics and nutrients derived from land use; and

3. Agua Fria River – Lake Pleasant Subwatershed, 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:

EPA (U.S. Environmental Protection Agency). January 2001. Protocol for Developing Pathogen TMDLs, First Edition. United States Environmental Protection Agency, Office of Water, Washington DC. EPA 841-R-00-002.

ADEQ, Arizona Department of Environmental Quality. 2005. Arizona's Integrated 305(b) Water Quality Assessment and 303(d) Listing Report, Agua Fria Watershed Assessment. http://www.azdeq.gov/environ/water/assessment/download/303-04/vd.pdf

EPA (U.S. Environmental Protection Agency). 2003. Clean Water Act Section 319, Nonpoint Source Program and Grants Guidelines for States and Territories. http://www.epa.gov/owow/nps/Section319/319guide03.html

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

Section 9: Summary of EPA's 9 Key Elements for Section 319 Funding

Introduction

All projects that apply for Section 319 funding under the Clean Water Act and administered through the Arizona Department of Environmental Quality must include nine key elements in their watershed-based plans. These elements are listed in Section 1 of this Watershed-Based Management Plan and are also discussed in the Nonpoint Source Guidance Document by the US EPA (http://www.epa.gov/owow/nps/319/index.html).

The nine key elements are described below and the corresponding sections of this NEMO Watershed-Based Management Plan are noted. Information and data to support this requirement can be found in these sections of this Plan.

Element 1: Causes and Sources.
NEMO Sections 6 and 7

The watershed-based plan must identify the sources that will need to be controlled to achieve load reductions established in the nonpoint source TMDL.

In addition, pollutants of concern must be identified, and the causes and sources (primary and secondary) of waterbody impairment (physical, chemical, and biological, both point and non-point sources) must be linked to each pollutant of concern.

Section 6 of the NEMO Watershed-based management plan prioritizes the subwatersheds for risk of impairment due to metals, sediment, organics and selenium nonpoint source pollution. In addition, the potential causes for each constituent are described so that the watershed group can begin identifying the source of the risk.

Section 7 of the NEMO plan discusses existing TMDLs in the watershed that identify known sources of waterbody impairment.

Element 2: Expected Load Reductions.
Not included in NEMO Plan

The plan must contain an overview of TMDL load reductions expected for each Best Management Practice, linked to an identifiable source (only required for sediment (tons/yr), nitrogen or phosphorus (lbs/yr)).

Element 3: Management Measures.
NEMO Sections 7 and 8

The plan must contain a description of the nonpoint source Best Management Practices or management measures and associated costs needed to achieve load reductions for the critical areas identified in which the measures will need to be implemented to achieve the nonpoint source TMDL.

Section 7 of the NEMO plan describes a variety of nonpoint source BMPs that may be applied for load reduction and management of metals, sediment, organics and selenium pollution.

Section 8 includes an example water quality improvement project for each of the four constituents (metals, sediment, organics and selenium) with specific example management measures.

Element 4: Technical and Financial Assistance.
NEMO Sections 7 and 8, and NEMO website www.ArizonaNEMO.org

The plan must include an estimate of the technical and financial assistance needed, including associated costs, and funding strategy (funding sources), and authorities the state anticipates having to rely on to implement the plan.

Section 7 includes several tables that include various management measures and their relative costs, life expectancy and load reduction potential.

Section 8 includes a list of possible funding sources and links for water quality improvement projects. In addition, the NEMO website (www.ArizonaNEMO.org) has an extensive list of links to a wide variety of funding sources.

Element 5: Information / Education Component.
NEMO Section 8

This is the information/education component intended to enhance public understanding and participation in selecting, designing, and implementing the nonpoint source management measures, including the outreach strategy with long and short term goals, and funding strategy.

Section 8 lists local resources that may be valuable in education and outreach to the local community or other targeted audiences. In addition, examples of local educational outreach projects are presented.

Element 6: Schedule.
NEMO Section 8

The plan must include a schedule for implementing, operating and maintaining the nonpoint source Best Management Practices identified in the plan.

Section 8 describes the importance of schedules in a water quality improvement project and presents an example schedule.

Element 7: Measurable Milestones.
NEMO Section 8

The plan must include a schedule of interim, measurable milestones for determining whether nonpoint source Best Management Practices or other control actions are being implemented and water quality improvements are occurring.

Section 8 describes some measurable milestones and presents an example schedule that includes milestones.

Element 8: Evaluation of Progress.
NEMO Section 8

The plan must contain a set of criteria used to determine whether load reductions are being achieved and substantial progress is being made towards attaining water quality standards, including criteria for determining whether the plan needs to be revised or if the Total Maximum Daily Load (TMDL) needs to be revised.

Section 8 describes how to evaluate the progress and success of a water quality improvement project and describes the key attributes that must be met for a successful project.

Element 9: Effectiveness Monitoring. Section 8

The plan must include a monitoring plan to evaluate the effectiveness of implementation efforts over time, measured against the set of criteria established in the Evaluation of Progress element (8).

Section 8 discusses the importance of project monitoring, and presents several example water quality and health constituents that should be monitored.

Conclusions

The NEMO Watershed based plans are structured to be a watershed wide, broad evaluation of the nine key elements. The community watershed groups, as they apply for 319 Grant Funds to implement projects, will need to readdress each of these 9 key elements for their specific watershed project.

Table 1: Subwatershed Classification for Risk of Impairment, Agua Fria Watershed.

Arizona's Integrated 305(b) Assessment and 303(d) Listing Report (ADEQ, 2004) includes water quality data and assessments of water quality in several surface waterbodies across the Agua Fria watershed. This table summarizes the surface waterbody data used to assess the risk of impairment for each 10-digit HUC subwatershed; some HUCs may have more than one surface waterbody assessed within the watershed, some have none. The table includes the ADEQ water quality data (sampling and assessment status) and the NEMO risk classification assigned to individual surface waterbodies within each subwatershed. It also includes the NEMO risk classification for each subwatershed, which is determined by the highest risk level of the surface waterbodies within that subwatershed.

The four levels of NEMO risk classification are defined in Section 6: extreme, high, moderate, and low. This table is organized to determine the relative risk of nonpoint source water quality degradation due to metals, sediment, organics and selenium for each 10-digit HUC subwatershed based on existing ADEQ water quality data. See the footnotes at the end of the table for more information and definitions of abbreviations, and Section 6 for the NEMO ranking values assigned to each risk classification.

<table>
<tr><th colspan="3">Subwatershed</th></tr>
<tr><td colspan="3">Ash Creek and Sycamore Creek Subwatershed
HUC 1507010201
Combined Classification for Risk of Impairment:
• Metals: Moderate due to insufficient data at Little Ash Creek.
• Sediment: Moderate due to insufficient data at Little Ash Creek.
• Organics: Moderate due to insufficient data at Little Ash Creek.
• Selenium: Moderate due to insufficient data at Little Ash Creek.</td></tr>
<tr><th>Surface Waterbody</th><th colspan="2">Water Quality Data:
Sampling and Assessment Status[1,2,3]</th></tr>
<tr><td rowspan="2">Sycamore Creek
from Tank Canyon to Agua Fria River

ADEQ ID: 15070102-024B

One sampling site at this surface waterbody.</td><td>Sampling</td><td>• Metals: arsenic, beryllium, antimony, selenium, mercury, cadmium, chromium, copper, manganese, zinc, fluoride, boron.
• Sediment: total dissolved solids, turbidity.
• Organics: E. coli, pH, dissolved oxygen, nitrogen as ammonia, n-kjeldahl, phosphorus.
• Selenium: selenium.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Currently assessed as "Attaining all uses".

Surface Waterbody risk classification:
• Metals: Low.
• Sediment: Low.
• Organics: Low.
• Selenium: Low.</td></tr>
</table>

Little Ash Creek from headwaters to Ash Creek ADEQ ID: 15070102-039 One sampling site at this surface waterbody.	Sampling	• **Metals**: arsenic (1), beryllium (1), antimony (1), mercury (t1) (d1), chromium (t1) (d 1), zinc (t1) (d1), cadmium (t1) (d2), copper (t1) (d2), lead (t1), manganese (t1), fluoride (1), boron (1). • **Sediment:** total dissolved solids (2), turbidity. • **Organics:** *E. coli* (1), pH (2), dissolved oxygen (2), nitrogen as ammonia (2), n-kjeldahl (2), nitrite/nitrate, phosphorus (2). • **Selenium:** selenium (t1).
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" due to insufficient monitoring data. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data. • **Sediment:** Moderate due to insufficient data. • **Organics:** Moderate due to insufficient data. • **Selenium:** Moderate due to insufficient data.
Subwatershed		
Big Bug Creek – Agua Fria River Subwatershed **HUC 1507010202** **Combined Classification for Risk of Impairment:** • **Metals:** High due to exceedances at: Lynx Creek from headwaters to 34 34 29 / 112 21 05; Unnamed tributary from headwaters to Lynx Creek; Blue John Creek from unnamed tributary to Lynx Creek. • **Sediment:** High due to exceedances at Fain Lake. • **Organics:** High due to exceedances at Galena Gulch from headwaters to Agua Fria River. • **Selenium:** Moderate due to insufficient data at numerous sites.		
Surface Waterbody	**Water Quality Data:** **Sampling and Assessment Status**[1,2,3]	
Agua Fria River from Sycamore Creek to Big Bug Creek ADEQ ID: 15070102-023 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** cadmium (t) (d1), chromium (t) (d1), copper (t) (d1), mercury (t) (d1). • **Sediment:** total dissolved solids (1). • **Organics:** pH (1), nitrogen as ammonia (1), nitrogen as ammonia (1), n-kjeldahl (1), phosphorus (1). • **Selenium:** selenium (t) (d1).

	Status	Parameters exceeding standards: None. Currently assessed as "Attaining all uses." Surface Waterbody risk classification: • **Metals:** Low. • **Sediment:** Low. • **Organics:** Low. • **Selenium:** Low.
Sycamore Creek from Tank Canyon to Agua Fria Rive ADEQ ID: 15070102-024B One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic, beryllium, antimony, mercury, cadmium, chromium, copper, manganese, zinc, fluoride, boron. • **Sediment:** total dissolved solids, turbidity. • **Organics:** *E. coli*, pH, dissolved oxygen, nitrogen as ammonia, n-kjeldahl, phosphorus. • **Selenium:** selenium.
	Status	Parameters exceeding standards: none. Currently assessed as "Attaining all uses". Surface Waterbody risk classification: • **Metals:** Low. • **Sediment:** Low. • **Organics:** Low. • **Selenium:** Low.
Lynx Creek from headwaters to 34 34 29 / 112 21 05 13 miles ADEQ ID: 15070102-033A One sampling site at this surface waterbody.	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: unknown Currently assessed as "Inconclusive". Placed on Planning List in 2002 due to past cadmium, copper and zinc exceedances (1/1 each). Surface Waterbody risk classification: • **Metals:** High due to insufficient data and past exceedances. • **Sediment:** Moderate due to insufficient data. • **Organics:** Moderate due to insufficient data. • **Selenium:** Moderate due to insufficient data.
Unnamed tributary from headwaters to Lynx Creek ADEQ ID: 15070102-124 Three sampling sites at this surface waterbody.	Sampling	• **Metals:** One sample each: aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thallium, vanadium, zinc. • **Sediment:** turbidity (1). • **Organics:** n-kjeldahl (1). • **Selenium:** selenium (1).

	Status	Parameters exceeding standards: cadmium (d) (1/1), copper (d) (1/1), zinc (d) (1/1). Currently assessed as "Inconclusive" due to insufficient monitoring data. Placed on Planning List due to cadmium, copper and zinc exceedances. Surface Waterbody risk classification: • **Metals:** High due to exceedances and insufficient data. • **Sediment:** Moderate due to insufficient data. • **Organics:** Moderate due to insufficient data. • **Selenium:** Moderate due to insufficient data.
Blue John Creek from headwaters to unnamed tributary to Lynx Creek ADEQ ID: 15070102-471 One sampling site at this surface waterbody.	Sampling	• **Metals:** aluminum (1), antimony (1), arsenic (1), beryllium (1), barium (1), calcium (1), cadmium (1), chromium (1), cobalt (1), copper (1), iron (1), lead (1), magnesium (1), manganese (t) (1), mercury (1), nickel (1), sodium (1), sulfate (1), silver (1), thallium, vanadium (1), zinc (1) fluoride (1), chlorine (1). • **Sediment:** total dissolved solids (1), turbidity (1). • **Organics:** n-kjeldahl (1), phosphorus (1). • **Selenium:** selenium (1).
	Status	Parameters exceeding standards: cadmium (d) (1/1), copper (d) (1/1), zinc (d) (1/1). Currently assessed as "Inconclusive" due to insufficient monitoring data. Placed on the planning list due to cadmium, copper and zinc exceedances. Surface Waterbody risk classification: • **Metals:** High due to exceedances. • **Sediment:** Moderate due to insufficient data. • **Organics:** Moderate due to insufficient data. • **Selenium:** Moderate due to insufficient data.

Galena Gulch from headwaters to Agua Fria River 6 miles ADEQ ID: 15070102-745	Sampling	No current monitoring data.
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive". Added to Planning List in 2002 due to insufficient data and cyanide exceedances in older data. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data. • **Sediment:** Moderate due to insufficient data. • **Organics:** High due to insufficient data and past exceedances. • **Selenium:** Moderate due to insufficient data
Fain Lake ADEQ ID: 15070102-0005 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (1), barium (1). beryllium (1), manganese (1), antimony (1), mercury (1), cadmium (1), chromium (1), copper (1), lead (1), nickel (1), silver (1), zinc (1). • **Sediment:** turbidity (1). • **Organics:** nitrogen as ammonia (1), n-kjeldahl (1), phosphorus (1), pH (1). • **Selenium:** selenium (1).
	Status	Parameters exceeding standards: turbidity (1/1) Currently assessed as "Inconclusive" due to insufficient monitoring data, and placed on Planning List due to exceedance of former turbidity standard. Surface Waterbody risk classification: • **Metals:** Moderate due to insufficient data. • **Sediment:** High due to exceedances. • **Organics:** Moderate due to insufficient data. • **Selenium:** Moderate due to insufficient data.
Lynx Lake ADEQ ID: 15070102-0860 Eight sampling sites at this surface waterbody.	Sampling	• **Metals:** cadmium (d 2), chromium (d 2), copper (d 2), lead (d 2), nickel (d 2), silver (d 2), zinc (d 2), arsenic (t), barium (t), beryllium (t), manganese (t), antimony (t), mercury (t). • **Sediment:** turbidity (2). • **Organics:** n-kjeldahl, phosphorus, nitrogen as ammonia, dissolved oxygen, *E. coli* (1). • **Selenium:** selenium (t).

<table>
<tr><td></td><td>Status</td><td>Parameters exceeding standards: lead (t) (2/5), manganese (t) (3/7).

Currently assessed as “Attaining some uses” and placed on Planning List due to:
1. Lead exceedances.
2. Manganese exceedances; and
3. Missing core parameters: turbidity, Escherichia coli, total boron, total mercury, dissolved metals (copper and cadmium).

Surface Waterbody risk classification:
• Metals: High due to exceedances.
• Sediment: Moderate due to missing data.
• Organics: Moderate due to missing data.
• Selenium: Moderate due to missing data.</td></tr>
<tr><td colspan="3">Subwatershed</td></tr>
<tr><td colspan="3">Black Canyon Creek Subwatershed
HUC 1507010203
Combined Classification for Risk of Impairment:
• Metals: Extreme due to exceedances at Turkey Creek from unnamed tributary to Poland Creek.
• Sediment: Moderate due to missing data at both surface waterbodies.
• Organics: Moderate due to missing data at both surface waterbodies.
• Selenium: Moderate due to missing data at both surface waterbodies.</td></tr>
<tr><td>Surface Waterbody</td><td colspan="2">Water Quality Data:
Sampling and Assessment Status[1,2,3]</td></tr>
<tr><td rowspan="2">Turkey Creek from headwaters to unnamed tributary at 34 19 28 / 112 21 28

ADEQ ID: 15070102-036A

Three sampling sites at this surface waterbody.</td><td>Sampling</td><td>• Metals: zinc, lead, cadmium, copper.</td></tr>
<tr><td>Status</td><td>Parameters exceeding standards: none.

Currently assessed as “Inconclusive” and placed on Planning List due to missing core parameters: turbidity/SSC, total boron, dissolved oxygen, Escherichia coli, and total metals (manganese and mercury).

Surface Waterbody risk classification:
• Metals: Moderate due to missing data.
• Sediment: Moderate due to missing data.
• Organics: Moderate due to missing data.
• Selenium: Moderate due to missing data.</td></tr>
</table>

Turkey Creek from Unnamed tributary at 34 19 28 / 112 21 28 to Poland Creek ADEQ ID: 15070102-036B Eight sampling sites at this surface waterbody.	Sampling	• **Metals:** **c**admium, copper, lead, zinc, arsenic (2), mercury (2).
	Status	Parameters exceeding standards: arsenic (d) (1/16), cadmium (d) (2/9), copper (d) (2/13), lead (d) (7/18), zinc (d) (3/18). Currently assessed as "Impaired" due to dissolved cadmium copper, lead and zinc exceedances. Placed on the Planning List due to arsenic exceedances and missing core parameters: *Escherichia coli*, total boron, total manganese, and turbidity/SSC. Surface Waterbody risk classification: • **Metals:** Extreme due to exceedances. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.

Subwatershed

Bishop Creek Subwatershed
HUC 1507010204

Combined Classification for Risk of Impairment:

- **Metals:** Low due to no exceedances.
- **Sediment:** Low due to no exceedances.
- **Organics:** Low due to no exceedances.
- **Selenium:** Low due to no exceedances.

Surface Waterbody	Water Quality Data: Sampling and Assessment Status[1,2,3]	
Agua Fria River from Sycamore Creek to Big Bug Creek ADEQ ID: 15070102-023 Two sampling sites at this surface waterbody.	Sampling	• **Metals:** cadmium (t) (d 1), chromium (t) (d 1), copper (t) (d 1), mercury (t) (d 1). • **Sediment:** total dissolved solids (1). • **Organics:** pH (1), nitrogen as ammonia (1), nitrogen as ammonia (1), n-kjeldahl (1), phosphorus (1). • **Selenium:** selenium (t) (d 1).
	Status	Parameters exceeding standards: None. Currently assessed as "Attaining All Uses." Surface Waterbody risk classification: • **Metals:** Low. • **Sediment:** Low. • **Organics:** Low. • **Selenium:** Low.

Subwatershed		
Agua Fria River – Lake Pleasant Subwatershed **HUC 1507010205** **Combined Classification for Risk of Impairment:** • **Metals:** Moderate due to limited data at Lake Pleasant. • **Sediment:** Moderate due to limited data at Lake Pleasant. • **Organics:** Moderate due to limited data at Lake Pleasant. • **Selenium:** Moderate due to limited data at Lake Pleasant.		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status**[1,2,3]	
Agua Fria River from Little Squaw Creek to Cottonwood Creek ADEQ ID: 15070102-017 One sampling site at this surface waterbody.	Sampling	• **Metals:** arsenic (t) (d),beryllium (t) (d),antimony (t) (d),cadmium (t) (d),chromium (t) (d),copper (t) (d),lead (t), manganese (t), mercury (t), zinc (t) (d), fluoride, boron. • **Sediment:** total dissolved solids, turbidity. • **Organics:** *E. coli*, pH, dissolved oxygen, nitrogen as ammonia, n-kjeldahl, nitrite/nitrate, phosphorus. • **Selenium:** selenium (t) (d).
	Status	Parameters exceeding standards: none. Currently assessed as "Attaining All Uses." Surface Waterbody risk classification: • **Metals:** Low. • **Sediment:** Low. • **Organics:** Low. • **Selenium:** Low.
Lake Pleasant ADEQ ID: 15070102-1100 Five sampling sites at this surface waterbody.	Sampling	• **Metals:** arsenic (t) (d 2), beryllium (t) (d 2), antimony (t) (d 2), cadmium (t) (d 2), chromium (t) (d 2), copper (t) (d 2), zinc (t) (d 2), lead (t) (d 2), manganese (t) (d 2), mercury (t) (d 2), fluoride, boron. • **Sediment:** turbidity, total dissolved solids. • **Organics:** *E. coli*, n-kjeldahl, phosphorus, nitrogen as ammonia, pH, dissolved oxygen, solvents. • **Selenium:** selenium (t) (d 2).

	Status	Parameters exceeding standards: ammonia (1/25), dissolved oxygen (1/38), pH (1/32), selenium (2/17). Currently assessed as "Attaining some uses" and placed on Planning List due to: 1. Ammonia exceedances. 2. Selenium exceedances. and 3. Missing core parameter: *Escherichia coli*. Surface Waterbody risk classification: • **Metals:** Moderate. • **Sediment:** Moderate. • **Organics:** Moderate. • **Selenium:** Moderate.

Subwatershed

Cave Creek – Arizona Canal Diversion Channel Subwatershed
HUC 1507010206

Combined Classification for Risk of Impairment:

- **Metals:** Moderate due to missing data at both Arizona Canal waterbodies.
- **Sediment:** Moderate due to missing data at both Arizona Canal waterbodies.
- **Organics:** Moderate due to missing data at both Arizona Canal waterbodies.
- **Selenium:** Moderate due to missing data at both Arizona Canal waterbodies.

Surface Waterbody	Water Quality Data: Sampling and Assessment Status[1,2,3]	
Cave Creek from headwaters to Cave Creek Dam ADEQ ID: 15060106B-026A Two sampling sites at this surface waterbody.	Sampling	• **Metals:** Cadmium, chromium, copper, arsenic (t), beryllium (t), lead (t), manganese (t), zinc (t), antimony (t), mercury (t) fluoride, boron,. • **Sediment:** turbidity, total dissolved solids. • **Organics:** nitrogen, phosphorus, dissolved oxygen, pH, E. coli, nitrogen as ammonia. • **Selenium:** selenium (t).
	Status	Parameters exceeding standards: none. Currently assessed as "Attaining All Uses". Surface Waterbody risk classification: • **Metals:** Low. • **Sediment:** Low. • **Organics:** Low. • **Selenium:** Low.

Arizona Canal from Granite Reef Dam to Cholla WTP ADEQ ID: 15060106B-099A Five sampling sites at this surface waterbody.	Sampling	• **Metals:** aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thorium, vanadium, zinc, anions, cations, fluoride. • **Sediment:** turbidity, total dissolved solids. • **Organics:** Nitrogen, nitrogen as ammonia, dissolved oxygen, pH, phosphorus, VOC. • **Selenium:** selenium.
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" and placed on the Planning List due to missing core parameters: total arsenic, total fluoride, and total metals (chromium, copper, lead, manganese and mercury). Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.
Arizona Canal from Cholla WTP to HUC Boundary ADEQ ID: 15060106B-099B One sampling site at this surface waterbody.	Sampling	• **Metals:** aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thorium, vanadium, zinc, anions, cations, fluoride. • **Sediment:** turbidity. • **Organics:** Nitrogen, nitrogen as ammonia, dissolved oxygen, pH, phosphorus, VOC, total dissolved solids. • **Selenium:** selenium.
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" and placed on the Planning List due to missing core parameters: field pH and total metals (copper, lead and manganese) Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.

Subwatershed		
Trilby Wash – Trilby Wash Basin Subwatershed **HUC 1507010207** **No data collected.** **Combined Classification for Risk of Impairment:** • **Metals:** Moderate due to lack of monitoring data. • **Sediment:** Moderate due to lack of monitoring data. • **Organics:** Moderate due to lack of monitoring data. • **Selenium:** Moderate due to lack of monitoring data.		

Subwatershed		
New River Subwatershed **HUC 1507010208** **Combined Classification for Risk of Impairment:** • **Metals:** Moderate due to missing and limited data at all waterbodies. • **Sediment:** Moderate due to missing and limited data at all waterbodies. • **Organics:** Moderate due to missing and limited data at all waterbodies. • **Selenium:** Moderate due to missing and limited data at all waterbodies.		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status[1,2,3]**	
New River from headwaters to Interstate 17 ADEQ ID: 15070102-006A One sampling site at this surface waterbody.	Sampling	• **Metals:** mercury (d 1), cadmium (d 1), copper (d 1). • **Sediment:** turbidity (1). • **Organics:** n-kjeldahl (1), nitrogen as ammonia (1), phosphorus (1), pH (1). • **Selenium:** Selenium (d 1).
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" due to insufficient monitoring data. Surface Waterbody risk classification: • **Metals:** Moderate due to limited data. • **Sediment:** Moderate due to limited data. • **Organics:** Moderate due to limited data. • **Selenium:** Moderate due to limited data.
Arizona Canal from Cholla WTP to HUC Boundary ADEQ ID: 15060106B-099B One sampling site at this surface waterbody.	Sampling	• **Metals:** aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thorium, vanadium, zinc, anions, cations, fluoride. • **Sediment:** turbidity, total dissolved solids. • **Organics:** nitrogen, nitrogen as ammonia, dissolved oxygen, VOC, pH, phosphorus. • **Selenium:** selenium.

	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" and placed on the Planning List due to missing core parameters: field pH and total metals (copper, lead and manganese) Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.
Grand Canal from HUC boundary 15070102 to New River ADEQ ID: 15070102-250 One sampling site at this surface waterbody.	Sampling	• **Metals:** dissolved only. • **Sediment:** none. • **Organics:** nutrients. • **Selenium:** none.
	Status	Parameters exceeding standards: none Currently assessed as "Inconclusive" and placed on Planning List due to missing core parameters: field pH and total metals (copper, lead and manganese) Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.

Subwatershed		
Agua Fria River below Lake Pleasant Subwatershed **HUC 1507010209** **Combined Classification for Risk of Impairment:** • **Metals:** Moderate due to missing data at all surface waterbodies. • **Sediment:** Moderate due to missing data at all surface waterbodies. • **Organics:** Extreme due to dissolved oxygen and pH exceedances at Cortez Park Lake. • **Selenium:** Moderate due to missing data at most waterbodies.		
Surface Waterbody	**Water Quality Data: Sampling and Assessment Status[1,2,3]**	
Arizona Canal from Granite Reef Dam to Cholla WTP ADEQ ID: 15060106B-099A Five sampling sites at this surface waterbody.	Sampling	• **Metals:** aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thorium, vanadium, zinc, anions, cations, fluoride. • **Sediment:** turbidity total dissolved solids. • **Organics:** Nitrogen, nitrogen as ammonia, dissolved oxygen, pH, VOC, phosphorus. • **Selenium:** selenium.
	Status	Parameters exceeding standards: none. Currently assessed as “Inconclusive” and placed on the Planning List due to missing core parameters: total arsenic, total fluoride, and total metals (chromium, copper, lead, manganese and mercury). Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.
Arizona Canal from Cholla WTP to HUC Boundary ADEQ ID: 15060106B-099B One sampling site at this surface waterbody.	Sampling	• **Metals:** aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, thorium, vanadium, zinc, anions, cations, fluoride. • **Sediment:** total dissolved solids, turbidity. • **Organics:** Nitrogen, nitrogen as ammonia, dissolved oxygen, pH, phosphorus, VOC. • **Selenium:** selenium.

	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" and placed on the Planning List due to missing core parameters: field pH and total metals (copper, lead and manganese) Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.
Buckeye Canal from Gila River to South Extension Canal ADEQ ID: 15070101-209 One sampling site at this surface waterbody.	Sampling	No current monitoring data or detailed information available. Past partial suites.
	Status	Parameters exceeding standards: none. Currently assessed as "Inconclusive" and placed on the planning list due to missing core parameters: total boron and total metals (copper, lead and manganese). Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.
Grand Canal from HUC boundary 15070102 to New River ADEQ ID: 15070102-250 One sampling site at this surface waterbody.	Sampling	• **Metals:** dissolved only. • **Sediment:** none. • **Organics:** nutrients. • **Selenium:** none.
	Status	Parameters exceeding standards: none Currently assessed as "Inconclusive" and placed on Planning List due to missing core parameters: field pH and total metals (copper, lead and manganese) Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Moderate due to missing data. • **Selenium:** Moderate due to missing data.

Cortez Park Lake 2 acres ADEQ ID: 15060106B-0410 Six sampling sites at this surface waterbody.	Sampling	• **Metals:** 2 total metals: arsenic, beryllium, cadmium, chromium, copper, lead, manganese, thallium, nickel, silver, zinc, antimony, mercury. • **Sediment:** turbidity (1). • **Organics:** nitrogen as ammonia, nitrogen, phosphorus, dissolved oxygen, pH, NO2 (1), NO3 (1). • **Selenium:** selenium.
	Status	Parameters exceeding standards: dissolved oxygen (5/25); pH (8/25). Currently assessed as "Impaired", and placed on Planning List due to: 1. Fish kill in 1999 related to an algal bloom. 2. Missing core parameters: *Escherichia coli*, total boron and total mercury. Surface Waterbody risk classification: • **Metals:** Moderate due to missing data. • **Sediment:** Moderate due to missing data. • **Organics:** Extreme due to dissolved oxygen and pH exceedances. • **Selenium:** Moderate.

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 is 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:
(d) = dissolved fraction of the metal or metalloid (after filtration), ug/L
(t) = total metal or metalloid (before filtration), ug/L
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: O2 (mg/L)
E. coli: Escherichia coli bacteria (CFU/100mL)
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.
nitrite/nitrate: 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: tds, (mg/L)
total solids: (t) Solids
total suspended solids: (t) Suspended Solids
turbidity: Measurement of suspended matter in water sample (NTU)
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.

Designated Uses:
AgI: Agricultural Irrigation. Surface water is used for the irrigation of crops.
AgL: Agricultural Livestock Watering. Surface water is used as a supply of water for consumption by livestock.
A&Ww: Aquatic and Wildlife Warm water Fishery. Surface water used by animals, plants, or other organisms (excluding salmonid fish) for habitation, growth, or propagation, generally occurring at elevations less than 5000 feet.
FC: Fish Consumption. Surface water is used by humans for harvesting aquatic organisms for consumption. Harvestable aquatic organisms include, but are not limited to, fish, clams, crayfish, and frogs.
FBC: Full Body Contact. Surface water use causes the human body to come into direct contact with the water to the point of complete submergence (e.g., swimming). The use is such that ingestion of the water is likely to occur and certain sensitive body organs (e.g., eyes, ears, or nose) may be exposed to direct contact with the water.

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, from http://www.azdeq.gov/environ/water/assessment/2004.html.

Appendix B - Selected References
Agua Fria Watershed

Arizona Department of Environmental Quality. 1998. Arizona Unified Watershed Assessment for the Clean Water Action Plan, Oct. 1, 1998.

Arizona Department of Environmental Quality. 1998. Arizona Water Quality Assessment 1998. Volume I – Assessment Process and Analysis, 101 pp. Volume II – Assessment Data and Standards, 159 pp.

Arizona Department of Transportation. 1993 (rev. 1994). Highway Drainage Design Manual Hydrology. Prepared by NBS/Lowry Engineers & Planners, Inc. and George V. Sabol Consulting Engineers, Inc. Res. Project No. HPR-PL-1-43(281).

Arizona Department of Water Resources. 1999. Third Management Plan, 2000-2010, Prescott Active Management Area, October 1999.

Baker, M.B., L.F. DeBano, and P.F. Ffolliott. 1997. Hydrologic Regimes in Chaparral on the Battle Flat Demonstration Area. Proceedings of the 1997 Meetings of the Hydrology Section, Arizona-Nevada Academy of Science. April 19, 1987, University of Nevada, Las Vegas, Nevada.

Barnett, L. O., Hawkins, R.H., Guertin, P.D. 2002. Reconnaissance Watershed and Hydrologic Analysis on the Upper Agua Fria Watershed. School of Renewable Natural Resources, University of Arizona, Tucson, Arizona.

Bureau of Land Management. 1993. Agua Fria, Arizona, Potential Wild and Scenic River Suitability Assessment. September, 1993. Phoenix District. Phoenix, Arizona.

Bureau of Reclamation. 1981. Inflow Design Flood Study, New Waddell Dam site, Agua Fria River, Arizona. Arizona Projects Office. Phoenix, Arizona. April, 1981.

Daly, C., Taylor, G.H., and Gibson, W.P. 1997. The PRISM approach to mapping precipitation and temperature. In reprints: 10th Conference on Applied Climatology, Reno, NV, American Meteorological Society, p. 10-12.

Dava and Associates. 2001. Yavapai County, Arizona General Plan, Phase 1, December 17, 2001. Yavapai County. Prescott, Arizona.

Dieterich, J.H. and A.R. Hibbert. 1988. Fire History in a Small Ponderosa Pine Stand Surrounded by Chaparral. In: Effects of fire management of southwestern natural resources: Proceedings of the Symposium, Nov. 15-17, 1988, Tucson, AZ. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, 1990. General technical report RM 191, pp. 168-173.

Enterline, Max. 2001. Watershed Restoration Action Strategy, Upper Agua Fria Watershed. Arizona Department of Environmental Quality.

Faust, A.E. 2003. Effect of the Choice of Pedotransfer Function on Recharge Estimates. M.S. Thesis, Hydrology and Water Resources, University of Arizona.

Freethey, G.W. and T.W. Anderson. 1986. Predevelopment Hydrologic Conditions in the Alluvial Basins of Arizona and Adjacent Parts of California and New Mexico. U.S. Geological Survey Hydrologic Investigations Atlas HA-664, scale 1:500,000, 3 sheets.

Halpenny, Leonard C. 1970. Effect of Cordes Lakes Development upon Streamflow in Agua Fria River. Water Development Company, Tucson, AZ. unpublished report.

Langenheim, V.E., DeWitt, E., Wirt, L. 2005. Preliminary Geophysical Framework of the Upper and Middle Verde River Watershed, Yavapai County, Arizona. U.S. Geological Survey, Open-File Report 2005-1154.

Lenart, Melanie. 2005. Will the Drought Continue? Southwest Climate Outlook. CLIMAS Feature Article. The University of Arizona, Tucson. Available online at http://www.ispe.arizona.edu/climas/forecasts/articles/wetspell_March2005.pdf

León, E. and Ferré, T. 2003. A Conceptual Model of Groundwater Flow in the Upper Agua Fria. Prepared in fulfillment of a Rural Watersheds Initiative Grant from the Arizona Department of Water Resources.

Littin, G.R. 1981. Maps Showing Ground-Water Conditions in the Agua Fria Areas, Yavapai and Maricopa Counties, Arizona. U.S. Geological Survey Water Resources Investigations Report, 81-0804, 2 sheets, scale 1:250,000.

Maxwell, K.D. and V.P. Holbrook. 2002. Pacific Decadal Oscillation and Arizona Precipitation. Western Regional Technical Attachment No. 02-08. National Oceanic & Atmospheric Administration. www.wrh.noaa.gov/wrh/02TAs/0208

McCain, R. G. 1976. Relationship Between Water Loss from Stream Channels and Gravity and Seismic Measurements: Beaver Creek Watershed 7, Coconino County, Arizona. M.S. Thesis, Northern Arizona University, Flagstaff, Arizona.

McPhee, J., A. Coomrie and G. Garfin. 2004. Drought and Climate in Arizona: Top Ten Questions & Answers. CLIMAS, The University of Arizona, Tucson. Available online at http://www.ispe.arizona.edu/climas/pubs/topten.html

Pope, G.L., P.D. Rigas and C.F. Smith. 1998. Statistical Summaries of Streamflow Data and Characteristics of Drainage Basins for Selected Streamflow-Gaging Stations in Arizona through Water Year 1996. U.S. Geological Survey Water Resources Investigations Report 98-4225.

Prescott National Forest. 2001. Watershed Condition Assessment for Select Verde River 5th Code Watersheds. Prepared to address critical habitat for spikedace and loach minnow. Prescott National Forest, Prescott, Arizona.

Rosebrook, J.J. and J.S. Rosebrook. 1994. "The Old Black Canyon Highway", Arizona Highways, August 1994, pp. 5-11, as quoted in Cordes Lakes/Spring Valley/Highway 69 Corridor Community Plan, page 2.

Scott, P.S. 1994. Basic Geologic and Hydrologic Information, Bradshaw Mountains, Yavapai County, Arizona. Arizona Geological Survey Open-File Report 94-2.

Scholtz, J.F. 1969. Investigation of Low-Stage Transmission Losses in Stream Channels on Watersheds 7, 9, 11, and 12, Beaver Creek Experimental Drainage Basin, Coconino County, Arizona. Submitted to Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.

Schuyler, J.D. 1903. Report on the Water Supply of the Agua Fria River, and the Storage Reservoir Project of The Agua Fria Water and Land Company for Irrigation in the Gila River Valley, Arizona. Hayden Arizona Historical Foundation, Arizona State University, Tempe, Arizona.

Sellers, W.D. and Hill, R.H., eds. 1974. Arizona Climate 1931-1972. University of Arizona Press, Tucson, AZ. 616 pp.

U.S. Army Corps of Engineers. 1988. Hydrology for Evaluation of Flood Reduction by New Waddell Dam, Agua Fria River below New Waddell Dam to the New River Confluence. U.S. Army Engineer District, Los Angeles, California. Sept. 1988.

Ward, M.B. 1977. The Volcanic Geology of the Castle Hot Springs Area, Yavapai County, Arizona. M.S. Thesis, Arizona State University, Tempe, Arizona. 74 pp.

Wilson, B.M. 1990. Crown King and the Southern Bradshaws: A Complete History. Crown King Press. Mesa, Arizona.

Wilson, R.P. 1988. Water Resources of the Northern Part of the Agua Fria Area Yavapai County, Arizona. Prepared by the U.S. Geological Survey. Arizona Department of Water Resources Bulletin 5.

Yavapai County. 1986. Black Canyon City Community Plan Update. Prepared by Yavapai County Planning staff with participation by Black Canyon City Advisory Committee.

Yavapai County Planning and Building Department. 1995. Cordes Lakes/Spring Valley/Highway 69 Corridor Community Plan. Yavapai County.

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.

References:

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook No. 703. USDA, Washington D.C.

Van Remortel, R. 2004. Soil & Landform Metrics: Programs and U.S. Geodatasets Version 1.1. Environmental Protection Agency. Las Vegas, NV.

Data Sources*:

U.S. Department of Agriculture, Natural Resources Conservation Service.
Major Land Resource Area Map, National Land Cover Dataset (NLCD). July 15, 2003. ftp-fc.sc.egov.usda.gov/NHQ/pub/land/arc_export/us48mlra.e00.zip

State Soils Geographic (STATSGO) Dataset. April 17, 2003. http://www.ncgc.nrcs.usda.gov/branch/ssb/products/statsgo/

U.S. Geological Survey.
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: Southwest GAP Analysis Project Regional Provisional Land Cover dataset. September, 2004. http://earth.gis.usu.edu/swgap/

- 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.

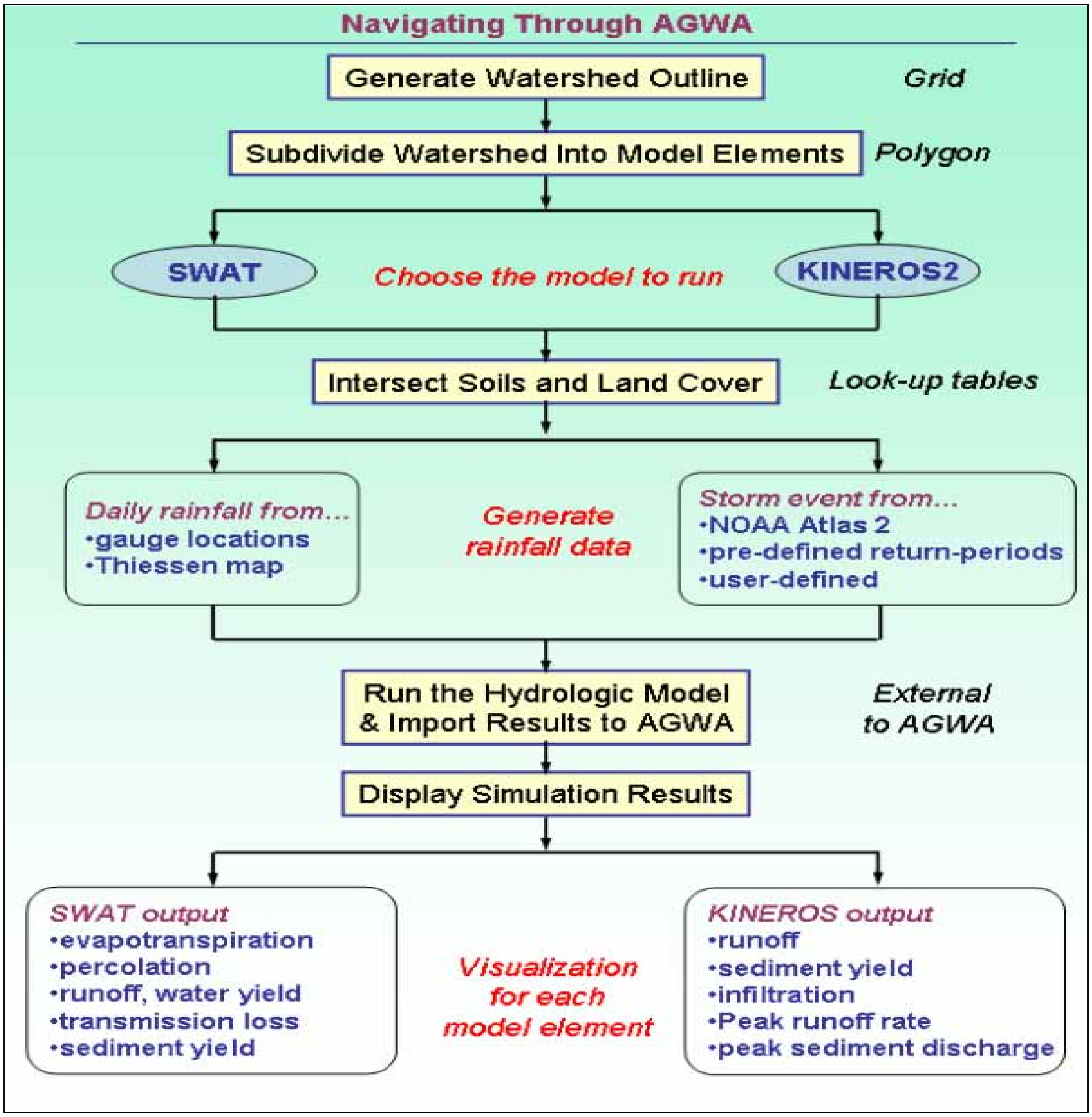


Figure D-1: Flow chart showing the general framework for using KINEROS2 and SWAT in AGWA.

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.

<u>References:</u>

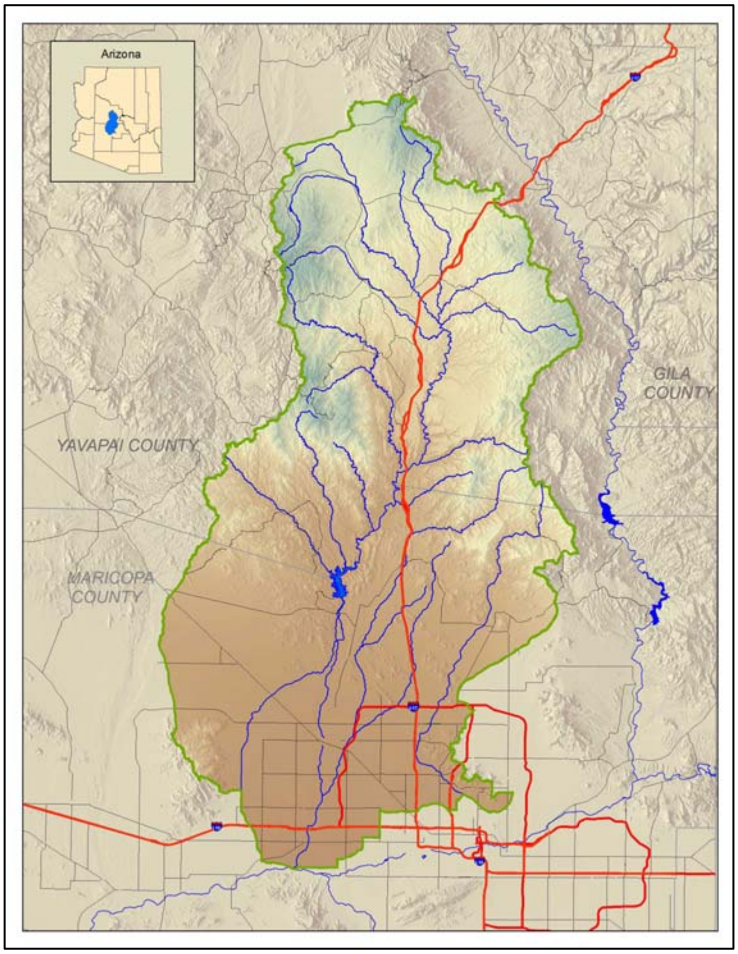
Arnold, J.G., J. R. Williams, R. Srinivasan, K.W. King, and R. H. Griggs. 1994. SWAT-Soil & Water Assessment Tool. USDA, Agricultural Research Service, Grassland, Soil and Water Research Laboratory, Temple, Texas.

Burns, I.S., S. Scott, L. Levick, M. Hernandez, D.C. Goodrich, S.N. Miller, D.J. Semmens, and W.G. Kepner. 2004. Automated Geospatial Watershed Assessment (AGWA) - A GIS-Based Hydrologic Modeling Tool: Documentation and User Manual *Version 1.4*. http://www.tucson.ars.ag.gov/agwa/

RS/GIS Laboratory, 2004. Southwest Gap Regional Provisional Landcover. http://earth.gis.usu.edu/swgap
Land cover / land use. Sept. 24, 2004.

Williams, J.R. 1969. Flood routing with variable travel time or variable storage coefficients. Trans. ASAE 12(1):100-103.

Agua Fria River Watershed – Arizona
Rapid Watershed Assessment
April 2007



Prepared by:
USDA Natural Resource Conservation Service – Arizona
University of Arizona, Water Resources Research Center

In cooperation with:
Arizona Association of Conservation Districts
Arizona Department of Agriculture
Arizona Department of Environmental Quality
Arizona Department of Water Resources
Arizona Game & Fish Department
Arizona State Land Department
USDA Forest Service
USDI Bureau of Land Management

Released by:

Sharon Megdal
Director
University of Arizona
Water Resources Research Center

David McKay
State Conservationist
U.S. Department of Agriculture
Natural Resources Conservation Service

Principle Investigators:

Dino DeSimone – Natural Resources Conservation Service, Phoenix, Arizona
Keith Larson – Natural Resources Conservation Service, Phoenix, Arizona
Kristine Uhlman – Water Resources Research Center, University of Arizona
D. Phil Guertin – School of Natural Resources, University of Arizona
Deborah Young – Associate Director, Cooperative Extension, University of Arizona

Agua Fria River – 15070102
8-Digit Hydrologic Unit
Rapid Watershed Assessment

Section 1: Introduction

Overview of Rapid Watershed Assessments

A Rapid Watershed Assessment (RWA) is a concise report containing information on natural resource conditions and concerns within a designated watershed. The "rapid" part refers to a relatively short time period to develop the report as compared to a more comprehensive watershed planning effort. The "assessment" part refers to a report containing maps, tables and other information sufficient to give an overview of the watershed and for use as a building block for future planning. RWAs look at physical and socioeconomic characteristics and trends, as well as current and future conservation work.

The assessments involve the collection of readily available quantitative and qualitative information to develop a watershed profile, and sufficient analysis of that information to generate an appraisal of the conservation needs of the watershed. These assessments are conducted by conservation planners, using Geographic Information System technology, assessing current levels of resource management, identifying priority resource concerns, and making estimates of future conservation work. Conservation Districts and other local leaders, along with public land management agencies, are involved in the assessment process.

An RWA can be used as a communication tool between the Natural Resources Conservation Service (NRCS) and partners for describing and prioritizing conservation work in selected watersheds. RWAs provide initial estimates of conservation investments needed to address the identified resource concerns in the watershed. RWAs serve as a platform for conservation program delivery, provide useful information for development of NRCS and Conservation District business plans, and lay a foundation for future watershed planning.

General Description of the Agua Fria River Watershed

The Agua Fria River Watershed is located in the central portion of the state of Arizona, southeast of the city of Prescott, and north of Phoenix. (Figure 1-1). The watershed can be defined as the area drained by the Agua Fria River to the confluence with the Gila River west of the Phoenix metropolitan area near Avondale. The watershed comprises 1.79 million acres (2,785 square miles), and is located 51% in Yavapai County and 49% in Maricopa County. Thirty-eight percent of the land is managed by BLM, 30% is State Trust Land, 16% is private land, 9% is managed by the Forest Service, 5% is USFS & BLM wilderness areas, and 3% is state park land.

The watershed includes the Cities of Avondale, Carefree, Cave Creek Glendale, Peoria, and Prescott Valley. There are two U.S. Department of Agriculture (USDA) Service Centers located in Avondale and Prescott Valley. Conservation assistance is provided through seven Natural Resource

Conservation Districts: Chino Winds, Verde, Tonto, East Maricopa, Agua Fria-New River, Wickenberg, and Buckeye Valley (Figure 1-1).

The area is mostly rangeland with a mixture of cropland and urban development. The watershed's one large lake, Lake Pleasant, is used for water storage and recreation. Rangeland and most forestlands are grazed year around by cattle, except at lower elevations where grazing is seasonal with stocker cattle in years with good winter-spring rainfall.

Irrigation land is used for cotton, alfalfa, barley, and other small grains. Where water supply is available, lettuce, carrots, cabbage, cauliflower, melons, among other market vegetables, and citrus are grown. Land available for cultivation is being encroached upon by rapid urbanization in the larger communities.

Resource concerns in the watershed include soil erosion, excessive runoff (causing flooding or ponding), aquifer overdraft, contaminants in surface and ground water, air quality, declining threatened plant & animal species, invasive plants, and fish & wildlife habitat degeneration.

Section 2: Physical Description

The Agua Fria River Watershed in Arizona is defined as the area drained by the Agua Fria River to the confluence with the Gila River west of the Phoenix metropolitan area near Avondale. The watershed is located in the central part of the state, from the western part of Phoenix, north to the Prescott area.

Watershed Size

The Agua Fria River Watershed covers approximately 2,784 square miles, representing about 2.4% of the state of Arizona. The watershed has a maximum approximate width of 46 miles east-west, and a maximum length of 90 miles north-south.

The Agua Fria River Watershed was delineated by the U.S. Geological Survey and has been subdivided by the NRCS into smaller watersheds or drainage areas. Each drainage area has a unique hydrologic unit code (HUC) number and a name based on the primary surface water feature within the HUC. These drainage areas can be further subdivided into even smaller watersheds as needed. The Agua Fria has an 8-digit HUC of 15070102 and contains the following 10-digit HUCs:

- 1507010201 (Ash Creek and Sycamore Creek);
- 1507010202 (Big Bug Creek-Agua Fria River);
- 1507010203 (Black Canyon Creek);
- 1507010204 (Bishop Creek);
- 1507010205 (Agua Fria River-Lake Pleasant), 1507010206 (Cave Creek-AZ Canal Diversion Channel), 1507010207 (Trilby Wash-Trilby Wash Basin);
- 1507010208 (New River); and,
- 1505010209 (Agua Fria River below Lake Pleasant, Figure 1-2).

Geology

The Agua Fria River Watershed is characterized by a narrow, rugged valley rising up from the desert floor of the Phoenix Basin, steadily gaining in elevation as the watershed extends up and over a lava plateau and to the edge of the southern boundary of the Verde River Watershed. The geology of the watershed is complex, varying widely in age, rock-type, and structure (Figure 2-1).

The Agua Fria Valley is formed by erosion of the Bradshaw Mountains. Subsidence along this zone eventually caused both the Verde River to the north and west, and the Agua Fria, to stop flowing, forming a series of ancient lakes and deposition of lake sediments.

Damming of the Agua Fria also occurred due to multiple lava flows which originated from a source to the northeast. The mountains and ridges that border the watershed are composed of metamorphic rocks (rocks that undergo change due to extreme heat or pressure) which form mountains in the southern portion of the watershed; mesas to the east; and the Bradshaw Mountains to the west. The central portion of the valley consists of stream deposits of sand, silt and gravel with stream-rounded pebbles and lava flows, commonly lying on soil zones baked by the heat of the flowing lava.

The rocks consist primarily of granite that weathers to rounded boulders and knobs, and flaky, silvery rocks. Flat-lying layers of whitish limestone, siltstone, and water-laid volcanic ash are found in lake sediments, and lava flows cap the higher mesas. Near Cordes Junction, loosely consolidated stream and lake deposits are capped with volcanic rock, and a lava plateau forms the drainage divide between Turkey Creek (an Agua Fria tributary) and the Verde River Watershed to the west (Chronic, 1983).

Sunset Point Rest Area on Interstate Route 17 looks down on Black Canyon, named for the dark metamorphic rocks that give it its name. The Bradshaw Mountains are walled with the same rock but also is composed of a larger mass of granite.

Along the edge of the Mogollon Rim (the boundary of the Colorado Plateau Highlands), lava flows cascaded from the plateau surface, draining and forming poorly drained, nearly flat-lying mesas in the eastern margin of the Agua Fria.

Figure 2-1 shows the geology of the Agua Fria River Watershed,

Soils

Soils within the Agua Fria River Watershed are diverse and formed as the result of differences in climate, vegetation, geology, and physiography.

Detailed soils information for the watershed is available from the Natural Resources Conservation Service (NRCS) and the U.S. Forest Service (USFS). The USFS maintains Terrestrial Ecosystem Surveys on National Forest Lands within the watershed. Lands outside of National Forests are included within the following NRCS Soil Surveys: “Soil Survey of Yavapai County, AZ, Western Part”; “Soil Survey of the Black Hills-Sedona Area, AZ, Parts of Coconino and Yavapai Counties”; “Soil Survey of Maricopa County, AZ, Central Part”; “Soil Survey of Eastern Maricopa and Northern Pinal Counties Area, AZ”; and “Soil Survey of Aguila-Carefree Area, AZ, Parts of Maricopa and Pinal Counties, AZ.” Soils data and maps from these Soil Surveys can be accessed through the NRCS Web Soil Survey website: http://websoilsurvey.nrcs.usda.gov.

Common Resource Areas

The USDA, Natural Resources Conservation Service (NRCS) defines a Common Resource Area (CRA) as a geographical area where resource concerns, problems, or treatment needs are similar (NRCS 2006). It is considered a subdivision of an existing Major Land Resource Area (MLRA). Landscape conditions, soil, climate, human considerations, and other natural resource information are used to determine the geographic boundaries of a Common Resource Area.

The Agua Fria River Watershed is comprised of 6 Common Resource Areas (Figure 2-2 and Table 2-1).

Beginning at the lower end of the watershed, CRA 40.3 "Colorado Sonoran Desert" occurs at elevations ranging from 300 to 1200 feet. Precipitation averages 3 to 7 inches per year. Vegetation includes creosotebush, white bursage, brittlebush, Mormon tea, teddybear cholla, elephant tree, smoke tree, ocotillo, and big galleta. The soils in the area have a hyperthermic soil temperature regime and a typic aridic soil moisture regime. The dominant soil orders are Aridisols and Entisols. Deep, stratified, coarse to fine-textured soils occur on floodplains and alluvial fans. Deep, medium and moderately coarse-textured limy soils occur on fan terraces.

CRA 40.2 "Middle Sonoran Desert" occurs at slightly higher elevations, ranging from 1200 to 2000 feet with precipitation averaging 7 to 10 inches per year. Vegetation includes saguaro, palo verde, creosotebush, triangle bursage, brittlebush, prickly pear, cholla, desert saltbush, wolfberry, bush muhly, threeawns, and big galleta. The soils in the area have a hyperthermic soil temperature regime and a typic aridic soil moisture regime. The dominant soil orders are Aridisols and Entisols. Deep, stratified, coarse to fine-textured soils occur on floodplains and alluvial fans. Deep, moderately fine and fine-textured and gravelly, moderately fine-textured soils occur on fan terraces. Shallow to a hardpan, limy, gravelly, medium and moderately coarse-textured soils occur on fan terraces. Shallow, very gravelly and cobbly, moderately coarse to moderately fine-textured soils and rock outcrop occur on hills and mountains.

CRA 40.1 "Upper Sonoran Desert" occurs at elevations ranging from 2000 to 3200 feet with precipitation averaging 10 to 13 inches per year. Vegetation includes saguaro, palo verde, mesquite, creosotebush, triangle bursage, prickly pear, cholla, wolfberry, bush muhly, threeawns, ocotillo, and globe mallow. The soils in the area have a thermic soil temperature regime and a typic aridic soil moisture regime. The dominant soil orders are Aridisols and Entisols. Shallow, cobbly and gravelly soils and rock outcrop occur on hills and mountains. Deep, gravelly, medium to fine-textured soils occur on fan terraces.

These three Common Resource Areas (40.3, 40.2 and 40.1) occur within the Basin and Range Physiographic Province which is characterized by numerous mountain ranges rising abruptly from broad, plain-like valleys and basins. Igneous and metamorphic rock classes dominate the mountain ranges and sediments filling the basins represent combinations of fluvial, lacustrine, colluvial and alluvial deposits.

Table 2-1: Agua Fria River Watershed - Common Resource Areas

Common Resource Area Type	Area (sq. mi.)	Percent of Watershed
40.3 Colorado Sonoran Desert	**97.30**	**3.5**
40.2 Middle Sonoran Desert	**935.84**	**33.6**
40.1 Upper Sonoran Desert	**374.64**	**13.5**
38.1 Lower Interior Chaparral	**1,299.05**	**46.6**
38.2 Interior Chaparral – Woodlands	**23.97**	**0.8**
35.1 Colorado Plateau Mixed Grass Plains	**54.37**	**1.9**

Data Sources: GIS map layer "cra". Arizona Land Information System (ALRIS 2004). Natural Resource Conservation Service (NRCS 2006)

Moving up the watershed, CRA 38.1 "Lower Interior Chaparral" occurs at elevations ranging from 3000 to 4500 feet. Precipitation averages 12 to 16 inches per year. Vegetation includes canotia, one-seed juniper, mesquite, catclaw acacia, jojoba, turbinella oak, ratany, shrubby buckwheat, algerita, skunkbush, tobosa, vine mesquite, bottlebrush squirreltail, grama species, curly mesquite, desert needlegrass and New Mexico feathergrass. The soils in the area have a thermic soil temperature regime and an ustic aridic moisture regime. The dominant soil orders are Aridisols and Mollisols. Shallow, gravelly and cobbly, moderately coarse to moderately fine-textured soils and rock outcrop occur on hills and mountains. Shallow to deep, gravelly, cobbly and stony, fine-textured soils occur on basaltic plains, mesas and hills. Deep, gravelly, medium to fine-textured soils occur on fan terraces.

CRA 38.2 "Interior Chaparral – Woodlands" occurs at elevations ranging from 4000 to 5500 feet with precipitation averaging 16 to 20 inches per year. Vegetation includes turbinella oak, hollyleaf buckthorn, desert buckbrush, one-seed juniper, alligator juniper, pinyon, algerita, sugar sumac, prairie junegrass, blue grama, curly mesquite, bottlebrush squirreltail, muttongrass, cane beardgrass, plains lovegrass and bullgrass. The soils in the area have a thermic to mesic soil temperature regime and an aridic ustic soil moisture regime. The dominant soil orders are Alfisols and Mollisols. Moderately deep and deep, gravelly and cobbly, moderately coarse to fine-textured soils occur on mountains.

These two Common Resource Areas (38.1 and 38.2) occur within the Transition Zone Physiographic Province which is characterized by canyons and structural troughs or valleys. Igneous, metamorphic and sedimentary rock classes occur on rough mountainous terrain in association with less extensive sediment filled valleys.

At the upper end of the watershed occurs CRA 35.1 "Colorado Plateau Mixed Grass Plains" with eelevations ranging from 5100 to 6000 feet. Precipitation averages 10 to 14 inches per year. Vegetation includes Stipa species, Indian ricegrass, galleta, and blue grama, fourwing saltbush, winterfat, and cliffrose. The soils in the area have a mesic soil temperature regime and an ustic aridic soil moisture regime. The dominant soil orders are Aridisols and Entisols. Deep, gravelly, moderately fine and fine-textured soils occur on floodplains and valley slopes and plains. Shallow, gravelly, medium-textured and deep, medium and moderately fine-textured soils occur on plains and hills.

CRA 35.1 occurs within the Colorado Plateau Physiographic Province which is characterized by a sequence of flat to gently dipping sedimentary rocks eroded into plateaus, valleys and deep canyons. Sedimentary rock classes dominate the plateau with volcanic fields occurring for the most part near its margin.

Slope Classifications

Slope, as well as soil characteristics and topography, are important when assessing the vulnerability of a watershed to erosion. Approximately 42.6% of the Agua Fria Watershed has a slope greater than 15%, while 39.1% of the watershed has a slope less than 5%. The Agua Fria River Watershed below Lake Pleasant watershed is relatively flat, with only 11.6% of its area over 15% slope, and 80.1% less than 5% slope. The Black Canyon Creek and Agua Fria – Lake Pleasant watersheds are relatively steep, with 74.7% and 77.9% of the area greater than 15% slope, respectively (Table 2-2 and Figure 2-3).

Table 2-2: Agua Fria River Watershed Slope Classifications.

Watershed Name	Area (sq. mi.)	Percent Slope		
		0-5%	5-15%	>15%
Ash Creek and Sycamore Creek 1507010201	261	15.1	34.2	50.7
Big Bug Creek-Agua Fria River 1507010202	324	22.3	31.1	46.6
Black Canyon Creek 1507010203	244	7.4	17.9	74.7
Bishop Creek 1507010204	236	18.1	24.2	57.7
Agua Fria River-Lake Pleasant 1507010205	372	6.2	15.9	77.9
Cave Creek-Arizona Canal Diversion Channel 1507010206	288	51.0	14.7	34.2
Trilby Wash-Trilby Wash Basin 1507010207	242	71.1	10.9	18.0
New River 1507010208	353	56.9	15.3	27.8
Agua Fria River below Lake Pleasant 1507010209	464	80.1	8.3	11.6
Agua Fria River Watershed	2,784	39.1	18.4	42.6

Data Sources: Derived from DEM, obtained from U.S. Geological Survey, April 8, 2003 http://edc.usgs.gov/geodata/

Streams, Lakes and Gaging Stations

The locations of active and inactive gaging stations, and their respective annual mean stream flow, are found in Table 2-3.1. Agua Fria River near Rock Springs has the largest annual stream flow with 78.80 cfs. Skunk Creek near Phoenix has the lowest annual stream flow with 1.48cfs. Table 2.3.2 lists major lakes and reservoirs in the Agua Fria River Watershed, as well as their watershed position, surface area, elevation and dam name. Trilby Wash Basin and Lake Pleasant are the largest surface waters with areas of 2,068 and 2,042 acres respectively. The next largest water body is Fain Lake which covers 1,015 acres. Table 2-3.3 lists the major streams and their lengths. Stream lengths range from 167.6 miles for Agua Fria to 29.0 miles for Big Bug Creek (Figure 2-4).

Riparian Vegetation

The Arizona Game & Fish Department has identified and mapped riparian vegetation associated with perennial waters in response to the requirements of the state Riparian Protection Program (July 1994). This map was used to identify riparian areas in the Agua Fria Watershed (Figure 2-5).

Seven of the ten types of riparian areas occur within this watershed. Riparian areas encompass approximately 1,715 acres (2.7 sq. mi.) or 0.04% of the entire watershed. Mixed Broadleaf comprises about 1,025 acres (1.6 sq. mi., or 59.8%) of the riparian areas, and Strand (the area alongside the stream channel, or shore) comprises about 337.9 acres (0.53 sq. mi., or 19.7%).

The Ash Creek and Sycamore Creek watershed has the greatest amount of riparian vegetation with about 577 acres (0.90 square miles). The Bishop Creek and Agua Fria – Lake Pleasant watersheds also have large amounts of riparian vegetation with 421 acres (0.66 sq. mi.) and 338 acres (0.51 sq. mi.) respectively. The Trilby Wash-Trilby Wash Basin and New River watersheds have no riparian vegetation associated with perennial waters. Table 2-4 lists riparian vegetation types and areas for each watershed.

Table 2-3.1: Agua Fria River Watershed USGS Stream Gages and Annual Mean Stream Flow.

USGS Gage ID	Site Name	Begin Date	End Date	Annual Mean Stream Flow (cfs)
	Active Gages			
9512280	Cave Creek Below Cottonwood Creek near Cave Creek	1981	2005	6.57
9512450	Agua Fria River near Humboldt	1/1/2001	12/30/2004	3.89
9512500	Agua Fria River near Mayer	1/1/1940	12/30/2004	22.25
9512800	Agua Fria River near Rock Springs	1/1/1971	12/30/2004	78.89
9513780	New River near Rock Springs	1/1/1966	12/30/2004	12.06
9513860	Skunk Creek, near Phoenix	1/1/1968	12/30/2004	1.48
	Inactive Gages			
9512300	Cave Creek near Cave Creek	1959	1967	4.07
9512400	Cave Creek at Phoenix	1990	1991	3.17
9512495	Perry Canal near Mayer	1/1/1941	12/30/1958	0.45
9512501	Sycamore Dam Site Total *	1/1/1941	12/30/1959	24.09
9512501	Sycamore Dam Site Total *	1/1/1978	12/30/1980	85.3
9512600	Turkey Creek near Cleator	1/1/1980	12/30/1991	11.26
9512830	Boulder Creek near Rock Springs	1/1/1984	12/30/1992	3.25
9512970	Cottonwood Creek near Waddell Dam	1/1/1984	12/30/1992	0.35
9513000	Agua Fria River at Waddell Dam	1/1/1915	12/30/1918	320.87
9513500	Lake Pleasant at Waddell Dam	N/A	N/A	N/A
9513650	Agua Fria River at El Mirage	1/1/1994	12/30/1997	0.085
9513700	Agua Fria River Tributary at Youngtown	1/1/1962	12/30/1967	0.016
9513800	New River at New River	1/1/1961	12/30/1981	13.96
9513835	New River at Bell Road, near Peoria *	1/1/1968	12/30/1983	11.31
9513835	New River at Bell Road, near Peoria *	1/1/1991	12/30/1992	7.78
9513910	New River near Glendale *	1/1/1965	12/30/1969	11.19
9513910	New River near Glendale *	1/1/1991	12/30/1997	32.41
9513970	Agua Fria River at Avondale	1/1/1968	12/30/1981	35.25

**Discontinuous years of data*
Data Sources: USGS website, National Water Information System
http://waterdata.usgs.gov/nwis/

Table 2-3.2: Agua Fria River Watershed Major Lakes and Reservoirs.

Lake Name (if known)	Watershed	Surface Area (acre)	Elevation (feet above mean sea level)	Dam Name (if known)
Trilby Wash Basin	Trilby Wash-Trilby Wash Basin	2,068	1,348	McMicken Dam
Lake Pleasant	Agua Fria River-Lake Pleasant	2,042	1,570	Carl Pleasant Dam
Fain Lake	Big Bug Creek-Agua Fria River	1,015	4,600	not known
Flood Pool for White Tanks #3 Flood Retarding Structure	Agua Fria River below Lake Pleasant	261	1,202	White Tanks #3 Flood Retarding Structure
Hank Raymond Lake	Agua Fria River below Lake Pleasant	78	1,438	Camp Dyer Diversion Dam
Lynx Lake	Big Bug Creek-Agua Fria River	49	5,532	Lynx Lake Dam
Dawn Lake	New River	36	1,160	not known
Viewpoint Lake	New River	32	1159	not known
Lake Bonita	Agua Fria River below Lake Pleasant	29	1,409	not known
Caterpillar Tank	Agua Fria River below Lake Pleasant	12	1,535	not known
Layton Tank	Agua Fria River-Lake Pleasant	8	2,786	not known
Mesa Reservoir	Big Bug Creek-Agua Fria River	6	5,108	Mesa Reservoir Dam

Data Sources: GIS data layer "Lakes", Arizona State Land Department, Arizona Land Resource Information System (ALRIS), February 7, 2003 http://www.land.state.az.us/alris/index.html

Table 2-3.3: Agua Fria River Watershed Major Streams and Lengths.

Stream Name	Watershed	Stream Length (miles)
Agua Fria River	Agua Fria River below Lake Pleasant; Agua Fria River-Lake Pleasant; Ash Creek and Sycamore Creek; Big Bug Creek-Agua Fria River; Bishop Creek	167.6
New River	New River	58.7
Cave Creek	Cave Creek-Arizona Canal Diversion Channel	45.6
Ash Creek	Ash Creek and Sycamore Creek	39.7
Beardsley Canal	Agua Fria River below Lake Pleasant	30.6
Castle Creek	Agua Fria River-Lake Pleasant	30.4
Skunk Creek	Bishop Creek	30.4
Trilby Wash	Trilby Wash-Trilby Wash Basin	30.3
Turkey Creek	Black Canyon Creek	30.2
Big Bug Creek	Big Bug Creek-Agua Fria River	29.0

Data Sources: GIS data layer "Streams", Arizona State Land Department, Arizona Land Resource Information System (ALRIS), October, 10, 2002. http://www.land.state.az.us/alris/index.html

Table 2-4: Agua Fria River Watershed Riparian Vegetation (acres) by 10-digit Watershed (Part 1 of 2).

Riparian Vegetation Community	Ash Creek and Sycamore Creek 1507010201	Big Bug Creek-Agua Fria River 1507010202	Black Canyon Creek 1507010203	Bishop Creek 1507010204	Agua Fria River-Lake Pleasant 1507010205
Conifer Oak	-	1.78	-	-	-
Cottonwood Willow	-	-	-	-	2.16
Flood Scoured	-	2.58	-	9.94	148.03
Mesquite	-	93.85	0.26	6.99	83.43
Mixed Broadleaf	545.52	82.34	-	355.79	17.76
Strand	31.63	55.29	-	48.10	86.30
Tamarisk	-	-	-	-	-
Total Area (acres)	577.15	235.85	0.26	420.84	337.67

Table 2-4: Agua Fria River Watershed Riparian Vegetation (acres) by 10-digit Watershed (Part 2 of 2).

Riparian Vegetation Community	Cave Creek-Arizona Canal Diversion Channel 1507010206	Trilby Wash-Trilby Wash Basin 1507010207	New River 1507010208	Agua Fria River below Lake Pleasant 1507010209	Agua Fria River Watershed
Conifer Oak	-	-	-	-	1.78
Cottonwood Willow	1.13	-	-	-	3.29
Flood Scoured	-	-	-	-	160.56
Mesquite	-	-	-	-	184.53
Mixed Broadleaf	24.11	-	-	-	1025.53
Strand	-	-	-	116.60	337.93
Tamarisk	-	-	-	1.07	1.07
Total Area (acres)	25.24	0.00	0.00	117.67	1714.68

Data Sources: GIS data layer "natveg", Arizona State Land Department, Arizona Land Resource Information System (ALRIS), June 12, 2003 http://www.land.state.az.us/alris/index.html

Land Cover

The Riparian Vegetation map (Figure 2-5) and Land Cover map (Figure 2-6) were created from the Southwest Regional Gap Analysis Project land cover map (Lowry et. al, 2005).

The Land Cover map, and Table 2-5, show 10 different land cover types are found within the watershed, including vegetation communities, developed land, open water, and agriculture. The most common land cover type over the entire watershed is Sonoran Paloverde Mixed Cacti Desert Scrub encompassing 21.59% of the watershed. The next most common types are Developed, Medium-High Intensity (14.18%), Mogollon Chaparral (12.94%), and Sonora-Mojave Creosote bush – White Bursage Desert Scrub (10.65%).

Note: There are a total of 26 GAP vegetation categories present within the Agua Fria River Watershed boundary. Some of these categories occur only in small concentrations, and are not visible at the small scale in which the maps are displayed. It was decided that some of the vegetation categories would be logically grouped in order to increase the legibility of the map. In collaboration with NRCS, Project NEMO staff were able to create a total of 10 grouped GAP vegetation categories.

Table 2-5: Agua Fria River Watershed Southwest Regional GAP Analysis Project Land Cover, Percent of 10-digit Watershed (Part 1 of 2).

Watershed / Land Cover	Ash Creek and Sycamore Creek 1507010201	Big Bug Creek-Agua Fria River 1507010202	Black Canyon Creek 1507010203	Bishop Creek 1507010204	Agua Fria River-Lake Pleasant 1507010205
Agriculture*	0.10%	0.30%	--	--	--
Apacherian-Chihuahuan Grassland and Mesquite Scrub	22.95%	23.18%	24.38%	42.23%	*11.14%*
Developed	0.58%	9.56%	0.61%	1.53%	*0.36%*
Madrean Pine Oak Woodland	3.30%	5.80%	11.50%	2.15%	*1.71%*
Madrean Pinyon-Juniper Woodland	42.72%	25.33%	7.81%	19.06%	*1.80%*
Mogollon Chaparral	26.59%	27.11%	31.46%	23.01%	*18.35%*
Open Water		0.03%			*3.81%*
Rocky Mountain Ponderosa Pine Woodland	3.41%	8.50%	6.41%	0.43%	*0.57%*
Sonora-Mojave Desert Scrub	0.03%	0.04%	17.81%	0.09%	*0.25%*
Sonoran Desert Scrub	0.32%	0.16%	0.02%	11.51%	*62.02%*
Area (Sq.mi.)	260.56	324.13	244.06	236.44	371.83

Not necessarily irrigated land.

Table 2-5: Agua Fria River Watershed Southwest Regional GAP Analysis Project Land Cover, Percent of10-digit Watershed (Part 2 of 2)

Watershed / Land Cover	Cave Creek-Arizona Canal Diversion Channel 1507010206	Trilby Wash – Trilby Wash Basin 1507010207	New River 1507010208	Agua Fria River below Lake Pleasant 1507010209	Percent Of Total
Agriculture*	--	--	1.08%	21.90%	3.84%
Apacherian-Chihuahuan Grassland and Mesquite Scrub	8.80%	0.12%	5.79%	33.65%	13.68%
Developed	43.51%	2.21%	27.06%	--	15.15%
Madrean Pine Oak Woodland	1.25%	--	0.65%	--	2.61%
Madrean Pinyon-Juniper Woodland	9.16%	0.18%	7.46%	--	11.38%
Mogollon Chaparral	4.14%	0.47%	3.66%	--	13.72%
Open Water	0.03%	--	0.09%	--	0.54%
Rocky Mountain Ponderosa Pine Woodland	--	--	--	--	1.98%
Sonora-Mojave Desert Scrub	5.01%	45.13%	15.84%	17.29%	9.40%
Sonoran Desert Scrub	28.10%	51.90%	38.36%	27.17%	27.72%
Area (Sq.mi.)	288.39	242.17	353.18	464.30	2785.06

**Not necessarily irrigated land.*
Data Sources: GIS data layer "Arizona Gap Analysis Project Vegetation Map", University of Arizona, Southern Arizona Data Services Program, 2004 http://sdrsnet.srnr.arizona.edu/index.php
Originated by Arizona Game & Fish Department, Habitat Branch, 1993, this dataset was digitized from the August 1980 David E. Brown & Charles H. Lowe 1:1,000,000 scale, 'Biotic Communities of the Southwest'.

Meteorological Stations, Precipitation and Temperature

For the 30 years (1961-1990) of precipitation data used in this report, the average annual precipitation for the Agua Fria River Watershed is 15.1 inches. The Black Canyon Creek watershed receives the most rainfall with 19.9 inches of rain in an average year, while the Agua Fria River below Lake Pleasant watershed typically receives only 9.8 inches. The valley floor surrounding the Agua Fria main channel receives less rain than the surrounding mountains. The Agua Fria River below Lake Pleasant watershed had the highest maximum temperature at 87.3 ^{o}F, while the Black Canyon Creek watershed had the lowest temperature at 39.0 ^{o}F. Figure 2-7 shows the meteorological station locations and the distribution of precipitation over the watershed, and Table 2-6 shows the precipitation, temperatures and names of the meteorological stations. Some stations have more than one location on the figure because they have been moved from one site to another by the National Weather Service.

Table 2-6: Agua Fria River Watershed Meteorological Stations, Temperature (°F) and Precipitation (in/yr) with Recent Long-term Records.

10-digit Watershed Name	Meteorological Stations and Map ID	Temperature (°F)			Precipitation (in/yr)		
		Min.	Max.	Avg.	Min.	Max.	Weighted Average
Ash Creek and Sycamore Creek 1507010201	None	-	-	-	15.0	25.0	18.4
Big Bug Creek-Agua Fria River 1507010202	None	-	-	-	15.0	27.0	18.8
Black Canyon Creek 1507010203	Cordes (N) Crown King (O)	46.9 39.0	75.7 67.9	61.3 53.5	13.0	31.0	19.9
Bishop Creek 1507010204	Black Canyon City (C)	55.9	83.6	69.8	13.0	23.0	17.4
Agua Fria River-Lake Pleasant 1507010205	Castle Hot Springs 4 N (I)	56.0	83.6	69.8	11.0	31.0	16.6
Cave Creek-Arizona Canal Diversion Channel 1507010206	Carefree (E) Cave Creek (J) Deer Valley (P)	56.6 53.4 54.2	82.0 83.1 85.2	69.3 68.3 69.7	9.0	23.0	14.0
Trilby Wash-Trilby Wash Basin 1507010207	Wittmann (AL)	54.4	84.2	69.3	9.0	17.0	12.1
New River 1507010208	Marinette (U)	52.9	86.9	69.9	9.0	25.0	13.2
Agua Fria River below Lake Pleasant 1507010209	Alhambra (A) Litchfield Park (T) Thornburg Ranches (AF)	53.0 53.6 50.5	86.1 87.3 84.8	69.6 70.5 67.6	7.0	17.0	9.8
Agua Fria River Watershed	-	-	-	-	*7.0*	*31.0*	*15.1*

Data Sources: Western Regional Climate Center (WRCC), Temperature data. July 15, 2004. http://www.wrcc.dri.edu/summary/climsmaz.html

Land Ownership/Management

In the Agua Fria River Watershed, there are 8 different land ownership/management entities (Figure 2-8 and Table 2-7). Private individuals are the largest land owners, representing 33.91% of the watershed. The Forest Service and the State of Arizona (State Trust Lands) are the next most significant land owners with 26.65% and 22.47% of the watershed.

Table 2-7: Agua Fria River Watershed Land Ownership/Management (Percent of each 10-digit Watershed) (part 1 of 2).

Land Owner	Ash Creek and Sycamore Creek 1507010201	Big Bug Creek-Agua Fria River 1507010202	Black Canyon Creek 1507010203	Bishop Creek 1507010204	Agua Fria River-Lake Pleasant 1507010205
BLM	1.86%	11.34%	25.43%	8.65%	37.68%
Military	-	27.28%	-	-	-
Private	-	37.47%	3.96%	3.67%	16.15%
State Parks and Recreation Areas	-	-	-	-	3.20%
State Trust	4.83%	23.90%	6%	32.54%	29.65%
State Wildlife & Management Areas	-	-	-	-	-
USFS	87.50%	-	49.91%	52.29%	8.64%
USFS & BLM Wilderness Areas	2.72%	-	14.68%	2.85%	4.69%
Area (square miles)	*261*	*325*	*244*	*236*	*372*

Table 2-7: Agua Fria River Watershed Land Ownership/Management (Percent of each 10-digit Watershed) (part 2 of 2).

Land Owner	Cave Creek-Arizona Canal Diversion Channel 1507010206	Trilby Wash-Trilby Wash Basin 1507010207	New River 1507010208	Agua Fria River below Lake Pleasant 1507010209	Agua Fria River Watershed
BLM	1.45%	8.32%	3.08%	9.17%	12.28%
Military	-	0.15%	-	0.72%	0.13%
Private	58.46%	36.38%	39.05%	72.74%	33.91%
State Parks and Recreation Areas	2.39%	10.95%	0.50%	2.06%	2.03%
State Trust	13.15%	44.21%	33.65%	15.10%	22.47%
State Wildlife & Management Areas	0.01%	-	0.67%	-	0.09%
US Forest Service	25.54%	-	23.08%	-	26.65%
USFS & BLM Wilderness Areas	-	-	-	0.21%	2.44%
Area (square miles)	*288*	*24*	*353*	*464*	*2,78*

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

Land Use

The land cover condition during the early 1990's was determined using the National Land Cover Dataset (NLCD). The NLCD classification contains 21

different land cover categories; however, these categories have been consolidated into five land cover types (Figure 2-9 and Table 2-8). The five groupings for the land cover categories are:

- Crop, which includes confined feeding operations; cropland and pasture; orchards, groves, vineyards, nurseries and ornamental horticulture; other agricultural land.

- Forest, includes areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover

- Water, identifies all areas of surface water, generally with less than 25% cover of vegetation/land cover

- Range, which includes herbaceous rangeland; mixed range; shrub and brush rangeland.

- Urban, which includes residential areas; commercial and services; industrial and commercial complexes; mixed urban or built-up land; other urban or built-up land; strip mines quarries and gravel pits; transportation, communication and utilities.

The most common land cover type is Range which makes up 76.04% of the watershed. Urban land is the next most common type with 19.41% of the total area.

USGS, NLCD Land Cover Class Definitions, http://landcover.usgs.gov/classes.php

Mines - Primary Ores

There are1,061 mineral extraction mines recorded with the Office of the Arizona State Mine Inspector in the Agua Fria River Watershed. Table 2-9 and Figure 2-10 show the types of ores being mined in the Agua Fria watershed. There are 386 mines whose ore type is unknown. The most common known ore types are gold, copper, silver, and sand and gravel.

2-8: Agua Fria River Watershed Land Use, Percent of 10-digit Watershed

Land Cover/Location	Crop	Forest	Urban	Range	Water	Area (sq.mi.)
Ash Creek and Sycamore Creek	0.10%	6.66%	0.57%	92.68%	--	260.56
Big Bug Creek-Agua Fria River	0.30%	14.17%	9.51%	76.00%	0.03%	324.13
Black Canyon Creek	--	17.65%	0.61%	81.74%	--	244.06
Bishop Creek	--	2.54%	1.51%	95.95%	--	236.44
Agua Fria River-Lake Pleasant	--	2.28%	0.35%	93.57%	3.80%	371.83
Cave Creek-Arizona Canal Diversion Channel	--	1.24%	43.15%	55.60%	0.03%	288.39
Trilby Wash-Trilby Wash Basin	--	--	2.20%	97.80%	--	242.17
New River	1.07%	0.65%	26.91%	71.28%	0.09%	353.18
Agua Fria River below Lake Pleasant	21.83%	--	33.54%	44.55%	0.08%	464.30
Percent of Agua Fria Watershed	3.82%	4.55%	15.06%	76.04%	0.54%	2785.06

Data Sources: GIS data layer "mines", Arizona State Land Department, Arizona Land Resource Information System (ALRIS), February 7, 2002 http://www.land.state.az.us/alris/index.html

Table 2-9: Agua Fria River Watershed Mines – Primary Ores.

Ore Type	Total Number of Mines	Ore Type	Total Number of Mines
Unknown	386	Sodium	3
Gold	260	Calcium	2
Copper	125	Clay	2
Silver	81	Pumice	2
Sand & Gravel	55	Zinc	2
Lead	27	Aluminum	1
Iron	19	Antimony	1
Tungsten	19	Arsenic	1
Stone	16	Barium	1
Manganese	14	Chlorine	1
Mica	12	Columbium	1
Uranium	8	Diatomite	1
Mercury	6	Geothermal	1
Beryllium	5	Magnesium	1
Feldspar	3	Perlite	1
Gemstone	3	Vermiculite	1

Note: If a mine contains more than one ore, only the major ore is noted.
Data Source: Natural Resource Conservation Service (NRCS).

Section 3: Resource Concerns

Introduction

Conservation Districts and other local leaders, along with NRCS and other resource management agencies, have identified priority natural resource concerns for this watershed. These concerns can be grouped under the broad resource categories of Soil, Water, Air, Plants, or Animals (SWAPA). Refer to Table 3-1 for a listing of priority resource concerns by land use within the Agua Fria River Watershed.

Soil Erosion

Soil erosion is defined as the movement of soil from water (sheet and rill or gully) or wind forces requiring treatment when soil loss tolerance levels are exceeded. Sheet and rill erosion is a concern particularly on rangeland and forest land in areas of shallow soils and poor vegetative cover. Soil loss results in reduced water holding capacity and plant productivity. Gully erosion can be a significant problem in areas of steep slopes and deep soils. Loss of vegetative cover and down-cutting of streams contribute to gully formation. Wind erosion is locally significant where adequate vegetative cover is not maintained.

Conservation practices applied to address this resource concern are generally those that help improve vegetative cover, stabilize sites, and control water flows. Practices may include critical area planting, deferred grazing, grade stabilization structures, herbaceous wind barriers, prescribed grazing, range planting, stream channel stabilization, tree and shrub establishment, water and sediment control basins, water spreading, windbreak establishment, and wildlife upland habitat management.

Soil Condition

Soil condition is a resource concern on cropland whenever soil tilth is poor or soil compaction is excessive. Poor soil tilth results whenever unsuitable combinations of minerals, air, water, and organic matter occur, resulting in low microbial activity and chemical reactions. Soil compaction results from excessive compressing of soil particles and aggregates by machines or livestock, thus affecting plant-soil-moisture-air relationships. Soil condition can become a problem whenever a field is excessively tilled or tilled when the soil is wet, lack of crop rotation, and lack of addition of organic matter. Poor soil condition reduces root growth and plant productivity.

Conservation practices applied to address this resource concern are generally those that improve plant cover, improve soil organic matter, improve soil microbial activity, reduce tillage operations, or mechanically break up compacted soils. Practices may include deep tillage, conservation cover, conservation crop rotation, cover & green manure crop, irrigation water management, mulching, nutrient management, pest management, residue management, tree and shrub establishment, and waste utilization. Reduced tillage passes and addition of

Table 3-1: Agua Fria Priority Resource Concerns by Land Use

Resource Category	Cropland Concerns	Rangeland Concerns	Forest Concerns	Urban Concerns
Soil Erosion		Sheet & Rill Erosion	Sheet & Rill Erosion	Roads & Construction Sites
Soil Condition	Soil Compaction & Organic Matter Depletion			
Water Quality	Excessive Nutrients & Organics & Pesticides in Ground Water	Excessive Suspended Sediment in Surface Water	Excessive Suspended Sediment in Surface Water	Excessive Nutrients & Organics & Pesticides in Ground Water
Water Quantity	Inefficient Use on Irrigated Land & Aquifer Overdraft			Inefficient Use on Irrigated Land & Aquifer Overdraft
Air Quality	Particulate Matter (PM 10)			Particulate Matter (PM 10)
Plant Condition		Plant Productivity, Health & Vigor	Plant Productivity, Health & Vigor	
Noxious & Invasive Plants		Noxious & Invasive Plants	Noxious & Invasive Plants	
Domestic Animals		Inadequate Quantities & Quality of Feed & Forage & Water	Inadequate Quantities & Quality of Feed & Forage & Water	
Species of Concern		T&E Species & Declining Species & Species of Concern	T&E Species & Declining Species & Species of Concern	

(NRCS, 2007)

organic matter from cover crops or residue will improve soil condition.

Water Quality

The Arizona Department of Environmental Quality (ADEQ) assesses surface water quality to identify which surface waters are impaired or attaining designed uses and to prioritize future monitoring. Impaired waters, as defined by Section 303(d) of the federal Clean Water Act, are those waters that are not meeting the state's water quality standards for designated uses. Attaining waters meet state water quality standards for designated uses. Strategies are implemented on impaired waters to reduce pollutant loadings so that surface water quality standards will be met, unless impairment is *solely* due to natural conditions.

Once a surface water has been identified as impaired, activities in the watershed that might contribute further loadings of the pollutant are not allowed. Agencies and individuals planning future projects in the watershed must be sure that activities will not further degrade these impaired waters and are encouraged through grants to implement strategies to reduce loading. One of the first steps is the development of a Total Maximum Daily Load (TMDL) analysis to empirically determine the load reduction needed to meet standards.

The *Draft 2006 Status of Ambient Surface Water Quality in Arizona* (ADEQ 2007) indicates that generally surface water quality is excellent where monitored and assessed (Figure 3-1). However, the following surface waters in the Agua Fria Basin are impaired:

- Cortez Park Lake is a 2 acre lake in the Phoenix metropolitan area, and located in the Agua Fria Below Lake Pleasant Sub-Basin. It is impaired based on high pH and low dissolved oxygen, which may indicate excessive nutrient loading. Added to impaired waters list in 2004, a TMDL is scheduled to be initiated in 2007.

- Turkey Creek, from an unnamed tributary to Poland Creek, is in the Black Canyon Sub-Basin. This 21 miles long reach is impaired by copper and lead. A TMDL has been completed and is in the final stages of review for approval by EPA (January 2007).

The draft assessment indicates that the following lakes and streams were either attaining all or some of their designated uses (other designated uses were assessed as “inconclusive.”)

- Lynx Lake is a 50 acre lake near Prescott and located in the Big Bug-Agua Fria Sub-Basin. Attaining some uses, lead exceeded a standard in one of three sampling events and manganese exceeded standards in four of five sampling events. (Note that EPA may add this to the impaired waters list due to manganese.)

- Lake Pleasant was recently expanded to 8900 acres and is located in the Agua Fria-Lake Pleasant Sub-Basin. Attaining all uses although low dissolved oxygen occurred during two of 15 sampling events and high pH in one of 15 sampling events may indicate occasional excessive nutrient loading.

- Fain Lake is a 1015 acre reservoir in Lynx Creek near Prescott, and located in the Big Bug Creek-Agua Fria Sub-Basin. Assessed as attaining some uses, low dissolved oxygen occurred during one of three sampling events.

- Turkey Creek, from headwaters to an unnamed tributary, is a 9.1 mile reach located in the Black Canyon Sub-Basin. It was assessed as attaining some uses. Insufficient monitoring data to assess some designated uses. No exceedances.

- Agua Fria River, from State Route 169 to Yarber Wash, is a 17.8 mile reach in the Big Bug Creek-Agua Fria Sub-Basin.

Attaining all uses and no exceedances.

- Agua Fria River, from Sycamore Creek to Big Bug Creek, is a 9.1 mile reach primarily located in the Big Bug Creek-Agua Fria Sub-Basin. Attaining all uses and no exceedances.

- Agua Fria River, from Little Squaw Creek to Cottonwood Creek, is a 5.8 mile reach in the Agua Fria-Lake Pleasant Sub-Basin. Attaining all uses and no exceedances.

- Cave Creek, from headwaters to Cave Creek Dam, is a 32.9 mile reach in the Cave Creek-Arizona Canal Diversion Channel Sub-Basin. Attaining all uses and no exceedances.

- Sycamore Creek, from Tank Canyon to Agua Fria River, is a 17.6 mile reach in the Ash Creek-Sycamore Creek Sub-Basin. Attaining all uses and no exceedances.

Water Quantity

The Agua Fria and its tributaries are generally intermittent streams except for some perennial stretches where impermeable bedrock forces groundwater into the streambed. The basin is bounded on the north by Hickey Mountain, on the west by the Bradshaw and Buckhorn Mountains, on the south by Lake Pleasant, and on the east by the Black Hills and New River Mountains.

Development of groundwater resources is increasing in the Agua Fria basin. Population growth in recent years has resulted in increased pumpage. Despite increased groundwater pumpage, water levels generally have not declined in the basin. The only area of declining water levels is around Cordes Junction where declines of several feet have been reported (Wilson, 1988). This suggests that overall the basin is still in a steady-state situation. Total groundwater reserves in the Agua Fria basin are estimated to be 3.5 million acre-feet.

(http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/content/map/UppAguFri.htm)

Air Quality

Northern Maricopa County, which constitutes the lower section of the Agua Fria Watershed, is designated by EPA as a Non-Attainment Area because it does not meet EPA PM-10 Standards (Figure 3-2). The non-attainment area is identified as the “PM-10 Boundary” on Figure 3-2. The county is required to draw up and follow a plan to reduce the amount of PM-10 generated in order to put the area in compliance with the EPA standard. Local sources of PM-10 include agricultural operations, housing construction, vacant lots and unpaved roads. The implementation plan and a history of the process are found at ADEQ, http://www.azdeq.gov/environ/air/plan/notmeet.html#phoenix.

The EPA defines particulate matter as the term for solid or liquid particles found in the air. Some particles are large enough to be seen as soot or smoke. Other particles are so small they can only be detected with an electron microscope. PM-10 particles are very small and can have adverse health effects because of their ability to reach the lower regions of the respiratory tract. Exposure to PM-10 can result in: effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. Children, older people, and people with chronic lung disease, are particularly sensitive to particulate matter (EPA website http://epa.gov/air/airtrends/aqtrnd95/pm10.html).

Plant Condition

Plant condition is a resource concern whenever plants do not manufacture sufficient food to continue the growth cycle or to reproduce. Plant condition is frequently a concern on rangeland where proper grazing management is not being applied.

Conservation practices applied to address this resource concern are generally those that maintain or improve the health, photosynthetic capability, rooting and reproductive capability of vegetation. Practices may include brush management, critical area planting, deferred grazing, fencing, forest stand improvement, herbaceous wind barriers, nutrient management, pest management, prescribed grazing, prescribed burning, range planting, recreation area improvement, riparian forest buffers, tree and shrub establishment, wetland development or restoration, wildlife upland habitat management, wildlife watering facility, wildlife wetland habitat management, and windbreak establishment.

Noxious and Invasive Plants

Noxious and invasive plants are a resource concern whenever these species cause unsuitable grazing conditions for livestock or wildlife and due to their potential to out-compete native species which are generally preferred for wildlife habitat value. Increases in noxious and invasive plants result from control of wildfires, poor grazing management, and other causes.

Conservation practices applied to address this resource concern are generally those that control the establishment or reduce the population of noxious and invasive plant species. Practices may include brush management, deferred grazing, fencing, forest stand improvement, pest management, prescribed burning, prescribed grazing, and wildlife upland habitat management.

Bark Beetle, Drought and Wildfire

Over the past several years, Arizona has experienced increased piñon and ponderosa pine mortality due to outbreaks of several species of Ips beetles and the western pine beetle. Low tree vigor caused by several years of drought and excessively dense stands of trees have combined to allow beetle populations to reach outbreak levels. These insects are native to ponderosa pine forests and piñon-juniper woodlands of the Southwest, and normally only attack a small number of diseased or weakened trees. Healthy trees are usually not susceptible to these beetles.

The vegetation communities in the Agua Fria Watershed are mostly desert shrubland and grassland, with only about 29% being forested lands subject to bark beetle infestation. Based on an analysis of the Forest Service GIS data, approximately 100 acres of forested federal lands in the Agua Fria have been affected by bark beetles, or only about 0.02 percent. This analysis only addresses Federal forested lands. The four forest types where bark beetles occur in the Agua Fria Watershed are Madrean Pine-Oak Forest and Woodland, Rocky Mountain Ponderosa Pine Woodland, Mogollon chaparral, and Madrean Pinyon-Juniper Woodland.

The Climate Assessment for the Southwest (CLIMAS) website (www.ispe.arizona.edu/climas) provides information on Arizona's drought status. Recent precipitation events have placed the area of Arizona that encompasses the Agua Fria Watershed in moderate drought status. However, the watershed remains abnormally dry. The long term drought status remains moderate, persisting throughout the watershed, but possibly intensifying in the northern portion of the watershed, with some improvement possible in the southern portion.

The Southwest Coordination Center (gacc.nifc.gov/swcc/predictive/outlooks/outlooks.htm) places the northern portion of the Agua Fria Watershed in the Normal category for significant wildland fire activity potential due to favorably moist conditions. However, the southern portion remains in the Above Normal category due to persisting drought conditions.

Domestic Animal Concerns

Domestic animal concerns occur whenever the quantity and quality of food are not adequate to meet the nutritional requirements of animals, or adequate quantity and quality of water is not provided. This is frequently a concern on rangeland when changes in species composition resulting from poor grazing management reduce the availability of suitable forage.

Conservation practices applied to address this resource concern are generally those that maintain or improve the quantity, quality, and diversity of forage available for animals, reduce the concentration of animals at existing water sources, and insure adequate quantity and reliability of water for the management of domestic animals. Practices may include brush management, deferred grazing, fencing, pest management, prescribed burning, prescribed grazing, pipelines, ponds, range planting, water spreading, wells, spring development, watering facility, and wildlife upland habitat management.

Species of Concern

There are 55 threatened and endangered species listed for Arizona. (U. S. Fish and Wildlife Service website, http://ecos.fws.gov) In 1990 Arizona voters created the Heritage Fund, designating up to $10 million per year from lottery ticket sales for the conservation and protection of the state's wildlife and natural areas. The Heritage Fund allowed for the creation of the Heritage Data Management System (HDMS) which identifies elements of concern in Arizona and consolidates information about their status and distribution throughout the state. (Arizona Game & Fish website, 2006, http://www.azgfd.gov/w_c/heritage_program.shtml)

The Agua Fria Watershed contains 8 of the 55 threatened or endangered species listed for Arizona (Table 3-2). One of the species found in the Agua Fria watershed is the Mexican Spotted Owl (U.S. Fish & Wildlife Service, 2004). The Upper Agua Fria River contains the entire Mexican spotted owl habitat that occurs in the Agua Fria watershed. The Mexican spotted owl was listed as threatened on April 14, 1993, and a recovery plan was approved in December 1995. The distributional pattern of the Mexican spotted owl is more distinct than that of the other subspecies (Noon and McKelvey 1992).

The Mexican spotted owl appears to use a wider range of habitat types than the other subspecies. These unique aspects of the ecology of this owl require unique approaches for management. Habitat management plans may need to consider not only areas occupied by owls but also intervening areas, even where such areas are very different in habitat structure from areas typically occupied by spotted owls. (U.S. Fish & Wildlife Service, 2004)

The watershed also contains portions of desert tortoise habitat. The desert tortoise is listed as a wildlife of special concern by Arizona Game and Fish. The desert tortoise generally occupies Sonoran Desert habitat, along rocky slopes and bajadas, ranging from 508 feet to 5,250 feet in elevation. Although the desert tortoise is not listed as threatened or endangered, Arizona law prohibits removing these creatures from the wild or taking them across state lines. Desert tortoise are threatened by habitat fragmentation, illegal capture, invasion of exotic species, road kill, and predation. (Arizona Game & Fish website, 2006, http://www.gf.state.az.us/w_c/desert_tortoise.shtml).

Table 3-2: Agua Fria River Watershed Species of Concern Classifications and Observation [(1)]

Common Name	Species Name	USESA (2)	USFS (3)	BLM (4)	STATE (5)	Range of Observation
American Peregrine Falcon	Falco peregrinus anatum	SC	S		WSC	2005
Arizona Agave	Agave arizonica	No status			HS	1987-1992
Arizona Giant Sedge	Carex ultra		S	S		2001
Arizona Phylox	Phlox amabilis		S			1970-1973
Arizona Myotis (bat)	Myotis occultus	SC		S		1986-1994PRE
Arizona Toad	Bufo microscaphus	SC	S			1978-1996
Bald Eagle	Haliaeetus leucocephalus	LT,PDL	S		WSC	2004
Bald Eagle	Haliaeetus leucocephalus (wintering pop.)	LT,PDL	S		WSC	2005
Bat Colony						1993-2003
Belted Kingfisher	Ceryle alcyon				WSC	1994
Bigelow Onion	Allium bigelovii				SR	1977-1980
California Fan Palm	Washingtonia filifera				SR	1981
California Leaf-nosed Bat	Macrotus californicus	SC			WSC	1993-2000
Cave Myotis (bat)	Myotis velifer	SC		S		1986-1999PRE
Common Black-Hawk	Buteogallus anthracinus		S		WSC	1993-2005
Desert Pupfish	Cyprinodon macularius	LE			WSC	1993-2004
Desert Sucker	Catostomus clarki	SC		S		1980-2003
Designated Critical Habitat for Gila chub	CH for Gila intermedia					
Designated Critical Habitat for Mexican spotted owl	CH for Strix occidentalis lucida					
Eastwood Alum Root	Heuchera eastwoodiae		S			1976-2001SU
Flannel Bush	Fremontodendron californicum			S	SR	1985-2002
Fringed Myotis (bat)	Myotis thysanodes	SC		S		1994
Gila Chub	Gila intermedia	LE	S		WSC	1980-2003
Gila Longfin Dace	Agosia chrysogaster chrysogaster	SC		S		1980-2003
Gila Topminnow	Poeciliopsis occidentalis occidentalis	LE			WSC	1975-2004
Greater Western Bonneted Bat	Eumops perotis californicus	SC				1986PRE
Maricopa Tiger Beetle	Cicindela oregona maricopa	SC	S	S		1978-1995
Mazatzal Triteleia	Triteleia lemmoniae				SR	1965

Common Name	Species Name	USESA (2)	USFS (3)	BLM (4)	STATE (5)	Range of Observation
Mexican Spotted Owl	Strix occidentalis lucida	LT	S		WSC	1997-2004
Mt. Dellenbaugh Sandwort	Arenaria aberrans		S			2003
Northern Goshawk	Accipiter gentilis	SC	S		WSC	1993
Northern Mexican Gartersnake		SC	S		WSC	1980-1992
Pale Townsend's Big-eared Bat	Corynorhinus townsendii pallescens	SC				1994
Pocketed Free-tailed Bat	Nyctinomops femorosaccus			S		1993
Roundtail Chub	Gila robusta	SC	S		WSC	1965
Sonoran Desert Tortoise	Gopherus agassizii (Sonoran Population)	SC			WSC	1977-2004
Southwestern Willow Flycatcher	Empidonax traillii extimus	LE	S		WSC	2004
Speckled Dace	Rhinichthys osculus	SC		S		1980-2003
Toumey Agave	Agave toumeyana var. bella				SR	1976-1980
Verde Rim Springsnail	Pyrgulopsis glandulosa	SC	S	S		2001
Western Burrowing Owl	Athene cunicularia hypugaea	SC		S		2001-2005
Western Red Bat	Lasiurus blossevillii				WSC	2002
Western Yellow Bat	Lasiurus xanthinus				WSC	2002
Western Yellow-billed Cuckoo	Coccyzus americanus occidentalis	C	S		WSC	1993-2003PR
Yuma Clapper Rail	Rallus longirostris yumanensis	LE			WSC	2003
	Opuntia engelmannii var. flavispina				SR	1977
	Opuntia engelmannii var. flavispina				SR	NO DATE

Data Sources: Arizona Land Information System (ALRIS), Natural Resource Conservation Service (NRCS). *Status Definitions as Listed by Arizona Game and Fish Department, Nov. 26, 2006 http://www.gf.state.az.us/w_c/edits/hdms_status_definitions.shtml*

(1) Proposed for Listing: **(USESA) Federal U.S. Status** ESA Endangered Species Act (1973 as amended) US Department of Interior, Fish and Wildlife Service

(2) Listed:
LE Listed Endangered: imminent jeopardy of extinction.
LT Listed Threatened: imminent jeopardy of becoming Endangered.
PDL Proposed for Delisting

Candidate (Notice of Review: 1999):
C Candidate. Species for which USFWS has sufficient information on biological vulnerability and threats to support proposals to list as Endangered or Threatened under ESA. However, proposed rules have not yet been issued because such actions are precluded at present by other listing activity.

SC Species of Concern. The terms "Species of Concern" or "Species at Risk" should be considered as terms-of-art that describe the entire realm of taxa whose conservation status may be of concern to the US Fish and Wildlife Service, but neither term has official status (currently all former C2 species).

(3) USFS US Forest Service (1999 Animals, 1999 Plants)
US Department of Agriculture, Forest Service, Region 3

S Sensitive: those taxa occurring on National Forests in Arizona which are considered sensitive by the Regional Forester.

(4) BLM US Bureau of Land Management (2000 Animals, 2000 Plants)
US Department of Interior, BLM, Arizona State Office

S Sensitive: those taxa occurring on BLM Field Office Lands in Arizona which are considered sensitive by the Arizona State Office.

(5) State Status
NPL Arizona Native Plant Law (1993) Arizona Department of Agriculture

HS Highly Safeguarded: no collection allowed.

SR Salvage Restricted: collection only with permit.

WSC Wildlife of Special Concern in Arizona. Species whose occurrence in Arizona is or may be in jeopardy, or with known or perceived threats or population declines, as described by the Arizona Game and Fish Department's listing of Wildlife of Special Concern in Arizona (WSCA, in prep).

<u>Resource Concern Summary</u>

Local leaders have identified watershed health as a priority concern for the Agua Fria River Watershed. This includes both the upland areas of the watershed and the riparian or stream course areas. The condition of the upland areas is integral to the hydrologic function, such that when precipitation falls on the land its disposition is affected by the soil and vegetation, which in turn are affected by land uses, both historical and current. The amount of the precipitation which immediately runs off the land surface, and that which infiltrates into the soil to either be used for plant growth or to recharge groundwater, is dependent on this critical interface.

The desert and semi-desert ecosystems have developed in a climatic regime of wide fluctuations of precipitation, ranging from drought to flood. Human uses superimposed on that climatic regime can tend to exacerbate or ameliorate their effects on soils and vegetation. For example, early settlers brought in herds of livestock and eventually exceeded the capacity of the range, especially during drought periods. Changes in vegetation resulted, which in turn affect watershed condition. Large areas have seen increases in pinyon-juniper and reduced grasses and fibrous rooted plants. A number of introduced plants have also increased at the expense of native species. This has been the case on both some of the uplands and in riparian areas. Examples include annual plants such as cheatgrass (*Bromus tectorum*) and foxtail (*Bromus rubens*) on uplands and salt cedar (*Tamarix pentandra*) in riparian areas.

With rapidly increasing development of private lands and accelerated recreational use of public lands, impacts to vegetation and the soil surface may affect hydrologic function. An increasing concern is the dumping and littering of waste materials, including some which are toxic, on public and private lands. This is particularly the case along major transportation arteries such as I-17 and Highway 69 and on public and state trust lands surrounding communities.

Large areas of the watershed are in chaparral vegetation with lesser portions in ponderosa pine. These were subject to frequent fires prior to European settlement. Many decades of fire suppression have resulted in the buildup of fuel loads which, when ignited, burn with flame height and heat release sufficient to kill ponderosa pine overstory and create a situation vulnerable to heavy storm runoff and erosion during the first monsoon seasons following the fire.

Riparian areas are quite limited in area but highly important to both humans and wildlife. Maintenance of base flow of stream segments and springs is necessary for the health of these critical areas. (adapted from Barnett, Hawkins & Guertin, 2004).

Conservation Progress/Status

Conservation progress for the previous five years in the Agua Fria River Watershed has focused on addressing the following primary resource concerns:

- Soil Condition – Organic Matter Depletion
- Water Quantity – inefficient Water Use on Irrigated Land
- Water Quality – Excessive Nutrients and organics in Ground Water
- Air Quality – Particulate Matter Less than 10 Micrometers (PM10)

The following table presents conservation accomplishments in this watershed during fiscal years (FY) 2002 through 2006, according to the NRCS Progress Reporting (Table 3-3).

Table 3-3: Agua Fria River Watershed Conservation Treatment Applied

Agua Fria River Watershed (15070102) Conservation Treatment Applied	FY02-06 TOTAL
Air Management (acres)	99
Comprehensive Nutrient Management Plan (number)	3
Conservation Crop Rotation (acres)	149
Irrigation Land Leveling (acres)	368
Irrigation System, Sprinkler (acres)	412
Irrigation Water Conveyance, Ditch and Canal Lining, (feet)	1,239
Irrigation Water Conveyance, Pipeline, Underground, Plastic (feet)	12,595
Irrigation Water Management (acres)	1,868
Nutrient Management (acres)	752
Pest Management (acres)	565
Prescribed Grazing (acres)	1,000
Residue Management, Seasonal (acres)	696
Upland Wildlife Habitat Management (acres)	100

Section 4: Census, Social and Agricultural Data

This section discusses the human component of the watershed and the pressure on natural resources caused by humans and by population change.

Population Density, 1990

Census block statistics for 1990 were compiled from information prepared by Geo-Lytics (Geo-Lytics, 1998). These data were linked with census block data and used to create a density map (Figure 4-1) through a normalization process using a grid of 7 km squares. This process involves calculating density per census block and intersecting it with the grid, which is then used to calculate the number of people and thus density per grid square.

Table 4-1 shows the tabulated minimum, maximum and mean number of people per square mile in 1990 for each watershed. In 1990, the mean population density for the entire watershed was 305 people per square mile. The Agua Fria River below Lake Pleasant watershed had the highest population density with an average of 901 people per square mile, and a maximum of 7179. The Ash Creek and Sycamore Creek watershed had the lowest density with an average of only 1.71 people per square mile.

Population Density, 2000

The Census Block 2000 statistics data were downloaded from the Environmental Systems Research Institute (ESRI) website (ESRI Data Products, 2003) and are shown in Table 4-2. A population density map (Figure 4-2) was created from these data. The mean population density in 2000 was 437 people per square mile. The Cave Creek – Arizona Canal Diversion Channel and the Agua Fria River below Lake Pleasant watersheds had nearly the same population density with approximately 1,123 and 1,236 people per square mile, respectively. The Agua Fria River below Lake Pleasant watershed had the highest maximum density of 9,208 people per square mile.

Population Density Change, 1990-2000

The 1990 and 2000 population density maps were used to create a population density change map. The resulting map (Figure 4-3) shows population increase or decrease over the ten year time frame. Overall, mean population density increased by 132 people per square mile during this ten year time period. Three watersheds had similar, large increases in average population: Agua Fria River below Lake Pleasant, New River, and Cave Creek – Arizona Canal Diversion Channel.

Table 4-3 shows the change in population density from 1990 to 2000 in people per square mile. The Ash Creek and Sycamore Creek watershed experienced a mean decrease of 0.22 people per square mile.

Housing Density, 2000 and 2030

The Watershed Housing Density Map for the years 2000 and 2030 were created with data developed by David M. Theobald (Theobald, 2005). Theobald developed a nationwide housing density model that incorporates a thorough way to account for land-use change beyond the “urban fringe.”

Exurban regions are the "urban fringe", or areas outside suburban areas, having population densities greater than 0.68 – 16.18 ha (1.68 – 40 acres) per unit. Theobald stresses that exurban areas are increasing at a much faster rate than urban sprawl, are consuming much more land, and are having a greater impact on ecological health, habitat fragmentation and other resource concerns.

Theobald estimates that the exurban density class has increased at a much faster rate than the urban/suburban density classes. Theobald's model forecasts that this trend will continue and may even accelerate by 2030. This indicates that development patterns are shifting more towards exurban, lower density, housing units, and are thereby consuming more land. He suggests that exurban development has more overall effect on natural resources because of the larger footprint and disturbance zone, a higher percent of impervious surfaces.

Figure 4-4 and Table 4-4, Agua Fria River Watershed Housing Density for 2000, identifies mostly "rural" housing densities (>40 acres per unit) for the Cave Creek/Carefree area. Figure 4-5 and Table 4-5, Agua Fria River Watershed Housing Density for 2030, projects much higher housing "urban" densities (<0.6 acres per unit) for the same area. Similarly, "undeveloped" and "rural" farming areas west of Phoenix in 2000 become "exurban" and "suburban" in 2030.

Table 4-1: Agua Fria River Watershed 1990 Population Density (people/square mile)

10-digit Watershed Name	Area (sq. miles)	Population Density (people/sq.mi.)		
		Min	Max	Mean
Ash Creek and Sycamore Creek - 1507010201	260.55	0	46.00	1.71
Big Bug Creek-Agua Fria River - 1507010202	324.14	0	1,090.86	45.14
Black Canyon Creek - 1507010203	244.07	0	167.43	6.29
Bishop Creek - 1507010204	236.45	0	167.43	6.57
Agua Fria River-Lake Pleasant - 1507010205	371.81	0	129.43	2.00
Cave Creek-Arizona Canal Diversion Channel - 1507010206	288.47	0	6,190.29	839.43
Trilby Wash-Trilby Wash Basin - 1507010207	242.18	0	137.14	12.57
New River - 1507010208	353.18	0	6,190.29	488.86
Agua Fria River below Lake Pleasant - 1507010209	464.31	0	7,178.86	901.14
Total Agua Fria Watershed	*2,785*	*0*	*7,179*	*305*

Note: Adjacent watersheds may share a grid square. Data Sources: Census block statistics for 1990 were compiled from a CD prepared by Geo-Lytics (GeoLytics, Inc.1998. Census 1990. Census CD + Maps. Release 3.0.)

Table 4-2: Agua Fria River Watershed 2000 Population Density (people/square mile)

Watershed Name	Area (sq. mi.)	Population Density (people/sq.mi.)		
		Min	Max	Mean
Ash Creek and Sycamore Creek - 1507010201	260.55	0	16.11	1.54
Big Bug Creek-Agua Fria River - 1507010202	324.14	0	2,490.12	92.84
Black Canyon Creek - 1507010203	244.07	0	526.09	15.92
Bishop Creek - 1507010204	236.45	0	526.09	13.03
Agua Fria River-Lake Pleasant - 1507010205	371.81	0	341.16	4.93
Cave Creek-Arizona Canal Diversion Channel - 1507010206	288.47	0	6,377.48	1,123.38
Trilby Wash-Trilby Wash Basin - 1507010207	242.18	0	965.74	28.51
New River - 1507010208	353.18	0	6,377.48	794.50
Agua Fria River below Lake Pleasant - 1507010209	464.31	0	9,208.12	1,235.97
Total Agua Fria Watershed	*2,785*	*0*	*9,208*	*437*

Note: Adjacent watersheds may share a grid square. Data Sources: ESRI Data Products, Census 2000, October 17, 2003. http://www.esri.com/data/

Table 4-3: Agua Fria River Watershed Population Density Change 1990-2000 (people/square mile)

Watershed Name	Area (sq. mi.)	Population Density (people/sq.mi.)		
		Min	Max	Mean
Ash Creek and Sycamore Creek - 1507010201	260.55	0	-38.07	-0.22
Big Bug Creek-Agua Fria River - 1507010202	324.14	0	1,399.05	47.69
Black Canyon Creek - 1507010203	244.07	0	358.51	9.72
Bishop Creek - 1507010204	236.45	0	358.51	6.44
Agua Fria River-Lake Pleasant - 1507010205	371.81	0	211.73	3.07
Cave Creek-Arizona Canal Diversion Channel - 1507010206	288.47	0	2,468.24	283.93
Trilby Wash-Trilby Wash Basin - 1507010207	242.18	0	882.31	15.89
New River - 1507010208	353.18	0	2,468.24	305.65
Agua Fria River below Lake Pleasant - 1507010209	464.31	0	2,180.42	334.69
Total Agua Fria Watershed	2,785	0	2,468	132

Note: Adjacent watersheds may share a grid square. Data Sources: Derived from data from the GIS data used for tables 4-1 and 4-2.

Table 4-4: Agua Fria River Watershed Housing Density 2000 (Percent of Watershed) (Part 1 of 2)

Housing Density	Big Bug Creek-Agua Fria River 1507010202	Ash Creek and Sycamore Creek 1507010201	Bishop Creek 1507010204	New River 1507010208	Cave Creek-Arizona Canal Diversion Channel 1507010206
Undeveloped Private	4.80%	1.00%	1.82%	7.40%	7.10%
Rural	6.01%	2.80%	0.14%	4.21%	4.19%
Exurban	5.17%	0.86%	0.95%	11.61%	21.47%
Suburban	0.34%	-	0.27%	4.14%	7.13%
Urban	0.15%	-	0.03%	7.49%	10.86%

Table 4-4: Agua Fria River Watershed Housing Density 2000 (Percent of Watershed) (Part 2 of 2)

Housing Density	Agua Fria River below Lake Pleasant 1507010209	Trilby Wash-Trilby Wash Basin 1507010207	Agua Fria River-Lake Pleasant 1507010205	Black Canyon Creek 1507010203	Agua Fria River Watershed	Agua Fria River Watershed (sq. miles)
Undeveloped Private	23.44%	20.86%	12.66%	0.78%	33.90%	277
Rural	14.54%	12.74%	7.50%	1.25%	22.41%	183
Exurban	9.30%	5.13%	0.11%	1.81%	22.64%	185
Suburban	4.49%	0.25%	0.05%	0.13%	7.22%	59
Urban	11.70%	0.08%	0.04%	<0.01%	13.83%	113

Source: Theobald, D. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10(1): 32. [online] URL: http://www.ecology and society.org/vol10/iss1/art32/

Table 4-5: Agua Fria River Watershed Housing Density Projections 2030 (Percent of Watershed) (Part 1)

Housing Density	Big Bug Creek-Agua Fria River 1507010202	Ash Creek and Sycamore Creek 1507010201	Bishop Creek 1507010204	New River 1507010208	Cave Creek-Arizona Canal Diversion Channel 1507010206
Undeveloped Private	0.85%	0.28%	0.33%	1.52%	1.36%
Rural	2.72%	1.73%	1.38%	1.78%	1.27%
Exurban	10.80%	2.65%	0.43%	8.70%	13.38%
Suburban	1.00%	0.01%	0.27%	6.04%	7.72%
Urban	1.10%	-	0.79%	16.81%	27.02%

Table 4-5: Agua Fria River Watershed Housing Density Projections 2030 (Percent of Watershed) (Part 2)

Housing Density	Agua Fria River below Lake Pleasant 1507010209	Trilby Wash-Trilby Wash Basin 1507010207	Agua Fria River-Lake Pleasant 1507010205	Black Canyon Creek 1507010203	Agua Fria River Watershed	Agua Fria River Watershed (sq. miles)
Undeveloped Private	4.94%	5.11%	2.03%	0.39%	6.98%	57
Rural	1.73%	3.36%	17.04%	0.57%	13.10%	107
Exurban	27.32%	29.02%	1.12%	2.56%	39.16%	320
Suburban	5.29%	1.30%	0.06%	0.29%	9.30%	76
Urban	24.20%	0.27%	0.10%	0.17%	31.46%	257

Source: Theobald, D. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10(1): 32. [online] URL: http://www.ecology and society.org/vol10/iss1/art32/

<u>Agua Fria River Watershed Agricultural Statistics</u>

Arizona is known as one of the most productive and efficient agricultural regions in the world, with beauty that also provides the food and fiber to sustain life in the desert. Arizona is also one of the most diverse agricultural producing states in the nation, producing more than 160 varieties of vegetables, livestock, field crops and nursery stock. The climate, natural resources, agribusiness infrastructure and farm heritage help make agriculture a $9.2 billion dollar industry employing more than 72,000 individuals.

According to the United States Department of Agriculture's, 2002 Census, there are more than 7,000 farms and ranches, seventy-eight percent of which are owned by individuals or families. The total farmland in Arizona is comprised of more than 26,000,000 acres with irrigated crops on 1,280,000 acres and pasture for animals on 23,680,000.

Agriculture in general on the Agua Fria River Watershed is comprised of:

- Considerable grazing land for many livestock operations
- Multiple recreational equestrian facilities
- A few equestrian breeding facilities
- Several small dairy facilities
- Multiple nursery facilities
- A few small hog facilities
- A significant number of apiary (honey bee) operations
- A few citrus orchards
- A few plantings of pecans
- A significant amount of rose production
- A mixed variety of crops including:
    - Cotton
    - Alfalfa
    - Corn
- Small grains
- Potatoes
- A variety of melons
- A variety of green leafy vegetables

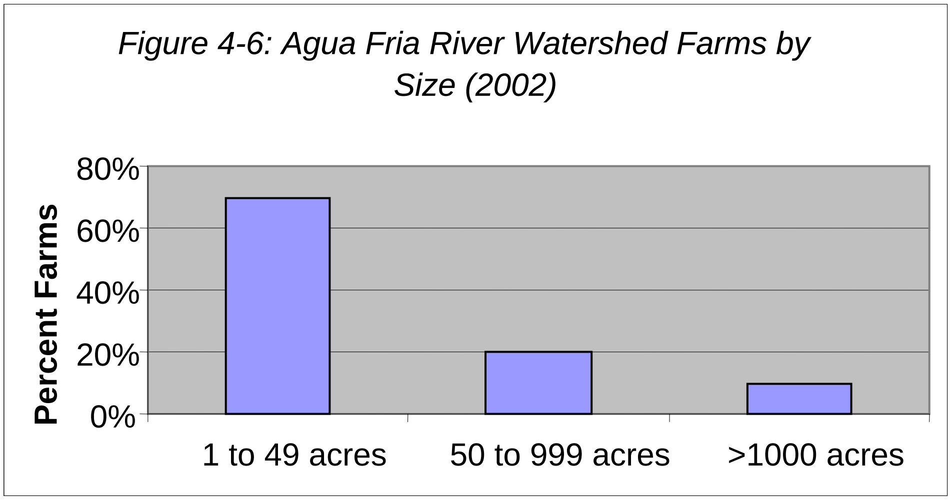
Data Source:

The NASS (National Agricultural Statistics Service, United States Department of Agriculture) has farm data by zip code. We used the U.S. Census Bureau ZIP Census Tabulation Areas (ZCTA) to generate maps. A typical 5-digit ZCTA (there are 3-digit ZCTAs as well) is typically nearly identical to a 5-digit U.S. Postal Service ZIP code, but there are some distinctions. Unlike ZIP codes, ZCTA areas are spatially complete and they are easier to map. The Bureau created special XX ZCTAs (ZCTAs with a valid 3-digit ZIP but with "XX" as last two characters of the code) which represent large unpopulated areas where it made no sense to assign a census block to an actual ZIP code. Similarly, HH ZCTAs represent large bodies of water within a 3-digit zip area. There is typically no population in either an XX or HH ZCTA.

Data is withheld by NASS for categories with one to four farms. This is to protect the identity of individual farmers. Farm counts for these zip codes are included in the "State Total" category. Some categories only contained stars instead of numbers. Each star was counted as one farm. But because each star could represent as many as 4 farms, each number on the tables are actually greater than or equal to the number listed. In some cases this results in percentages that add up to more or less that 100 percent.

Tables Include data from zip codes both contained within the watershed and zip codes crossing watershed boundaries.

A total of five zip code areas contained no NASS data about agricultural practices. Three of the zip codes that lie within AF Watershed contained no information from NASS databases. Two of the zip codes that lie partially within AF Watershed had no information in NASS databases. NASS assumed that no information for those areas meant that there was no agricultural activity taking place within that zip code area. In addition, 13 zip code areas were listed as XX (4) or HH (9), meaning that these are new zip code areas formerly covered by water or were uninhabited, respectively.

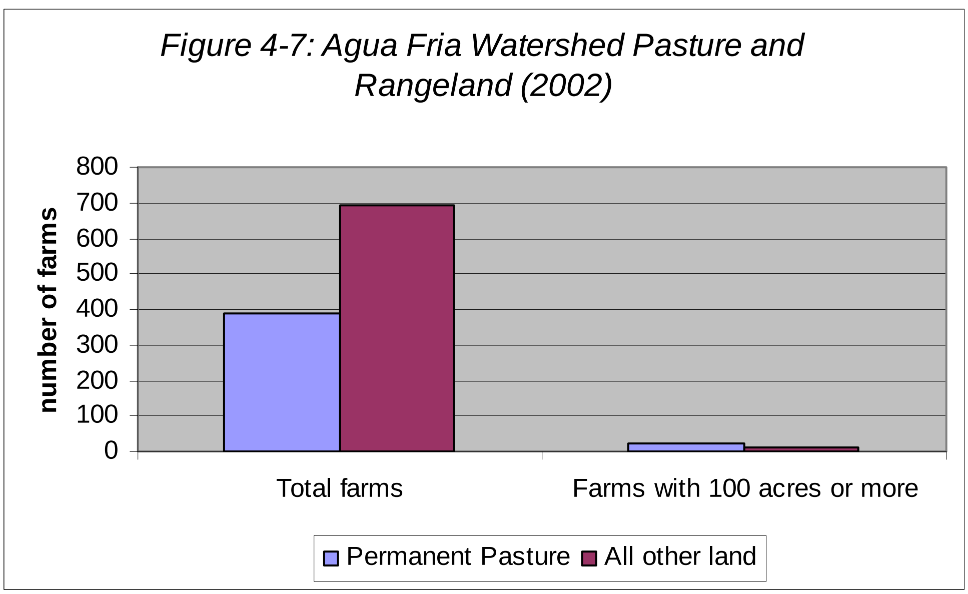


Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)

Table 4-6: Agua Fria Watershed Farms by Size (2002)

All farms	1 to 49 acres	50 to 999 acres	>1000 acres
1173	70%	20%	10%

Percents rounded.
Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)



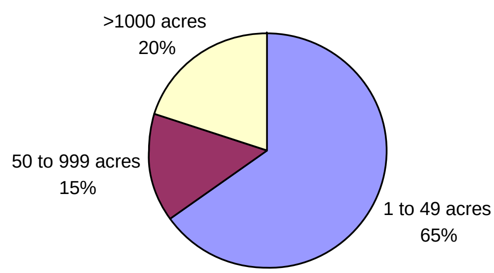
Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)

Table 4-7: Agua Fria Watershed Pasture and Rangeland (2002)

Category	Total farms	Farms 100 acres or more
Permanent pasture and rangeland	381	20%
All other land	694	10%

Percents rounded. Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)

Figure 4-8: Agua Fria Watershed Cropland Harvested (2002)



Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)

Table 4-8: Agua Fria Watershed Cropland Harvested (2002)

Total farms	1 to 49 acres	50 to 999 acres	>1000 acres
413	65%	15%	20%

Percents rounded. Data source: NASS (National Agricultural Statistics Service, United States Department of Agriculture)

Section 5: Resource Assessment Tables

The following Resource Assessment Tables summarize current and desired future natural resource conditions for the Agua Fria River Watershed. The tables present information on benchmark and future conservation systems and practices, qualitative effects on primary resource concerns, and estimated costs for conservation implementation. Conservation District board members, NRCS conservationists, and other people familiar with conservation work in the watershed were consulted for estimating current and future natural resource conditions. To contribute additional or updated information for this watershed, visit the NRCS Arizona website: www.az.nrcs.usda.gov/programs.

The tables show three levels of conservation treatment (Baseline, Progressive, Resource Management System) for each of the major land uses (crop, range, forest, urban) within the watershed. **Baseline** is defined as a low level of conservation adoption with landowners who are typically not participating in conservation programs. There are, however, a few practices that have been commonly adopted by all landowners in this watershed. **Progressive** is defined as an intermediate level of conservation adoption with landowners who are actively participating in conservation programs and have adopted several practices but not satisfied all of the Quality Criteria in the NRCS Field Office Technical Guide. **Resource Management System** (RMS) is defined as a complete system of conservation practices that addresses all of the Soil, Water, Air, Plant, and Animal (SWAPA) resource concerns typically seen for this land use in this watershed.

For each land use, the results of the assessment are presented in two parts. Part 1 (Assessment Information) summarizes the conservation practices at each treatment level and the quantities of practices for current benchmark conditions and projected future conditions. Part 1 also displays the four primary resource concerns, along with individual practice effects and an overall Systems Rating (ranging from a low of 1 to a high of 5) indicating the effectiveness of the conservation system used at each treatment level. Part 2 (Conservation Cost Table) summarizes the installation, management, and related costs by conservation practice and treatment level for the projected future conditions by federal and private share of the costs. Part 2 also displays the benchmark and future conservation conditions status bars.

Credit goes to NRCS in Oregon for development of the template for these Resource Assessment Tables.

NOTE: the numbers in the first column of each table represent NRCS conservation practice codes.

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102				LANDUSE ACRES	68,102		
LANDUSE TYPE	CROP				TYPICAL UNIT SIZE ACRES	1,000		
ASSESSMENT INFORMATION					CALCULATED PARTICIPATION	75%		
	Benchmark Conditions	Future Conditions			RESOURCE CONCERNS			
Conservation Systems by Treatment Level	Total Units	Existing Unchanged Units	New Treatment Units	Total Units	Soil Condition – Organic Matter Depletion	Water Quantity – Inefficient Water Use on Irrigated Land	Water Quality – Excessive Nutrients and Organics in Groundwater	Air Quality – Particulate matter less than 10 micrometers in diameter (PM 10)
Baseline				**System Rating ->**	**1**	**5**	**2**	**0**
Irrigation Land Leveling (ac.) 464	4,256	1,064	0	1,064	0	4	0	0
Irrigation System, Surface and Subsurface (ac.) 443	17,026	4,256	0	4,256	0	4	0	0
Irrigation Water Conveyance, Ditch and Canal Lining (ft.) 428	17,026	4,256	0	4,256	2	4	2	0
Irrigation Water Conveyance, Pipeline (ft.) 430	8,513	2,128	0	2,128	2	5	3	0
Structure for Water Control (no.) 587	17	4	0	4	0	3	0	0
Total Acreage at Baseline	**17,026**	**4,256**	**0**	**4,256**				
Progressive				**System Rating ->**	**4**	**5**	**4**	**3**
Conservation Crop Rotation (ac.) 328	17,026	4,256	4,256	8,513	4	3	1	3
Irrigation Land Leveling (ac.) 464	8,513	3,192	1,064	4,256	0	4	0	0
Irrigation System, Surface and Subsurface (ac.) 443	8,513	4,256	0	4,256	0	4	0	0
Irrigation Water Conveyance, Ditch and Canal Lining (ft.) 428	85,128	25,538	17,026	42,564	2	4	2	0
Irrigation Water Conveyance, Pipeline (ft.) 430	17,026	6,385	2,128	8,513	2	5	3	0
Irrigation Water Management (ac.) 449	17,026	4,256	4,256	8,513	4	5	5	3
Residue Management, Seasonal (ac.) 344	8,513	2,128	2,128	4,256	3	1	-1	3
Structure for Water Control (no.) 587	85	26	17	43	0	3	0	0
Total Acreage at Progressive Level	**17,026**	**4,256**	**4,256**	**8,513**				
RMS				**System Rating ->**	**4**	**5**	**4**	**3**
Conservation Crop Rotation (ac.) 328	34,051	46,820	8,513	55,333	4	3	1	3
Irrigation Land Leveling (ac.) 464	34,051	42,564	12,769	55,333	0	4	0	0
Irrigation System, Microirrigation (ac.) 441	3,405	3,405	2,128	5,533	0	4	0	0
Irrigation System, Sprinkler (ac.) 442	3,405	3,405	2,128	5,533	0	4	0	0
Irrigation System, Surface and Subsurface (ac.) 443	34,051	48,948	6,385	55,333	0	4	0	0
Irrigation Water Conveyance, Ditch and Canal Lining (ft.) 428	340,510	412,868	140,460	553,329	2	4	2	0
Irrigation Water Conveyance, Pipeline (ft.) 430	68,102	85,128	25,538	110,666	2	5	3	0
Irrigation Water Management (ac.) 449	34,051	46,820	8,513	55,333	4	5	5	3
Nutrient Management (ac.) 590	34,051	34,051	21,282	55,333	3	1	5	1
Pest Management (ac.) 595	34,051	34,051	21,282	55,333	0	1	0	0
Residue and Tillage Management, Mulch Till (ac.) 345	17,026	17,026	10,641	27,666	3	1	-1	3
Residue Management, Seasonal (ac.) 344	17,026	23,410	4,256	27,666	3	1	-1	3
Structure for Water Control (no.) 587	341	413	140	553	0	3	0	0
Total Acreage at RMS Level	**34,051**	**34,051**	**21,282**	**55,333**				

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102				LANDUSE ACRES		68,102	
LANDUSE TYPE	CROP				TYPICAL UNIT SIZE ACRES		1,000	
CONSERVATION COST TABLE					CALCULATED PARTICIPATION		75%	

	FUTURE	FEDERAL				PRIVATE		
Conservation Systems by Treatment Level	New Treatment Units	Installation Cost 50%	Management Cost - 3 yrs 100%	Technical Assistance 20%	Total Present Value Cost	Installation Cost 50%	Annual O & M + Mgt Costs 100%	Total Present Value Cost
Progressive								
Conservation Crop Rotation (ac.) 328	4,256	$0	$127,691	$25,538	$139,312	$0	$42,564	$65,521
Irrigation Land Leveling (ac.) 464	1,064	$532,047	$0	$106,409	$638,456	$532,047	$31,923	$666,517
Irrigation System, Surface and Subsurface (ac.) 443	0	$0	$0	$0	$0	$0	$0	$0
Irrigation Water Conveyance, Ditch and Canal Lining (ft.) 428	17,026	$68,102	$0	$13,620	$81,722	$68,102	$2,724	$79,577
Irrigation Water Conveyance, Pipeline (ft.) 430	2,128	$10,641	$0	$2,128	$12,769	$10,641	$426	$12,434
Irrigation Water Management (ac.) 449	4,256	$0	$127,691	$25,538	$139,312	$0	$42,564	$65,521
Residue Management, Seasonal (ac.) 344	2,128	$0	$38,307		$41,793	$0	$12,769	$19,656
Structure for Water Control (no.) 587	17	$2,554	$0		$3,065	$2,554	$102	$2,984
Subtotal	**4,256**	**$613,344**	**$293,690**	**$181,407**	**$1,056,429**	**$613,344**	**$133,071**	**$912,210**
RMS								
Conservation Crop Rotation (ac.) 328	8,513	$0	$255,383	$51,077	$278,623	$0	$85,128	$131,041
Irrigation Land Leveling (ac.) 464	12,769	$6,384,563	$0	$1,276,913	$7,661,475	$6,384,563	$383,074	$7,998,208
Irrigation System, Microirrigation (ac.) 441	2,128	$1,596,141	$0	$319,228	$1,915,369	$1,596,141	$159,614	$2,268,493
Irrigation System, Sprinkler (ac.) 442	2,128	$1,808,959	$0	$361,792	$2,170,751	$1,808,959	$72,358	$2,113,759
Irrigation System, Surface and Subsurface (ac.) 443	6,385	$0	$0	$0	$0	$0	$0	$0
Irrigation Water Conveyance, Ditch and Canal Lining (ft.) 428	140,460	$561,842	$0	$112,368	$674,210	$561,842	$22,474	$656,509
Irrigation Water Conveyance, Pipeline (ft.) 430	25,538	$127,691	$0	$25,538	$153,230	$127,691	$5,108	$149,207
Irrigation Water Management (ac.) 449	8,513	$0	$255,383	$51,077	$278,623	$0	$85,128	$131,041
Nutrient Management (ac.) 590	21,282	$0	$638,456	$127,691	$696,558	$0	$212,819	$327,603
Pest Management (ac.) 595	21,282	$0	$638,456	$127,691	$696,558	$0	$212,819	$327,603
Residue and Tillage Management, Mulch Till (ac.) 345	10,641	$0	$271,344		$296,037	$0	$90,448	$139,231
Residue Management, Seasonal (ac.) 344	4,256	$0	$76,615		$83,587	$0	$25,538	$39,312
Structure for Water Control (no.) 587	140	$21,069	$0		$25,283	$21,069	$843	$24,619
Subtotal	**21,282**	**$10,500,264**	**$2,135,636**	**$2,527,180**	**$14,930,305**	**$10,500,264**	**$1,355,349**	**$14,306,627**
Grand Total	**25,538**	**$11,113,608**	**$2,429,326**	**$2,708,587**	**$15,986,734**	**$11,113,608**	**$1,488,420**	**$15,218,836**

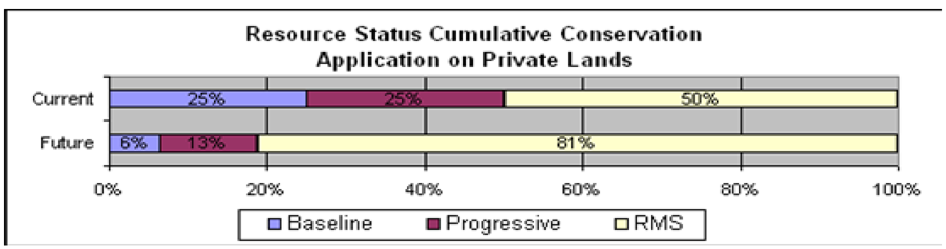


Chart Refers To	
Landuse Type	CROP
Calculated Participation Rate	75%

Average PV Costs per Ac		
System	**Federal**	**Private**
Prog	$248.20	$214.32
RMS	$701.55	$672.24

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102	LANDUSE ACRES	1,355,859
LANDUSE TYPE	RANGE	TYPICAL UNIT SIZE ACRES	50,000
ASSESSMENT INFORMATION		CALCULATED PARTICIPATION	50%

	Benchmark Conditions	Future Conditions			RESOURCE CONCERNS			
Conservation Systems by Treatment Level	Total Units	Existing Unchanged Units	New Treatment Units	Total Units	Soil Erosion – Sheet and Rill	Water Quality – Excessive Suspended Sediment and Turbidity in Surface Water	Plant Condition – Productivity, Health and Vigor	Domestic Animals – Inadequate Quantities and Quality of Feed and Forage
Baseline				**System Rating ->**	**1**	**3**	**0**	**0**
Fence (ft.) 382	67,793	33,896	0	33,896	0	1	1	1
Pipeline (ft.) 516	67,793	33,896	0	33,896	3	3	0	0
Watering Facility (no.) 614	136	68	0	68	0	4	1	0
Total Acreage at Baseline	**677,930**	**338,965**	**0**	**338,965**				
Progressive				**System Rating ->**	**4**	**3**	**4**	**4**
Fence (ft.) 382	169,482	101,689	67,793	169,482	0	1	1	1
Pipeline (ft.) 516	169,482	101,689	67,793	169,482	3	3	0	0
Prescribed Burning (ac.) 338	33,896	16,948	16,948	33,896	1	1	4	4
Prescribed Grazing (ac.) 528	338,965	169,482	169,482	338,965	5	3	5	5
Watering Facility (no.) 614	136	102	34	136	0	4	1	0
Total Acreage at Progressive Level	**338,965**	**169,482**	**169,482**	**338,965**				
RMS				**System Rating ->**	**4**	**4**	**5**	**5**
Brush Management (ac.) 314	33,896	33,896	33,896	67,793	4	4	5	3
Fence (ft.) 382	338,965	440,654	237,275	677,930	0	1	1	1
Pipeline (ft.) 516	338,965	440,654	237,275	677,930	3	3	0	0
Prescribed Burning (ac.) 338	33,896	50,845	16,948	67,793	1	1	4	4
Prescribed Grazing (ac.) 528	338,965	508,447	169,482	677,930	5	3	5	5
Range Planting (ac.) 550	33,896	33,896	33,896	67,793	4	2	5	5
Upland Wildlife Habitat Management (ac.) 645	338,965	338,965	338,965	677,930	0	0	4	1
Watering Facility (no.) 614	339	441	237	678	0	4	1	0
Wildlife Watering Facility (no.) 648	68	68	68	136	0	4	1	0
Total Acreage at RMS Level	**338,965**	**338,965**	**338,965**	**677,930**				

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102	LANDUSE ACRES	1,355,859
LANDUSE TYPE	RANGE	TYPICAL UNIT SIZE ACRES	50,000
CONSERVATION COST TABLE		CALCULATED PARTICIPATION	50%

	FUTURE	FEDERAL				PRIVATE		
Conservation Systems by Treatment Level	New Treatment Units	Installation Cost 50%	Management Cost - 3 yrs 100%	Technical Assistance 20%	Total Present Value Cost	Installation Cost 50%	Annual O & M + Mgt Costs 100%	Total Present Value Cost
Progressive								
Fence (ft.) 382	67,793	$101,689	$0	$20,338	$122,027	$101,689	$4,068	$118,824
Pipeline (ft.) 516	67,793	$271,172	$0	$54,234	$325,406	$271,172	$10,847	$316,863
Prescribed Burning (ac.) 338	16,948	$423,706	$0	$84,741	$508,447	$423,706	$8,474	$459,402
Prescribed Grazing (ac.) 528	169,482	$127,112	$0	$25,422	$152,534	$127,112	$0	$127,112
Watering Facility (no.) 614	34	$16,948	$0	$3,390	$20,338	$16,948	$1,017	$21,232
Subtotal	**169,482**	**$940,627**	**$0**	**$188,125**	**$1,128,753**	**$940,627**	**$24,405**	**$1,043,432**
RMS								
Brush Management (ac.) 314	33,896	$2,033,789	$0	$406,758	$2,440,546	$2,033,789	$40,676	$2,205,130
Fence (ft.) 382	237,275	$355,913	$0	$71,183	$427,096	$355,913	$14,237	$415,882
Pipeline (ft.) 516	237,275	$949,101	$0	$189,820	$1,138,922	$949,101	$37,964	$1,109,020
Prescribed Burning (ac.) 338	16,948	$423,706	$0	$84,741	$508,447	$423,706	$8,474	$459,402
Prescribed Grazing (ac.) 528	169,482	$127,112	$0	$25,422	$152,534	$127,112	$0	$127,112
Range Planting (ac.) 550	33,896	$1,016,894	$0	$203,379	$1,220,273	$1,016,894	$20,338	$1,102,565
Upland Wildlife Habitat Management (ac.) 645	338,965	$0	$1,321,963	$264,393	$1,442,266	$0	$440,654	$678,322
Watering Facility (no.) 614	237	$118,638	$0	$23,728	$142,365	$118,638	$7,118	$148,622
Wildlife Watering Facility (no.) 648	68	$33,896	$0	$6,779	$40,676	$33,896	$678	$36,752
Subtotal	**338,965**	**$5,059,049**	**$1,321,963**	**$1,276,202**	**$7,513,125**	**$5,059,049**	**$570,139**	**$6,282,807**
Grand Total	**508,447**	**$5,999,676**	**$1,321,963**	**$1,464,328**	**$8,641,878**	**$5,999,676**	**$594,544**	**$7,326,239**

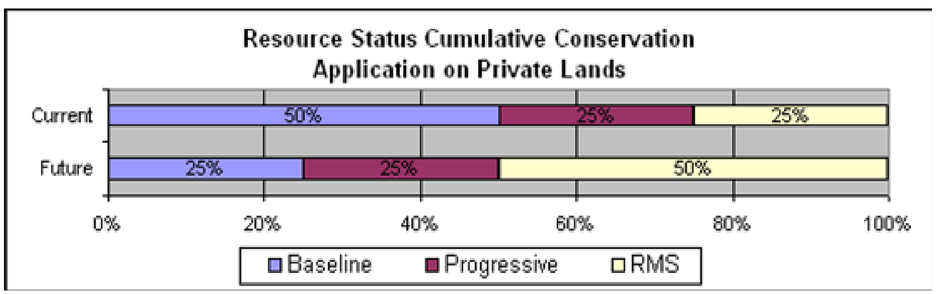


Chart Refers To	
Landuse Type	RANGE
Calculated Participation Rate	50%

Average PV Costs per Ac		
System	**Federal**	**Private**
Prog	$6.66	$6.16
RMS	$22.16	$18.54

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102				LANDUSE ACRES		80,430	
LANDUSE TYPE	FOREST				TYPICAL UNIT SIZE ACRES		50,000	
ASSESSMENT INFORMATION					CALCULATED PARTICIPATION		50%	
	Benchmark Conditions	Future Conditions			RESOURCE CONCERNS			
Conservation Systems by Treatment Level	Total Units	Existing Unchanged Units	New Treatment Units	Total Units	Soil Erosion – Sheet and Rill	Water Quality – Excessive Suspended Sediment and Turbidity in Surface Water	Plant Condition – Productivity, Health and Vigor	Domestic Animals – Inadequate Quantities and Quality of Feed and Forage
Baseline				**System Rating ->**	**1**	**3**	**0**	**0**
Fence (ft.) 382	4,022	2,011	0	2,011	0	1	1	1
Pipeline (ft.) 516	4,022	2,011	0	2,011	3	3	0	0
Watering Facility (no.) 614	8	4	0	4	0	4	1	0
Total Acreage at Baseline	**40,215**	**20,108**	**0**	**20,108**				
Progressive				**System Rating ->**	**4**	**3**	**4**	**4**
Fence (ft.) 382	10,054	6,032	4,022	10,054	0	1	1	1
Pipeline (ft.) 516	10,054	6,032	4,022	10,054	3	3	0	0
Prescribed Burning (ac.) 338	2,011	1,005	1,005	2,011	1	1	4	4
Prescribed Grazing (ac.) 528	20,108	10,054	10,054	20,108	5	3	5	5
Watering Facility (no.) 614	8	6	2	8	0	4	1	0
Total Acreage at Progressive Level	**20,108**	**10,054**	**10,054**	**20,108**				
RMS				**System Rating ->**	**5**	**4**	**5**	**3**
Brush Management (ac.) 314	2,011	2,011	2,011	4,022	4	4	5	3
Fence (ft.) 382	20,108	26,140	14,075	40,215	0	1	1	1
Pipeline (ft.) 516	20,108	26,140	14,075	40,215	3	3	0	0
Prescribed Burning (ac.) 338	2,011	3,016	1,005	4,022	1	1	4	4
Prescribed Grazing (ac.) 528	20,108	30,161	10,054	40,215	5	3	5	5
Tree/Shrub Establishment (ac.) 612	2,011	2,011	2,011	4,022	5	1	4	-3
Upland Wildlife Habitat Management (ac.) 645	20,108	20,108	20,108	40,215	0	0	4	1
Watering Facility (no.) 614	20	26	14	40	0	4	1	0
Wildlife Watering Facility (no.) 648	4	4	4	8	0	0	0	0
Total Acreage at RMS Level	**20,108**	**20,108**	**20,108**	**40,215**				

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102	LANDUSE ACRES	80,430
LANDUSE TYPE	FOREST	TYPICAL UNIT SIZE ACRES	50,000
CONSERVATION COST TABLE		CALCULATED PARTICIPATION	50%

	FUTURE	FEDERAL				PRIVATE		
Conservation Systems by Treatment Level	New Treatment Units	Installation Cost 50%	Management Cost - 3 yrs 100%	Technical Assistance 20%	Total Present Value Cost	Installation Cost 50%	Annual O & M + Mgt Costs 100%	Total Present Value Cost
Progressive								
Fence (ft.) 382	4,022	$6,032	$0	$1,206	$7,239	$6,032	$241	$7,049
Pipeline (ft.) 516	4,022	$16,086	$0	$3,217	$19,303	$16,086	$643	$18,796
Prescribed Burning (ac.) 338	1,005	$25,134	$0	$5,027	$30,161	$25,134	$503	$27,252
Prescribed Grazing (ac.) 528	10,054	$7,540	$0	$1,508	$9,048	$7,540	$0	$7,540
Watering Facility (no.) 614	2	$1,005	$0	$201	$1,206	$1,005	$60	$1,259
Subtotal	**10,054**	**$55,798**	**$0**	**$11,160**	**$66,958**	**$55,798**	**$1,448**	**$61,897**
RMS								
Brush Management (ac.) 314	2,011	$120,645	$0	$24,129	$144,774	$120,645	$2,413	$130,809
Fence (ft.) 382	14,075	$21,113	$0	$4,223	$25,335	$21,113	$845	$24,670
Pipeline (ft.) 516	14,075	$56,301	$0	$11,260	$67,561	$56,301	$2,252	$65,787
Prescribed Burning (ac.) 338	1,005	$25,134	$0	$5,027	$30,161	$25,134	$503	$27,252
Prescribed Grazing (ac.) 528	10,054	$7,540	$0	$1,508	$9,048	$7,540	$0	$7,540
Tree/Shrub Establishment (ac.) 612	2,011	$9,551	$0	$1,910	$11,461	$9,551	$191	$10,356
Upland Wildlife Habitat Management (ac.) 645	20,108	$0	$78,419	$15,684	$85,556	$0	$26,140	$40,238
Watering Facility (no.) 614	14	$7,038	$0	$1,408	$8,445	$7,038	$422	$8,816
Wildlife Watering Facility (no.) 648	4	$2,011	$0	$402	$2,413	$2,011	$40	$2,180
Subtotal	**20,108**	**$249,333**	**$78,419**	**$65,550**	**$384,755**	**$249,333**	**$32,805**	**$317,649**
Grand Total	**30,161**	**$305,131**	**$78,419**	**$76,710**	**$451,713**	**$305,131**	**$34,253**	**$379,546**

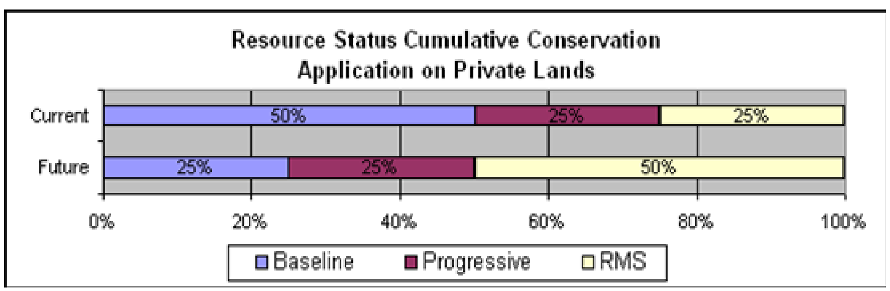


Chart Refers To	
Landuse Type	FOREST
Calculated Participation Rate	50%

Average PV Costs per Ac		
System	**Federal**	**Private**
Prog	$6.66	$6.16
RMS	$19.13	$15.80

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102				LANDUSE ACRES		268,540	
LANDUSE TYPE	URBAN				TYPICAL UNIT SIZE ACRES		10	
ASSESSMENT INFORMATION					CALCULATED PARTICIPATION		22%	
	Benchmark Conditions	Future Conditions			RESOURCE CONCERNS			
Conservation Systems by Treatment Level	Total Units	Existing Unchanged Units	New Treatment Units	Total Units	Soil Condition – Organic Matter Depletion	Water Quantity – Inefficient Water Use on Irrigated Land	Water Quality – Excessive Nutrients and Organics in Groundwater	Air Quality – Particulate matter less than 10 micrometers in diameter (PM 10)
Baseline				**System Rating ->**	**0**	**0**	**0**	**0**
No Conservation Practices being applied at this level	0	0	0	0	0	0	0	0
Total Acreage at Baseline	**241,686**	**193,349**	**0**	**193,349**				
Progressive				**System Rating ->**	**2**	**3**	**3**	**1**
Irrigation System, Surface and Subsurface (ac.) 443	6,714	3,357	12,084	15,441	0	0	0	0
Irrigation Water Management (ac.) 449	13,427	6,714	24,169	30,882	4	5	5	3
Total Acreage at Progressive Level	**13,427**	**6,714**	**24,169**	**30,882**				
RMS				**System Rating ->**	**3**	**4**	**4**	**2**
Atmospheric Resource Quality Management (ac.) 370	13,427	13,427	30,882	44,309	2	0	0	3
Irrigation System, Microirrigation (ac.) 441	1,343	1,343	3,088	4,431	0	4	0	0
Irrigation System, Sprinkler (ac.) 442	1,343	1,343	3,088	4,431	0	4	0	0
Irrigation System, Surface and Subsurface (ac.) 443	13,427	16,784	27,525	44,309	0	0	0	0
Irrigation Water Management (ac.) 449	13,427	20,141	24,169	44,309	4	5	5	3
Nutrient Management (ac.) 590	13,427	13,427	30,882	44,309	3	1	5	1
Pest Management (ac.) 595	13,427	13,427	30,882	44,309	0	1	0	0
Total Acreage at RMS Level	**13,427**	**13,427**	**30,882**	**44,309**				

WATERSHED NAME & CODE	AGUA FRIA RIVER - 15070102	LANDUSE ACRES	268,540
LANDUSE TYPE	URBAN	TYPICAL UNIT SIZE ACRES	10
CONSERVATION COST TABLE		CALCULATED PARTICIPATION	22%

Conservation Systems by Treatment Level	FUTURE New Treatment Units	FEDERAL Installation Cost 50%	FEDERAL Management Cost - 3 yrs 100%	FEDERAL Technical Assistance 20%	FEDERAL Total Present Value Cost	PRIVATE Installation Cost 50%	PRIVATE Annual O & M + Mgt Costs 100%	PRIVATE Total Present Value Cost
Progressive								
Irrigation System, Surface and Subsurface (ac.) 443	12,084	$0	$0	$0	$0	$0	$0	$0
Irrigation Water Management (ac.) 449	24,169	$0	$725,058	$145,012	$791,041	$0	$241,686	$372,040
Subtotal	**24,169**	**$0**	**$725,058**	**$145,012**	**$791,041**	**$0**	**$241,686**	**$372,040**
RMS								
Atmospheric Resource Quality Management (ac.) 370	30,882	$0	$555,878	$111,176	$606,465	$0	$185,293	$285,231
Irrigation System, Microirrigation (ac.) 441	3,088	$2,316,158	$0	$463,232	$2,779,389	$2,316,158	$231,616	$3,291,807
Irrigation System, Sprinkler (ac.) 442	3,088	$2,624,979	$0	$524,996	$3,149,974	$2,624,979	$104,999	$3,067,273
Irrigation System, Surface and Subsurface (ac.) 443	27,525	$0	$0	$0	$0	$0	$0	$0
Irrigation Water Management (ac.) 449	24,169	$0	$725,058	$145,012	$791,041	$0	$241,686	$372,040
Nutrient Management (ac.) 590	30,882	$0	$926,463	$185,293	$1,010,775	$0	$308,821	$475,384
Pest Management (ac.) 595	30,882	$0	$926,463	$185,293	$1,010,775	$0	$308,821	$475,384
Subtotal	**30,882**	**$4,941,136**	**$3,133,862**	**$1,615,000**	**$9,348,419**	**$4,941,136**	**$1,381,235**	**$7,967,119**
Grand Total	**55,051**	**$4,941,136**	**$3,858,920**	**$1,760,011**	**$10,139,460**	**$4,941,136**	**$1,622,921**	**$8,339,159**

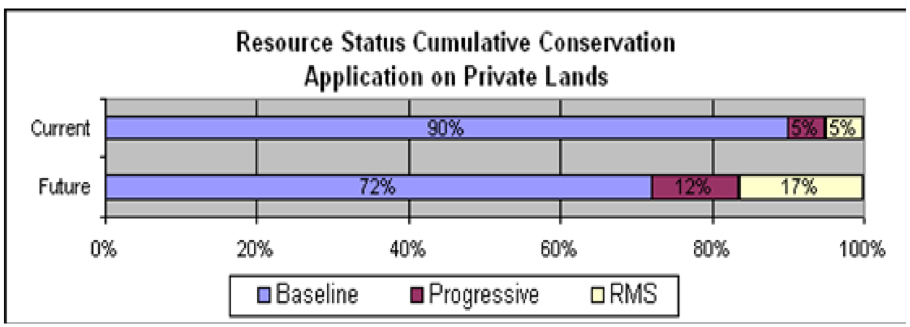


Chart Refers To	
Landuse Type	URBAN
Calculated Participation Rate	22%

Average PV Costs per Ac		
System	**Federal**	**Private**
Prog	$32.73	$15.39
RMS	$302.71	$257.99

Section 6: References

Agua Fria National Monument (http://www.geocities.com/afnmus/Geology.html).

Arizona Association of Conservation Districts (http://www.aaocd.org/).

Arizona Dept. of Agriculture (http://www.azda.gov/).

Arizona Dept. of Environmental Quality Water Quality Monitoring & Assessment (http://azdeq.gov/environ/water/assessment/assess.html).

Arizona Department of Environmental Quality. Draft 2006 Status of Ambient Surface Water Quality in Arizona – Arizona's Integrated 305(b) Assessment and 303(d) Listing Report. Arizona Department of Environmental Quality, Phoenix, Arizona.

Arizona Department of Environmental Quality, Air Quality Division, http://www.azdeq.gov/environ/air/plan/notmeet.html#phoenix.

Arizona Department of Water Resources, Arizona Drought Preparedness Plan, Background & Impact Assessment Section, Governor's Drought Task Force, Governor Janet Napolitano, October 8, 2004. http://www.azwater.gov/dwr/content/find_by_program/GDTF/conclusion/Background_Section_100804FINAL.pdf.

Arizona Department of Water Resources, Arizona Water Atlas, (http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/content/water_atlas/).

Arizona Department of Water Resources, Upper Agua Fria Basin, http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/content/map/UppAguFri.htm.

Arizona Game & Fish Dept. Heritage Database http://www.azgfd.gov/w_c/edits/species_concern.shtml).

Arizona Game & Fish Department, 2006, Desert Tortoise, http://www.gf.state.az.us/w_c/desert_tortoise.shtml0).

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), GIS data layer "Geology," February 7, 2003. http://www.land.state.az.us/alris/index.html.

Arizona State Land Department, Arizona Land Resource Information System (ALRIS),GIS data layer "Lakes," February 7, 2003, http://www.land.state.az.us/alris/index.html.

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), GIS data layer “mines”, February 7, 2002 http://www.land.state.az.us/alris/index.html.

Arizona State Land Department, Arizona Land Resource Information System (ALRIS), GIS data layer “natveg”, June 12, 2003 http://www.land.state.az.us/alris/index.html.

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

Arizona State Land Department, Arizona Land Resource Information System (ALRIS); GIS data layer “Streams”, Arizona, October, 10, 2002 http://www.land.state.az.us/alris/index.html.

Barnett, L. R.H. Hawkins, and P. Guertin*.2001, Reconnaissance Watershed and Hydrologic Analysis on the Upper Agua Fria Watershed,* University of Arizona, Tucson, Arizona.

Bureau of Land Management Arizona Website (http://www.blm.gov/az/st/en.html).

Chronic, Halka. 1983. Roadside Geology of Arizona. Mountain Press Publishing Company, Montana.

Climate Assessment for the Southwest (CLIMAS) website (www.ispe.arizona.edu/climas), information on Arizona's drought status.

ESRI Data Products, http://arcdata.esri.com/data/tiger2000/tiger_download.cfm Census 2000. October 17, 2003.

GeoLytics, Inc. 1998. Census 1990. Census CD + Maps. Release 3.0.

Litten, G.R., 1981, Maps showing ground-water conditions in the Agua Fria area, Yavapai and Maricopa Counties, Arizona – 1979: U.S. Geological Survey Open-File Report 81-804.

National Agricultural Statistics Service (http://www.nass.usda.gov/).

Natural Resources Conservation Service (NRCS), 2007, Table generated by NRCS Phoenix Office.

Natural Resources Conservation Service (NRCS), Agua Fria River Watershed Soil Data and Maps, http://websoilsurvey.nrcs.usda.gov.

Natural Resources Conservation Service (NRCS) Website 2006, Technical Guide – New Mexico http://www.nm.nrcs.usda.gov/technical/fotg/transmittals/fotg-1.doc

Natural Resources Conservation Service Arizona Website (http://www.az.nrcs.usda.gov/).

Natural Resources Conservation Service Arizona GIS Webpage (http://www.az.nrcs.usda.gov/technical/gis/index.html).

Natural Resources Conservation Service Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/).

Natural Resources Conservation Service Water & Climate Center (http://www.wcc.nrcs.usda.gov/).

Noon B.R. and K.S. McKelvey 1992. Stability Properties of the Spotted Owl Metapopulation in Southern California. Pages 187-206 in J. Verner et al., technical editors. The California Spotted Owl: A Technical Assessment of its current status. US Forest Service General Technical Report PSW – 133.

Southern Arizona Data Services Program, GIS data layer "Arizona Gap Analysis Project Vegetation Map", University of Arizona, 2004, http://sdrsnet.srnr.arizona.edu/index.php, originated by Arizona Game & Fish Department, Habitat Branch, 1993, this dataset was digitized from the August 1980 David E. Brown & Charles H. Lowe 1:1,000,000 scale, 'Biotic Communities of the Southwest'.

Southwest Regional GAP Project (http://fws-nmcfwru.nmsu.edu/swregap/.

Theobald, D. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10(1): 32. [online] URL: http://www.ecology and society.org/vol10/iss1/art32/.

United States Bureau of Land Management, Draft Agua Fria National Monument/Bradshaw-Harquahala Draft Resource Management Plan/Draft Environmental Impact Statement (DRMP/DFEIS) at https://www.blm.gov/eplanning/az_pn/builds/build217/index.htm.

United States Department of Agriculture, 2004, Arizona Bark Beetle Epidemics Fact Sheet and Information Bulletin, Southwestern Region, USDA Forest Service.

United States Environmental Protection Agency, Surf Your Watershed (http://www.epa.gov/surf/).

United States Environmental Protection Agency, Air Quality Trends, http://epa.gov/air/aritrends/aqtrnd95/pm10.html.

United States Fish & Wildlife Service. 2004. Mexican Spotted Owl, http://www.fws.gov/ifw2es/Documents/R2ES/MSO_Recovery_Plan.pdf.

United States Fish & Wildlife Service, Threatened and Endangered Species Listed for Arizona, http://ecos.fws.gov.

United States Fish & Wildlife Service Arizona Ecological Services (http://www.fws.gov/southwest/es/arizona/).

United States Forest Service, Forest Service, Fact Sheet "Arizona Bark Beetle Epidemics," produced by Forest Health Staff, Southwestern Region, USDA Forest Service, January 2004*, http://www.fs.fed.us/r3/prescott/forest-health/index.shtml.*

United States Forest Service (USFS), Terrestrial Ecosystem Surveys. Surveys are available for National Forest Lands within the watershed.

United States Forest Service Southwestern Region (http://www.fs.fed.us/r3/).

United States Geological Survey, NLCD Land Cover Class Definitions, http://landcover.usgs.gov/classes.php.

United States Geological Survey, April 8, 2003, derived from DEM, http://edc.usgs.gov/geodata/.

United States Geological Survey website, National Water Information System http://waterdata.usgs.gov/nwis/.

Western Regional Climate Center (WRCC), Temperature data. July 15, 2004. http://www.wrcc.dri.edu/summary/climsmaz.html.

Wilson, R. P. 1988. Water Resources of the Northern Part of the Agua Fria Area Yavapai County, Arizona. Prepared by the U.S. Geological Survey. Arizona Department of Water Resources Bulletin 5.

Yavapai County. 1986. Black Canyon City Community Plan Update.

GLOSSARY

Drainage Basin	A region or area bounded by a topographic divide and occupied by a drainage system, also known as a watershed.
Drought	There is no universally accepted quantitative definition of drought. Generally, the term is applied to periods of less than average precipitation over a certain period of time; nature's failure to fulfill the water wants and needs of man.
Flood	A flood is an overflow or inundation that comes from a river or other body of water and causes or threatens damage. It can be any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. It is also a relatively high flow as measured by either gage height or discharge quantity.
Ground Water	The supply of fresh and saline water found beneath the Earth's surface which is often used for supplying wells and springs. Because ground water is a major source of drinking water, there is a growing concern over areas where leaching agricultural or industrial pollutants are contaminating ground water.
Soil Moisture Regimes	**Aridic** is a soil moisture regime that has no water available for plants for more than half the cumulative time that the soil temperature at 50 cm (20 in.) below the surface is >5°C (41° F.), and has no period as long as 90 consecutive days when there is water for plants while the soil temperature at 50 cm (20 in.) is continuously >8°C (46°F.). **Udic** is a soil moisture regime that is neither dry for as long as 90 cumulative days nor for as long as 60 consecutive days in the 90 days following the summer solstice at periods when the soil temperature at 50 cm (20 in.) below the surface is above 5°C (41° F.). **Ustic** is a soil moisture regime that is intermediate between the aridic and udic regimes and common in temperate subhumid or semiarid regions, or in tropical and subtropical regions with a monsoon climate. A limited amount of water is available for plants but occurs at times when the soil temperature is optimum for plant growth.
Soil Orders	A soil order is a group of soils in the broadest category. In the current USDA classification scheme there are 12 orders, differentiated by the presence or absence of diagnostic horizons.
Soil Temperature Regimes	**Hyperthermic** is a soil temperature regime that has mean annual soil temperatures of 22°C (72°F.) or more and >5°C (41° F.) difference between mean summer and mean winter soil temperatures at 50 cm (20 in.) below the surface.

	Thermic is a soil temperature regime that has mean annual soil temperatures of 15°C (59°F.) or more but <22°C (72°F.), and >5°C (41° F.) difference between mean summer and mean winter soil temperatures at 50 cm (20 in.) below the surface. **Mesic** A soil temperature regime that has mean annual soil temperatures of 8°C (46°F.) or more but <15°C (59°F.), and >5°C (41° F.) difference between mean summer and mean winter soil temperatures at 50 cm (20 in.) below the surface.
Surface Water	Water on the earth's surface. Lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, wetlands, marshes, inlets, canals, and all other bodies of surface water, natural or artificial, inland or coastal, fresh or salt, navigable or non-navigable, and including the beds and banks of all watercourses and bodies of surface water, that are wholly or partially inside or bordering the state or subject to the jurisdiction of the state; except that waters in treatment systems which are authorized by state or federal law, regulation, or permit, and which are created for the purpose of waste treatment.
Watershed	The area of land that contributes surface run-off to a given point in a drainage system and delineated by topographic divides.

Acknowledgements

The following University of Arizona staff and students contributed to the production of this report.

Terry Sprouse
Erin Westfall
Lainie Levick
Melisa Kennedy
Ivan Parra
Myrtho Joseph
Dilruba Yeasmin
Ari Posner
Mickey Reed

NRCS Field Office, Area Office and State Office staff contributed to the development of this assessment.