ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Upper Tonto Creek
Intensive Survey

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The Arizona Department of Environmental Quality Shall preserve, protect and enhance the environment and public health, and shall be a leader in the development of public policy to maintain and improve the quality of Arizona's air, land and water resources.

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Executive Summary

An Intensive Survey of the Upper Tonto Creek Basin was conducted during the spring and summer of 1994. Data collected by Arizona Department of Environmental Quality staff were reviewed to determine what impacts Upper Tonto Creek was receiving from heavy summertime recreational use. In addition to recreational uses, other entities such as permitted facilities, church camps, housing areas, and campgrounds were also evaluated to determine what impacts they had on Upper Tonto Creek. Sample collection began in March of 1994 (winter background control sample) followed by monthly sampling in June through September with two samples taken during August.

Data indicate that overall the quality of water in Upper Tonto Creek is good. One water quality standard, the total nitrogen annual mean, was exceeded below the Arizona Game and Fish Department Hatchery. However, the exceedance only occurred immediately below the hatchery and not at any other downstream sites. No other water quality exceedances were noted throughout the survey. We concluded that heavy summertime recreational usage is not having any appreciable impact on the water quality of Upper Tonto Creek.

1.0 INTRODUCTION

The Arizona Department of Environmental Quality (ADEQ) enacted a Surface Water Intensive Survey Monitoring Program in 1993. The program was created to address specific pollution concerns in selected rivers, streams and creeks throughout Arizona. The Upper Tonto Creek Intensive Survey was designed to conduct a multi-year survey in the upper reaches of Tonto and Christopher Creeks. This report covers Phase I of the study which covers Upper Tonto Creek, while Phase II will cover Christopher Creek. These two creeks start as a series of springs below the Mogollon Rim and flow in a southerly direction for approximately 9 miles through the Upper Tonto Basin before entering the Hellsgate Wilderness Area. The area's natural beauty and cool summer climate attract people that enjoy a variety of outdoor activities. These activities include: hiking, fishing, camping, and sightseeing. ADEQ and U.S. Forest Service personnel were concerned that large summertime populations were contributing excessive nutrients and bacteria to Upper Tonto Creek and posing a health threat to the users of the creek. The effect of this summertime pressure on the creek is in addition to the only permitted facility discharging into the creek; The Arizona Game and Fish Department's Tonto Creek Hatchery.

With septic tanks and leach fields being the predominant means of sewage disposal in this area, contamination of groundwater and surface water with nutrients and bacteria was a concern. Contamination could be minimal to moderately high depending on several variables including density of homes with septic tanks in a specific area, construction and integrity of the tanks and the leach fields, the number of people in the home, depth to groundwater, porosity of the subsurface soils, and the proximity to flowing surface waters.

The intensive survey focused on five areas of concern along Upper Tonto Creek. They were: The Arizona Game and Fish Department Hatchery, the Baptist church camp and surrounding housing development, U.S. Forest Service campgrounds, Kohls Ranch residential area, and Arizona State University (ASU) Camp Tontozona.

2.0 OBJECTIVES

The lack of basic water quality data on Tonto Creek and the hypotheses that the fish hatchery, church camp, residential properties and campgrounds were adding excessive nutrients to the creek led to this survey. A monitoring program was designed to accomplish clearly stated monitoring objectives which included identifying present, or potential problems, identifying likely sources, and defining trends. The specific objectives of this intensive study were to determine:

1. Which nutrients, if any, and what amounts were being added to Upper Tonto Creek by the Arizona Game and Fish Department Hatchery;

2. If the Baptist church camp and adjacent summer homes were having any impacts on Upper Tonto Creek;

3. The level of impact campground usage along Upper Tonto Creek had on the overall water quality of the creek;

4. The level of impact the residential community of Kohls Ranch had on the water quality of Upper Tonto Creek;

5. The level of impact ASU Camp Tontozona had on the water quality of Upper Tonto Creek.

3.0 DESCRIPTION OF THE STUDY AREA

3.1 General: The Upper Tonto Basin comprises approximately 16,000 acres within the northeastern part of the Tonto National Forest in Gila County, Arizona. Two major perennial streams, Tonto Creek and Christopher Creek, and three minor streams, Hunter, Horton and Dick Williams Creeks, are located within the study area. Major springs in the survey area include: Tonto, Indian Garden, Nappa, Herman and See Springs. Elevation ranges from approximately 6,500 feet at the headwater springs to approximately 5,000 feet at the Hellsgate Wilderness Area in the lower end of the study area.

Two small unincorporated communities, Kohls Ranch and Christopher Creek, make up the largest population centers within the study area. In addition, several forest service campgrounds, church camps, and numerous summer cabins can be found throughout the study area. All are heavily used during the summer months.

3.2 Climate: The study area is characterized by mild summers and cold winters. The area receives an average of 27.2 inches of precipitation annually (National Weather Service, personal communication, 1994). The precipitation pattern is distinctly bimodal. Convectional storms, receiving water from the Gulf of Mexico, are common from July through September. Large frontal storms originating in the Pacific Ocean bring moisture to the area from December through March. Late spring and fall are characteristically dry. The thirty year average mean January temperature for the area is 34°F, while the thirty year average July temperature is 72°F (National Weather Service, personal communication, 1994).

3.3 Vegetation: The Upper Tonto Basin is covered by a conifer forest composed principally of ponderosa pine (Pinus ponderosa), and some douglas firs (Pseudotsuga menziesii) in its upper reach. At the Arizona Game and Fish Department Hatchery, some dominant riparian species of trees, shrubs, and grasses along Upper Tonto Creek are Arizona alder (Alnus oblongifolia), box elder (Acer negundo), canyon grape (Vitis arizonicus), and reed canary grass (Phalaris arundinacea). At the confluence of Tonto and Horton Creeks, dominant riparian species include Arizona alder, New Mexico locust (Robinia neomexican), bonpland willow (Salix bonplandiana), canyon grape, raspberry (Rubus strigosus) and reed canary grass. Along Upper Tonto Creek below Kohls Ranch, dominant riparian species include bonpland willow, Arizona alder, Western chokecherry (Prunus virginiana) and reed canary grass (Nelson and Baker, 1994).

3.4 Geology: Consolidated sedimentary rocks consisting of limestone, sandstone, and shale make up the geology of the Upper Tonto Basin. The basin fill is composed mainly of clay and silt and contains some gravel and sand (Denis, 1981).

4.0 STUDY DESIGN

The Upper Tonto Creek Basin Intensive Survey was divided into two phases to maximize sampling sites and collection frequency.

Phase I of the survey focused on Upper Tonto Creek from its headwaters to its confluence with Christopher Creek. Sampling was conducted from March - September 1994.

Phase II will focus on Christopher Creek from its headwaters to the confluence of Tonto Creek and to the beginning of the Hellsgate Wilderness Area. Sampling will be conducted during the summer of 1995.

This report summarizes the findings of Phase I of the Intensive Survey.

4.1 Surface Water Quality Standards and Designated Uses

Arizona's Surface Water Quality Standards (A.A.C. Title 18, Chapter 11,) list the following designated uses for Upper Tonto Creek:

A&Wc	Aquatic and Wildlife cold water fishery
FBC	Full Body Contact
FC	Fish Consumption
AgI	Agricultural Irrigation
AgL	Agricultural Livestock Watering

Numeric water quality standards that apply to this segment of Upper Tonto Creek are listed below and expressed in milligrams per liter(mg/l), unless otherwise noted:

	Annual mean	90th percentile	Single sample maximum
Total nitrogen:	0.50	1.00	2.00
Total phoshorus	0.10	0.20	0.80
Turbidity	10 nephelometric turbidity units (NTU)		
pH Maximum	9.0 standard units (su)		
pH Minimum	4.5 standard units (su)		
Dissolved Oxygen Minimum	7.0		

4.2 Water Quality Variables

The following variables were monitored at each sampling site throughout the survey period.

Lab Tests	• Total Dissolved Solids (TDS)	• Total Phosphorus (TP)
	• Total Suspended Solids (TSS)	• Potassium (K)
	• Nitrite/Nitrate total (NO_2+NO_3)	• Chloride (Cl)
	• Total Kjeldahl Nitrogen (TKN)	• Fluoride (F)
	• Ammonia (NH_3)	Sulfate (SO_4)
	Total Alkalinity (T.Alk.)	Bicarbonate ($HC0_3$)
Field Tests	• Turbidity	pH
	• Dissolved Oxygen (D.O.)	Electrical Conductivity (EC)
	Water Temperature	

Several of the variables listed above are effluent-related and are indicated by the • symbol. Each of these variables, with the exception of dissolved oxygen, are usually elevated in domestic sewage and effluent; all have been proven as effective tracers of septic tank effluent in fresh water streams and lakes (Hyde, 1994). The absolute levels and relative proportions of nitrogen and phosphorus can have a significant effect on a stream's ecology.

Algal blooms can develop in stream channels and become a nuisance if nutrient concentrations are excessive. Present information suggests that most streams in Arizona are nitrogen limited (Grimm and Fisher, 1986).

4.3 Bacteriological Variables

In addition to effluent-related variables, bacteria data were also collected to determine what bacteriological impacts were present on Upper Tonto Creek. Fecal coliform, fecal streptococcus, and Escherichia coli samples were collected at each site. On Upper Tonto Creek the only surface water quality standards for bacteria are for fecal coliform (FC). Expressed in colony forming units per 100 milliliters of water (cfu/100ml), the standards consist of these three limits:

1. **800** cfu/100ml: single sample maximum
2. **400** cfu/100ml: 90th% percentile, (10% of samples for a 30-day period)
3. **200** cfu/100ml: geometric mean of at least five samples (over a 30-day period)

Fecal coliform bacteria live in the intestinal tract of warm blooded animals and are excreted in the feces of animals. Although these bacteria are not pathogenic, they have long been used by the scientific and regulatory communities as an indicator organism for evaluating the microbiological suitability of waters for recreational use.

The potential sources of fecal coliform bacteria along Upper Tonto Creek are:

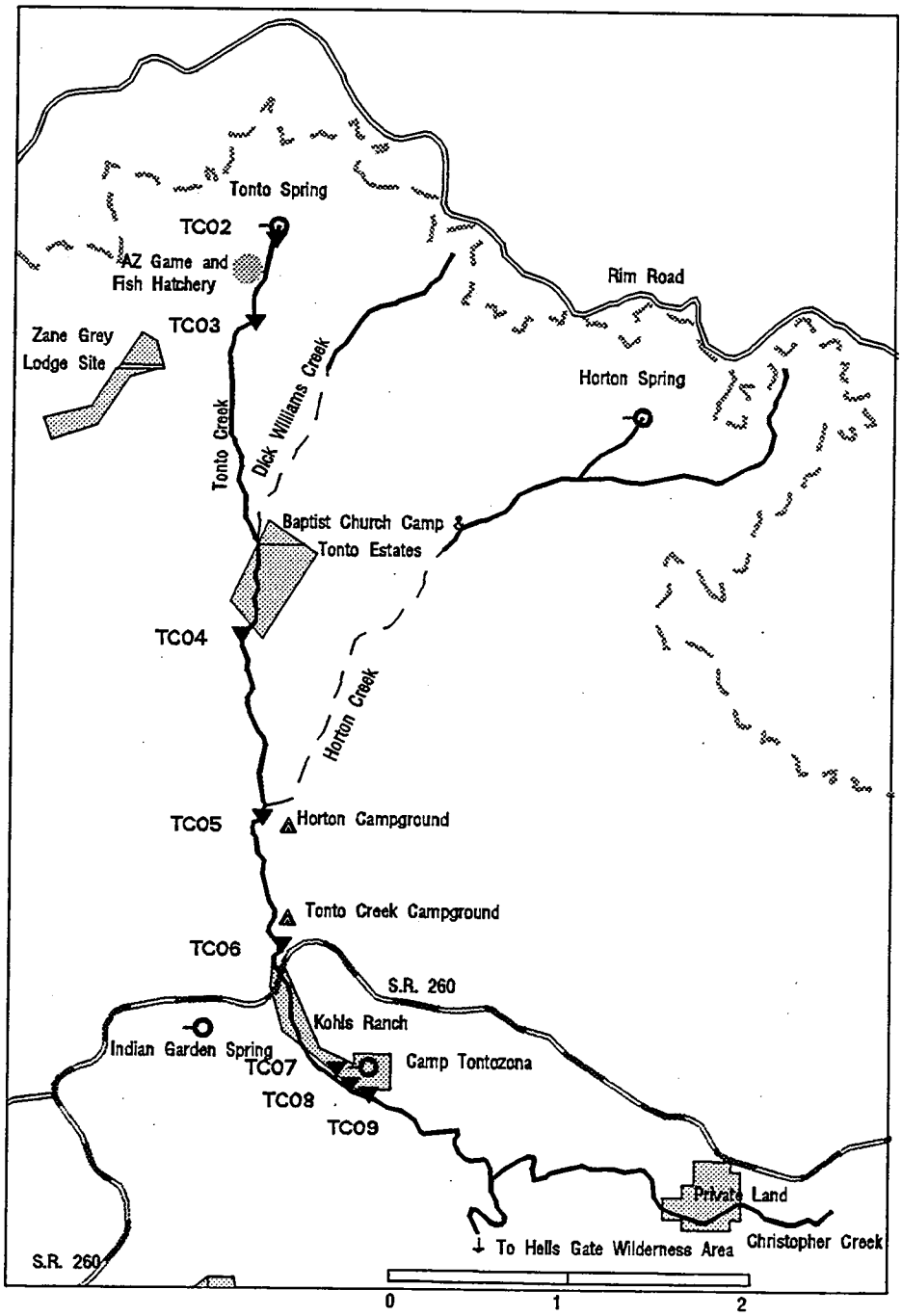
1. Sewage from private septic tanks
2. Spills from broken sewage and leach lines
3. Cattle grazing in and near the creek
4. Heavy recreational use of the creek by humans
5. Wildlife

4.4 Sample Sites and Description

Eight sample sites were selected for Phase I of the Upper Tonto Creek Intensive Survey. Seven sites were selected based on their proximity to suspected or known source impacts and one site was used as a control site. (Figure 1).

Figure 1. Upper Tonto Creek Intensive Survey Sampling Sites

Gila County, AZ



TC02- Upper Tonto Creek headwater spring: A small spring located high in the Upper Tonto Creek drainage and below the Mogollon Rim is the origin of Upper Tonto Creek. It is located in a remote area above any known impacts, including cattle grazing, according to Forest Service personnel. The site's inaccessibility, and lack of impacts made it a good upstream control.

TC03- Upper Tonto Creek below the Arizona Game and Fish Department Hatchery: The site is located approximately 60 feet below the fish hatchery discharge point to Upper Tonto Creek. Water is diverted from Upper Tonto Creek above the fish hatchery and passed through the hatchery to support trout raising operations. The hatchery produces native and non-native trout that are stocked in nearby streams and lakes. After the water has passed through a series of holding tanks and ponds, it is discharged back into Upper Tonto Creek below the hatchery.

The facility has been operating on Upper Tonto Creek since 1938 and has a National Pollution Discharge Elimination System (NPDES) Permit to discharge directly into Upper Tonto Creek. Comparing data at this site with the upstream control site will determine what impact the fish hatchery is having on Upper Tonto Creek.

TC04- Upper Tonto Creek below the Church Camp: The site is located on Upper Tonto Creek just downstream of a Baptist church camp and a small subdivision of cabins which are adjacent to Upper Tonto Creek. Septic systems are utilized by the church camp and by the individual cabins. Comparing data from this site with the upstream sites, will determine if impacts from cabins and the church camp are occurring.

TC05- Upper Tonto Creek below Horton Creek Campground: The site is located approximately 150 feet below the Horton Creek Campground. The campground is small but experiences heavy usage. It is a popular spot for camping, fishing, picnicking and playing in the creek. Comparing data from this site with the above three sites will determine what impacts camping and the other recreational activities are having on Upper Tonto Creek.

TC06- Upper Tonto Creek above State Highway 260 road crossing: The site is adjacent to the Tonto Creek Forest Service campground. It is the largest campground on Upper Tonto Creek and is usually full during the summer months. On several sampling visits to this site, cattle were seen grazing in the creek's riparian area. However, Forest Service personnel have stated that this area is off limits to grazing, and that no permits to graze have been issued.

Comparing data from this site to the above sites will determine what the accumulative impacts of camping, recreation and unauthorized grazing are having on the area. Due to the significant distance from the control site (TC02), elevation change, and anthropogenic changes in the creek, the site will also serve as a control site for the next three downstream sites.

TC07- Upper Tonto Creek below Kohls Ranch: The site is located on Upper Tonto Creek immediately below a residential area. The residential area consisting mostly of summer homes is located on both sides of the creek from the highway 260 road crossing to the beginning of the ASU Camp Tontozona facility. The housing area also includes a motel which has several cabins that are located on the banks of Upper Tonto Creek. Comparing data from this site to the above control site (TC06) will determine what impact the motel and summer homes are having on Upper Tonto Creek.

TC08- Camp Tontozona Spring: This small spring is located in a small drainage on Camp Tontozona property. The spring emerges near the camp's football practice field where the entire facility's septic leach lines are located. Comparing data from this site to above sites on Upper Tonto Creek will determine what affect, if any, this spring is having on the water quality of Upper Tonto Creek.

TC09- Upper Tonto Creek below Camp Tontozona: The site is located on Upper Tonto Creek approximately 225 feet below Camp Tontozona's downstream property boundary. Data collected at this site will be compared to sites TC06, and TC07 to determine what impacts Camp Tontozona facilities may be having on Upper Tonto Creek.

5.0 METHODS

5.1 Field

Sampling was conducted monthly from June through September with two samples collected in August to coincide with the peak of summer recreational activities. One winter background sample was taken in March. Upstream and downstream photographs were taken during each site visit.

Water samples were submitted to the Arizona Department of Health Service State Laboratory in Phoenix. Field measurements, photography, bacterial and water chemistry collection methods conformed with ADEQ Surface Water Monitoring Procedures (ADEQ, 1995) and ADEQ Quality Assurance Project Plan (ADEQ, 1991).

5.2 Laboratory

Bacterial and water chemistry analysis procedures followed Standard Methods for Examination of Water and Wastewater, 18th Edition (1992).

5.3 Statistical Analysis

A personal computer with QUATTRO PRO software was used for data entry and graphics. SAS for PC's was utilized for all statistical analyses. All references to "significantly greater" refer to $p < 0.05$ level of statistical significance. Where the control site was compared to downstream sites, tests were performed using the Dunnett's test on data ranked across sites (Kuehl, 1994).

The statistical convention used to handle values below the laboratory minimum reporting level was to transform them to a value half of the minimum reporting level, unless otherwise noted. Minimum reporting levels signify that the actual value is unknown, but lies somewhere between zero and the minimum reporting level.

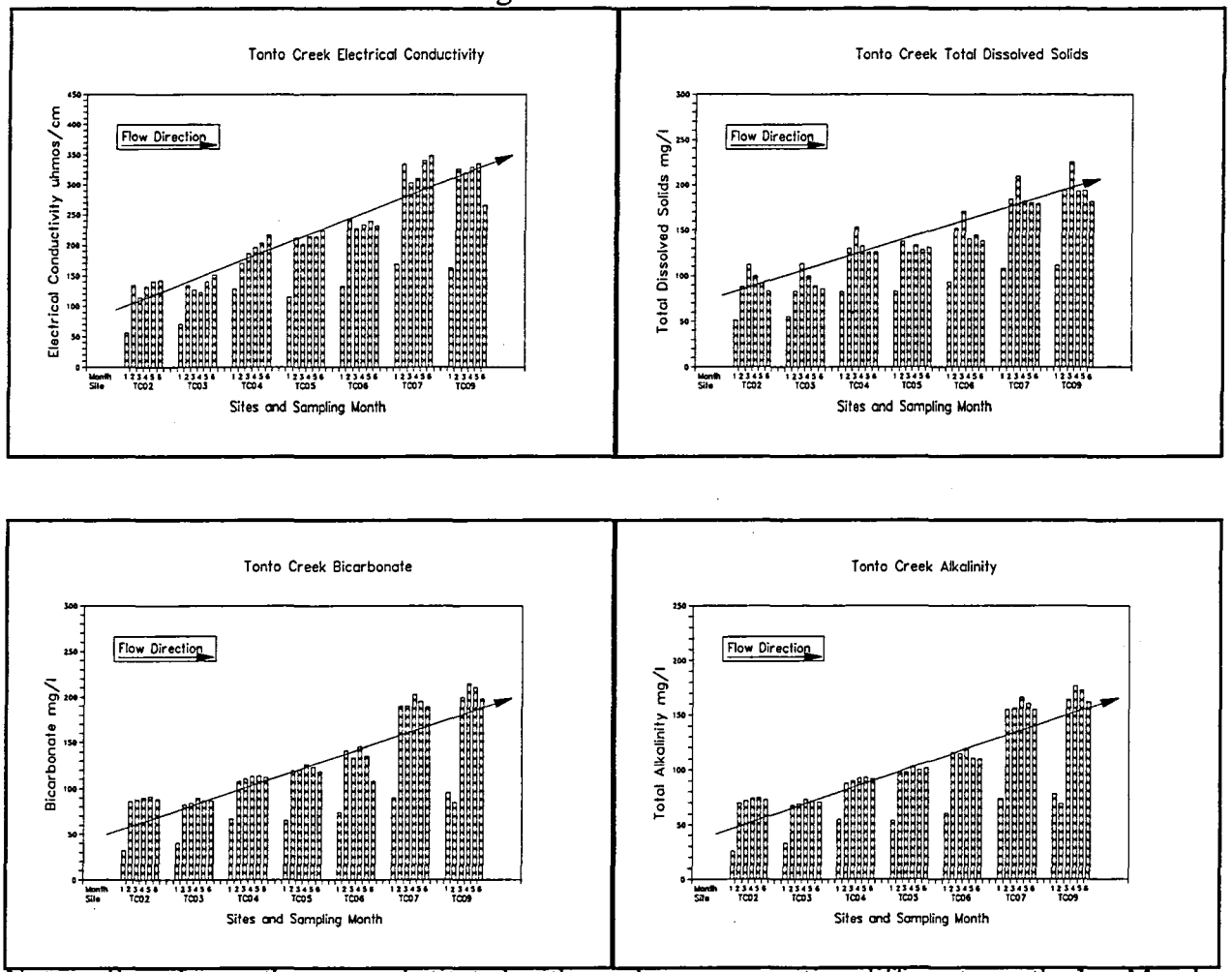
6.0 RESULTS AND DISCUSSIONS

6.1 General trends

Several variables displayed consistent trends along Upper Tonto Creek from the upstream control site to the furthest downstream sampling site in the survey. Electrical conductivity (EC), total dissolved solids (TDS), bicarbonate (HCO_3), and total alkalinity (T.Alk), displayed a steady increase from the control site to TC09 (Figure 2). Total phosphorus and fluoride were not detected at any site during the survey.

Nutrient variables TKN, NH_3, and NO_2+NO_3 were all elevated below the hatchery (TC03), but NH_3 and TKN returned to background levels at TC04, while NO_2+NO_3 levels peaked at TC04 before dropping. The only water quality exceedance discovered during the survey was an exceedance of the total nitrogen annual mean, which occurred below the hatchery.

FIGURE 2. Variables with Increasing Trends



Note: Sample months were substituted with numbers representing different months 1= March, 2= June, 3= July, 4= Early August, 5= Late August, 6= September.

6.2 Areas of concern

6.2.1 Below the Arizona Game and Fish Department Hatchery, (TC03)

Four variables at TC03 were found to be significantly greater at the 5% level of significance when compared to the control site at TC02. They were: turbidity and nutrients NO_2+NO_3, TKN, and total nitrogen (Table 1).

TABLE 1. Water Quality Variables Found to be Significantly Greater at TC03 When Compared to TC02.

Variable	NO_2+NO_3		TKN		Total N		Turbidity	
Site	TC02	TC03	TC02	TC03	TC02	TC03	TC02	TC03
Maximum	.12	.34	.23	.64	.33	.98	7.81	7.74
Mean	.06	.26	.12	.35	.18	.61	1.47	4.51

Note: All values are reported in milligrams per liter of water (mg/l), except turbidity which is reported in NTU.

It appears that the effluent from the hatchery could be having a direct effect on the nutrient levels found at TC03. Data indicate that water quality standards for the total nitrogen single sample maximum and the 90th percentile limits were met at this site during the survey period. However, the total nitrogen annual mean limit of 0.50 mg/l was exceeded by 0.11 mg/l during the survey. Whether this exceedance was caused from the hatchery discharge or from other natural sources is unknown at this point. Effluent discharge from the hatchery was never sampled, thus it is impossible to determine the actual source of the increase. However, the hatchery, which is required to sample its discharge, per its NPDES permit, has documented several violations of its total nitrogen permit limit over the past several years (Arizona Water Quality Assessment, 1994). The NPDES permit held by the fish hatchery specifies the following limits for its discharge into Upper Tonto Creek:

WATER QUALITY VARIABLE	PERMIT LIMIT	
	Daily Max.	Daily Avg.
Total nitrogen:	2.00 mg/l	0.50 mg/l
Total phosphorus:	0.80 mg/l	0.10 mg/l

The total nitrogen mean calculated at the control site was 0.18 mg/l. Downstream of the hatchery the total nitrogen mean was 0.61 mg/l, an increase of 0.43 mg/l and an exceedance of the water quality standard by 0.11 mg/l.

In the March winter sample, total nitrogen values at the control spring were 0.10 mg/l and 0.35 mg/l below the hatchery. This is more than a 50 percent reduction from the mean value calculated at both sites during the summer months. Perhaps the difference can be attributed to a greater volume of streamflow in the winter months causing greater dilution.

Although turbidity was significantly greater at TC03 when compared to TC02, its mean value was still well within the water quality standard of 10 NTU'S. In addition, TDS, TSS, Cl and K concentrations were slightly higher below the hatchery than at the control site, but increases in these variables were generally observed throughout the study area and are probably due to physical, chemical or biological changes, although increases could also be from contributing non-point source activities.

Bacteriological data revealed little difference between TC03 and TC02 (Table 2). No mean measurement exceeded the most stringent 200 cfu/100 ml water quality standard assigned this stream segment.

TABLE 2. Summary Statistics for Bacterial Data, March-September 1994

Site	Summary Statistic	Fecal Coliform	Fecal Streptococcus	Escherichia coli
TC02	Mean	6	48	14
	Maximum	12	109	23
TC03	Mean	7	44	26
	Maximum	20	87	40
TC04	Mean	32	117	38
	Maximum	52	195	54
TC05	Mean	41	150	38
	Maximum	83	522	103
TC06	Mean	27	105	27
	Maximum	75	183	86
TC07	Mean	41	155	40
	Maximum	91	305	77
TC08	Mean	26	102	12
	Maximum	140	382	44
TC09	Mean	48	104	26
	Maximum	107	228	64

Note: All values are reported in colony forming units per 100 milliliters of water (cfu/100ml).

6.2.2 Below the church camp and adjacent housing Area (TC04)

Data indicate that the chemical, and biological properties of Upper Tonto Creek are changing between this site and the control. T.Alk, TDS, EC, $HC0_3$, SO_4, pH, $N0_2+N0_3$, and FC all increased in concentration between these sites. Of those, SO_4, pH, $N0_2+N0_3$, and FC were significantly greater here compared to TC02 (upstream control) at the 5% level of significance (Table 3). However, no water quality variables were exceeded at this site.

TABLE 3. Mean of Water Quality Variables Found to be Significantly Greater at TC04 When Compared to TC02

Variable	SO_4		pH		NO_2+NO_3		FC	
Sites	TC02	TC04	TC02	TC04	TC02	TC04	TC02	TC04
Mean	5.0	13.98	7.95	8.51	.06	.35	6	32

NOTE: All values are expressed in mg/l except FC which are reported in cfu/100ml and pH in standard units.

Some of the increases were in sewage related variables. The exact source of the increase is unknown but the church camp and housing area could be considered as a possible source. As noted earlier, T. Alk., TDS, EC, and HCO_3 displayed a steady increase in concentration from the control site to TC09. Sulfates, which were not detected at the previous two sampling sites (minimum reporting limit 10 mg/l), were found at this site. Weathering of sulfur found in common igneous and sedimentary rocks yields oxidized sulfate which is soluble in water. Sulfate also occurs naturally in the form of rainfall (Hem, 1985). Eroded terranes of fine-grained sediments found in the area may provide the source of sulfate detected here.

One would expect levels of $N0_2+NO_3$ to be lower here than at TC03, however, values actually increased between these two sites. When one looks at the mean value for NO_2+N0_3 at the control site (0.06 mg/l), and below the hatchery (0.26 mg/l) and compares it to the mean values found at TC04 (0.35 mg/l), it is evident that some source is contributing to the increase. Fecal coliform and elevated pH levels, although significantly greater at this site when compared to the control, were within water quality standards. All other variables remained relatively constant between these two sites or were not detected.

Dick Williams Creek flows through the church camp and housing area and enters Upper Tonto Creek just above TC04. Stream flows from Dick Williams Creek were never observed entering Upper Tonto Creek during the sampling period, however, debris and other physical evidence suggest flows do occur occasionally. Surface and subsurface flows could possibly account for the small increase in discharge (0.03 cfs), between TC03 and TC04 and perhaps explain some of the chemical changes occurring in this area.

6.2.3 Below the U.S. Forest Service Horton and Tonto Creek Campgrounds (TC05, TC06)

These sites were the last sites that were compared to the upstream control site (TC02) for statistical differences. Many more variables were found to be significantly greater at the 5% significant level than at previous sites. These data indicate that the further from the control source the more chemical, and biological change takes place. Some variables were significantly greater at the 5% significant level only at TC05, some at both TC05 and TC06 and some just at TC06 (Table 4). The NO_2+NO_3 mean at TC05 was considerably lower here than at the previous site, however, concentrations are still well above the control mean.

TABLE 4. Mean of Water Quality Variables Found to be Significantly Greater at TC05 & TC06 When Compared to TC02

Variables	Sites		
	TC02	TC05	TC06
$N0_2+N0_3$ (mg/l)	0.06	0.19	0.10[1]
FC (CFU)	6	41	27[1]
pH (SO)	7.95	8.43	8.64
SO_4 (mg/l)	5.0	13.8	13.7
EC (μhmos/cm)	120	197	218
TDS (mg/l)	87.5	123[1]	140
$HC0_3$ (mg/l)	79.0	112[1]	123.0
T.Alk (mg/l)	64.8	92.2[1]	105.2

NOTE: 1= No statistical difference noted

The distance between TC02 and TC06 is approximately four river miles and there is an elevation loss of approximately 1200 feet. Several small drainages and creeks flow into Upper Tonto Creek either as surface or subsurface flow. It is likely that these inputs together with other anthropogenic impacts are responsible for the change in water quality. Although several water quality variables increased significantly, when compared with the control sites, changes between TC05 and TC06 were small and insignificant. There were no exceedances of water quality standards at these sites.

6.2.4 Below Kohls Ranch (TC07)

Data reveal that several variables increased or decreased in concentration between TC06 and TC07. Concentrations of three variables, Cl, D.O., and pH, were found to be significantly different at TC07 when compared to TC06. Cl concentrations at TC07 were twice as high when compared to TC06. Dissolved oxygen values and pH units decreased significantly between the sites (Table 5).

TDS, TSS, EC, $HC0_3$, T.Alk and FC concentrations all increased noticeably between TC06 and TC07 but were not statistically significant. Concentrations of TKN also increased while NO_2+NO_3 and SO_4 decreased.

Table 5. Mean Values of Water Quality Variables found to be Significantly Different at the 5% level between TC06 and TC07

Variables	Sites	
	TC06	TC07
Cl (mg/l)	1.12	2.24 - greater
pH (SU)	8.64	7.68 - less
D.O. (mg/l)	8.88	8.0 - less

As stated above, dramatic change occurs in some water quality variables between TC06 and TC07. Table 6 shows the percent of load change of several variables between these sites. Load is a function of discharge and is defined as the average volume of material being carried by the water over a 24 hour period.

Table 6 clearly indicates that the water quality of Upper Tonto Creek is dramatically changing between sites TC06 and TC07. For example, Cl concentrations increased +188.2 percent between these two sites. Chloride concentrations continue to increase downstream to TC09. This sudden and dramatic increase in variable loading is evident in this area. To further illustrate this point, when one looks at the distance between TC05 and TC06, which is equal to the distance between TC06 and TC07 (approximately one mile), little variation in variable loads can be seen between those two sites when compared to the increase between sites TC06 and TC07.

TABLE 6. Mean Daily Load (pounds/day) for selected Variables Comparing TC05, TC06, TC07 and TC09

Sites	Cl	TDS	HCO_3
TC05	0.016	1.887	1.744
TC06	0.017	2.374	2.100
% change between sites TC05 & TC06	+6.250	+25.8	+20.4
TC06	0.017	2.374	2.100
TC07	0.049	4.016	4.160
% change between sites TC06 & TC07	+188.2	+69.2	+98.1
TC07	0.049	4.016	4.160
TC09	0.061	4.939	4.576
% change between sites TC07 & TC09	+24.4	+22.9	+10.0

Sites	TSS	SO_4	T.Alk
TC05	0.034	0.204	1.439
TC06	0.046	0.217	1.810
% change between sites TC05 & TC06	+35.2	+6.3	+25.7
TC06	0.046	0.217	1.810
TC07	0.076	0.267	3.411
% change between sites TC06 & TC07	+65.2	+30.8	+88.4
TC07	0.076	0.267	3.411
TC09	0.087	0.323	3.747
% change between sites TC07 & TC09	+89.1	+48.8	+107.0

Notes:
1. Number of observations at each site was 5.
2. March sample was not included in mean calculation.

This leads to the question, "what causes the increase between TC06 and TC07"?.

In the one mile segment of Upper Tonto Creek between TC06 and TC07, mean streamflows increase 36%, (2.94 cfs to 4.0 cfs). The most likely source of this additional streamflow is the Indian Garden Spring which discharges into Upper Tonto Creek between TC06 and TC07. Samples from the spring were never collected thus, chemical and physical analyses and their impacts to Upper Tonto Creek cannot be evaluated. However, with several variables increasing and decreasing between these two sites, two possible explanations can be discussed.

The first explanation is that septic effluent from the unincorporated community of Kohls Ranch (approximately 50 cabins) is having an impact on the creek. The cabins were built between 30 and 50 years ago and each has its own separate septic system. Some septic effluent variables displayed levels consistent with pollution from domestic sewage. For example, between TC06 and TC07 TDS, TSS, TKN, Cl, turbidity and FC increased while D.O. values decreased. On the other hand, NO_2+NO_3 and K values did not change. NH_3, F, and TP were not detected at either site, which is not consistent with impacts from sewage sources.

The second, and more likely, explanation is groundwater/spring influence. This possible explanation is discussed in more detail in section 6.2.5 (Spring at Camp Tontozona).

6.2.5 Spring at Camp Tontozona (TC08)

This spring, located on ASU Camp Tontozona property, was included as a sampling site to determine its water quality and thus determine what impact its discharge had on Upper Tonto Creek. Water analyses from the spring indicate that it was chemically different from Upper Tonto Creek. Streamflow from the spring into Upper Tonto Creek was very small, around 5-10 gallons per minute. Concentrations of water quality variables measured in the spring water were generally much higher than what were measured in Upper Tonto Creek. For instance the mean Cl value at TC07 was 2.24 mg/l, while the spring mean was 5.83 mg/l. Variables of TDS, EC, T.Alk, and HCO_3 were generally twice as high in the spring water compared to Upper Tonto Creek at TC07.

Nutrient concentrations at the Camp Tontozona Spring (TC08) were similar to concentrations found at the control spring (TC02). Fecal coliform bacteria were virtually non existent in the spring. Although the spring water chemistry is different compared to Upper Tonto Creek, its streamflow volume is small and thus had little effect on Upper Tonto Creek's water chemistry. The spring water did not exceed any water quality standards.

If the concentrations that are found in this spring are indicative of what are found in groundwater and Indian Garden Spring, this might explain why several variables increased in concentration between TC06 and TC07. As stated before, the Indian Garden spring was never sampled and no groundwater data were collected in this survey to support this hypothesis.

6.2.6 Below Camp Tontozona (TC09)

The water quality below Camp Tontozona was similar to that at TC07. Only one variable pH, was significantly greater at TC09 compared to TC07. This pH value, although statistically significant, shows very little increase between the sites. The pH range found at TC07 and TC09 were well within the water quality standards. Nitrogen species were at times greater at TC09 compared to TC07 but no distinct trends were evident and no water quality exceedances were noted.

7.0 CONCLUSIONS

Water quality in Upper Tonto Creek is good. Total dissolved solids concentrations were low, ranging from 81.5 mg/l at the headwater springs to 183.2 mg/l at Camp Tontozona. Electrical conductivity values were also low ranging from 120 to 290 μmhos/cm. Hardness values ranged from 73 mg/l to 177 mg/l.

Several chemical variables were found to be elevated below the Arizona Game and Fish Department hatchery when compared to the upstream control site. These elevated variables show, that perhaps, the operation of the fish hatchery is having an effect on the water quality of Upper Tonto Creek. Nitrogen species ($N0_2+N0_3$, TKN, NH_3) were all elevated downstream of the hatchery, and the total nitrogen annual mean water quality standard was exceeded. This was the only water quality exceedance detected during the entire Phase I survey. In the March winter sample, the total nitrogen annual mean was 50% less than summer month means. This may be attributed to a greater volume of streamflow causing a dilution effect to take place. Whatever the reason for this reduction, it is clear that the total annual mean is not being exceeded throughout the year. Despite its size and the amount of discharge the hatchery contributes, its impact on Upper Tonto Creek appears to be minimal and short lived.

At the church camp site, data indicate that the water chemistry of Upper Tonto Creek is changing. Although there is a possibility that the change could be naturally occurring since a distance of several river miles separates this site from the control site, a more likely source for that change could be septic leachate from the church camp and adjacent housing area. NO_2+N0_3 concentrations here were the highest found in the survey. Streamflow measurements have increased considerably here as compared to the control site (0.36 cfs vs 2.76 cfs). Thus, groundwater contribution could be a source of the increased SO_4, TDS, T. Alk, $HC0_3$, EC and $N0_2+N0_3$ concentrations.

At the two Forest Service campgrounds, water quality variables remain fairly constant except for the four variables which increased slightly throughout the survey. Therefore, it appears that these campgrounds are not having any noticeable impact on Upper Tonto Creek.

Below the Kohls Ranch housing area, groundwater contributions or spring flow appear to be the cause of chemical changes between the campgrounds and Kohls Ranch. Streamflow increased by 36% from TC06 to TC07 and several variables increased or decreased in concentration between the sites. Comparing data from the spring at Camp Tontozona to the increased concentration of variables found below the Kohls Ranch housing area, supports the hypotheis that groundwater/spring influences are playing a major role in the increased loading taking place between these sites. What influence the housing area below Kohls Ranch plays in the change is uncertain at this point. Further testing of wells and springs in the area would be required to determine exactly what influence the housing area is having on Upper Tonto Creek.

Comparing data collected between the Kohls Ranch housing area and below Camp Tontozona, indicates that no distinct change occurs between the two sites. This indicates that activities at Camp Tontozona are not affecting water quality in Upper Tonto Creek.

Water quality at the Camp Tontozona spring was very different compared to Upper Tonto Creek. However, its small discharge into Upper Tonto Creek had little effect on the overall water quality of the creek.

Literature Cited

American Public Health Association (APHA). (1992). Standard Methods for the Examination of Water and Wastewater, 18th Edition. APHA, Washington, D.C.

Arizona Department of Environmental Quality (ADEQ). 1995. Surface Water Monitoring Procedures. ADEQ, Phoenix, Arizona.

Arizona Department of Environmental Quality (ADEQ). 1991. Quality Assurance Project Plan. ADEQ, Phoenix, Arizona.

Denis, E.E. 1981. Map Showing Ground-water Conditions in the Tonto Basin Area. 1979. U.S. Geological Survey Water-Resources Investigation. Open File Report 82-116, Tucson, Arizona.

Feachem, R.G., D.J. Bradley, H.Garelick and D. Mara 1983. Sanitation and Disease--Health Aspects of Excreta and Wastewater Management. John Willey and Sons, New York, New York.

Grimm, N.B. and Fisher, S.G. 1986. Nitrogen Limitation Potential of Arizona Streams and Rivers. Journal of the Arizona-Nevada Academy of Science.

Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water. USGS Survey Water Supply Paper 2254, U.S. Government Printing Office, Washington D.C.

Hyde, P.G. 1994. Elevated Fecal Coliform Levels in Nutrioso Creek and the Little Colorado River at Eager/Springerville, Apache County May and June, 1993.

Kuehl, R.O. 1994. Statistical Principles of Research Design and Analysis. Duxbury Press, Belmont, CA, 686p.

National Weather Service, (Personal Communication). 1994. Sky Harbor Airport Phoenix, Arizona.

Nelson, K. and Baker, S. 1994. Tonto Riparian Inventory and Monitoring Methods (unpublished). Tonto National Forest, Phoenix, Arizona.