Task 6
SWINE WASTE PROJECT
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Final
Water Quality Data Summary

Written By:
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1.0. Introduction:

As part of the objectives stated in the work plan, the Oklahoma Conservation Commission (OCC) monitored twelve streams in Hughes and Okfuskee Counties. Monitoring was initiated due to concerns from the Hughes and Okfuskee County Conservation Districts about the effects that confined hog facilities might have on the quality of streams within their districts. To aid the districts in their efforts, the OCC designed and implemented monitoring activities to determine the current water quality and biological status to later determine the level of impact due to confined hog facilities.

The monitoring program was designed to assess streams in the area, specifically focusing on watersheds where operations may be located. Twelve stream sites were monitored during the duration of this project. Water quality, biological, and habitat information was collected for two years.

Table 1: Monitoring Sites

Stream Name	Legal Description	Waterbody I.D.	County
Bad Creek	e bound. 16 10N 12E	OK520500-01-0170G	Okfuskee
Big Creek	e bound. 35 6N 9E	OKTEMP-0414	Hughes
Bird Creek (downstream)	se6 6N 9E	OK520800-01-0050G	Hughes
Bird Creek (upstream)	se35 7N 8E	OK520800-01-0050M	Hughes
Flatrock Creek	ne10 10N 10E	OK520500-01-0280G	Okfuskee
Greasy Creek	se 28 9N 11E	OK520500-02-0020G	Hughes
Hilliby Creek	se2 13N 7E	OK520700-03-0270G	Okfuskee
Little Wewoka Creek	sw29 9N 10E	OK52500-02-0090T	Seminole
Nuyaka Creek	nw26 13N 10E	OK520700-02-0200G	Okfuskee
Salt Creek	nw36 6N 10E	OKTEMP-0415	Hughes
Walnut Creek	nw22 13N 9E	OK520700-03-0020G	Okfuskee
Wewoka Creek	sw29 9N 10E	OK520500-02-0010A	Hughes

2.0. Water Quality Sampling

Water samples were collected for two years quarterly (every three months) during base flow conditions. Water samples for basic nutrients and inorganic parameters were collected in 1-quart high-density polyethylene (HDPE) plastic bottles with polyethylene lids and foam liners. Care was taken when sampling to rinse each container a minimum of three times and sample upstream from any area disturbed by the sampler. At the surface water quality monitoring sites, two-quart samples were taken for various laboratory analyses. Each bottle was then labeled with the location, time, date, and preservation method with indelible ink. The following table lists parameters, preservatives, and holding times for each type of sample.

Table 2: Parameters, preservatives, and holding times

Parameter	*Container*	*Preservative*	*Holding Time*
Dissolved Oxygen	*in-situ*	none	-
Specific Conductance	*in-situ*	none	-
pH	*in-situ*	none	-
Temperature	*in-situ*	none	-
Alkalinity	plastic	ice	24 hours
Turbidity	plastic	ice	24 hours
Total Kjeldahl Nitrogen	plastic	H_2SO_4 within 24 hours/ ice	7 days
Nitrate	plastic	H_2SO_4 within 24 hours/ ice	7 days
Total Phosphorus	plastic	H_2SO_4 within 24 hours/ ice	28 days
Total Suspended Solids	plastic	ice	4 days
Sulfate	plastic	ice	28 days
Chloride	plastic	ice	7 days
Hardness	plastic	ice	7 days
Benthic macroinvertebrates	-	Ethyl Alcohol	-
Fish	-	10% Formalin Solution	-
Instantaneous Discharge	*in situ*	-	-

Sampling procedures can be found in Oklahoma Conservation Commission Standard Operating Procedures (*OCC SOP #10*). In-situ measurements were made for the parameters pH, dissolved oxygen, specific conductivity, water temperature, alkalinity, turbidity, and instantaneous discharge. Specific procedures for collection of these parameters are found in OCC SOP # 1,7, 9, 12, 13, and 37. Of the two samples collected, one sample was preserved with concentrated sulfuric acid and the other was placed immediately on ice (refer to table1 for specific parameters and preservation methods).

All samples were delivered with a chain of custody. Each custody form was completed prior to delivery. Location information, container quantities, parameters to be measured, and applicable comments were included with the custody forms.

3.0. Biological and Habitat Assessment

Biological monitoring is an integral part of a water quality program. Chemical sampling data shows what is happening at that specific point in time. Biological sampling looks at both long-term and short-term affects of water quality and habitat quality. This information coupled with chemical data is a powerful tool for water quality analysis.

Biological sampling followed EPA rapid bioassessment protocols (RBP) (*EPA, 1989*) as modified by OCC. Collection protocols can be found in OCC's SOP (*OCC SOP #29, 30, 31, 35, 36, and 39*).

3.1. Macroinvertebrate Collections

Macroinvertebrate collections were completed to assess the physical and chemical water quality of the selected streams for this project. Three habitat types are collected, if present, during the macroinvertebrate collections within the reaches. Riffle collections are the primary collection type utilized for analysis, however, if the riffle habitat is not present, streamside vegetation and/or woody debris will be collected. These habitats generally offer stability and refuge for aquatic invertebrates to live, feed, and reproduce. When one or more habitat type(s) are not available throughout the reach of interest, the other(s) are used. Invertebrate sampling is done at base flow conditions, when the community has had no major stream events that may scour the habitat and/or lower their numbers during the index periods.

3.1.1. Rocky Riffle Collections

A riffle is described as a "sudden downward change in stream level of the streambed as such that the surface of the water is disrupted by waves" (*OCC SOP #29, revision 1*). Collection and assessment methods are geared toward flowing water. Lotic invertebrates typically need stable substrate to live, feed, and reproduce. Samples collected for this project were sent to the CCHDOC for enumeration and identification by a professional taxonomist.

3.1.2. Streamside Vegetation Collections

Streamside vegetation habitats include any streamside vegetation that offers fine structure for invertebrates to dwell upon or within (*OCC SOP #30, revision 1*). This habitat can be fine root masses of grasses, sedges, or trees. Collection methods and analysis are geared towards communities that live in flowing environments. Collections must be made from substrates submerged long enough to be colonized by bacteria, fungus, and algae. Freshly submerged roots at elevated flow are unacceptable habitat to collect from. Samples collected for this project were sent to the CCHDOC for enumeration and identification.

3.1.3. Woody Debris

Suitable substrates for woody debris include wood with or without bark that has been in the stream long enough to develop a natural community of bacteria, fungus, algae, and invertebrates. The woody debris must also have enough flow for filtering animals to feed on suspended material and be exposed to the range of water quality changes within the stream. Collection protocol is described in OCC SOP (*OCC SOP #31, revision 1*).

3.2. Fish Collections

The fish collection protocol is discussed in OCC SOP (*OCC SOP 35, revision 2*). The collection procedure follows a modified version of the EPA Rapid Bioassesment Protocol V (*EPA, 1989*). Fish collection generally involves the use of two methods, seining and electroshocking. Together, these methods produce a representative collection of the fish community. Collections are 400 meters in length. The OCC uses a Coffelt CPS backpack shocker powered by a 300-ma 120 volts generator. Seines range in size and depth. It is up to the crew leader collecting the site to determine the appropriate length and depth of net to use. All fish that are not field identified are placed in a 1-gallon polyethylene jar with a 10% formalin solution. The formalin solution fixes the fish and they are later preserved in ethanol for final identification by a professional taxonomist. All fish that are field identified are inspected, and representative specimens are photographed, noted, and released.

The Index of Biotic Integrity (IBI) is taken from EPA Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA, 1989). It is similar to the habitat suitability score in that it measures several different attributes of the fish community, compares them to a reference stream, assigns points to each attribute, and then sums the points to arrive at a score. The IBI score indicates the quality of the fish community.

3.2.1. Electroshocking

Electroshocking is typically used for collecting from habitat that a seine is unsuitable to collect from, such as large logjams, dense tree roots, undercut banks, and rocky banks. Shocking is most effective at conductivity levels of 250-600 micro-seimens. All fish that cannot be readily field identified are fixed with 10% formalin in a prelabeled 1-gallon jug. A professional taxonomist completes the final identification.

3.2.2. Seining

Seining is used for collecting fish in more open water were snags and other debris are not extensive. However in some areas of very high conductivity, seining may be the only option. In these cases the crew leader must decide when habitats have been sufficiently collected. For an in depth discussion of seining, refer to OCC SOP (*OCC SOP #35, revision 2*).

4.0. Habitat Assessment

The habitat assessment was designed to assess habitat quality related to it's ability to support biological communities in the stream. OCC's habitat assessment adheres to a modified version of the EPA RBP (*EPA, 1989*). The assessment is based on particular parameters grouped into three categories (*EPA 1989*). The three primary categories that are assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate makeup, stable cover, canopy, and flow. Macro scale assesses the channel morphology, sediment depositions, and other parameters. The third category looks at the riparian zone quality, width, and general makeup (trees, shrubs, vines, and grasses) as well as bank features. Bank erosion, and streamside vegetative cover are incorporated into this section. Quantitative weighting is given to each of these sections in relation to their biological significance. Scores are computed and assigned as an evaluation of that stream section and riparian zone. Habitat assessments are completed for a reach that is 400-meters long, with measurements for each parameter every twenty meters. Further information on habitat assessment can be found in OCC SOP (*OCC SOP #39, revision 7*).

5.0. Laboratory Materials and Methods

Because of poorly definable action levels and decision criteria, water quality analysis methods and associated detection limits were based on precedent and available technology. Detection limits for nutrients allowed for measurement of least impaired waters as well as determining levels of impairment. Precision and accuracy of all data must, of course, be as true as possible. As a general rule, precision and accuracy had to be within plus or minus ten percent except for parameters approaching detection limits, where practical considerations require a wider range of acceptable precision and accuracy. The precision and accuracy criteria presented in CCHDOC Laboratory Quality Assurance Plan were suitable for this study. CCHDOC insured data quality through the use of analysis control charts for precision and accuracy following Section 1020 of *Standard Methods* (*Standard Methods 1992*). With these charts, warning limits of plus or minus two standard deviations were established along with control limits of plus or minus three standard deviations.

5.1. Methods of Water Quality Analysis

Water quality samples were analyzed within appropriate holding times as described in Table 2 (*EPA, 1983b*). Procedures followed OCC SOP (*OCC SOP # 7, 9, 12, 13, 14*). Further discussion can be found in OCC SOP. Specific readings taken in situ included pH, dissolved oxygen, specific conductance, turbidity, alkalinity, and discharge. Meters were calibrated and/or checked for accuracy prior to each sampling event. Each meter was calibrated and evaluated quarterly at the quarterly calibration day. All problems associated with meters were documented and brought to the attention of the Monitoring Coordinator and the Quality Assurance Officer. Further action was taken at that point when possible to either correct errors or prevent future errors and suspect data was flagged.

Temperature

Water temperature was measured in situ using a YSI Model 30 Conductivity Meter. Temperature measurements were calibrated quarterly. Further information for temperature collection can be found in OCC SOP (*OCC SOP #7, revision 0*).

Dissolved Oxygen (DO)

Dissolved oxygen was measured in situ utilizing a YSI Model 55 dissolved oxygen meter. The meter was calibrated in situ for atmospheric partial pressures prior to any measurement readings. Further discussion about dissolved oxygen measurements can be found in OCC SOP (*OCC SOP #9, revision 1*) and the manufacture's manual.

Hydrogen Ion Activity (pH)

Hydrogen ion activity was measured using a Cole Parmer Model 59002 portable pH meter and later replaced with YSI Model 60. Prior to measurement readings, the meter was calibrated according to OCC SOP (*OCC SOP 14, revision 1*) and the manufacturer's manual. Calibration buffer standards 4, 7, and 10 were used to acquire a 2-point calibration.

Conductivity

Electrical conductivity was measured *in situ* using a YSI Model 30 Conductivity meter. The measurement protocol is outlined in OCC SOP (*OCC SOP #1, revision 1*). Quarterly calibration checks were performed against standard solutions of 84 and 1413 µS (high and low ranges).

Alkalinity

Field alkalinity measurements were made using a Hach Digital Titration Kit as outlined in OCC SOP (*OCC SOP #13, revision 0*). Equipment was visually and mechanically checked at each quarterly calibration day. Precision was checked at each quarterly calibration day.

Turbidity

Turbidity was measured in situ using a Hach Model 2100A Turbidity meter following OCC SOP protocols (*OCC SOP #12, revision 0*). The meter's calibration was checked prior to and after each sampling run. The meter was also recalibrated and checked at each quarterly calibration day.

Flow Measurement

Flow was measured in situ using a Marsh McBirney 2000 Flo-Mate digital flow meter with a 10-foot sensor lead. Measurement procedures are outlined in OCC SOP *(OCC SOP # 37, revision 2*). The meter was calibrated prior to each sampling trip and at each quarterly meter calibration day.

5.2. Laboratory Analytical Methods

Water samples were collected and delivered to the CCHDOC for parameters that could not be measured in-situ. These parameters and their holding times are listed in Table 2. A basic description of each analyzed parameter follows.

Hardness

Polyvalent metallic cations are the cause of water hardness. In fresh water environments, the major cause is due to calcium and magnesium although iron, strontium, aluminum, and manganese can contribute to hardness under elevated conditions. In order to standardize reporting, hardness was reported as mg/L as calcium carbonate ($CaCO_3$). Using a standard format, water can be classified as being soft, moderately hard, hard, or very hard (see Table 3). Although there is uncertainty associated with the effect that hardness has on the aquatic environment, there is an overall benefit associated with increased hardness. The debate is focused around the chemical mechanisms involved with the positive water quality effects. For instance, is the toxicity of various metals reduced due to the formation of metal complexes or is the effect associated with one of the principal cations contributing to hardness (*EPA, 1986*). However, it has been shown that the toxicity of metals in water containing carbonate hardness is greatly reduced (*EPA, 1986*). Typically, the effect of toxic metals and other trace metals is increased with decreasing pH, with the exception of selenium and arsenic. Some metals are not as sensitive to hardness and thus standards are written to adjust for pH, hardness, and metal availability.

Table 3: Classification of Water By Hardness Content (*EPA, 1986*).

HARDNESS CLASSIFICATION	
mg/L $CaCO_3$	**Classification**
0 - 75	Soft
75 - 150	Moderately hard
150 - 300	Hard
300 - above	Very hard

Nitrogen, Nitrate

Nitrate is of concern primarily because of eutrophication and drinking water concerns such as human health (at concentrations above 10 mg/l), taste, odor, and high water treatment costs. Nitrate is also a concern in streams and rivers from the aspect of aesthetics and wildlife support. The toxic effect of nitrate on warm water fish species does not become a concern until levels approach 90 mg/L (Knepp and Arkin, 1973). However, aquatic algae and macrophyte growth depends on nitrate, other macro/micronutrients, and light for growth. Elevated levels of nitrate are often measured in streams with high levels of algal growth. This algal growth, often termed a “bloom”, adds decaying organics, which bacteria ingest. This bacterial action depletes the oxygen levels within the system, causing stress or even death to other aquatic organisms.

Nitrogen, Nitrite

Nitrite is of concern because it is toxic to warm water fish species and because it has some effects on human health with respect to drinking water. Nitrite levels at or below 5 mg/L should adequately protect most species of warm water fish (*McCoy, 1972*). Nitrite is an intermediate state of nitrogen, and typically not found in high concentrations in surface waters.

Nitrogen, Organic (TKN)

According to Standard Methods (APHA *et al*, 1989), organic nitrogen is defined as organically bound nitrogen in the trinegative oxidation state. This definition does not include all organic nitrogen forms, but most forms such as proteins, peptides, and numerous other organic compounds comprise organic nitrogen. When organic nitrogen and ammonia are determined together, the term Total Kjeldahl nitrogen (TKN) is used to indicate the combination. For this study, ammonia and organic nitrogen are reported together as TKN.

Phosphorous, Total

Phosphorous in the phosphate form is a macronutrient essential to plant growth. In most temperate surface waters, phosphorous is the nutrient that limits the growth of algae. In natural forms, phosphorous occurs almost solely as phosphate, which is classified into orthophosphate and organically bound phosphate. Of these two forms, over 90% of the phosphorous in unpolluted fresh water is found in the organic phosphate state. In terms of lake loading, phosphorous is often used as the primary measure of determining whether algae blooms will occur. Although the level that causes problems varies from lake to lake and depends upon the size of the streams and rivers that feed it, values above

0.020 to 0.050 mg/L are usually considered as excessive (*Lynch, 1992*). According to the EPA (*1986*), total phosphorous should not exceed 0.050 mg/L in flowing streams that enter water bodies (measured at the point of entry) or 0.025 mg/L in lakes or reservoirs. Flowing waters that do not discharge to water bodies can have 0.100 mg/L without eutrophication problems (*Mackenthun, 1973*).

Oklahoma's Water Quality Standards evaluate waters for the presence of excess nutrients (including phosphorus) based primarily on the presence of excess primary productivity. Without a quantifiable measure of excess primary productivity, waters are evaluated for excess phosphorus based on stream order, slope, turbidity, and nutrient concentrations.

Phosphorous, Orthophosphate

Orthophosphate refers to the inorganic, soluble form of phosphate. Orthophosphate is often referred to as "reactive phosphorus". This is the most stable form of phosphorus that is produced naturally as well as found in sewage. Generally, orthophosphate ions are readily available to algae. Measurement of orthophosphate can often be used as an indication of human pollution.

Total Suspended Solids

Organic and inorganic particulate matter physically entrained in the water is considered to be suspended solids. Suspended solids include sediments as well as detritus and planktonic organisms. Suspended solids are important because of aesthetic effects and also due to the adverse affects associated with aquatic life. A study conducted by the European Inland Fisheries Advisory Commission (*EIFAC, 1965*) identified the following effects of high-suspended solids concentrations:

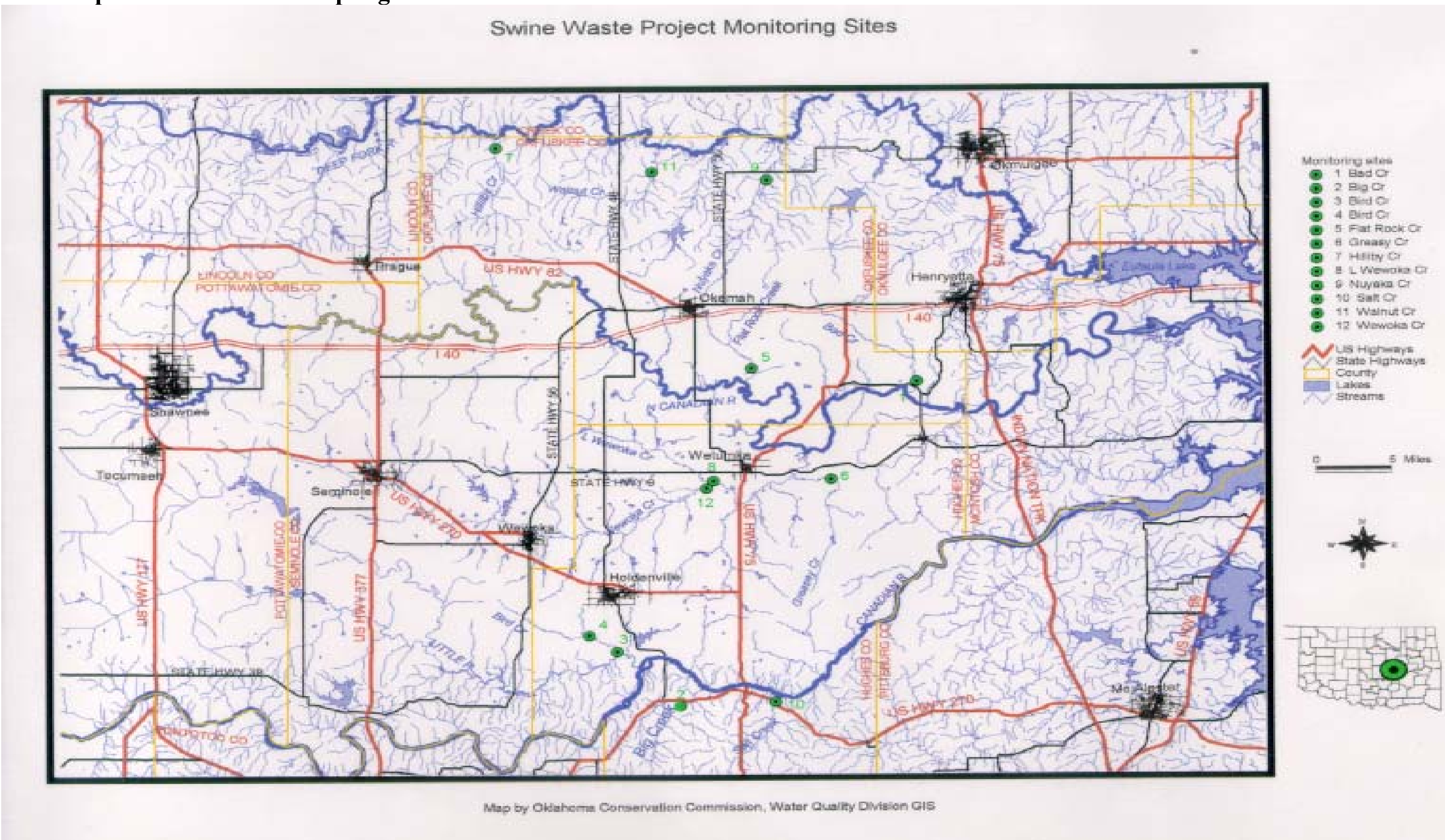
1. increased mortality and/or reduced growth rates;
2. prevention of successful development of fish eggs and larvae;
3. modification of natural movement and migration habits; and
4. reduction in the abundance of food available to fish species.

Suspended solids that settle out of suspension also adversely affect macroinvertebrates. Several studies have identified instances where invertebrate populations were significantly reduced. (Gammon, 1970, EIFAC, 1965, and Tebo, 1955).

6.0. Monitoring Activities

Twelve stream sites were monitored during this project. Water samples were collected every three months, benthic invertebrates were collected twice per year, and fish were collected from each site once. An aquatic habitat evaluation was performed along with each fish collection. This report summarizes the finding of the biological and chemical assessments of these streams. Monitoring locations are described in table 1 and a map of the project area and sites can be viewed below.

Map 1: Swine Waste Sampling Locations



6.1. Water Quality Results

The OCC monitored the water quality of twelve sites in Hughes and Okfuskee Counties. The narrative statements below are the results of seven field visits throughout the two-year project duration. It is noted that there are pre-existing impacts to many of the streams, including oilfield pollution that is evidenced by the high to very high chloride concentrations seen in several of the streams and the discharge from the towns of Holdenville, Okemah, and Wewoka. Holdenville discharges to a small stream that flows into Bird Creek, as does the Redarc catfish processing plant in Holdenville. The Bird Creek sites marked upstream and downstream are upstream and downstream of the point where this tributary enters the stream. Wewoka, Seminole, and several smaller communities discharge to Big Wewoka Creek. Okemah discharges to a tributary of Flatrock Creek. A total of seven sampling events were completed. It is not the intention of this report to interpret the results or to assess use support, but merely to summarize the findings of the water quality and biological assessments of these twelve streams. The following paragraphs and table 4 describe the results of the physical and chemical analysis of the sites monitored during the project. All water quality data is located in appendix 1 of this report.

Bad Creek had an average dissolved oxygen concentration of 7.50 mg/l. The minimum concentration was 4.80 mg/l and the maximum concentration was 10.10 mg/l. The average turbidity reading was 23.0 NTUs and the maximum-recorded reading was 48.0 NTUs. Chloride, sulfate, and TSS averaged 257.0, 15.0, and 15.0 mg/l, respectively. Ortho phosphorus ranged from 0.004 – 0.040 mg/l, with an average concentration of 0.017 mg/l. Total phosphorus concentration ranged from 0.050-0.100 mg/l. The average total phosphorus concentration was 0.063 mg/l. Total nitrogen ranged between 0.32-2.20 mg/l, with the average concentration of 0.92 mg/l. Nitrate concentrations ranged between 0.07-1.90 mg/l, the average concentration was 0.44 mg/l. Nitrite levels were all low and averaged at 0.002 mg/l. Ammonia concentrations were all at or below method detection limits. TKN ranged from 0.24-0.76 mg/l, the average concentration was 0.47 mg/l.

Bird Creek Downstream dissolved oxygen concentrations ranged between 6.90-18.70 mg/l. The average dissolved oxygen concentration was 12.60 mg/l. The pH at Bird Creek downstream ranged from 7.30-9.40, with the average of all reading being 8.30. Conductivity ranged between 683.0-1490.0 µS. The average conductivity was 878.0 µS. Turbidity values ranged between 2.6-40.0 NTU. The average turbidity was 16 NTU. Chloride, sulfate, and TSS maximum-recorded values were 290.0, 55.0, and 35.0 mg/l respectively. Ortho phosphorus ranged between 0.170-0.440 mg/l. The averaged concentration was 0.280 mg/l. Total phosphorus ranged from 0.260 mg/l to 1.40 mg/l. The average total phosphorus concentration was 0.670 mg/l. Total nitrogen ranged from 1.50-11.10 mg/l, with an average concentration of 4.80 mg/l. Nitrate concentration ranged from 0.26-2.70 mg/l, with an average concentration 1.10 mg/l. The minimum nitrite concentration 0.007 mg/l and the maximum nitrite concentration was 0.090 mg/l. The average nitrite concentration was 0.060 mg/l. Ammonia concentration ranged from 0.26-3.60 mg/l, with an average concentration of 1.70 mg/l. TKN ranged from 0.77-4.80 mg/l. The average concentration was 2.60 mg/l.

Bird Creek Upstream dissolved oxygen concentrations ranged from 6.60-11.10 mg/l, with an average concentration of 8.80 mg/l. The pH at Bird Creek upstream site ranged from 6.50-8.00. Conductivity ranged from 926.0 µS to 3920.0 µS. The average conductivity was 2393.0 µS. Turbidity ranged between 8.20-40.0 NTUs. The average turbidity for all seven sampling events was 16.0 NTUs. Chloride, sulfate, and TSS had maximum values of 1055.0, 58.0, and 39.0 mg/l respectively. Ortho phosphorus ranged from 0.004-0.050 mg/l, with an average concentration of 0.018 mg/l. Total phosphorus ranged from 0.020-0.070 mg/l, with an average concentration of 0.040 mg/l. Total nitrogen averaged 0.87 mg/l. Nitrate ranged from below detection limit to 1.70 mg/l. Nitrite ranged from below detection limit to 0.004 mg/l. The average concentration was 0.002 mg/l. Ammonia concentrations were all at or below detection limit. TKN ranged between 0.13-0.57 mg/l, with the average concentration 0.36 mg/l.

Flat Rock Creek dissolved oxygen concentrations ranged from 2.90-11.70 mg/l. The average oxygen concentration was 7.30 mg/l. The pH values all fell between 6.90-7.40. Conductivity ranged between 180.0-489.0 µS. Turbidity ranged between 10-40 NTUs, with an average of 22 NTUs. Chloride, sulfate, and TSS average values were 31.0, 12.0, and 17.0 mg/l. Ortho phosphorus ranged between 0.003-0.050 mg/l, with an average concentration of 0.019 mg/l. Total phosphorus ranged between 0.060-0.130 mg/l. The average concentration of total phosphorous was 0.094 mg/l. Total nitrogen average concentration was 0.87 mg/l. Nitrate ranged from less than method detection limit to 3.10 mg/l, with an average concentration of 0.50 mg/l. Nitrite ranged from 0.002-0.007 mg/l, with an average concentration of 0.004 mg/l. Ammonia concentration were all at or less than the method detection limit. TKN values ranged between 0.42-1.10 mg/l, with an average concentration of 0.75 mg/l.

Greasy Creek's dissolved oxygen concentration ranged from 3.50-12.30 mg/l, with an average concentration of 6.50 mg/l. The pH ranged between 6.90-7.60. The conductivity averaged 199.0 µS, with a maximum-recorded value of 354.0 µS. Turbidity ranged from 13.0 to 65.0 NTUs. The average turbidity at base flow conditions was 28.0 NTUs. Chloride, sulfate, and TSS average concentrations were 17.0,6.90,17.0 mg/l respectively. Ortho phosphorus ranged between 0.005-0.030 mg/l, with an average concentration of 0.014 mg/l. Total phosphorus ranged from 0.040-0.110 mg/l, with an average concentration of 0.074 mg/l. Total nitrogen ranged from 0.41 to 0.82 mg/l. The average concentration of total nitrogen was 0.58 mg/l. Nitrate nitrogen ranged from below detection to 0.26 mg/l, with an average concentration of 0.08 mg/l. Nitrate ranged from below detection limits to 0.26 mg/l, with an average concentration of 0.08 mg/l. Ammonia concentrations were all at or below method detection limits. TKN concentrations ranged from 0.26 mg/l to 0.64 mg/l, with an average concentration 0.50 mg/l.

Hilliby Creek dissolved oxygen concentrations ranged from 5.80-13.60 mg/l, with an average concentration of 9.60 mg/l. pH ranged from 7.00-9.00, with the average value of 8.00. Conductivity ranged from 268.0-660.0 µS. Turbidity ranged from 3.60-47.0 NTUs. The average turbidity during the project duration was 17.0 NTUs. Chloride, sulfate, and TSS measurements averaged 52.0, 2.60, and 11.0 mg/l respectively. Ortho phosphorus ranged from 0.002-0.020 mg/l, with the averaged concentration of 0.004 mg/l. Total phosphorus ranged from 0.030-0.200 mg/l, with the average concentration of 0.045 mg/l. The minimum recorded concentration of total nitrogen was 0.22 mg/l. The maximum-recorded concentration of total nitrogen was 1.20 mg/l. Nitrate ranged between 0.03-0.20 mg/l. The average concentration of nitrate was 0.13 mg/l. Nitrite ranged between 0.003-0.008 mg/l, with the average concentration of 0.005 mg/l. Ammonia concentrations were all at or below method detection limits. TKN ranged from 0.19 mg/l to a maximum-recorded value of 0.99 mg/l. The average TKN concentration was 0.42 mg/l.

Little Wewoka Creek dissolved oxygen concentrations ranged from 6.00-11.30 mg/l. The average dissolved oxygen concentration was 8.90 mg/l. pH ranged from 6.90-8.40. Conductivity ranged from

301.0-1230.0 µS. Turbidity readings ranged from 9.00-74.0 NTUs, with an average concentration of 37.0 NTUs. Chloride, sulfate, and TSS averaged 155.0, 12.0, 26.0 mg/L respectively. Ortho phosphorus ranged from 0.002-0.030 mg/l, with an average concentration of 0.011 mg/l. Total phosphorus ranged from 0.030-0.120 mg/l. The average concentration of total phosphorus was 0.067 mg/l. Total nitrogen ranged from 0.34-1.20 mg/l, with an average concentration of 0.70 mg/l. Nitrate ranged from less than method detection limit to a maximum concentration of 0.55 mg/l. The average concentration of Nitrate was 0.26 mg/l. Nitrite ranged between 0.001-0.008 mg/l, with an average concentration of 0.003 mg/l. Ammonia concentrations were all at or below method detection limits. TKN concentrations ranged from 0.19-0.83 mg/l, with the average concentration of 0.47 mg/l.

Big Wewoka Creek dissolved oxygen concentrations ranged from 6.00-11.30 mg/l, with an average concentration of 8.80 mg/l. pH reading ranged from 7.70-8.60. The average pH was 8.10. Conductivity ranged between 531.0-2130.0 µS. Chloride, sulfate, and TSS average concentrations were 365.0, 23.0, 41.0 mg/l. Ortho phosphorus ranged between 0.010-0.060 mg/l, with an average concentration of 0.025 mg/l. Total phosphorus ranged from 0.050-0.170 mg/l, with an average concentration of 0.116 mg/l. Total nitrogen ranged from 0.45-4.30 mg/l, with an average concentration of 1.40 mg/l. Nitrate minimum concentration was below detection limit and the maximum concentration was 2.70 mg/l. The average nitrate concentration was 0.63 mg/l. Nitrite ranged from 0.001-0.014 mg/l, with an average concentration of 0.006 mg/l. Ammonia minimum concentrations were below detection limits. The maximum concentration was measured at 0.60 mg/l. The average ammonia concentration was 0.15 mg/l. TKN concentrations ranged between 0.33-0.99 mg/l, with an average concentration of 0.63 mg/l.

Nuyaka Creek dissolved oxygen concentrations ranged between 3.60-11.0 mg/l, with an average concentration of 7.60 mg/l. pH readings ranged between 7.20-8.50. Conductivity ranged between 207.0-541.0 µS, with an average concentration of 340.0 µS. Turbidity values ranged between 12.0-55.0 NTUs. The average turbidity in Nuyaka Creek was 33.0 NTUs. Chloride, sulfate, and TSS readings averaged 33.0, 11.0, and 27.0 mg/l respectively. Ortho phosphorus ranged from 0.003-0.040 mg/l, with an average concentration of 0.018 mg/l. Total phosphorus ranged from 0.040-0.130 mg/l, with an average concentration of 0.085 mg/l. Minimum detected concentration of total nitrogen was 0.42 mg/l. The maximum detected concentration of total nitrogen was 1.20 mg/l. Nitrate ranged from 0.02-0.14 mg/l, with an average concentration of 0.11 mg/l. Nitrite ranged from below detection limits to a maximum of 0.004 mg/l. The average nitrite concentration was 0.002 mg/l. Ammonia concentrations were all at or below minimum method detection limits. TKN ranged from a minimum of 0.27 mg/l to a maximum of 1.20 mg/l. The average TKN concentrations were 0.75 mg/l.

Salt Creek dissolved oxygen concentration ranged from 3.90-12.50 mg/l, with an average concentration of 8.60 mg/l. pH ranged between 7.00-8.20. Conductivity ranged between 142.0-469.0 µS. The minimum recorded turbidity was 4.90 NTUs and the maximum was 51.0 NTU. The average turbidity was 22.0 NTUs. Chloride, sulfate, and TSS averaged 28.0, 15.0, 12.0 mg/l respectively. Ortho phosphorus ranged from 0.003-0.030 mg/l, with an average concentration of 0.013 mg/l. Total phosphorus ranged from 0.040-0.110 mg/l, with an average concentration of 0.062 mg/l. Minimum detected concentration of total nitrogen was 0.28 mg/l. The maximum detected concentration of total nitrogen was 1.20 mg/l. Nitrate ranged from less than detection to a maximum of 0.86 mg/l, with an average concentration of 0.19 mg/l. Nitrite ranged from 0.001 mg/l to a maximum of 0.003 mg/l. The average nitrite concentration was 0.002 mg/l. Ammonia concentration ranged from below detection limits to a maximum concentration of 0.08 mg/l. TKN ranged from a minimum of 0.22 mg/l to a maximum of 0.66 mg/l. The average TKN concentration was 0.39 mg/l.

Walnut Creek dissolved oxygen concentrations ranged from 0.40-13.36 mg/l. The average dissolved oxygen concentration was 9.80 mg/l. pH ranged from 7.0-9.0, with the average of 7.80. Conductivity ranged from 177.0-445.0 µS. The minimum turbidity reading was 4.20 NTUs and the maximum-recorded value was 52.0 NTUs. The average turbidity was 17.0 NTUs. Chloride, sulfate, and TSS all averaged 19.0, 15.0, and 9.50 mg/l respectively. Ortho phosphorus ranged from 0.002-0.0.040 mg/l, with an average concentration of 0.015 mg/l. Total phosphorus ranged from 0.020-0.080 mg/l, with average concentrations of 0.038 mg/l. Minimum detected concentration of total nitrogen was 0.23 mg/l. The maximum detected concentration of total nitrogen was 2.60 mg/l, with an average concentration of 0.75 mg/l. Nitrate ranged from less than detection to a maximum of 0.56 mg/l, with an average concentration of 0.16 mg/l. Nitrite ranged from 0.001 mg/l to a maximum of 0.004 mg/l. The average nitrite concentration was 0.002 mg/l. Ammonia concentrations were all below method detection limits. TKN ranged from a minimum of 0.20 mg/l to a maximum of 2.10 mg/l. The average TKN concentration was 0.58 mg/l.

Big Creek dissolved oxygen concentrations ranged from 4.90-13.10 mg/l, with an average concentration of 9.40 mg/l. pH ranged from 7.10-8.20, with an average value of 7.80. Conductivity values ranged from 223.0-535.0 µS. The average conductivity was 398.0 µS. The minimum-recorded turbidity was 3.50 NTU and the maximum-recorded turbidity value was 35.0 NTUs and the average turbidity was 16.0 NTUs. Chloride, sulfate, and TSS all averaged 23.0, 31.0, and 9.70 mg/l respectively**.** Ortho phosphorus ranged from 0.003-0.0.030 mg/l, with an average concentration of 0.015 mg/l. Total phosphorus ranged from 0.030-0.100 mg/l, with an average concentration of 0.054 mg/l. Minimum detected concentration of total nitrogen was 0.24 mg/l. The maximum detected concentration of total nitrogen was 0.53 mg/l, with an average concentration of 0.42 mg/l.. Nitrate ranged from less than detection to a maximum of 0.14 mg/l, with an average concentration of 0.096 mg/l. Nitrite ranged from 0.01 mg/l to a maximum of 0.02 mg/l. The average nitrite concentration was 0.02 mg/l. Ammonia concentrations were all below method detection limits. TKN ranged from a minimum of 0.16 mg/l to a maximum of 0.53 mg/l. The average TKN concentration was 0.33 mg/l.

Table 4: Water Quality Results

STREAM	DO	pH	conductivity	turbidity	chloride	sulfate	TSS	Ortho-P	Total-P	Total-N	Nitrate	Nitrite	Ammonia	TKN
BAD Cr. Avg.	7.5	7.3	957	23	257	15	15	0.017	0.063	0.92	0.44	0.002	<.05	0.47
Maximum	10.1	7.6	1954	11	660	37	19	0.04	0.1	2.2	1.9	0.002	<.05	0.76
Minimum	4.8	7.1	280	48	67	<2	7	0.004	0.05	0.32	0.07	0.001	<.05	0.24
BIRD Cr. dnst.Avg.	12.6	8.3	878	16	175	38	16	0.28	0.67	4.8	1.1	0.06	1.7	2.6
Maximum	18.7	9.4	1490	40	290	55	35	0.44	1.4	11.1	2.7	0.09	3.6	4.8
Minimum	6.9	7.3	683	2.6	59	18	6	0.17	0.26	1.5	0.26	0.007	0.26	0.77
BIRD Cr. upst.Avg.	8.8	7.5	2393	16	792	46	19	0.018	0.04	0.87	0.51	0.002	<.05	0.36
Maximum	11.1	8	3920	40	1055	58	39	0.05	0.07	2	1.7	0.004	<.05	0.57
Minimum	6.6	6.5	926	8.2	130	19	2.5	0.004	0.02	0.24	<.05	<.001	<.05	0.13
FLATROCK Avg.	7.3	7.2	316	22	31	12	17	0.019	0.094	0.87	0.5	0.004	<.05	0.75
Maximum	11.7	7.4	489	40	40	29	26	0.05	0.13	1.1	3.1	0.007	<.05	1.1
Minimum	2.9	6.9	180	10	18	<1	8	0.003	0.06	0.57	<.01	0.002	<.05	0.42
GREASY Avg.	6.5	7.1	199	28	17	6.9	17	0.014	0.074	0.58	0.08	0.003	<.05	0.5
Maximum	12.3	7.6	354	65	32	20	24	0.03	0.11	0.82	0.26	0.005	<.05	0.64
Minimum	3.5	6.9	77	13	5.5	<1	9.5	0.005	0.04	0.41	<.05	0.002	<.05	0.26
HILLIBYAvg.	9.6	8	496	17	52	2.6	11	0.004	0.045	0.68	0.13	0.005	<.05	0.42
Maximum	13.6	9	660	47	72	9.3	27	0.02	0.2	1.2	0.2	0.008	<.05	0.99
Minimum	5.8	7	268	3.6	28	<1	2	0.002	0.03	0.22	0.03	0.003	<.05	0.19
L. WEWOKA Avg.	8.9	7.8	776	37	155	12	26	0.011	0.067	0.7	0.26	0.003	<.05	0.47
Maximum	11.3	8.4	1230	74	264	26	46	0.03	0.12	1.2	0.55	0.008	<.06	0.83
Minimum	6	6.9	301	9	70	1.6	2	0.002	0.03	0.34	<.05	0.001	<.05	0.19
B. WEWOKA Avg.	8.8	8.1	1236	38	365	23	41	0.025	0.116	1.4	0.63	0.006	0.15	0.63
Maximum	13.1	8.6	2130	70	515	35	70	0.06	0.17	4.3	2.7	0.014	0.6	0.99
Minimum	4.8	7.7	531	7	140	11	9.5	0.01	0.05	0.45	<.05	0.001	<.05	0.33
NUYAKA Avg.	7.6	7.7	340	33	33	11	27	0.018	0.085	0.87	0.11	0.002	<.05	0.75
Maximum	11	8.5	541	55	54	29	44	0.04	0.13	1.2	0.14	0.004	<.05	1.2

STREAM	DO	pH	conductivity	turbidity	chloride	sulfate	TSS	Ortho-P	Total-P	Total-N	Nitrate	Nitrite	Ammonia	TKN
Minimum	3.6	7.2	207	12	14	<1	8.5	0.003	0.04	0.41	0.02	<.001	<.05	0.27
SALT Avg.	8.6	7.6	315	22	28	15	12	0.013	0.062	0.59	0.19	0.002	<.05	0.39
Maximum	12.5	8.2	469	51	43	29	20	0.03	0.11	1.2	0.86	0.003	0.08	0.66
Minimum	3.9	7	142	4.9	9	<2	5	0.003	0.04	0.28	<.05	0.001	<.05	0.22
WALNUT Avg.	9.8	7.8	310	17	19	15	9.5	0.015	0.038	0.75	0.16	0.002	<.05	0.58
Maximum	13.36.4	9	445	52	28	25	18	0.04	0.08	2.6	0.56	0.004	<.05	2.1
Minimum		7	177	4.2	12	<1	3	0.002	0.02	0.23	0.02	0.001	<.05	0.2
BIG Avg.	9.4	7.8	398	16	23	31	9.7	0.015	0.054	0.42	0.096	0.02	<.05	0.33
Maximum	13.1	8.2	535	35	30	40	20	0.03	0.1	0.53	0.14	0.02	<.05	0.53
Minimum	4.9	7.1	223	3.5	18	11	2	0.003	0.03	0.24	<.05	0.01	<.05	0.16

6.2. Fish Collection Results

Fish were collected once at each site during the project. Thirty-nine species of fish were collected from the stream sites in Hughes and Okfuskee Counties. The following tables list the species, numbers, and metrics used to analyze the fish that were collected. The collections were composed of 9,609 individual fish that were comprised of twelve different families and included 39 species of fish.

Fish Collected:

Bad Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	77	
Gizzard Shad	5	Total Taxa………………………………22
Longnose Gar	1	Darter & Madtom Species……………….1
Brook Silverside	5	Sunfish Species…………………….…….7
River Carpsucker	2	Sucker Species…………………………..2
Smallmouth Buffalo	1	Intolerant Species………………………..2
Channel Catfish	1	Proportion Tolerant Individuals…………16%
Yellow Bullhead	1	Proportion Omnivorous Individuals…….14%
Blackstripe Topminnow	3	Proportion Insectivorous Cyprinids……..3%
Bluegill Sunfish	2	Proportion Top Carnivores……………...4%
Green Sunfish	4	Total # of Individuals…………………...572
Longear Sunfish	342	
Orangespotted Sunfish	1	
Largemouth Bass	6	
Spotted Bass	12	
White Crappie	1	
Bluntnose Minnow	50	
Bullhead Minnow	14	
Central Stoneroller	17	
Red Shiner	10	
Suckermouth Minnow	16	
Redfin Darter	1	

Big Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	20	
Gizzard Shad	10	Total Taxa………………………………20
Brook Silverside	25	Darter & Madtom Species….…….……..1
River Carpsucker	6	Sunfish Species…………………………6
Channel Catfish	1	Sucker Species…………………………..1
Yellow Bullhead	3	Intolerant Species……………………..1
Blackstripe Topminnow	42	Proportion Tolerant Individuals…………40%
Bluegill Sunfish	4	Proportion Omnivorous Individuals….….42%
Green Sunfish	50	Proportion Insectivorous Cyprinids……...2%
Longear Sunfish	151	Proportion Top Carnivores……………...2%
Orangespotted Sunfish	2	Total # of Individuals…………………...577
Largemouth Bass	10	
White Crappie	1	
Bluntnose Minnow	39	
Bullhead Minnow	26	
Central Stoneroller	11	
Red Shiner	161	
Sand Shiner	4	
Suckermouth Minnow	10	
Logperch	1	

Bird Creek (Downstream)

Site Name	**Numbers Collected**	**Metric Results**
Mosquitofish	13	
Gizzard Shad	25	Total Taxa………………………………19
Spotted Gar	1	Darter Species & Madtom……………….0
Brook Silverside	1	Sunfish Species………………………….5
River Carpsucker	55	Sucker Species…………………………..2
Smallmouth Buffalo	1	Intolerant Species………………………..1
Freshwater Drum	1	Proportion Tolerant Individuals…………43%
Bluegill Sunfish	13	Proportion Omnivorous Individuals…….70%
Green Sunfish	5	Proportion Insectivorous Cyprinids……..17%
Longear Sunfish	33	Proportion Top Carnivores……………...0.5%
Orangespotted Sunfish	9	Total # of Individuals…………………...1796
Warmouth Sunfish	8	
Bluntnose Minnow	1	
Bullhead Minnow	418	
Emerald Shiner	301	
Plains Minnow	148	
Red Shiner	760	
Sand Shiner	2	
Suckermouth Minnow	1	

Bird Creek (upstream)

Site Name	**Numbers Collected**	**Metric Results**
Mosquitofish	25	
Channel Catfish	1	Total Taxa……………………………….12
Bluegill Sunfish	20	Darter & Madtom Species……………….0
Green Sunfish	13	Sunfish Species……………………….….6
Longear Sunfish	67	Sucker Species…………………………..0
Orangespotted Sunfish	5	Intolerant Species………………………..1
Largemouth Bass	5	Proportion Tolerant Individuals…………55%
White Crappie	2	Proportion Omnivorous Individuals….….64%
Bullhead Minnow	85	Proportion Insectivorous Cyprinids……..10%
Red Shiner	251	Proportion Top Carnivores……………...1%
Sand Shiner	48	Total # of Individuals…………………...527
Suckermouth Minnow	5	

Flat Rock Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	111	
Gizzard Shad	1	Total Taxa……………………………….22
Shortnose Gar	1	Darter & Madtom Species……………….1
Brook Silverside	18	Sunfish Species………………………….7
River Carpsucker	21	Sucker Species…………………………..1
Freshwater Drum	1	Intolerant Species………………………..1
Channel Catfish	5	Proportion Tolerant Individuals…………41%
Yellow Bullhead	4	Proportion Omnivorous Individuals…….51%
Bluegill Sunfish	8	Proportion Insectivorous Cyprinids……..3%
Green Sunfish	20	Proportion Top Carnivores……………...2%
Longear Sunfish	275	Total # of Individuals…………………...1073
Orangespotted Sunfish	9	
Warmouth Sunfish	7	
Largemouth Bass	15	
White Crappie	11	
Bluntnose Minnow	2	
Bullhead Minnow	216	
Central Stoneroller	5	
Common Carp	1	
Red Shiner	308	
Sand Shiner	33	
Orangebelly Darter	1	

Greasy Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	6	
Brook Silverside	50	Total Taxa……………………………….20
River Carpsucker	1	Darter & Madtom Species……………….2
Freshwater Drum	1	Sunfish Species………………………….5
Black Bullhead	1	Sucker Species…………………………..1
Channel Catfish	4	Intolerant Species………………………..2
Yellow Bullhead	10	Proportion Tolerant Individuals…………14%
Blackstripe Topminnow	3	Proportion Omnivorous Individuals…….16%
Bluegill Sunfish	46	Proportion Insectivorous Cyprinids……..2%
Green Sunfish	30	Proportion Top Carnivores……………...2%
Longear Sunfish	206	Total # of Individuals…………………...523
Warmouth Sunfish	4	
Largemouth Bass	2	
Bluntnose Minnow	43	
Bullhead Minnow	7	
Central Stoneroller	52	
Red Shiner	34	
Suckermouth Minnow	10	
Logperch	2	
Orangebelly Darter	11	

Hilliby Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	53	
Green Sunfish	10	Total Taxa……………………………..…..5
Warmouth Sunfish	5	Darter & Madtom Species…………...….0
Emerald Shiner	1	Sunfish Species………………………….2
Red Shiner	28	Sucker Species……………………...…..0
Sand Shiner	4	Intolerant Species…………….....………..0
		Proportion Tolerant Individuals…………90%
		Proportion Omnivorous Individuals…….28%
		Proportion Insectivorous Cyprinids……...5%
		Proportion Top Carnivores……………...5%
		Total # of Individuals…………………...101

Little Wewoka Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	30	
Gizzard Shad	37	Total Taxa……………………………21
Longnose Gar	1	Darter & Madtom Species…………….....1
Brook Silverside	3	Sunfish Species…………………………6
River Carpsucker	5	Sucker Species……………………….....2
Smallmouth Buffalo	1	Intolerant Species………………………..2
Channel Catfish	6	Proportion Tolerant Individuals…………22%
Flathead catfish	5	Proportion Omnivorous Individuals…….47%
Yellow Bullhead	1	Proportion Insectivorous Cyprinids….…..3%
Bluegill Sunfish	101	Proportion Top Carnivores……………...8%
Green Sunfish	29	Total # of Individuals…………………...589
Longear Sunfish	66	
Warmouth Sunfish	23	
Largemouth Bass	7	
White Crappie	8	
Bullhead Minnow	160	
Central Stoneroller	8	
Common Carp	4	
Red Shiner	72	
Suckermouth Minnow	19	
Redfin Darter	3	

Nuyaka Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	53	
Gizzard Shad	4	Total Taxa……………………………17
Channel Catfish	2	Darter & Madtom Species……………….0
Flathead catfish	1	Sunfish Species………………………….6
Yellow Bullhead	9	Sucker Species…………………………..0
Bluegill Sunfish	18	Intolerant Species………………………..1
Green Sunfish	25	Proportion Tolerant Individuals…………52%
Longear Sunfish	113	Proportion Omnivorous Individuals…….41%
Orangespotted Sunfish	2	Proportion Insectivorous Cyprinids……..2%
Largemouth Bass	12	Proportion Top Carnivores……………...8%
White Crappie	22	Total # of Individuals…………………...455
Bluntnose Minnow	9	
Bullhead Minnow	18	
Central Stoneroller	1	
Emerald Shiner	4	
Red Shiner	157	
Suckermouth Minnow	5	

Salt Creek

Site Name	Number Collected	Metric Results
Mosquitofish	18	
Gizzard Shad	106	Total Taxa……………………………….24
Longnose Gar	1	Darter & Madtom Species……………….1
Brook Silverside	51	Sunfish Species……………………….….8
River Carpsucker	29	Sucker Species…………………………..1
Freshwater Drum	2	Intolerant Species………………………..1
Channel Catfish	4	Proportion Tolerant Individuals…………20%
Yellow Bullhead	2	Proportion Omnivorous Individuals…….52%
Blackstripe Topminnow	12	Proportion Insectivorous Cyprinids……..2%
Bluegill Sunfish	60	Proportion Top Carnivores……………...4%
Green Sunfish	12	Total # of Individuals…………………...1032
Longear Sunfish	278	
Redear Sunfish	1	
Warmouth Sunfish	11	
Largemouth Bass	13	
Spotted Bass	10	
White Crappie	5	
Bluntnose Minnow	81	
Bullhead Minnow	133	
Emerald Shiner	10	
Red Shiner	185	
Sand Shiner	6	
Suckermouth Minnow	1	
Logperch	1	

Walnut Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	78	
Gizzard Shad	4	Total Taxa……………………………….19
Spotted Gar	9	Darter & Madtom Species……………….2
River Carpsucker	2	Sunfish Species…………………….…….5
Smallmouth Buffalo	1	Sucker Species…………………………..2
Channel Catfish	2	Intolerant Species……………………….2
Freckled Madtom	1	Proportion Tolerant Individuals…………81%
Yellow Bullhead	5	Proportion Omnivorous Individuals…….81%
Bluegill Sunfish	6	Proportion Insectivorous Cyprinids……..3%
Green Sunfish	1	Proportion Top Carnivores……………...3%
Longear Sunfish	60	Total # of Individuals…………………...1126
Largemouth Bass	10	
White Crappie	9	
Bullhead Minnow	59	
Common Carp	13	
Red Shiner	832	
Sand Shiner	31	
Suckermouth Minnow	1	
Redfin Darter	2	

Wewoka Creek

Site Name	Numbers Collected	Metric Results
Mosquitofish	3	
Gizzard Shad	1	Total Taxa……………………………….25
Longnose Gar	1	Darter & Madtom Species…………..….1
Shortnose Gar	3	Sunfish Species………………………….7
Spotted Gar	1	Sucker Species……………...………..2
Brook Silverside	1	Intolerant Species……………………...1
River Carpsucker	4	Proportion Tolerant Individuals…………28%
Smallmouth Buffalo	7	Proportion Omnivorous Individuals…….44%
Freshwater Drum		Proportion Insectivorous Cyprinids……..3%
Channel Catfish	11	Proportion Top Carnivores……………...7%
Flathead Catfish	2	Total # of Individuals…………………...324
Bluegill Sunfish	2	
Longear Sunfish	107	
Orangespotted Sunfish	16	
Redear Sunfish	1	
Largemouth Bass	2	
Spotted Bass	4	
White Crappie	1	
Bullhead Minnow	48	
Central Stoneroller	1	
Common Carp	1	
Red Shiner	87	
Sand Shiner	1	
Suckermouth Minnow	9	
Logperch	1	

Alabama Creek (upstream of Clearview Creek)

Site Name	Numbers Collected	Metric Results
Mosquitofish	5	
Brook Silverside	120	Total Taxa……………………………….17
Flathead Catfish	4	Darter & Madtom Species……………….2
Yellow Bullhead	19	Sunfish Species…………………………6
Bluegill Sunfish	19	Sucker Species…………………………..0
Green Sunfish	27	Intolerant Species………………………..2
Longear Sunfish	82	Proportion Tolerant Individuals…………13%
Warmouth Sunfish	5	Proportion Omnivorous Individuals…….8%
Largemouth Bass	5	Proportion Insectivorous Cyprinids……..6%
Spotted Bass	5	Proportion Top Carnivores……………...4%
Bluntnose Minnow	36	Total # of Individuals…………………...504
Central Stoneroller	94	
Common Carp	2	
Red Shiner	32	
Redfin Shiner	31	
Logperch	1	
Redfin Darter	17	

Alabama Creek (downstream of Clearview Creek)

Site Name	Numbers Collected	Metric Results
Gizzard Shad	3	
Brook Silverside	24	Total Taxa……………………………….20
River Carpsucker	2	Darter & Madtom Species………………1
Spotted Sucker	1	Sunfish Species…………………………..7
Channel Catfish	2	Sucker Species…………………………..2
Flathead Catfish	10	Intolerant Species………………………..2
Yellow Bullhead	19	Proportion Tolerant Individuals…………22%
Bluegill Sunfish	25	Proportion Omnivorous Individuals…….31%
Green Sunfish	33	Proportion Insectivorous Cyprinids……..5%
Longear Sunfish	88	Proportion Top Carnivores……………...6%
Warmouth Sunfish	4	Total # of Individuals…………………...419
Largemouth Bass	1	
Spotted Bass	12	
Largemouth Bass	1	
Bluntnose Minnow	65	
Central Stoneroller	31	
Golden Shiner	1	
Red Shiner	60	
Redfin Shiner	20	
Redfin Darter	17	

Table 5: List of Fish Collected During the Project

Mosquitofish	Redear Sunfish
Gizzard Shad	Warmouth Sunfish
Longnose Gar	Largemouth Bass
Shortnose Gar	Spotted Bass
Spotted Gar	White Crappie
Brook Silverside	Bluntnose Minnow
River Carpsucker	Bullhead Minnow
Smallmouth Buffalo	Central Stoneroller
Spotted Sucker	Common Carp
Freshwater Drum	Golden Shiner
Black Bullhead	Emerald Shiner
Channel Catfish	Plains Minnow
Flathead Catfish	Red Shiner
Freckled Madtom	Redfin Shiner
Yellow Bullhead	Sand Shiner
Blackstripe Topminnow	Suckermouth Minnow
Bluegill Sunfish	Logperch
Green Sunfish	Orangebelly Darter
Longear Sunfish	Redfin Darter
Orangespotted Sunfish	

6.3. Macroinvertebrate Results

Invertebrates were collected during the winter and summer index periods of 1996 and 1997. Ideally, three sample types would be collected from each site. Riffle, streamside vegetation, and woody debris are sampled, if available, from each site. Unfortunately only 83% of the sites had one or more sample types collected. Some of the reasons the samples were not collected are attributed to poor hydraulic conditions (elevated flow conditions and/or no flow conditions), water that was not accessible due to ice, and lack of the specific types of habitats. A much more in depth discussion concerning the macroinvertebrate collections is located in the discussions section of this report.

Table 6: Invertebrate Samples Collected and Analyzed

	Winter 1996	Summer 1996	Winter 1997	Summer 1997
Bad Creek	---	R,W	**W,** R	---
Big Creek	**R**	R,W	**W,**~~R~~	**R**
Bird Creek, dnst	---	W	**W**	**W**
Bird Creek, upst	---	~~W,R,V~~	---	---
Flat Rock Creek	**R**	**W,**~~R~~	~~W,R,V~~	**W,R,V**
Greasy Creek	~~W,R~~	~~W~~**,R,V**	W,R,V	**R**
Hilliby Creek	**W**	---	**W**	**W,V**
Nuyaka Creek	---	~~W~~**,R**	~~W,R~~	**R**
Salt Creek	**R**	**W,R**	**W,R,V**	---
Walnut Creek	**W**	---	**W**	**W,V**
Little Wewoka Creek	**R**	**W,**~~V~~	W,**R**	**R**
Wewoka Creek	**R**	---	**W**,R	**W,R**

W = Woody Debris Sample
R = Riffle Kick Sample
V = Streamside Vegetation Sample

Bold type = sample collected and processed & produced useable data
Normal type with ~~strikethrough~~ = sample collected & processed: data was rejected
Normal type with shading = sample lost due to accident or negligence
--- = no habitat present or stream had lost flow or was frozen solid

Winter 1996
Riffle

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma				16.9			17.3				16.6			14
mHBI$_{NC}$				5.2			6.11				5.6			4.9
EPT taxa/100 organisms				5.6			1.2				4.0			3
% Scrapers & filterers				44			26				12			08
% Shredders				0			0				01			0
% EPT				09			01				45			03
% Chironomids				33			48				29			77
% Dominant Taxa				38			21				18			62
Shannon –Weaver Index				3.06			3.20				3.77			2.16

Shaded columns represent potentially impaired communities that aren't used to describe the baseline condition

Winter 1996
Woody debris

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma									11.7			9.7		
mHBI$_{NC}$									4.94			5.3		
EPT taxa/100 organisms									4.3			1.6		
% Scrapers & filterers									35			17		
% Shredders									01			0		
% EPT									05			02		
% Chironomids									60			78		
% Dominant Taxa									41			34		
Shannon –Weaver Index									2.28			2.69		

Summer 1996
Woody debris

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma	12	13.2			10.5		10				11.6		17.2	
$mHBI_{NC}$	6.6	6.9			6.49		5.7				5.73		5.1	
EPT taxa/100 organisms	4.8	6.0			4.8		3				4.5		6.0	
% Scrapers & filterers	.12	.41			03		36				67		41	
% Shredders	0.0	0.0			0		0				0		01	
% EPT	.18	.67			53		03				11		34	
% Chironomids	.72	.19			42		61				20		25	
% Dominant Taxa	.63	.48			50		34				63		25	
Shannon –Weaver Index	2.02	2.35			2.12		2.30				2.12		3.21	

Shaded columns represent potentially impaired communities that aren’t used to describe the baseline condition

Summer 1996
Riffle

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma	17.5	10						10.7		11.6	13.8			
$mHBI_{NC}$	6.2	6.7						5.76		6.6	5.55			
EPT taxa/100 organisms	3.4	4.2						2.3		2.1	5.5			
% Scrapers & filterers	.32	.32						49		77	66			
% Shredders	0.0	0.0						02		02	01			
% EPT	.23	.48						14		02	15			
% Chironomids	.34	.38						11		15	10			
% Dominant Taxa	.33	.38						49		44	58			
Shannon –Weaver Index	2.78	2.51						2.59		2.18	2.30			

Winter 1997
Wood

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma			9.7	11		7.5			6.5		15.4	13.3		6.4
$mHBI_{NC}$			4.8	4.6		5.41			4.76		4.9	5.3		4.8
EPT taxa/100 organisms			2.9	2.2		.9			.8		5.8	2.9		.9
% Scrapers & filterers			10	27		02			15		13	42		08
% Shredders			0	0		0			0		0	0		0
% EPT			12	22		02			01		34	03		02
% Chironomids			74	46		93			82		43	50		92
% Dominant Taxa			72	35		56			76		22	34		73
Shannon –Weaver Index			1.63	2.64		1.79			1.18		3.40	2.61		1.48

Shaded columns represent potentially impaired communities that aren't used to describe the baseline condition

Winter 1997
Riffle

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma				9.5							18.9		14	
$mHBI_{NC}$				4.6							5.3		5.45	
EPT taxa/100 organisms				3.2							6.6		4.1	
% Scrapers & filterers				46							27		56	
% Shredders				0							01		0	
% EPT				20							24		10	
% Chironomids				27							28		36	
% Dominant Taxa				42							27		22	
Shannon –Weaver Index				2.32							3.41		3.20	

Summer 1997
Riffle

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma				15.9			9.1	14.4		12.5			20.5	
mHBI$_{NC}$				5.0			5.6	5.5		5.7			5.4	
EPT taxa/100 organisms				4.4			1.8	4.2		4.5			9.8	
% Scrapers & filterers				34			05	24		64			31	
% Shredders				01			0	01		1			1	
% EPT				27			02	16		18			36	
% Chironomids				31			92	47		22			39	
% Dominant Taxa				19			54	27		54			16	
Shannon –Weaver Index				3.47			1.91	3.27		2.48			3.96	

Summer 1997
Woody Debris

	Alabama Creek upst.	Alabama Creek dnst.	Bad Creek	Big Creek	Bird Creek upst.	Bird Creek dnst.	Flatrock Creek	Greasy Creek	Hilliby Creek	Nuyaka Creek	Salt Creek	Walnut Creek	L.Wewoka Creek	Wewoka Creek
# of taxa/100 organisma						7.6	8.3		20.2			13.6		14.3
mHBI$_{NC}$						5.82	5.45		5.13			5.2		4.8
EPT taxa/100 organisms						1	.9		6.1			4.9		5.7
% Scrapers & filterers						0	7		47			3		52
% Shredders						0	0		2			1		0
% EPT						2	3		23			6		55
% Chironomids						91	89		29			87		36
% Dominant Taxa						85	48		27			38		41
Shannon –Weaver Index						1.01	2.07		3.72			2.30		2.52

Shaded columns represent potentially impaired communities that aren’t used to describe the baseline condition

Table 7: Average Metric Scores by Season Not Including Flatrock Creek

	Summer Woody Debris	Summer Riffle	Winter Woody Debris	Winter Riffle
	n = 6	n = 9	n = 7	n = 4
# of Taxa	-----	-----	-----	-----
Average	14.6	14.1	11	16.6
Standard Deviation	3.37	3.41	2.85	2.01
Minimum	11.6	10	6.5	14
Maximum	20.2	20.5	15.4	18.9
$mHBI_{NC}$	-----	-----	-----	-----
Average	5.8	5.8	4.9	5.4
Standard Deviation	0.783	0.563	0.268	0.183
Minimum	5.1	5	4.6	5.2
Maximum	6.9	6.7	5.3	5.6
EPT Index	-----	-----	-----	-----
Average	5.4	4.5	2.9	5.1
Standard Deviation	0.725	2.27	1.68	1.25
Minimum	4.5	2.1	0.8	4
Maximum	6.1	9.8	5.8	6.6
% Scr. & Filt.	-----	-----	-----	-----
Average	35.2	45.4	22.7	34.8
Standard Deviation	23.63	19.16	12.2	19.28
Minimum	3	24	10	12
Maximum	67	77	42	56
% Shredders	-----	-----	-----	-----
% EPT	-----	-----	-----	-----
Average	26.5	22.1	11.3	22
Standard Deviation	22.1	13.52	12.46	16.79
Minimum	6	2	1	9
Maximum	67	48	34	45
% Chironomids	-----	-----	-----	-----
Average	42	27.4	61.9	31.5
Standard Deviation	29.65	13.43	16.15	3.7
Minimum	19	10	43	28
Maximum	87	47	82	36
% dom. taxon	-----	-----	-----	-----
Average	44	37.6	44.9	26.3
Standard Deviation	16.88	15.01	20.72	8.66
Minimum	25	16	22	18
Maximum	63	58	76	38
Shannon's Index	-----	-----	-----	-----
Average	2.62	2.84	2.35	3.36
Standard Deviation	0.685	0.599	0.737	0.309
Minimum	2.02	2.18	1.18	3.06
Maximum	3.72	3.96	3.4	3.77

7.0. Discussion of Water Quality Data

As discussed in the previous sections, the OCC monitored twelve streams in Hughes and Okfuskee Counties every quarter for a period of two years. A total of seven site visits were executed for water sampling during the project duration. The following section discusses the results of the physical and chemical analysis.

TKN levels averaged 2.60 mg/l at the Bird Cr. downstream. Site observations indicated high levels of algal and/or bacterial growth. All other TKN's were within the ranges found in areas of light to moderate human activity. Most of the Kjeldahl nitrogen measured is probably due to due to direct deposition of cow manure in the streams and is not cause for concern.

Ammonia was detected at very low levels in every stream except the two streams that have wastewater treatment plant discharges within their watersheds. At the lower Bird Creek site, ammonia concentrations were high enough, that, coupled with high pH levels, fish kills could have certainly occurred. No fish kills were observed during any of the site visits. An example of this type of situation occurred on 6/25/96 when the water temperature was 33°C, the pH was 8.87, and the total-ammonia was 2.5 mg/l. Under these conditions, the unionized ammonia concentration was 1.06 mg/l, high enough to be lethal to almost any kind of fish. Generally, levels of unionized ammonia greater than 0.05 mg/l are considered to be toxic to many different species of fish. Although both unionized and ionized ammonia are toxic, ionized ammonia is less than $1/50^{th}$ as toxic as unionized ammonia (Tabata 1962). Unionized ammonia toxicity is directly affected by pH, temperature, salinity, and exposure time. In this case, the ammonia toxicity in relation to the *National Criteria for Ammonia in Fresh Water* would have considered the total ammonia concentration mentioned above (at that pH level) an exceedence of acute criterion. The ammonia in both of these streams is likely due to the wastewater discharges. This is supported by the fact that all other streams had low levels despite having similar livestock and rural human populations.

Nitrite was measured at very low and certainly acceptable levels everywhere except in Bird Creek below Holdenville. These concentrations are again probably attributed to the wastewater discharge into the stream system.

Nitrate is present at acceptable levels in all streams except for the lower Bird Creek site. In several of the streams, nitrate was measured at levels near or below 0.10 mg/l, indicating that this may be an acceptable goal to achieve using non-point source best management practices.

As with the different forms of nitrogen, total phosphorous is within acceptable limits in all streams except for Bird Creek below Holdenville and in Big Wewoka Creek. Both of these streams have wastewater treatment plant discharges to them in addition to the nonpoint source runoff common to all of the area streams. It appears likely that these elevated phosphorus levels are likely due to the added wastewater. These are definitely concentrations that could cause problems. Elevated levels of phosphorous and nitrogen, with adequate light can cause excessive algal growth. With the accumulation of algal biomass, adding increasing amounts of decaying organics, increases the normal bacteria within the system to very high densities. These bacteria utilize oxygen or respire. This in turn, lowers the oxygen concentrations available for fish and macroinvertebrates. A combination of bacterial, animal, and algal respiration (to a much less significant effect) can reduce oxygen levels to lethal concentrations. When oxygen levels fall below 5.0 mg/l, fish become stressed and may be more susceptible to other impacts within the stream system such as elevated ammonia concentrations and pesticides. When dissolved oxygen falls below 3.0 mg/l, some species of fish will become oxygen deprived and eventually die.

Ortho-phosphate, while not present at the low levels, is present at concentrations between 0.011 and 0.019 mg/l in all streams except the two sites receiving effluent, Bird Creek and Big Wewoka Creek. This may indicate the lowest practical level that may be achievable given the agriculture in the area.

Sulfate concentrations in all streams were within acceptable limits and in fact seem in line with concentrations that are expected for this geographical region.

Chloride concentrations of 5.0 to 20.0 mg/l are probably natural to this area during times the streams are flowing. Taking into account summertime periods of low or no flow, average concentrations below 30 mg/l are probably indicative of unpolluted conditions. Many of these streams are much higher than 30 mg/l. Four creeks, Big, Bad, Wewoka, and Little Wewoka Creeks, had concentrations high enough to affect aquatic life.

pH falls within naturally occurring levels in all streams except for Bird Creek below Holdenville. The high values seen in this stream were due to high levels of algae and certainly contributed to ammonia toxicity and possibly increased stress on the species that did not die outright. This stress again would add to the collective of variables affecting the aquatic life within this system.

Dissolved oxygen was seen at minimum concentrations in four streams that otherwise appeared to be unpolluted. This is most likely due to the decay of naturally occurring organic substances. Available evidence indicates that indigenous fauna tolerate periodic episodes of this nature just fine so long as other pollutants such as pesticides, bacteria or elevated ammonia concentrations are not present. The only truly alarming dissolved oxygen (DO) readings were two readings at Big Wewoka Creek that approached 200% saturation in the summer. With these daytime DO saturations, the night time concentrations may drop to very low levels during the dark periods when algae, bacteria, and other life within the system are depleting the oxygen concentrations.

8.0. Discussion of the Biological and Habitat Assessments

8.1. Habitat Discussion

Alabama Creek, a small stream near the town of Clearview in Okfuskee County, was sampled as part of another project but is included in this biological analysis.

The results of the fish collection and habitat measurement effort generally support the results of the water quality measurements made over the two-year period in that there are no serious impacts of water quality on non-effluent receiving streams (Table 8). Most effects observed in the fish communities are alterations in community structure due to habitat degradation. Only one stream, Hilliby Creek, had habitat so degraded that many fish species were lost. Massive erosion and transport of sand into the site at Hilliby Creek had filled up the channel and removed all deep pools in the site at the time of collection. It will take a number of years for this reach of stream to recover. In the case of Hilliby Creek, habitat degradation was considerable, but in general, stream habitat was adequate to support most but not all of the fish species found in typical reference streams in this part of the state.

Instream Cover is an important component of stream habitat. It refers to structure that animals hide behind, inside, or under. It consists of things like submerged logs, cobble, boulders, submerged aquatic plants and other similar types of objects. A healthy riparian plant community is the biggest contributor to cover in streams that don't naturally have much cobble, gravel and boulder substrate. The riparian plant community contributes large and small woody debris to the stream. Riparian zones also contribute occasional rootwads as trees fall over and wash into the stream or as a meandering stream hollows out the area under the roots of a large tree on the stream bank. Another category of cover is submerged and emergent aquatic plants. Macrophyte beds are very important as nursery areas for many species of fish and they provide life long habitat for select species. Many common species of submerged macrophytes are easily wiped out by siltation and cattle that may graze or trample these beds.

Cobble, boulder and gravel are naturally scarce in many streams from this part of the state. Many riparian areas have been cleared to create pasture or fields, leaving little to no riparian plant community. Most streams in this part of the state are still recovering from the erosive effects of landuses that occurred decades ago. Finally, livestock have access to some of these streams and prevent the establishment of high quality macrophyte beds and riparian plant communities. For all of these reasons, all of the streams in this group scored fair to poor for instream cover. Five sites on four streams, Alabama (2 sites), Little Wewoka, Greasy and Big Creeks scored in the fair range for this parameter, averaging 6.4 points each. All other streams scored in the poor range. The amount and quality of instream cover likely influences the fish communities of the area streams. This habitat degradation is reversible and a score of 6.4 is a reasonable goal to aim for when restoration is attempted.

Pool Bottom Substrate is important to fish that live and/or reproduce in pools. Loose shifting substrate made of mud, loose sand and silt doesn't provide good habitat for the invertebrates that are the main food resource for pool dwelling fish. Additionally, fine loose substrate materials will cover and smother any fish eggs laid on or near the bottom of pools. For the same reasons that instream cover scored low, pool bottom substrate also scored low. This is also reversible habitat degradation. The same five streams (mentioned above) that scored the best for instream cover also scored the best for pool bottom substrate. These 5 streams average 7.9 points each for this parameter, which translates to about 40% to 50% stable pool bottom substrate. All area streams should be able to achieve this quality of pool bottom substrate should restoration be attempted.

Canopy is a measure of the quantity and quality of the shading within a reach of the stream segment being assessed. A dappled mixture is ideal, but dense shade is preferred to no shade. Because shade is provided by riparian zone plants, this parameter is related to several others, like instream cover, or bank stability, that also relate to the riparian plant community. This group of streams generally has poor canopy condition due to the eroded treeless banks that often have lateral pastures right up to the water's edge. This group of streams scored an average of 6.3 points for this parameter, which translates to an average canopy coverage of just under ten percent. Average canopy between ten percent and twenty-five percent provides adequate shade and is not an unreasonable expectation for streams of this size in this area. Only the sites on Greasy Creek and the upstream site on Alabama Creek had at least ten percent canopy.

Pool variability is a measure of the different depths of pools present within a reach of stream. Young fish require very shallow pools to begin their life in. As they grow, they require deeper pools. Fish whose maximum size is a few inches long can do well in a stream with few or no deep (>0.5 meters) pools, but all of the larger fish do much better if deep pools with adequate cover and water quality are present. To maintain a healthy, vital fish community, pools of many depths are required in balanced numbers. With the exception of Hilliby Creek, the streams in this study had good to excellent pool variability.

Percent Rocky Runs and Riffles is a measure of how much of the stream reach is composed of sections with swift current and shallow water flowing over a rocky substrate. This type of habitat is often required and almost always preferred by a group of fish composed of the darters, madtoms, and a few minnow species. Other fish use this habitat during limited portions of their life cycle. The rate of invertebrate production is generally highest in these areas. Rocky run and riffle areas are typically the most highly oxygenated areas of the stream. Fish that have adapted to life in this unique environment are often sensitive to the effects of siltation and low oxygen levels but will also be absent if their required habitat is missing. Members of this group are found in Okfuskee and Hughes Counties, so it is important to know if their absence from a stream is due to lack of their required habitat or lack of adequate water quality to support them. Rocky runs and riffles occur sporadically in most of the streams in these two counties. Because of this, we expect to find low numbers of this group of sensitive fish in all area streams provided the water quality is suitable for their life requirements. Rocky runs and rocky riffles occur throughout the study area but are uncommon enough so that they do not appear in every 400-meter reach of stream observed.

Six sites, Big, Greasy, Little Wewoka, Wewoka, and both sites on Alabama Creek had rocky runs and riffles present. All of these streams had at least one species present from this group. Four additional sites, Bad, Flat Rock, Salt, and Walnut Creeks had no rocky run and/or riffle habitats within the reaches evaluated, but did have either darters or madtoms. Their presence in these streams is undoubtedly due to the presence of rocky areas near to the reach assessed. Only four streams had no darters or madtoms. Two of these streams, Nuyaka and Hilliby Creeks, had adequate water quality to support these fish and their absence is assumed to be due to lack of sufficient habitat. The other two streams, both sites on Bird Creek, had both water quality, and habitat problems. Because these fish were found in most of the other study streams, and both sites on Bird Creek had water quality problems, it is felt that their absence is probably due to water quality effects.

Flow, or more properly, discharge, is the measure of how much water flows by a given point in the stream over a given time period. It is often measured in cubic feet of water per second or CFS. When we look at the list of fish collected from a stream, it is important to know how big the stream is. The expected species diversity increases as the stream size increases. To help insure fair comparisons, the OCC compares stream flows to each other during the driest part of summer, when the streams are not influenced by surface runoff. Only Bird Creek downstream of the Holdenville discharge and Wewoka Creek had appreciable flow during the time of the collections. Little to no flow characterizes area streams other than these two streams during the driest part of summer. This is the expected condition for these streams and is not any cause for alarm. However, lack of flow during the summer low flow period does make these streams especially vulnerable to pollution during the summer months.

Channel Alteration is a measure of point bar and island formation in an unstable streambed. It is due to sediment entering a stream faster than the stream can move it downstream. The sediment can be either from the land surface or from eroding stream banks. Channel alteration is related to pool bottom substrate and to instream cover. A stream with a high degree of channel alteration is likely to have little cover and an unstable substrate. Efforts to reduce channel alteration would almost certainly improve the other two parameters. Streams in this two county area varied widely for this parameter and do not show any particular trend. Four streams, Wewoka, Little Wewoka, Walnut, and Big Creeks, had 1/5 or less of the assessed reach affected by point bars or island formation. This is a very reasonable goal to strive towards when restoration is attempted on area streams.

Sinuosity is the ratio between stream distance between two points and the straight-line distance between the same two points. In the absence of human interference, sinuosity is a function of stream gradient and flow. As streams become more sinuous, they tend to have more instream cover and deeper pools. Streams of the area all had little to almost no sinuosity. The lack of sinuosity of these streams appears to be due to natural causes and is no cause for alarm.

Bank Stability is a measure of how much bank erosion is occurring in the assessed reach. All of the collection sites exhibited good to excellent bank stability, although, channel alteration and pool bottom substrate scores indicate that considerable sediment is being delivered to these streams. The source of this sediment could be upstream streambanks, brine impacted erosional sites, lateral gullies, roadside erosion, and/or soil erosion from the land surface. Because none of the assessed reaches of stream had bank stability problems, it is likely that other unassessed reaches also had good bank stability and the source of sediment to the streams is from some terrestrial source.

Streamside Cover is a measure of the type of vegetation that makes up the riparian vegetation. A fairly even mixture of grasses and forbes, shrubs, vines, and trees is ideal. Just as desirable is a riparian community composed of shrubs, vines, and small trees. Riparian communities dominated by large trees are scored lower than those of shrubs or mixed, but trees are considered superior to one composed only of grasses and forbes. These streams averaged 6.2 points for this parameter, although six sites scored eight or better. A score of eight points for this parameter is a reasonable goal to strive for should restoration be attempted an any area streams.

Most of the streams of this study received between 60 and 80 total points for their habitat evaluation. Through the work of this and similar projects, we know that the best habitat for streams of this size in this part of the state score between 80 and 100 points. Only Greasy Creek falls into this category; the habitat of all the other streams falls below the optimal level. This means that most of these streams are missing species of fish or numbers within a given species compared to what we would expect to collect if habitat were ideal. Much of the low scores these streams received are due to the presence of a loose sand substrate and a lack of rocky areas in the streams. Pool Bottom Substrate, Percent Rocky Runs and Riffles, and Channel Alteration were all low scoring parameters that could be improved by measures that reduce erosion and stabilize the bed load of the stream.

Lessening grazing pressure on the stream banks and improving the riparian plant communities would improve the instream cover, pool bottom substrate, canopy cover, channel alteration, and streamside cover of the study streams. While these streams will always tend towards the sandy side, enough of the habitat degradation is reversible that all of these streams have the potential to have good or better habitat.

Table 8: Habitat Metric Results

Stream Name	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover	Rocky Runs and Riffles	Flow	Channel Alteration	Sinuosity	Bank Stability	Stream Side Cover	* Streamside Vegetation	TOTAL
Bad Creek	2.2	2.7	9	4		0	0.4	6.7	0.5	15.8	4.6	46
Big Creek	9.4	8.2	10.8	2.3		9	15.2	12.3	2	15.4	8.8	79
Bird Creek (downstream)	0.5	2.1	19.6	3		0	5.8	6.7	0.3	15	8.9	62
Bird Creek (upstream)	0.6	2.5	19	3		0	0.2	7.7	1.4	18.8	4	57
Flat Rock Creek	0.9	2.1	19.9	6.6		0	0.3	6.7	1.8	18.2	3.6	60
Greasy Creek	4.1	9.2	19	14.1		7.5	0.8	9.9	1.9	16.6	3.4	87
Hilliby Creek	0.7	1.5	0	10.9		0	0.3	2.3	1.5	20	4.4	42
Little Wewoka Creek	7.5	5.8	13	2.6		5.9	0	7.7	0.6	16.8	4.2	64
Nuyaka Creek	0.8	3.9	12.1	9.6		0	0.4	11.1	0.6	17.6	8.5	65
Salt Creek	0.6	1.6	17.2	5.1		0	5.2	9.9	0.3	18.4	5	63
Walnut Creek	0.7	1.5	19.4	3.6		0	0.8	11.1	3	15.8	4.6	61
Wewoka Creek	1.7	1.6	14.6	3.3		2.2	20	13.7	0.5	18	8.5	84
**Alabama Creek (upstream)	6.1	8.5	20	15.2		5.9	0	7.7	1.9	11.4	9.5	86
**Alabama Cr. (downstream)	4.8	7.9	16.5	5.4		2.2	0	8.7	3.1	10.8	9.3	69

* An error was made in the determination of Bank Vegetative Stability. The bank Vegetative Stability scores from the habitat assessments were not used. The Bank Stability score was doubled to approximate the points lost from each assessment due to dropping of the Bank Vegetative Stability score.

** Alabama Creek, though not a part of this study, is used as a reference stream by OCC. It passes through the town of Clearview in Okfuskee County

8.2. Fish Discussion

The upper reach of Alabama Creek is immediately upstream of its confluence with Clearview Creek and is unimpaired and fully supporting all of its beneficial uses. The reach below Clearview Creek received excess sediment and sodium chloride from an abandoned commercial oilfield disposal site. The site was remediated in 1996 and the lower reach of Alabama Creek is now unimpaired and fully supporting its beneficial uses.

As mentioned above, Hilliby Creek has lost a significant number of fish species due to habitat degradation. The upper reach of Bird Creek appears to have lost species due to a combination of habitat degradation and possible water quality problems. The remaining streams ranged between the seventeen species found in Nuyaka and the upper reach of Alabama Creeks to the twenty-five species found in Wewoka Creek.

The Hilliby Creek fish community differs enough from all others in the study that it cannot be considered an unimpaired stream. Wewoka Creek's classification is uncertain. This stream is large enough that it should support a few more species of fish than were found there. The missing fish included darters and topminnows, fish that should have been collected there. Habitat is adequate for all of the missing fish, leading to a conclusion of questionable water quality of this stream. Wewoka Creek receives effluent from several municipalities, so there is a moderate probability that there is some amount of water quality degradation occurring.

The final stream that may have degraded water quality is Bird Creek. Upstream of its confluence with Holdenville's effluent stream, it had only twelve species. The missing species included the darters, bullheads, suckers, several minnows, topminnows, and the brook silverside. Habitat was probably not present to support the darters and/or suckers, but the other fish species should have been collected there. Bird Creek upstream had chloride concentrations that exceeded 1000 mg/l at times. This chloride concentration is high enough to explain the missing species and very likely is the cause of their disappearance.

Bird Creek below the confluence with Holdenville's effluent stream had a large and diverse collection of fish on the day of collection (Table 9). District staff mentioned that at times, this reach had no fish in it. This observation is supported by the occurrence of 1.06 mg/l of unionized ammonia on 6-25-96 which would have either killed fish in the stream or driven them downstream into the Little River. Because the Little River is so close to this site, recolonization would be rapid. However, as no fish kills are occurring or have been documented, this does not warrant a beneficial use classification below fully supporting. Unless future assessments indicate otherwise, the stream is fully supported.

For all streams except Hilliby and Bird Creek (upstream), Total Taxa ranged from seventeen to twenty-five with an average of 20.5. It appears that all area streams are capable of supporting at least 17 fish species in the absence of any water quality or habitat degradation. Darter and Madtom Species ranged from zero to two species with an average of 1.1. All area streams should be capable of supporting at least one darter or madtom species provided the local geology allows for some rocky habitat somewhere within the stream. All streams that had minimal habitat for darters and madtoms had at least one species present. As mentioned previously, four additional streams with no rocky run or riffle habitats in the assessed reach also had at least one darter or madtom species present. Any darter and/or madtom presence is probably an indicator of good to excellent conditions in this part of the state.

Sunfish Species ranged from five to eight species with an average of 6.2 in all streams except Hilliby Creek, which had only two sunfish species. These are pool dependant species that were probably forced out of Hilliby Creek by the excessive sediment at that site. There is no reason that every stream in the area with pools at least 0.5 m deep should not have at least five species from the Centrarchidae (sunfish family).

Sucker Species ranged from zero to two species with an average of 1.3. With the exception of one spotted sucker, all of the suckers collected were either buffalo species or carpsuckers. These are fairly tolerant fish, and every stream in the area with pools at least 0.5 meter deep should have at least one of these species present.

Intolerant Species ranged from one to two species with an average of 1.5. There were five intolerant species collected in area streams in these collections. They include the Spotted Sucker, Freckled Madtom, Suckermouth Minnow, Orangebelly Darter, and the Redfin Darter. With the exception of the Spotted Sucker, all of these fish probably require at least a small amount of stable gravel/coble/boulder/bedrock substrate within the stream. All area streams with at least one or two percent of their substrate composed of some type of rock should be able to support at least one of these species.

The remaining metrics showed wide variation. At this time, it is probably not prudent to generalize about the desired range for these metrics in this part of the state. It will take quite a bit more survey work to separate out desirable from undesirable scores for these metrics. Percent Tolerant Individuals ranged from thirteen percent to eighty one percent and averaged thirty three percent. Percent Omnivorous Individuals range from eight percent to eighty one percent and average forty one percent. Percent Insectivorous Cyprinids ranged from two percent to seventeen percent and average 4.3 percent. Percent Top Carnivores range from 0.5 percent to eight percent, averaging 4.2 percent. Total individuals collected range from 324 to 1796 and average 749 individuals collected.

Table 9: Fish Community Metric Results

Stream Name	# taxa	Darter and Madtom Species	Sunfish sp.	Sucker Species	Intolerant Species	% Tolerant	% Omnivore	% Insectivorous Cyprinids	% Top Canivorous	Total Species
Alabama Creek (upstream)	17	2	6	0	2	13%	8%	6%	4%	504
Alabama Creek (downstream)	20	1	7	2	2	22%	31%	5%	6%	419
Bad Creek	22	1	7	2	2	16%	14%	3%	4%	572
Big Creek	20	1	6	1	1	40%	42%	2%	2%	577
Bird Creek (downstream)	19	0	5	2	1	43%	70%	17%	0.50%	1796
Bird Creek (upstream)	12	0	6	0	1	55%	64%	10%	1%	527
Flatrock Creek	22	1	7	1	1	41%	51%	3%	2%	1073
Greasy Creek	20	2	5	1	2	14%	16%	2%	2%	523
Hilliby Creek	5	0	2	0	0	90%	28%	5%	5%	101
Little Wewoka Creek	21	1	6	2	2	22%	47%	3%	8%	589
Nuyaka Creek	17	0	6	0	1	52%	41%	2%	8%	455
Salt Creek	24	1	8	1	1	20%	52%	2%	4%	1032
Walnut Creek	19	2	5	2	2	81%	81%	3%	3%	1126
Wewoka Creek	25	1	7	2	1	28%	44%	3%	7%	324

Tolerant fish are: Mosquito Fish, Green Sunfish, Black Bullheads & Red Shiners

Omnivorous Fish are: Gizzard Shad, Red Shiners, Carp, Bluntnose Minnows, Bullhead Minnows & River Carpsuckers

Top Carnivores are: All Gars, All Black Bass, Flathead Catfish, Channel Catfish, Warmouth Sunfish, and White Crappie

8.3. Invertebrate Discussion

Invertebrates were collected during the winter and summer index periods of 1996 and 1997. From twelve streams, for four index periods, a total of 48 sampling episodes should have taken place under ideal conditions. Again, under ideal conditions, three samples, woody debris, riffle kick, and streamside vegetation would have been collected from each site during each index period. If all sample types at each site had been collected, there would be a total of 144 samples collected for this study. Only eighty three percent of the sites for all index periods had any kind of invertebrate sample collected. The eight sites that had no samples collected were either frozen solid or had ceased to flow. Of the 40 sampling episodes that were performed during the four index periods, six had all three types of samples collected. The remaining 34 sampling episodes had either one or two of the three sample types collected. This happens when a particular habitat type does not exist within the 400-meter reach of stream that composes a site. Streams without woody riparian vegetation rarely have enough woody debris to sample. Likewise, streams with badly eroding banks often do not have enough streamside vegetation to sample, and not all streams have enough rocky substrate to form riffles.

Samples that are collected, sub sampled, and identified sometimes produce data that has to be rejected. Generally this happens when the investigators (“pickers”) that do the sub sampling, “pick” too many or too few animals, or when greater than twenty percent of the sub sample is composed of members of the Simulidae (Blackflies). Sub samplers are trained not to count Blackfly larvae and to make sure that the sub sample is composed of between 80 and 150 individuals. Nevertheless, some mistakes are inevitable and the data must be rejected. Twelve samples, representing seven sampling episodes had to be rejected for one of these reasons.

Data can also be lost when samples are lost or damaged due to either accident or negligence. This reason for losing data should be minimal, but in the case of this project, it was not. Eleven samples from seven sampling episodes were lost and produced no data.

For all of these reasons, there was not enough invertebrate data collected for this project to do anything more than describe it in very general terms.

The upstream site on Bird Creek produced no samples with useable data. One site, Bad Creek had only one sample out of twelve potential samples collected and identified. Obviously, there is very little that can be said about a stream’s invertebrate community with so much missing data. Many of the streams had data from two or three index periods, but usually there was no single sample type that was collected from any of the three index periods for a particular stream. At this time, it is not possible to directly compare a woody debris sample to a riffle sample or to a streamside vegetation sample, so effectively we have to treat most streams as if only two index periods were collected.

The approach taken here is to describe typical communities of streams that appear to be unpolluted as judged by their fish communities and their water quality data. While this does not serve to classify these particular streams, it provides a vague picture of what the area reference condition is for both woody debris and riffle habitats of unpolluted streams. There were only four streamside vegetation samples that produced useable data, so this habitat type is not discussed. Both Bird Creek sites as well as

Wewoka Creek appear to be affected by water quality problems as indicated by their water quality and fish data, and are not included in this analysis.

Flatrock Creek receives effluent from the town of Okemah. Neither the fish community nor the water quality data indicate that it suffers any ill effects at the monitoring site. The invertebrates however, consistently indicate some level of impairment in Flatrock Creek. It is provisionally included among the polluted streams and not used for the computation of average conditions. This stream scored lower than all others on seven of eight metrics using the summer woody debris samples. It scored lower than all others on seven of eight metrics using the summer riffle samples. No samples were collected from winter season woody debris in this stream, but it scored lower than all other streams on four of eight metrics using the winter riffle samples. When regional reference streams are established for this area, Flatrock Creek should be resampled and monitored for impairment to its invertebrate community.

The following descriptions are based on woody debris and riffle samples taken from the remaining eleven streams (Table 7). Caution must be used when comparing metric scores for a habitat type and season to metric scores from other seasons or habitat types. These are small samples and each grouping of sample types and seasons are composed of different streams. Variation seen may be due to unaccounted for differences between riffles or woody debris from stream to stream. Variation may also be due to other types of sampling errors, natural stream-to-stream variation, and/or to differences in water quality. While these descriptive statistics give us a fair estimate of what average conditions are, they give us a less dependable estimate of variability. Until the variability in this geographical area is more fully described, these averages should be used only as general guidelines.

Number of taxa averaged 14.6 and 14.1 in the summer woody debris and riffle samples respectively. The ranges were similar for both sets of samples lying between 11.6 and 20.2 in the woody debris samples and 10.0 and 20.5 in the riffle samples. Winter samples were more variable, ranging between 6.5 and 15.4 and averaging 11.0 for the woody debris samples. The winter riffle collections averaged 16.6 taxa and ranged from 14.0 to 18.9.

The **modified Hilsenhoff Biotic Index** averaged 5.8 for both riffle and woody debris samples collected during the summer. The range was 5.0 to 6.9. This is a large range for this metric and was probably due to the relative amount of stagnation occuring, as these streams approached extreme low/no flow conditions during the summer low flow period. Winter season scores had both lower averages and smaller ranges. The winter woody debris samples averaged 4.9 and ranged from 4.6 to 5.3. The winter riffle samples averaged 5.4 and ranged from 5.2 to 5.6.

The **EPT Index** is the total number of taxa contributed to the sample by the Ephemeroptera, Plecoptera, and Trichoptera orders. This is a robust metric that has proved useful in all stream types across the United States. The summer woody debris samples averaged 5.4 and ranged from 4.5 to 6.1. The summer riffle samples averaged 4.5 and ranged from 2.1 to 9.8. The winter woody debris samples averaged 2.9 and ranged from 0.8 to 5.8. Many of these samples were surprisingly low in EPT taxa. Winter samples are typically richer in EPT taxa than summer samples. No reason for these low numbers was seen, although it could have been due to limited amounts of poor quality substrate or some other unobserved habitat limitation. Winter riffle samples averaged 5.1 EPT taxa and ranged from 4.0 to 6.6. The fact that the winter riffle numbers are in the expected range gives credence to the notion that the low woody debris sample numbers were related to poor quality habitat.

Percent scrapers and filterers exhibited considerable variability, but averaged between 22.7 and 45.4 for all sample groups. Numbers ranged from three percent to seventy-seven percent.

Percent shredders is a useful metric in many areas of the country and in some areas of Oklahoma. Most of these samples had zero percent shredders, however, and the highest number observed was two percent. Obviously, no discrimination between streams is possible with this limited range and this metric probably serves no purpose in this area of the state.

Percent EPT averaged 26.5 percent and ranged from six percent to 67% in the summer woody debris samples. It averaged 22.1% and ranged from 2% to 48% in the summer riffle samples. The metric averaged 11.3% and ranged from 1% to 34% for the winter woody debris samples. It averaged 22% and ranged from 9% to 45% in the winter riffle samples.

Percent Chironomids averaged 42% and ranged from 19% to 87% in the summer woody debris samples. They averaged 27.4% and ranged from 10% to 47% in the summer riffle samples. The average for the winter woody debris samples was 61.9% and the range was 43% to 82%. The average for the winter riffle samples was 31.5% and the range was 28% to 36%.

The **average density of the dominant taxon** in the summer woody debris samples was 44% and ranged from 25% to 63%. It averaged 37.6% and ranged from 16% to 58% in the summer riffle samples. Winter woody debris samples averaged 44.9% and ranged from 22 to 76% while winter riffle samples averaged 26.3% and ranged from 18 to 38%.

The **Shannon-Weaver Index** averaged 2.62 and ranged from 2.02 to 3.01 in the summer woody debris samples. It averaged 2.84 and ranged from 2.18 to 3.96 in the summer riffle samples. Winter woody debris samples averaged 2.35 and ranged from 1.18 to 3.40 while winter riffle samples averaged 3.36 and ranged from 3.06 to 3.77.

The summer woody debris and riffle samples, along with the winter riffle samples metrics meet expectations for stream invertebrates in streams of this size in this part of the state. There is no tendency for any of these three groups to score higher or lower than each other. The invertebrates from the winter woody debris samples are questionable. They consistently score lower than the other three groups. These samples represent collections from both 1997 and 1998, so the low scores are unlikely to be due to the climate of one particular year. It is also unlikely that any of these low scores were due to lowered water quality since the corresponding riffle samples appear normal. More study of more area streams over a longer time period is needed to see if this is an actual phenomenon or an artifact of poor habitat or sampling error due to some unknown cause.

9.0. Conclusions

While the samples taken from these streams over the course of two years do not constitute a collection of data large enough to determine reference conditions for the Central Oklahoma Texas Plains Ecoregion or beneficial use support for those streams, they do allow us to characterize the streams of Okfuskee and Hughes Counties during the years of 1996 and 1997. They also give us a fair picture of the variability due to natural causes to expect in area streams so that in the future, we will not confuse natural variability with water quality effects due to some unknown source of pollution.

Most notably, in the absence of point sources of pollution and concentrated areas of non-point sources of pollution, we see that nutrient concentrations of the various forms of both nitrogen and phosphorus are low. All streams without point sources and one, Flatrock Creek, that did have a point source in the upper reaches of its watershed, possess nutrient concentrations within the range where we do not expect to observe problems caused by nutrients.

Despite the fact that the majority of area streams lose flow in the summer, they have sufficient pools to maintain a healthy and diverse fish community. Most of the area streams contain at least a few sensitive species of bottom dwelling fish, a diverse sunfish community, and reasonable numbers of insectivorous minnows. The fish within Bird Creek appear to be partially limited by a combination of salinity and effluent. The most sensitive of the bottom dwelling fish, the darters and madtoms, are missing from Wewoka Creek despite the fact that adequate habitat for them is abundant at the collection site. The cause for the absence of these fish is unknown but may be related to upstream municipal wastewater dischargers and areas of old oilfield contamination. Hilliby Creek fish are limited by habitat alterations caused by upstream sediment inputs. At this time, the most significant threat to area fish communities is habitat alteration caused by poor maintenance of riparian conditions.

Benthic invertebrate communities of streams that contained no point sources or significant salt pollution met or exceeded expectations. A diverse community containing several sensitive taxa was collected from these streams. The Hilsenhoff Biotic Index indicated moderate levels of organic enrichment in the summer and lower levels in the winter. The higher summertime levels are probably due to stagnation caused by loss of flow in the summertime. These streams typically have a diverse and moderately abundant EPT community and moderate numbers of the mostly tolerant Chironomid family. Uniformly low metric scores from the woody debris habitat in winter need further study before any meaning is assigned to this particular habitat in this season.

Based on a combination of fish, invertebrate, and water quality data, two streams look to be of sufficient quality to include them in the larger reference stream database for the Central Oklahoma Texas Plains ecoregion. These streams are Salt Creek and Little Wewoka Creek.

The goals of this study were to conduct a monitoring program to characterize the water quality and stream ecology to measure the effectiveness of an education program to help swine producers reduce NPS pollution. Based on water quality monitoring data, there appears to currently be no adverse impacts from the swine industry on water quality. However, due to the project period coincinding with the infant stages of the growing swine industry, perhaps it is more appropriate that this data be used to characterize area streams prior to the installation of a significant number of confined animal operations, specifically swine operations, so that any future impacts caused by these operations could be determined. These goals have been met and if the need to resample ever occurs, the data exists to make this sort of determination.

10.0. Bibliography

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Appendix 1: Water Quality

Bad Creek OK520500-01-0170G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	6.1	7.28	1340	28	19	176	315	22.8	246		17.5	0.07		-0.05		0.68	-0.05
10-Jan-96	9	7.38	1954	3	39	131	660	37.3	430		18	0.06		1.89		0.29	-0.003
25-Jun-96	6.9	7.58	1120	30	14	110	240	-2	196		9	0.05		0.64		0.36	-0.05
15-Oct-96	7.13	7.08	523	18.3	16	91	136	5.26	131	368	14	0.06	0.012	0.162	0.002	0.51	
07-Jan-97	10.13	7.08	546	5.5	10.8	72	208	24.1	157		7	0.05	0.004	0.072	0.001	0.24	-0.05
07-Apr-97	8.38	7.4	280.2	15.2	48.4	30	67	13.4	70	251	17	0.1	0.04	0.08	0.002	0.76	
15-Jul-97	4.8	7.38	934	27.8	17.4	153	175	6.61	204		19.2	0.05	0.01	0.25	0.002	0.45	
03-Nov-97	3.35	7.31	486	13.8	15.8	116	160	10.9	150		6.5	0.08	0.007	0.5	-0.005	0.46	

Big Creek OKTEMP-0414

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	5.5	6.76	61.2	25.2													
10-Jan-96	6.14	6.84	59.1	31.5													
25-Jun-96	6.43	6.8	63.6	26.3													
15-Oct-96	5	6.67	65.3	22.4			5.1					0.047	0.001	-0.05	0.001	0.39	0.02
08-Jan-97	10.34	6.14	23.8	11.5	64	10											
08-Apr-97	10.5	6.18	25.6	12.8	42	16											
15-Jul-97	10.39	6.37	28.2	12.7	31.5	18											
04-Nov-97	10.35	6.15	29.4	12.3	27.5	14	3					0.07	0.005	0.14	0.002	0.36	-0.05

Salt Creek OKTEMP-0415

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	3.9	6.99	469	25.6	15	140	39.5	12.6	144		20	0.08		-0.05		0.65	-0.05
10-Jan-96	12.5	7.94	238	3	43	51	18	25.1	74		14	0.05		0.86		0.34	0.08
25-Jun-96	8.8	8.2	462	31	15.1	123	42.5	-2	145		5	0.04		0.17		0.3	-0.05
15-Oct-96	7.45	7.6	294	21.5	4.87	114	23	4.4	114	184	5	0.04	0.006	0.05	0.001	0.23	
08-Jan-97	11.44	7.62	198.6	4.8	16.2	110	27	28.8	120		13	0.06	0.003	0.132	0.001	0.22	-0.05
08-Apr-97	8.76	7.2	141.5	13.6	50.6	51	9.3	11.4	62	146	16	0.11	0.03	0.01	0.003	0.66	
15-Jul-97	7.59	7.6	400	32.3	15.3	145	37	19	144		12.6	0.057	0.011	0.13	0.002	0.33	
04-Nov-97	7.35	7.63	378.3	11.3	6.06	120	35	23.9	128		11.5	0.04	0.004	0.14	-0.005	0.26	

Bird Creek (down) OK520800-01-0050G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	6.9	7.26	875	27	31	186	133	30.8	226		34.7	0.67		0.259		1.51	0.26
10-Jan-96	10.1	7.87	1487	4	11	180	290	54.7	270		16.5	0.73		2.71		4.84	3.57
25-Jun-96	13.2	8.87	608	33	14	175	59.2	18.1	178		7.5	1.38		1.98		4.66	2.5
15-Oct-96	18.71	9.36	881	23	3.65	170	175	33.1	230	539	6	0.38	0.336	1.29	0.007	0.77	
08-Jan-97	14.56	7.97	790	4.5	8.43	218	278	44.8	344		13	0.31	0.17	0.73	0.067	1.5	0.62
08-Apr-97	7.68	7.7	683	15.3	39.6	159	126	50.8	222	491	31	0.93	0.44	0.55	0.085	4.15	
15-Jul-97	17.22	9.33	820	33.6	2.11	166	166	33.9	192		6	0.257	0.188	0.46	0.077	0.92	
04-Nov-97	16.68	8.39	609	15.1	5.02	335	65	34.6	350		7.6	0.36	0.244	7.4	0.207	1.26	

Bird Creek (up) OK520800-01-0050M

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	7.1	6.48	3920	28	10	184	1055	53.4	582		12	0.04		-0.05		0.47	-0.05
10-Jan-96	10.6	7.35	1063	2	14	154	940	19.3	530		20	0.03		0.88		0.41	0.003
25-Jun-96	6.6	7.96	3010	33	9.6	139	735	51.8	464		19	0.03		1.73		0.31	-0.05
15-Oct-96	8.21	7.98	2646	22.1	14.3	189	895	47	242	1869	15	0.05	0.014	0.084	-0.001	0.29	
08-Jan-97	11.1	7.29	1542	4.2	8.24	207	790	47	498		2.5	0.02	0.004	0.11	0.001	0.13	-0.05
08-Apr-97	9.86	7.79	926	14.6	39.6	137	130	42.6	246	662	39	0.07	0.05	0.58	0.003	0.57	
15-Jul-97	8.1	7.6	3646	32.9	15.5	208	1000	58	584		28.3	0.038	0.004	0.2	0.004	0.36	
04-Nov-97	5.1	7.92	1468	13.7	28.5	160	445	47.7	340		15.8	0.09	0.01	1.2	0.004	0.53	

Flatrock Creek OK520500-01-0280G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	7.5	7.25	489	27	17	150	39.5	25.3	148		23.3	0.09		-0.05		0.81	-0.05
10-Jan-96	11.7	7.38	363	3	27	93	40	15.3	116		17.3	0.09		0.1		0.47	-0.003
25-Jun-96	6	7.31	434	30	31	128	32.5	-2	112		26.3	0.11		0.04		1.05	-0.05
15-Oct-96	5.08	6.94	236.4	17.9	10	100	18	1.4	98	174	11	0.06	0.009	0.16	0.002	0.42	
07-Jan-97	10.77	7.18	226.4	5.1	10.2	93	40	29	114		8	0.08	0.003	0.15	-0.001	0.66	-0.05
08-Apr-97	7.43	7.27	179.5	14.6	39.9	65	19.1	10.3	70	175	17	0.13	0.05	0.03	0.007	0.99	
15-Jul-97	2.85	6.96	281	28.2	20.8	111	25	-1	90		18.2	0.1	0.013	0.33	0.005	0.87	
03-Nov-97	6.25	7.43	336.2	13.3	18.7	98	45	13.7	90		10.3	0.09	0.005	0.14	0.001	0.65	

Greasy Creek OK520500-02-0020G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	3.5	7.02	279	28	15	84	26	2.09	90		16.7	0.07		-0.05		0.64	-0.05
10-Jan-96	12.3	7.33	354	3	13	110	26	7.71	104		15	0.04		-0.01		0.41	-0.003
25-Jun-96	4	7	215	32	30.1	80	10	-2	78		24	0.08		-0.05		0.54	-0.05
15-Oct-96	5.43	7.13	108.3	20.1	25.6	52	5.5	3.63	53	99	12	0.07	0.009	0.136	0.004	0.58	
07-Jan-97	8.88	6.9	148.7	6.7	28.3	62	32	19.7	76		9.5	0.11	0.005	0.16	0.002	0.26	-0.05
08-Apr-97	7.32	6.91	77.1	14.6	64.8	41											
15-Jul-97	4.23	7.56	211	31.3	19.5	117	13	-1	76		20.3	0.056	0.013	0.26	0.005	0.56	
03-Nov-97	8.92	7.66	268.6	13	12.6	93	30	-1	90		15.3	0.04	0.001	0.1	-0.005	0.47	

Hilliby Creek OK520700-03-0270G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	8.1	7.02	619	32	8.4	205	62	-2	248		6.8	0.03		0.17		0.35	-0.05
10-Jan-96	13.1	8.96	660	4	9	184	57	4.7	232		6.5	0.02		0.03		0.19	-0.003
25-Jun-96	7.5	8.2	575	27	33	177	54	-2	214		26.5	0.11		0.11		0.99	-0.05
15-Oct-96	8.61	8.16	550	16.6	3.84	224	72	2.6	271	440	3	0.03	0.005	0.097	0.003	0.2	
07-Jan-97	13.55	7.83	268.4	1	15.3	157	42	1.58	218		11.5	0.04	0.002	0.18	0.003	0.3	-0.05
07-Apr-97	10.42	7.96	282.6	13.7	46.8	31	28.3	9.32	162	229	21	0.06	0.02	0.09	0.004	0.49	
15-Jul-97	5.77	7.99	520	27.3	6.75	190	50	-1	220		1.99	0.024	0.009	0.2	0.008	0.42	
03-Nov-97	11.87	8.04	423.4	9.3	13	210	65	-1	240		5.5	0.04	0.004	0.23	-0.005	0.25	

Nuyaka Creek OK520700-02-0200G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	8.6	7.68	420	29	43	128	27.5	7.41	146		38	0.11		-0.1		1.17	-0.05
10-Jan-96	10.62	8.46	541	4	36	183	50	28.8	196		31	0.07		0.1		0.5	-0.003
25-Jun-96	5.9	7.67	533	27	39	157	54	-2	186		44.3	0.13		0.12		0.86	0.03
15-Oct-96	4.5	7.24	207	16.2	14.3	103	14.3	-1	101	161	11	0.09	0.017	0.121	0.001	0.75	
07-Jan-97	10.95	7.46	231	4.5	12.2	99	46	26	136		8.5	0.04	0.003	0.139	-0.001	0.27	-0.05
07-Apr-97	8.71	7.62	211.5	15	55.3	67	21.6	13.2	96	194	32	0.08	0.04	0.02	0.003	0.95	
15-Jul-97	3.55	7.56	236	27.5	29.3	150	20	-1	126		25.2	0.074	0.011	0.3	0.004	0.75	
03-Nov-97	6.76	7.46	161.3	11.3	13.2	75	15	-1	68		90.6	1.5	0.07	0.06	0.004	1.1	

Walnut Creek OK520700-03-0020G

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	8	8.08	445	32	4.2	160	28	21.9	173		5.6	0.04		-0.05		0.23	-0.05
10-Jan-96	13.1	8.98	407	6	9	118	16	24.5	140		8	0.02		0.02		0.21	0.003
25-Jun-96																	
15-Oct-96	8	7.59	271	17.5	5.32	154	12	-1	156	200	3	0.02	0.005	0.101	0.001	0.2	
07-Jan-97	13.29	7.08	190	1.4	19.6	143	24.5	20.3	148		13.5	0.03	0.002	0.218	0.001	0.29	-0.05
06-Apr-97	10.09	7.55	177	14.5	52.4	85	12.9	15	101	181	18	0.08	0.04	0.09	0.002	0.5	
15-Jul-97	6.41	7.71	369	27.6	9.94	179	20	10.8	158		8.86	0.037	0.014	0.56	0.004	2.05	
03-Nov-97	11.78	7.95	268	10.6	5.16	138	25	1.69	132		5.5	0.03	0.001	0.12	-0.005	0.31	

Wewoka Creek OK520500-02-0010A

Date	DO	pH	Cond	Temp	Turb	Alk	Chloride	Sulfate	Total Hardness	TDS	TSS	Total Phosphorus	Total Ortho Phosphorus	Nitrate	Nitrite	TKN	Ammonia
31-Jul-95	7.3	7.76	2130	30	54.5	120	515	31.2	286		70	0.14		-0.05		0.66	-0.05
10-Jan-96	13.1	8.57	1635		7	122	415	34.6	280		10	0.13		2.66		0.99	0.6
25-Jun-96	6.6	7.91	531	32	50.2	118	218	14.9	184		53.5	0.12		0.63		0.62	-0.05
15-Oct-96	8.86	8.18	1525	20	8	152	450	10.5	284	990	10.5	0.05	0.016	0.123	0.001	0.33	
08-Jan-97	12.54	8.14	916	3.8	8.3	174	490	30.9	318		9.5	0.07	0.01	0.274	0.014	0.41	-0.05
08-Apr-97	8.36	7.76	583	15.1	69.8	104	140	10.6	156	402	67	0.17	0.06	0.46	0.005	0.68	
15-Jul-97	4.82	8.2	1332	32.1	60.6	149	325	28.4	216		63.4	0.135	0.014	0.3	0.002	0.72	
04-Nov-97	12.35	8.98	922	10.4	29.8	143	35	24.3	170		37.7	0.13	0.06	0.56	-0.005	0.63	