8425541

Jarman, Ron Leon

THE DEVELOPMENT OF AQUATIC ECOREGIONS IN OKLAHOMA

The University of Oklahoma PH.D. 1984

University
Microfilms
International 300 N. Zeeb Road, Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark __√__.

1. Glossy photographs or pages __✓__
2. Colored illustrations, paper or print __✓__
3. Photographs with dark background __✓__
4. Illustrations are poor copy ______
5. Pages with black marks, not original copy ______
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages __✓__
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) ____________ lacking when material received, and not available from school or author.
12. Page(s) ____________ seem to be missing in numbering only as text follows.
13. Two pages numbered ____________. Text follows.
14. Curling and wrinkled pages ______
15. Other ____

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE DEVELOPMENT OF AQUATIC ECOREGIONS IN OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

By

RON JARMAN

Norman, Oklahoma

1984

THE DEVELOPMENT OF AQUATIC

ECOREGIONS IN OKLAHOMA

A DISSERTATION

APPROVED FOR THE DEPARTMENT OF CIVIL

ENGINEERING AND ENVIRONMENTAL SCIENCE

By

Larry Canter

[illegible]

Jim F. Harp

Marvin W. Baker Jr.

James M. Robertson

ACKNOWLEDGEMENT

The waters of Oklahoma are a precious resource. They are in capable hands due to the abundance of dedicated professionals and citizens who are concerned with this dwindling and precious commodity. My research committee is a group of the best known and most concerned of this elite corps. Dr. Larry Canter is known worldwide for his professional approach, thoroughness, and environmental concern. Dr. Jim Robertson has trained a tremendous number of environmental scientists and engineers in the special needs of environmental protection and cautioned them on the tragic costs of less than an all out effort. Dr. Jim Harp is the acknowledged expert in Oklahoma on the characteristics and movement of water (it flows downhill and pools in low places). This reputation is well deserved and justly earned. Dr. Marvin Baker is known as "Mr. Environment" to most bureaucrats in Oklahoma. His incisive intelligence and calm wit has aided me in many volatile situations, both on the job and in graduate school. Dr. Thomas Peace agreed to serve on my committee in a time of special need. As a co-worker, fellow bureaucrat and accomplished environmentalist we have always been on the same side in spite of usually being in opposing state agencies.

The Oklahoma Water Resources Board (OWRB) has been a special place for me during the last five years. Jim Barnett, Director, has enabled me to pursue my goal of statewide water improvement almost unheeded and always with a great deal of support. My fellow workers at the Board have provided support, counsel and an ear for my thoughts throughout this project. Dr. Main Hutcheson has spent many hours trapped in a car on some highway with me as the discussion turned from fishing to methods to protect the waters of the state. James Adams has supported my forays into philosophical water management and filled in for me in trying times. Many co-workers, such as Jim Gopal, Gary Shapiro, Dr. Jim Grimshaw, Mike Bastian, and Shon Simpson have patiently listened to my ideas, offered suggestions and provided technical advice.

This project could not have been completed without the special help of the drafting and data processing departments of the OWRB. James Leewright, Mike McGaugh and Gladys Haywood spent large amounts of time and provided their special skills in an uncomprising fashion which produces products unequaled in any group that I'm aware of. Jann Hook's aoilities in data manipulation were invaluable in producing a product out of a mass of data. She was able to try and try again, looking for some magic. Chris Flasch picked up the torch in an especially trying time and put forth a special effort to help find success.

Sheila Hand typed the document, made it complete and kept me on the right track to get it finished. In her spare time she worked all day, took care of her family, and managed to give proper and complete advice on the professional and private lives of the OWRB Water Quality Division staff.

Endless thanks to my wife Sandy, for keeping me moving, fighting for me to have time and sacrificing her needs, wants and desires for this common goal. I look forward to many years of togetherness to compensate for the time lost.

Three fellow environmentalists should be credited with the support necessary for me to complete this project. B. J. "Jim" Gopal was a continual friend and hard worker in the effort. He gave tirelessly of his time and advice, staying after work, spending holidays and reviewing data sets. He is a primary cause for the data producing something meaningful. Jim Lazorchak provided an excellent sounding board for my ideas, a knowledgeable source for keeping my goals in sight and most importantly he said the right words at the right time which produced success. Dr. Charles Marshall has given a special kind of support throughout this effort. From the first days of preparing a project proposal to reviewing the drafts he has been supportive, knowledgeable and helpful. In addition, he helped me maintain a "you can do it" attitude which is the only way I was able to complete this project. Thanks to all of you.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF FIGURES

ABSTRACT

This study was to determine if a technique could be developed for assigning aquatic ecoregions to streams in Oklahoma. It was determined that watershed attributes, generally available on a statewide basis, can be used to develop a conceptual framework on which to manage and protect the waters of the state.

Eight broad scale geographic properties were used to define differences in 381 watersheds which could be spatially represented as regions. These properties were evaluated by three cluster analysis techniques and each watershed provisionally assigned to a region based on the results. The provisional assignments were evaluated by discriminant analysis. Five ecoregions were designated based on these techniques. Ninety-five watersheds were withheld from final assignment to an ecoregion.

Regional differences were then compared through fish collections from a broadly scattered pattern. The resulting analysis tends to support the regions developed by objective multivariate techniques.

Statistical validity was evaluated but hampered by the small sample size of the evaluation data set.

The project provided insight into the variation of the waters of Oklahoma and produced an objective, reasonable and economical grouping to be used in the protection and management of these waters for future generations.

DEVELOPMENT OF AQUATIC ECOREGIONS IN OKLAHOMA

CHAPTER I

INTRODUCTION

Since the earliest recorded times man has attempted to group details into larger units for simplicity of understanding. Since early man could only see a short distance it was an easy and natural task to group these surroundings. Large plants became "trees," smaller plants "brush" and the smallest visible plants "grass." This grouping carried through with "food," "clothing" and "animals." Each of these natural groupings belie the complexity within each group. There are thousands of species of trees throughout the world and usually dozens in a specific geographic location. The desire of early man to develop groupings grew from an innate need to "comprehend" and "understand" his environment.

Modern day man exhibits this same strong tendency and develops both natural and artificial groups. However, this does not impede the natural processess from operating in a complex manner. So man pursues his own classification in ways which sometimes defies description.

After separating space from earth the next breakdown is the separation of land and water. The continents are separately considered from islands. Within each continent there may be several countries composed of states or provinces. Each state is further subdivided into counties, cities and any number of arbitrary demarcations. However, streams flow across these boundaries in many cases, and air flows across the earth with only slight alteration from surface features.

Within these unnatural areas on the earth, man does have a need to classify by natural systems to preserve, protect and conserve his environment and his heritage. Although most natural systems are far too complex to describe with a general classification, there does exist tendencies in nature which can be utilized to affect a general understanding of the processes in an area.

For this dissertation it is desirable to pursue the development of a classification scheme for the aquatic resources within the political boundaries of the State of Oklahoma. This classification is intended to aid in the overall management of the state's waters. It is an artificial system, yet its basis is the natural aquatic systems as they exist in Oklahoma.

The protection of the water resources of Oklahoma from water quality impairment by man's activities has been a large, expensive and admirable effort during the last decade. The results of this effort have shown few real successes, few failures, and many holding actions. However, the potential for preserving and improving Oklahoma's waters still exists and largely depends on the development of an effective management program involving all levels of public agencies, industry, special interest groups and the academic community. The development of an effective water quality management program is dependent upon four basic program needs: an adequate data base; good communication between administrators and the public; logical interpretation of needs; and informed decision making.

Oklahoma's water quality standards provide the legal base for effective management. Due to shortfalls in the four basic program needs mentioned above the standards have continued to evolve for 15 years. The current water quality standards will need to change in the future to adequately protect Oklahoma's water resources.

One basic shortcoming of the current standards is the inability to recognize and provide for the large ecological diversity of Oklahoma's waters. The future success of the use of the standards could depend on the ability to recognize and provide for distinct areas of ecological differences.

Carried to extremes, the recognition of diverse aquatic types could result in many sets of standards, each of which apply to only a specific water body. As desirable as this would be, the cost to evaluate and establish these site specific standards would, in most cases, outweigh the benefits. Alternatively, a study to recognize the similarities of various bodies of water could enable an effective but less intensive study of individual streams or lakes.

Streams are complex aquatic ecosystems with characteristics which are a direct result of the unique set of circumstances in each individual watershed. If the various chemical, physical, and biological factors are similar between watersheds than the streams should be ecologically similar. This will vary with scale and it is important to determine an appropriate scale for use in the development of ecologically similar areas.

"Every classification that is more than an academic exercise has an objective that extends beyond the creation of the classification system itself." (Witmer, 1978). The objective of this dissertation is to develop an aquatic classification system from which the state's water quality standards can be adjusted to provide protective yet reasonable criteria. Recognition of the natural diversity and regional similarities of Oklahoma is an important first step in this development. The recommendations made in this paper are directed to the state's water quality standards setting agency, the Oklahoma Water Resources Board.

The scope of this study is:

(1) to evaluate watershed characteristics which may impact stream water quality for type and scale of impact;

(2) to select those characteristics which have the greatest impact on stream quality for use in the development of regions of ecological similarity;

(3) to collect and apply appropriate data from the State of Oklahoma for analysis of impact; and

(4) to utilize significant data for the prediction of resulting stream quality in the development of ecologically similar regions in Oklahoma.

The successful completion of these steps can provide an important step in producing a strong and protective, yet reasonable and enforceable water quality management program.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

To classify aquatic regions for the State of Oklahoma requires a thorough understanding of its natural strengths and weaknesses along with its history and its natural tendencies. This chapter is intended to provide a cursory description of these factors along with adequate details to provide the reader with an understanding of the state's diversity.

Oklahoma, the 46th state of the United States, has a land mass of 69,919 square miles (181,089 square kilometers) and a 1980 population of 3,025,226. Approximately 70 percent of the population live in urban areas. The terrain varies from the rolling, timbered hills in the east to the treeless high plains in the west. The state is included in five physiographic Provinces as listed by Fenneman, 1928. These include: (1) Central Plains; (2) Great Plains; (3) Ozark Plateau; (4) West Gulf Coastal Plains; and (5) the Ouachita Uplift. The general topography slopes to the east as rolling plains. Locally hilly and mountainous areas exist. These generally rise only a few hundred feet above the surrounding plain but the Ouachita Mountains of the southeast rise as much as 2,000 feet above their base. Other major hilly areas include the Cherokee and Flint Hills of the northeast, the Wichita Mountains of the southwest and the Arbuckle Mountains of south-central Oklahoma. Elevations range from 4,973 feet on Black Mesa in the Panhandle to 287 feet near the southeastern corner of the state.

Geology

Geologically, Oklahoma is a very complex state (Pettyjohn, et al., 1983). Uplifted and faulted rocks occupy the northeastern part, while to the south lie the arcuate faults and upturned strata that form the ridges and valleys of the Ouachita Mountains. Although topographically subdued, the Arbuckle Mountains in south-central Oklahoma are likewise faulted and upturned, with some strata even being vertical. Here occur the oldest rocks that outcrop in Oklahoma. In the southwest are the Wichita Mountains, which are folded, faulted and cored by Cambrian granite and gabbro.

Lying between the Ozark Uplift and the Ouachita Mountains is the Arkoma Basin, an area of downwarped rocks that extend downward more than 26,000 feet below sea level. South of the Arbuckle Mountains is the Ardmore Basin, where sedimentary strata occur at depths greater than 35,000 feet. The Anadarko Basin, north of the Wichita Mountains is also deeply downwarped and has received a great amount of oil and gas development in recent times.

Most of the rocks that outcrop in Oklahoma are of sedimentary origin, consolidated from sediments deposited during the Paleozoic Era and covering about 75 percent of the state. Locally, some of these formations achieve a thickness of 40,000 feet. The oldest of these are the Precambrian granites and rhyolites formed 1.05 to 1.35 billion years ago. Precambrian and Cambrian igneous and metamorphic rocks underlie all of the state, and provide the "floor" upon which all younger rocks rest.

Nonmarine shales and sandstones characterize the Mesozoic sedimentary rocks of Oklahoma. Shallow seas covered southern and western Oklahoma during some of the era's Cretaceous Period, and marine deposits resulted in limestone and shale. The Panhandle is covered by rocks of Tertiary Period except for scattered areas along streams, where Permain and Mezozoic rocks crop out. Since the beginning of the Tertiary Period, none of the state has been covered by sea water. Cretaceous strata in the southeast slope southward. The Quaternary Period through the present is characterized as a time of erosion. Rocks and loose sediment at the surface are being weathered to soil, then the soil particles are carried away to streams and rivers. As a result the soil exists in the stream beds, on the banks and in the bottoms of man-made lakes. Sand and sand dunes form the wide flood plains of the major rivers.

Climate

Oklahoma is divided into two general climatic regions, the humid east and the semi-arid west. The demarcation of these regions is not well defined as indicated in Figure 1, the average annual precipitation from 1970-1979 (OWRB, 1980). The geographical distribution of rainfall decreases sharply from east to west, ranging from 56-inches in the southeastern corner to 15-inches in the western Panhandle. Frequency of rainfall in excess of 0.01 inches per day ranges from 95-100 days per year in the east to 70-80 days in the western part of the state.

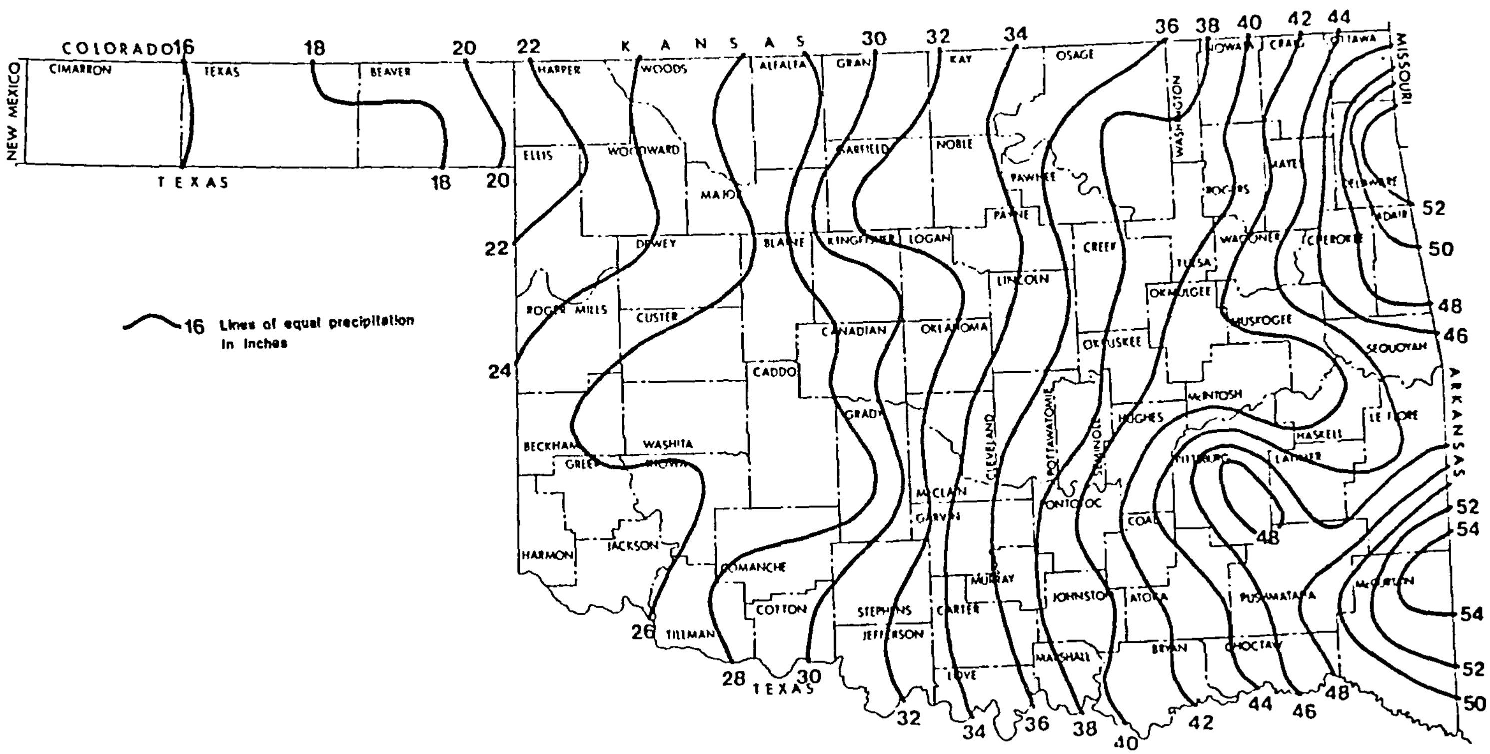


Figure 1. **AVERAGE ANNUAL PRECIPITATION (In Inches)**
(Period 1970-79)

Data - National Oceanic and Atmospheric Administration (1970-79)

Summers are long and hot, while winters are shorter and less severe than the plains states lying to the north. Moist air currents from the Gulf of Mexico temper the weather during most of the year, but cool moist air masses from the Pacific and cold dry Canadian air masses influence winter temperatures.

Snowfall varies inversely with rainfall in the state. It ranges from less than 2-inches per year in the east to more than 20-inches per year in the western part of the Panhandle. Rarely does snow remain on the ground more than a few days but strong winds may cause drifting during blizzard conditions. Maximum precipitation occurs in the spring. May is usually the wettest month with rainfall decreasing until fall, the second wettest season. January is Oklahoma's driest month.

Mean annual temperatures range from 64°F along the southern border to 60°F in the northeastern part of the state. This decreases westward across the state to 57°F in the western part of the Panhandle. January mean temperatures ranges from 48°F in south-central Oklahoma to 28°F in parts of the Panhandle. July mean temperatures ranged from 78°F in the western part of the Panhandle to 84°F in southwestern and north-central Oklahoma.

Annual lake evaporation averages 48-inches in the eastern part of the state to 64-inches in the southwestern corner. Evapotranspiration and percolation consumes an average of 80% of annual rainfall. Generally, over much of the western third of the state evapotranspiration equal rainfall. As a result a soil moisture deficiency exists for much of the year. This reduces groundwater recharge and stream flow through dry period of the year.

Social

Although Oklahoma is one of the newer states in the nation it is one of the oldest in terms of human occupation. The abundant game on the plains attracted hunters of the Clovis and Folsom cultures during the period from 10,000 to 15,000 years ago. Other tribes followed and eventually a high culture developed during the period from 500-1300 A.D. producing pottery, textiles, metalware and sculpture. This culture apparently fell to an onslaught of primitive people from the western plains.

Europeans first visited Oklahoma in 1541 when Francisco Vasquez de Coronado traveled through the state. Oklahoma remained largely unsettled until 1830 when the U.S. Congress reserved Oklahoma for settlement by Indian tribes from the eastern United States. By 1880 more than 60 tribes had joined indigenous peoples in "Indian Territory." Although some tribes did till the land and produce crops the Indian occupation had little impact on the natural environment of the territory.

By 1889 pressure from white settlers and the illegal activity of the Sooners resulted in the opening of large portions of Indian Territory to white settlement. The resulting removal of the prairie vegetation has had long lasting negative impact on the natural environment of the state. The combined effect of worldwide depression and a local drought in the 1930's resulted in the next major shift in Oklahoma's social development. Unable to cope with the severe economic and environmental conditions many of the farm families out-migrated from the state or into urban areas. This has resulted in an adjustment of farm size and number which more nearly coincides with the varied climate of the state.

In recent years the state has experienced rapid social and economic growth. This is evidenced by marked escalation in population, income, agricultural production and industrial development. In-migration resumed in the 1960's and this growth trend continues. The Tulsa and Oklahoma City metropolitan areas account for more than half of the state's population. In 1910 only 19.2 percent of the population lived in cities and towns. By 1940 this figure had grown to 37.6 percent, and in the 1970's had reached 68 percent. This type of growth and population concentration has been accomplished both in concert with and in opposition to the environment. Due to the current status of social development in Oklahoma the State has a wide diversity of water problems. Some of these are severe.

Water

Water has always been the most precious resource in Oklahoma. Always too much or too little, early man in the state was tied closely to the streams and springs. Since the state has few natural lakes, development of civilization occurred along stream courses. Travel through the area was by established routes from water hole to water hole. As white settlers moved into the new state, wells were dug, ponds were built to catch rainwater and springs were utilized to their limit. Although the state has changed dramatically since those early days, with huge water development projects, hundreds of thousands of ponds and deep water wells, there still exists a major dependence on the state's water resources.

Oklahoma is drained by two major rivers; the Arkansas in the north, and the Red in the south (Figure 2). The Arkansas River and its tributaries drain 44,491 square miles, which comprises about two-thirds of the state; the Illinois River drains a large area of Ozark Upland; the Verdigris and Grand (Neosho) Rivers in the northeast; the Poteau River in the southeast; the Cimarron River from the Panhandle to near Tulsa; and the Salt Fork River which drains large natural salt deposit. The Arkansas River enters Oklahoma from Kansas near Newkirk, flows southeasterly past Tulsa, then Muskogee, and flows out of the state into Arkansas at Ft. Smith. Both the mainstem and its tributaries are impounded by dams to form many large size reservoirs. Included on the mainstem is the McClellan-Kerr Navigation System which connects the Tulsa area with the Gulf ports of the southeastern United States.

The Red River and its tributaries drain 24,978 square miles of Oklahoma. This is the remaining one-third of the land mass in the state. The Red rises in the High Plains of eastern New Mexico, traverses the Texas Panhandle and forms the southern boundary of Oklahoma. It skirts the southern edge of the Ouachita Mountains and flows into the Gulf Coastal Plain of southwest Arkansas and Northern Louisiana. Major tributaries of the Red in Oklahoma are the Elm, Salt and North Fork Rivers in southwestern Oklahoma, the Washita River traversing Oklahoma from its western border to the south-central part of the state, the Blue, Little and Kiamichi Rivers and Muddy and Clear Boggy Creeks in southeastern Oklahoma. Several impoundments have been constructed on the tributaries but only one, Lake Texoma, exists on the mainstem.

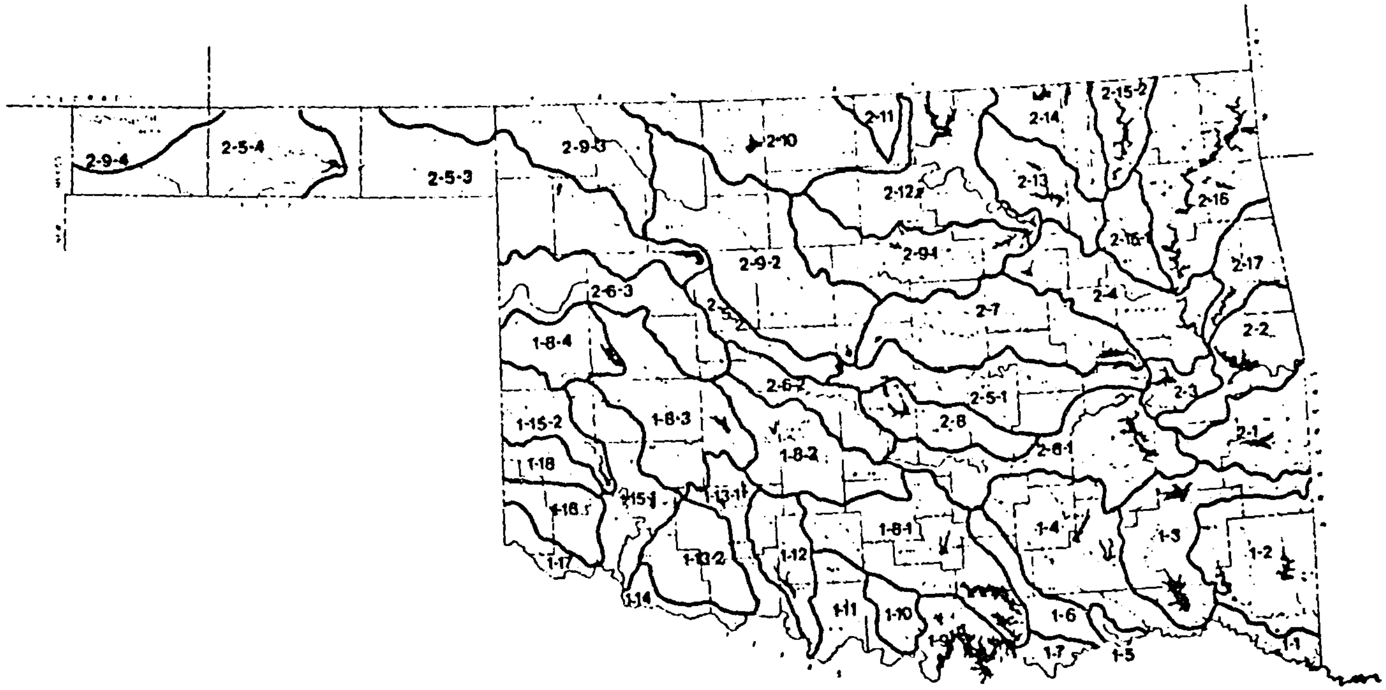


Figure 2. **OKLAHOMA STREAM SYSTEMS**

Figure 2. (Cont.)
OKLAHOMA STREAM SYSTEMS

RED RIVER AND TRIBUTARIES

Stream System	
1-1	Main stem from Arkansas state line to mouth of Kiamichi River
1-2	Little River
1-3	Kiamichi River
1-4	Muddy Boggy River
1-5	Main stem from mouth of Muddy Boggy to mouth of Blue River
1-6	Blue River
1-7	Main stem from mouth of Blue River to mouth of Washita River
1-8-1	Washita River from the confluence with the Red River to the USGS Gage Number 07328500 just west of Pauls Valley
1-8-2	Washita River from the USGS Gage Number 07328500 just west of Pauls Valley to USGS Gage Number 07326500 near Anadarko
1-8-3	Washita River from the USGS Gage Number 07326500 near Anadarko to Foss Dam
1-8-4	Washita River from Foss Dam to Texas state line
1-9	Main stem from mouth of Washita River to mouth of Walnut Bayou
1-10	Walnut Bayou
1-11	Mud Creek
1-12	Beaver Creek
1-13	Cache Creek
1-13-1	Cache Creek and Red River between the mouths of Beaver and Cache Creeks
1-13-2	Deep Red Run and West Cache Creek to the confluence with Cache Creek
1-14	Main stem from Cache Creek to North Fork Red River
1-15-1	North Fork Red River from the confluence with the Red River to Altus Dam near Lugert
1-15-2	North Fork Red River from Altus Dam near Lugert to the Texas state line
1-16	Salt Fork Red River
1-17	Prairie Dog Town Fork Red River
1-18	Elm Fork Red River

ARKANSAS RIVER AND TRIBUTARIES

Stream System	
2-1	Poteau River
2-2	Main stem from Arkansas state line to mouth of Canadian River
2-3	Canadian River from mouth, to mouth of North Canadian River
2-4	Main Stem from mouth of Canadian River to Keystone Dam
2-5-1	North Canadian River from the confluence with the Canadian River to the diversion dam at Lake Overholser
2-5-2	North Canadian River from the diversion dam at Lake Overholser to Canton Dam
2-5-3	North Canadian River from Canton Dam to Optima Dam
2-5-4	North Canadian River from Optima Dam to the New Mexico state line
2-6-1	Canadian River from the mouth of the North Canadian River to the mouth of Walnut Creek near Purcell
2-6-2	Canadian River from the mouth of Walnut Creek near Purcell to the USGS Gage Number 07228500 near Bridgeport
2-6-3	Canadian River from the USGS Gage Number 07228500 near Bridgeport to the Texas state line
2-7	Deep Fork River
2-8	Little River
2-9-1	Cimarron River from its mouth to the USGS Gage Number 07160000 near Guthrie
2-9-2	Cimarron River from the USGS Gage Number 07160000 near Guthrie to the USGS Gage Number 07158000 near Waynoka
2-9-3	Cimarron River from the USGS Gage Number 07158000 near Waynoka to the Kansas state line
2-9-4	Cimarron River from the Colorado state line to the New Mexico state line
2-10	Salt Fork Arkansas River
2-11	Chikaskia River
2-12	Main stem from Keystone Dam to Kansas state line
2-13	Bird Creek
2-14	Caney River
2-15-1	Verdigris River from mouth to Oologah Dam
2-15-2	Verdigris River from Oologah Dam to the Kansas state line
2-16	Grand (Neosho) River
2-17	Illinois River

Stream flow in the major rivers is large with a mean annual flow of 30,921 cubic feet per second (cfs) in the Arkansas River at VanBuren, Arkansas, 11,612 cfs in the Red River at Index, Arkansas, and 2,923 cfs in the Little River at the Oklahoma State Line (Mize, 1975). Stream flow corresponds largely with precipitation patterns; very large in the east, and very small in the west. Average annual runoff, composed of surface runoff and groundwater flows to the surface, vary from 20-inches in the southeast to 0.2-inches in the Panhandle. The runoff is generally distributed through the year in a cycle corresponding with precipitation events. In most of the state two periods of high stream flow exists; the largest in the spring and a lesser peak in the fall. Because of greater precipitation this pattern is more pronounced in the eastern part of the state. Of tremendous impact on water use and the natural biota are the low flow periods which occur in the late summer and to a lesser extent in mid-winter. For all but the major rivers and a few spring fed streams the low flow expected for a 7-day period every two years (7Q2) is zero (Huntzinger, 1978). In the smaller streams in the state zero flow will be encountered during the winter period. In almost all streams the zero flow will occur in late summer which produces severe impact on the stream ecosystem. Water temperatures during this period couples with low flow to produce critical conditions for most streams.

Also of critical importance are the high flow periods when major amounts of top soil are transported down the stream channels. Flooding occurs frequently in the state during the spring thunderstorm period. Flood control is a major purpose for most of the state's impoundments with water supply, recreation, hydropower and navigation of lesser importance.

Water quality of Oklahoma's streams is highly variable. Natural contamination is common in the west while man-made pollution is widespread and tends to concentrate in urbanized areas. In the west natural salt springs and flats increase chlorides in the streams while soil and rock strata add minerals. In the populous central and eastern Oklahoma, municipal and industrial effluents degrade many streams, restricting their beneficial uses. However, many of the streams in eastern Oklahoma are of excellent quality and have reasonably uniform flow. The quality of stream water depends on many factors which occur in its watershed. Unique factors, such as; geology, flow, land use, slope, erodibility and man's development combine to produce a stream of some resulting quality.

Water of the Arkansas River in western and central Oklahoma is highly mineralized and nutrient rich. The Salt Fork and Cimarron Rivers are impacted by natural chloride contributions in their upper basins. The chloride concentration in some reaches exceeds that of sea water. The Cimarron also contains high levels of gypsum, which contribute to the river's poor water quality.

The North Canadian, Deep Fork and Canadian Rivers are nutrient-rich and highly mineralized. Municipal and industrial discharges in central Oklahoma have degraded these rivers in recent years.

Northeastern Oklahoma offers both good and poor quality streams. The Grand (Neosho) and Illinois Rivers are of excellent quality throughout their lengths although nutrification is increasing at an alarming rate. The Verdigris and Caney Rivers are of poor quality due to high total dissolved solids. Because of upstream contamination the lower portion of the Arkansas River is of poor quality.

The general water quality of the Red River Basin is poor from the Texas Panhandle to Lake Texoma due to high mineral and nutrient levels. Natural salt flats in the Texas Panhandle emit high levels of chlorides into the Red River greatly impacting its use. The Salt and North Fork Rivers also receive natural salt contamination increasing the overall contamination in the Basin. Nutrients are increased with the addition of flow from Cache and Mud Creeks to the river. This is a result of large municipal and industrial discharges in the basins. The Washita River is a turbid, hard water stream which drains a large portion of southwestern Oklahoma. Due to the nature of the soils and geology of this basin the levels of sulphates, chlorides and turbidity increases as it flows downstream.

The quality of water in the Red River improves significantly with the addition of high quality waters from the Blue River and Muddy and Clear Boggy Creeks. These streams, along with the Kiamichi and Little Rivers produce a stream of acceptable quality.

Land Use

Oklahoma's land use varies from unimproved rangeland, virgin forest and riparian zones to intensely urbanized cities, intensive farmland and industrialized areas. Large areas of the state have returned to near natural condition while urban areas have spread out to produce some of the largest cities in the nation in land area. However, almost all of the state is being utilized by man in some fashion. Many of these have a significant impact on the land, the vegetation and the ecology of the streams in the state. Any development of regions must consider the use of the land, its performance and its effect on streams of the area.

Agricultural land use in Oklahoma is usually classified into four types: 1) cropland - any use which results in the annual tilling of the soil and harvest of a crop directly from the field; 2) pasture - any area which has been planted with grass which is used as a direct food for livestock; 3) rangeland - any area which is or has been allowed to reach a climax vegetation which is used as food for livestock; and 4) forestland - any area whose predominate climax vegetation is trees which may or may not be harvested as crop.

The agricultural use of land in the state follows the east-west trend of rainfall. In the arid west cropland is altered by the shortage of rainfall. In the east farming must be managed to compensate for the removal of nutrients by leaching. Exceptions to the general rule exist in the west by the development of ground and surface water resources which result in extensive crop production in these areas. Although irrigation occurs in all but four counties in the state (McIntosh, Mayes, Delaware, and Craig), it is far more prevalent in the western half.

Agricultural usage of the land varies from farm to farm and from year to year. In many areas multi-use occurs on the same plot of land. During winter months it is common practice to graze cattle on wheat pasture to aid in "stooling" of the wheat which produces a fuller head of grain being less susceptable to subsequent spring storms. Legumes are planted in some areas in alternate years to "fix" nitrogen in the soil and reduce fertilizer costs.

Major areas of forestland are confined to the eastern one-third of the state. In this part of the state the topography is more severe and the generalized condition is the occurrence of cropland in the valleys and forestland on the hills and ridges. The cropland is generally developed for fruits and vegetables. Extensive tree farming occurs in the southeast with very little tree farming in the Ozark Plateau.

In the central one-third of the state the topography is rolling, rainfall adequate, and the soils generally fertile. A great mixture of crops are produced including: wheat; peanuts; grain sorgham; hay; corn; and cotton. In addition, large amounts of livestock are produced including: beef cattle; dairy products; hogs; and poultry.

In the western one-third of the state the low average annual rainfall dictates a predominance toward rangeland and low moisture crops, such as wheat. In most of this area the two crops are managed concurrently. Hay is produced in several varieties as the third most important crop. The development of water resources has produced two large areas of extensive irrigation. A large portion of the Panhandle has been converted to cropland to utilize the groundwater available in the Ogallala aquifer. Crops produced in this area are generally corn and grain sorgham. Development of surface water supplies on the North Fork of the Red River in southwestern Oklahoma has resulted in conversion of rangeland to cropland and increased the production of cotton.

Urban land use is at its greatest in the history of the state. However, the majority of the counties in the state still have less than 50 persons per square mile (U.S. Bureau of the Census, 1980). Only two counties (Oklahoma and Tulsa) have greater than 500 persons per square mile. Three counties (Comanche, Cleveland, and Washington) have a population between 101 and 500 persons per square mile and twelve counties have a population between 51 and 100 persons per square mile. Generally the population trend is from low in the west to high in the east. The exceptions to this rule are population centers around Oklahoma City and Tulsa and centers around military installations in Lawton and Enid. The overall state population increased by 18.2 percent between 1970 and 1980.

Oklahoma's cities are spread out, resulting in large land masses for even intermediate size towns. A complete transportation system also exists which uses large amounts of land. Some industrial complexes exist although not to the extent of many eastern states.

Biological Characteristics

The biota of the state varies as much as the climate, geology and land use because it is impacted by these factors and is the result of the combination of factors in a given area. Several investigators have reported on the biota of the state (Bruner, 1931; Rice and Penfound, 1959; Webb, 1970; Blair and Hubbell, 1938; Duck and Fletcher, 1943; Miller and Robison, 1973). This summary is largely described from these sources.

Vegetation

Two plant formations are present in Oklahoma. The Decidous Forest (Acer-Fagus) Formation reaches its western limit in the state and three associations of the Grassland (Stipa-Bouteloua) Formation are found. These are the true prairie, mixed prairie, and short grass plains (Bruner, 1931).

The Decidous Forest is predominant in the eastern one-third of the state and extends as fingers stretching westward along stream bottom areas. It is represented by a single association, the oak-hickory (Quercus-Hicoria) forest. It occurs principally in the mountainous Ozark and Ouachita regions because of high rainfall and humidity. The following oaks are common or abundant: Quercus schneckii; Q. nigra; Q. velutina; Q. rubra; Q. marilandica; and Q. stellata. Of lesser abundance are various hickories such as: Hicoria ovata; H. laciniosa; H. cordiformis; H. myristicaeformis; and H. Buckley. Hickories usually constitute a small percentage of a stand.

Three other forest communities have a definite relationship with the climax decidous forest. These are the subclimax short-leaf pine (Pinus echinata) consocies; the postclimax associes of blackjack (Q. marilandica and post oak (Q. stellata) intermixed with hickory in the sandy uplands; and the flood plain forest of elms and ash (Ulmus-Fraxinus) associes which extend far into the grassland climax.

An extensive oak-hickory savannah separates the two climax forest areas in east-central Oklahoma. This area is characterized by varying degrees of dominance of woodland and grassland. It is essentially a transition community between forest and prairie whose extent and character are controlled by the sandy texture of the soil. The dominant trees are blackjack and post oak which occur in about equal numbers. The grasslands associated with the forests in the savannah, range from subclimax in the eastern part to true prairie in the west.

A considerable extension of forest has taken place in Oklahoma through the production of ravines in grassland by accelerated erosion, and subsequent invasion by trees. Many trees have been planted in cities, around farmsteads, and in shelterbelts. It is probable there are more trees today than at any other time in the history of Oklahoma (Rice and Penfound, 1959).

The grasslands lie principally in the western half of the state, although a large tongue of the Cherokee Prairie District (Blair and Hubbell, 1938) extends into northeastern Oklahoma from southeast Kansas. The eastern grassland is subclimax since it occurs in an area with a potential forest climate. The dominants are coarse, tall, sod-forming grasses such as: *Andropogon* sp.; *Panicum virgatum*; and *Elymus canadensis*. Historically, because of prairie fires, forest had not developed in this area. Since the early settlement of Oklahoma, wildfires have decreased, resulting in an expansion of forest. The eastern grassland extends far into western Oklahoma in sandy soils along principle streams. The tall, coarse, deeply rooted grasses can occur in these areas because of the substrate which absorbs most of the precipitation and at the same time forms a natural surface mulch which inhibits evaporation. In these areas the eastern grasslands are postclimax.

The true prairie (Stipa-Koeleria) association lies to the west of the savannah. The dominant residents are: Andropogon sp.; Bouteloua racemosa; Agropyron smithii; and Sporobolus asper. Many legumes, composites, primroses, etc. grow in the sod formed by the tall grasses.

The mixed prairie (Stipa-Bouteloua) association is dominated by a mixture of tall and short grasses. The shorter bluestems (Andropogon scoparius and A. saccharoides) are the chief tall grasses along with Agropyron sp. and Bouteloua gracilis, B. hirsuta and Bulbilis dactyloides. This is a transition zone between the true prairie on the east and the short grass plains on the west. Dry periods of long duration are frequent and abundant desiccation occurs due to winds. During arid conditions the short grasses have an advantage over the tall ones, especially in upland areas. Hence, the area is characterized by extensive alternes and mixtures of tall and short grasses.

The short grass plains (Bulbilis-Bouteloua) association largely occupies the Panhandle area of the state. It is characterized by an almost pure growth of the short grasses which form a low sod-mat and consitute the most xeric type of vegetation. The water content of the soil is usually low because of limited precipitation. The fine textured soils are capable of holding the moisture that infrequently occurs. The short grasses are capable of quickly reviving after a period of drought and are remarkably adapted to the conditions imposed by this environment.

Terrestrial Fauna

As with all other characteristics of Oklahoma there is a strong east-west zonation for terrestrial animals. Many of the forms which exist in the eastern portion of the state reach the western limit of their range within the state's boundaries. Conversely, many western forms reach the eastern limit of their range in Oklahoma. There is very little north-south zonation in the state.

Jack rabbits and cottontails are the most ubiquitous of Oklahoma's mammals. Other prevalent inhabitants include the coyote, prairie dog, mink, otter, opossum, gray squirrel, fox squirrel, raccoon, and skunk. Deer are found in every county in the state, antelope occur in the Panhandle and elk are being transplanted into eastern Oklahoma from the southwest part of the state. Seventy-three species of mammals have been recorded from Oklahoma. Twenty-four are wide-ranging species whose range extends beyond the state in all directions. Twenty-two are eastern forms that reach the western limit of their range in the state. Twenty-two are western species which reach their eastern limits in the state. Northern limits of range are reached by only six species and southern limits by only two species (Blair and Hubbell, 1938).

Blair and Hubbell (1938) state there are three principal mammalian fauna represented in Oklahoma. These are: 1) the eastern deciduous forest fauna composed of the chipmunk, the brown cave bat, and game animals previously mentioned; 2) the southern Rocky Mountain fauna composed of mule deer, western chipmunk, cliff mouse, white throated woodrat, mule-eared bat, coyote, and rabbits; 3) the grasslands of the Great Plains fauna composed of deer mouse, cotton rat, prairie vole, wood mouse, pine vole, Carolina shrew and ubiquitous species previously mentioned.

Sutton (1977) lists 423 species of birds found or expected to be found in Oklahoma. Many of these are migrants through the state which occur only in certain seasons. Few are as constrained to a specific area as most other animals. However, the assemblage of bird species reflect the same zonation as the mammals.

Nice and Nice (1924) indicated Oklahoma's avifauna in the eastern third of the state is almost exclusively indicative of the eastern United States. Species listed to indicate this were: black vulture; red-cockaded woodpecker; acadian flycatcher; chipping sparrow; scarlet tanager; yellow-throated vireo; white-eyed vireo; black and white, prothonotory, pine, prairie, hooded, parula, and ceruleun warblers; redstart, ovenbird, brown-headed nuthatches; and wood thrush. There are no distinctively western birds among the breeders and only a few middle western species.

The avifauna of the central portion of the state show a loss of many eastern forms and also few western birds. More than two-thirds of the breeding birds are eastern forms, about one-sixth western and one-sixth middle-western. Some of the birds which nest in both eastern and central Oklahoma are: the red-bellied woodpecker; yellow-shafted flicker; chuck-will's widow; ruby-throated hummingbird; crested flycatcher; phoebe; wood pewee; crow; eastern meadowlark; American goldfinch; field sparrow; cardinal; indigo bunting; painted bunting; summer tanager; red-eyed vireo; sycamore warbler; Kentucky warbler; catbird; turfted titmouse; blue-gray gnatcatcher; and robin.

In the Panhandle there exists a preponderance of western birds. About two-thirds of the breeders are western birds, one-fifteenth middle western and one-fifth eastern. Common birds are: mountain plover; scaled quail; roadrunner; Texas and Lewis woodpeckers; red-shafted flicker; say phoebe; woodhouse and pinion jays; bullock, oriole and Brewer blackbirds; Cassin sparrow; canyon towhee; lazuli and lark buntings; rock and canyon wrens; and lead-colored bush-tit. For the breeding birds of the state only 15 percent range over the entire state, 50 percent are eastern forms, 8 percent middle western and 28 percent western.

Ninety-five reptiles are listed by Webb (1970) to exist in Oklahoma. The bulk of these have eastern faunal affinities. Most of the turtles and snakes are from eastern forms but most of the lizards have western faunal affinities. Forty-nine eastern forms are present of which nine are statewide and the remainder reach their western limit in Oklahoma. Twelve are confined to the eastern one-third of the state. Twenty-one extend westward but are limited by the grasslands and seven extend westward until they are limited by the High Plains.

Thirty-four reptile forms are western of which five are statewide and twenty-nine reach their eastern limits in Oklahoma. Five are confined to the Panhandle and twelve extend eastward to the forestland. The other twelve are limited only by the Ozark and Ouachita highlands.

Aquatic Fauna

Two major factors influence the distribution of fish in Oklahoma. One is the general east-west variation in climate which influences all biota. The other is a constraining factor since movement is limited to water bodies as pathways for migration and colonization. Fish movement is limited by this dependence on water, both by the physical limits and the chemical and ecological relationships. An analysis of species range by Miller and Robison (1973) indicated they also do not correlate perfectly with physiographic features of the state. Nonetheless, when it is considered that fishes are limited to streams, rivers and lakes, it is noteworthy to find there is considerable overlap in the patterns of fish with other faunal groups that have been studied.

Several assemblages of fishes are found in the state. The most diverse and specialized assembly occurs principally in the eastern third of the state. In the more arid western part of the state the diversity of fishes is more limited and specialization of fish species to individual habitats is much less prevalent. Only ten species of fish are shown by Miller and Robison (1973) to have been found throughout the state except for the Panhandle. But even these, generally rugged and adaptable species, are often found only in certain habitat. For example, the largemouth bass may be found in most ponds in the state but will seldom be found in adjoining streams unless stream velocity is very small.

Of the seventeen species collected statewide, six are minnows of the family Cyprinidae (plains, suckermouth, and bullhead minnows; emerald and red shiners; and carp), six are members of the family Centrarchidae (green, orangespotted, bluegill, longear and redear sunfishes and largemouth bass), three are members of the family Ictaluridae (black and yellow bullheads and channel catfish), a member of the family Catostomidae (river carpsucker), and the gizzard shad of the family Clupiadae.

An important factor when considering fish distribution and abundance in Oklahoma is the tremendous impact of impoundments on the fish assemblage. The state has few natural impoundments and none of any size. In the last fifty years the construction of ponds, lakes and reservoirs has created an entirely new aquatic habitat for native fish species. Table 1 summarizes the impoundments in Oklahoma from Lambou, et al. (1965) estimated for the year 1974.

This tremendous amount of additional habitat is having a dramatic impact on the fishes that exist in Oklahoma. Many of the native species (white and black crappie, largemouth bass, channel catfish, green, bluegill, longear and redear sunfish, golden shiner and fathead minnow) thrive in the impounded conditions of the smaller lakes and ponds. However, the pelagic habitat of the large reservoirs favor a different assemblage of species, such as: gizzard shad; white bass, river carpsucker; carp; smallmouth and bigmouth buffalo; flathead catfish; and longnose gar. Much of this spread in the range of the native species has been aided by rearing and stocking programs of the Oklahoma Department of Wildlife Conservation. In addition, the importation of exotic species (striped bass, walleye, muskellunge and northern pike) has artifically added to the range of these species.

By minimizing the impact of impoundments it is possible to recognize species occurrence within the state which does have some pattern. A group of fish which includes the rosyface and steelcolor shiners, freckled madtom, blackspotted topminnow, bluntnose darter,

Table 1. Summary of Impoundments developed in Oklahoma.

IMPOUNDMENT TYPE	AVERAGE SIZE (Acres)	TOTAL NUMBER IN OKLAHOMA	TOTAL ACREAGE
Farm Ponds	1.5	200,000	440,473
Soil Conservation Service (upstream flood control)	27.5	2,400	66,000
Special SCS Structures	300	175	52,500
Other Small Lakes	-	-	28,803
Reservoirs	10,722	65	696,934
Total		202,640	1,284,710

channel darter and spotted sucker seem to occur in about the eastern third of the state. As a subcategory of the eastern part of the state is the distinctive assemblage of species which occurs in the Ozark Uplift. This group is composed of roughly twenty-one species represented by both endemic Ozark species and species found in clear, cooler waters of the northeastern U.S. and the highlands of the southeastern U.S. Also distinctive is a lowland group from the Little, Kiamichi and Red Rivers of far southeastern Oklahoma. In this area the streams are more sluggish and the species represented are common in the southeastern coastal plain. This group includes eighteen species which are seldom collected in Oklahoma outside this area.

A group of "eastern" species including the bigeye shiner, redbelly dace, stoneroller, black redhorse, golden redhorse, log perch, and orangethroat darter inhabit the streams emanating from the Wichita Mountains in southwestern Oklahoma. This is probably due to the relatively clear water, uniform flow and steeper gradients of the streams in this area.

In Oklahoma the species known only from the Red River and its major tributaries are the chain pickerel, Red River shiner, chub shiner, blacktail shiner, Mississippi silversides, western sand darter and striped mullet. Only the Arkansas River shiner seems to be limited to the Arkansas River. The only species which seem to be strictly western forms are the plains killifish and the Red River pupfish.

A final group of species are inhabitants of the major rivers in the state. They include: shovelnose sturgion; paddlefish; alligator gar; American eel; speckled chub; flathead chub; silver chub; river shiner; siverband shiner; sand shiner; highfin carpsucker; blue sucker; black buffalo; blue catfish; river darter; and walleye.

Although some statistical analyses have been conducted on fish distribution patterns (Echelle and Schnell, 1976; Stevenson, et al., 1974; and Felley, 1980) a general statewide pattern has not been conclusively determined.

Description Summary

From this description of Oklahoma a graphic summary can be drawn. Oklahoma is: 1) a state of diverse environments; 2) these environments tend to be more extreme in an east-west orientation than north-south; 3) climate (rainfall) seems to have an overriding impact on the resulting environment; 4) man's impact on the environment has been moderately severe; and 5) the water resources of the state have been greatly impacted by man's activities. The further protection of the state's water resources will depend on the development of a statewide management program which recognizes the diversity of the state and uses that acknowledge its development.

CHAPTER III

THE DEVELOPMENT OF REGIONS

Ecoregion description requires an understanding of the science and art of regional geography. For centuries man has been describing areas on the earth. The techniques utilized in this quest to understand and describe the earth will provide the "tools" for this study. This chapter is a literature review of the field of geography as it applies to the development of regions.

The study of areas on the earth's surface in geography. Geography is a field which predated recorded history. One goal of geography is to understand areas of the earth. What has caused areas? How are they different? Why are they different? This goal and these questions encompass the field of regional geography. Regional geography and the regional concept have been described as: the core of geography (James, 1952); the proving ground of geographic theory (Hart, 1981); and the heart of geography (Platt, 1957). This field can aid in the development of aquatic regions for the State of Oklahoma.

Region has been given many definitions by geographers:

- An area delineated on a basis of general homogeneity of land character and of occupance. - R. S. Platt (1957).

- A domain where many dissimilar beings, artifically brought together, have subsequently adapted themselves to a common existence. - P. Vidal de la Blache (1926).
- An area throughout which a particular set of physical conditions will lead to a particular type of economic life. - R. E. Dickinson (1964).
- An area whose physical conditions are homogeneous. - W. L. G. Joerg (1914).
- An area characterized throughout by similar surface features and which is contrasted with neighboring areas. - N. M. Fenneman (1928).
- A complex of land, air, plant, animal, and man regarded in their special relationship as together constituting a definite, characteristic portion of the earth's surface. - A. J. Herbertson (1905).
- An area on the earth's surface homogeneous with respect to announced criteria. - P. E. James (1952).
- An area of any size, throughout which accordant areal relationships between phenomena exists. - D. Whittlesey (1954).

However, J. F. Hart (1981) stated emphatically,

> Regions are subjective artistic devices, and they must be shaped to fit the hand of the individual user. There can be no standard definition of a region, and there are no universal rules for recognizing, delimiting and describing regions.

James (1952), Whittlesey (1954), and Minshull (1967) all concur that whatever the term "Region" describes it must be based on announced criteria. Once these selected criteria have been applied to a portion of the face of the earth geographic generalizations can be developed. Each homogeneous area, so defined by announced criteria, must be evaluated in terms of the purpose for which they are made. It is only then the regional differences, if they exist, can be evaluated and/or measured. The face of the earth with its complex associations of phenomena could theoretically yield an infinite variety of regional patterns, each delineated by the application of different criteria. Effective development of regions is founded on the selection of meaningful criteria. Actual regions may not exist in nature but may be more accurately described as a continuum. Therefore, an understanding of the types and characteristics of regions is paramount to the development of accurate regions for any stated purpose.

To understand the characteristics of regions it is helpful to be familiar with the processes that result in regional variation. James (1952) lists three general groups of processes at work on the face of the earth. These processes differ in the nature of the sequence of change, the methods of measuring and describing them, and in the temop or rate of change. Physical and chemical processes proceed in accordance with the well known formulated laws of physics and chemistry. Biological processes are described by less precise laws but are no less important. They also are modified by a much shorter time scale than the physical and chemical processes. Much more dynamic, unpredictable, and less controllable by natural law are the cultural processes. They are subdivided into economic, social, and political areas. Cultural processes are often strongly impacted by the natural processes. Areal differences on the earth are a reflection of the operation of all these processes as they are associated in specific places.

Whittlesey (1954) suggests three basic types of regions exist: 1) those defined in terms of single features; 2) those defined in terms of multiple features; and 3) those defined in terms which approach the totality of human occupance of area.

Single feature regions are described in terms of only one parameter. Generally, this is described or mapped by developing lines of equal value. If adequate data is available these regions are relatively simple to develop and can be used in tandem with other single feature regional maps to accurately describe broad areas.

Multiple feature regions are differentiated on the basis of combinations or associations of features. They may be constructed through matching single feature regions or they may be sufficiently distinctive and cohesive to be observed and mapped directly in the field. They fall into three subtypes:

(1) Associations of intimately connected features which are highly cohesive because they have been produced by one kind of process. Examples are climate, soil type or types of agricultural land use.

(2) Associations of features less intimately connected than those of the preceding because they have been produced by different kinds of processes. Political regions fall into this category.

(3) Associations of features only very loosely connected. Two primary forms of this type are various natural and cultural regions.

A third major type of region described by Whittlesey is differentiated in terms of the entire content of human occupance of an area. This region is envisioned as an association of both natural and social featues. It is virtually impossible to describe and evaluate all factors in this type of area because of its complexity coupled with differences in scale, sequences and effect by its descriptive criteria. Whittlesey proposed the term "compage" as a region including the sum total of all these relevant factors which affect the human occupance of an area.

Regardless of the criteria used to describe a set of regions they may all be grouped under two headings: uniform or nodal. Uniform regions are only uniform within the limits set by the descriptive criteria. To be uniform the criteria generally allow a certain range of variation. Nodal regions are homogeneous with respect to internal structure or organization. This structure includes a focus and a surrounding area tied to the focus by lines of circulation or variation from the characteristics at the focus. Hart (1981) describes this variation succinctly by stating, "Within-region variance is less than between-region variance." He further states that,

> Regionalization is a form of taxonomy, or classification, which is useful only to the extent that individual categories (such as classes, regions or sampling strata) are related to other important variables and thus have greater explanatory power than the entire universe of which they are a part.

Fenneman (1928) described the best region as the one that permits the largest possible number of general statements before detailed requirements and exceptions become necessary.

For any regional development scheme there are two general approaches to the development of regions. One technique is to identify an area, such as a land mass, and subdivide this area into appropriate regional units based on selected criteria. The other is to identify a small areal unit, defined by selected criteria, and synthesize it into appropriate size regions. In both cases it is preferable to select and arrange these units into hierarchial divisions to provide the format for division or synthesis of other units. The emphasis on and the importance of certain criteria vary widely with the technique used.

The divisional technique utilizes widely available data, such as climatic summaries, to make judgement on broad regional variations and similarities. The boundary lines between regions are broad and sometimes atypical of the focus of the area. The synthesis technique starts with a discrete area described by very rigid criteria. These criteria are then evaluated outward from the core area until the criteria no longer describe the area. The synthesis method requires a great deal of field data and normally a large amount of statistical analysis to formulate sharp regional boundaries.

A special discipline of geography exists which specializes in applying the scientific method to geography. This discipline, systematic geography, has developed numerous statistical techniques for synthesizing regions based on digitized data. The basic aim of systematic geography is to generate a deeper understanding of objects of study and systems of interest (Wilson, 1981). Three primary objectives generally exist in seeking to understand complicated areas: 1) establishing frameworks to handle complexity; this generally involves systematic descriptions of the area, determining its structure, and finding relevant processes; 2) identifying systemic behaviour; wherein synergistic and antagonistic impacts are evaluated; and 3) determining the applicability of findings to similar systems; therein producing an ability to forecast impacts and results.

Studies in systematic geography deal with particular features and sets of features, such as central places, crops, climate, landforms and the quality of life. Stoddert (1965) states,

> The value of systems analysis lies not only in its emphasis on organization, structure and functional dynamics, but by its general system properties, it brings geography back into the realm of the natural sciences, and allows us to participate in the scientific revolutions of this century from which the Kantian exceptionalist position excluded us. It links geography with the mainstream of modern scientific thought, in systems analysis and related disciplines, and opens up as yet unexpected possibilities in the application of geography to the whole field of information, theory and communication techniques.

Hart (1981) states,

> The regional side of geography is concerned with patterns, associations, and synthesis; the systematic side is concerned with analysis of the processes that help us understand and explain these patterns and associations; and they are two sides of the same coin, geography.

This description came from his presidential address to the Association of American Geographers and was the introduction to an appeal for the two basic disciplines of geography to unify for a common betterment. Since both utilize an assortment of tools in developing regions it should be possible to utilize the best of both in the development of regions.

Minshull (1967) expresses the need to make the following clear, at the beginning or end of a regional development study:

(1) The scope and degree of generalization.

(2) The criteria used to define each topic and each region.

(3) The reliability and sources of the information.

(4) The dates of the information and the study.

(5) The purpose of the study.

The geographical study of regions is appropriate for determination of aquatic ecoregions in Oklahoma. Functional tools of both regional and systematic geography will be needed in this development. It is perceived that general ecoregion boundaries may be established by the use of the more subjective regional methods. The final delineation of individual watersheds into separate ecoregions may be possible through the use of statistical analysis. However, the understanding that regions are a concept of the human mind is important in the development of any regional scheme.

CHAPTER IV

CLASSIFICATION OF NATURAL AREAS

Natural resource classification has received a great deal of attention in the last two decades. This is due to the growing interest in protecting the total environment of the world and the strong need to manage our nation's natural areas on a continental basis. Classification in its strictest sense means ordering or arranging objects into groups on the basis of their similarities or relationships. This chapter is intended to acquaint the reader with the efforts of classifying portions of the earth on the basis of natural features. Any classification that is more than an academic exercise has objectives that extend beyond the creation of the classification system itself. Three basic objectives are commonly expressed in classification studies (Witmer, 1978):

(1) To give names to objects and groups of objects.

(2) To transmit information about those objects.

(3) To allow generalizations to be made about the objects.

Frayer, et al. (1978) state that any classification system must be:

(1) Flexible, general, and of wide geographic applicability in order to predict many kinds of information over a range of environmental situations.

(2) Professionally credible, preferably through experimental validation.

(3) Formed on concepts and logic that are explainable to nontechnical people.

(4) Logical, consistent, and objectively quantifiable so as to function within an empirical, computer-operated information system.

(5) Designed and documented so that regular professional staff can, with nominal training, use the system to identify and map field sites.

No single classification can meet all these criteria, but any system should be objective and explainable. The purpose of any specific classification should be explicit. Only then can the generalizations made about the classes be understood and evaluated.

The science of classification is named taxonomy. Six guiding principles exist for the selection of taxonomic groupings. They are not limited to any specific subfield of taxonomy, but apply to all aspects of scientific thought. Bailey (1978b) states they are:

(1) Classification is a prerequisite of all conceptual thought, whatever the subject matter of that thought.

(2) The primary function of classification is to construct classes about which we can make inductive generalizations.

(3) The particular classes we construct always arise in connection with a particular purpose.

(4) The classification which we adopt for any set of objects depends on the particular field in which we wish to make

inductive generalizations. Different fields of generalizations call for different classifications.

(5) Clearly some classifications are of more general use than others. Those which serve a larger number of purposes are called natural, while those serving a more limited number are termed artificial.

(6) It is clear from the above there cannot be one ideal and absolute scheme of classification for any particular set of objects. Instead there must always be a number of classifications, differing in their bases according to the purpose for which they have been constructed.

Taxonomic classification of sites involves four steps:

(1) Sampling selected characteristics of sites.

(2) Analyzing the characteristics by a variety of techniques.

(3) Considering alternative groupings of sites and selecting a grouping appropriate for the stated purpose.

(4) Defining the classes as simply and precisely as possible for uniform application to objects not included in the sampling.

The taxonomic approach seeks to establish regions by grouping sites with similar properties. Under the regional approach, areas are subdivided into natural units on the basis of spatial patterns that affect resource use and natural processes. The appropriate system depends on the kind of information needed. Regionalization then becomes basically a mapping procedure which subdivides identifiable areas into units which can be described by a discrete group of criteria. The method generally used involves:

(1) Defining the criteria to be used.

(2) Applying these criteria to the landscape and drawing proposed boundary lines.

(3) Field checking the criteria and lines.

(4) Preparing class descriptions including summaries of the variations in basic characteristics.

Most classification studies are developed on a hierarchial system. The most widely used in the United States is that proposed by Nevin M. Fenneman (1928) as a result of the work of a committee of the Association of American Geographers. This system began by dividing the continent of North America into eight strongly characterized parts, all being represented in the United States and all but two of them in Canada. These are called major divisions. Units of the next smaller order are called provinces. Units of the third order are called sections. The term district was used to denote areas of undetermined boundaries which were of smaller size than sections. Atwood (1940) developed this further and Crowley (1967) added the term Domain as a group of divisions characterized by loosely related climates. In many ways these domains correspond to Koppen's (1931) larger climatic types. This scheme was also used by Bailey (1976 and 1981) to describe the terrestrial ecoregions of the United States.

Many disciplines have developed classification schemes of varying detail and scope. The Forest Service of the U.S. Department of Agriculture has been active in the development of classification schemes. In 1954 the Society of American Foresters developed a national classification system. Kuchler (1967) updated the classification according to principles described by Kuchler (1964), and Bailey (1976) improved his system to make it more meaningful and workable. A wetlands classification system has also been developed (Cowardin, 1978). Hydrologists and other disciplines have access to a classification system that uses remote sensor data on land use and cover for land resource planning (Anderson, et al., 1972, 1976). There is also a watershed ordering system for organizing water information (Water Resources Council, 1968). Soil scientists have a soil classification system developed by the Soil Conservation Service that can be easily utilized by land use planners. Land managers, soil scientists and hydrologists in the Forest Service utilize a land systems classification developed by Wertz and Arnold (1972) that efficiently coordinates their inputs for optimum results. It considers land-form, lithology, relief, climate, soils, and vegetation. A hierarchy for ecosystems is adapted from Bailey by Platts (1980) as a potential system to integrate land and aquatic classification. This is shown as Figure 3. The theory behind this approach for integrating a fishery classification with the Wertz and Arnold and Bailey classifications was that streams are controlled by the lands around them and the hydrology of their drainage basins. In other words, streams that drain similar lands that have been formed by similar processes will be similar. They will be relatively uniform in structure regardless of where they occur.

ECOCLASS (Corliss, et al., 1973) and ECOSYM (Davis and Henderson, 1976) attempted to develop a comprehensive framework for clasification and mapping of terrestrial and aquatic ecosystems through a component

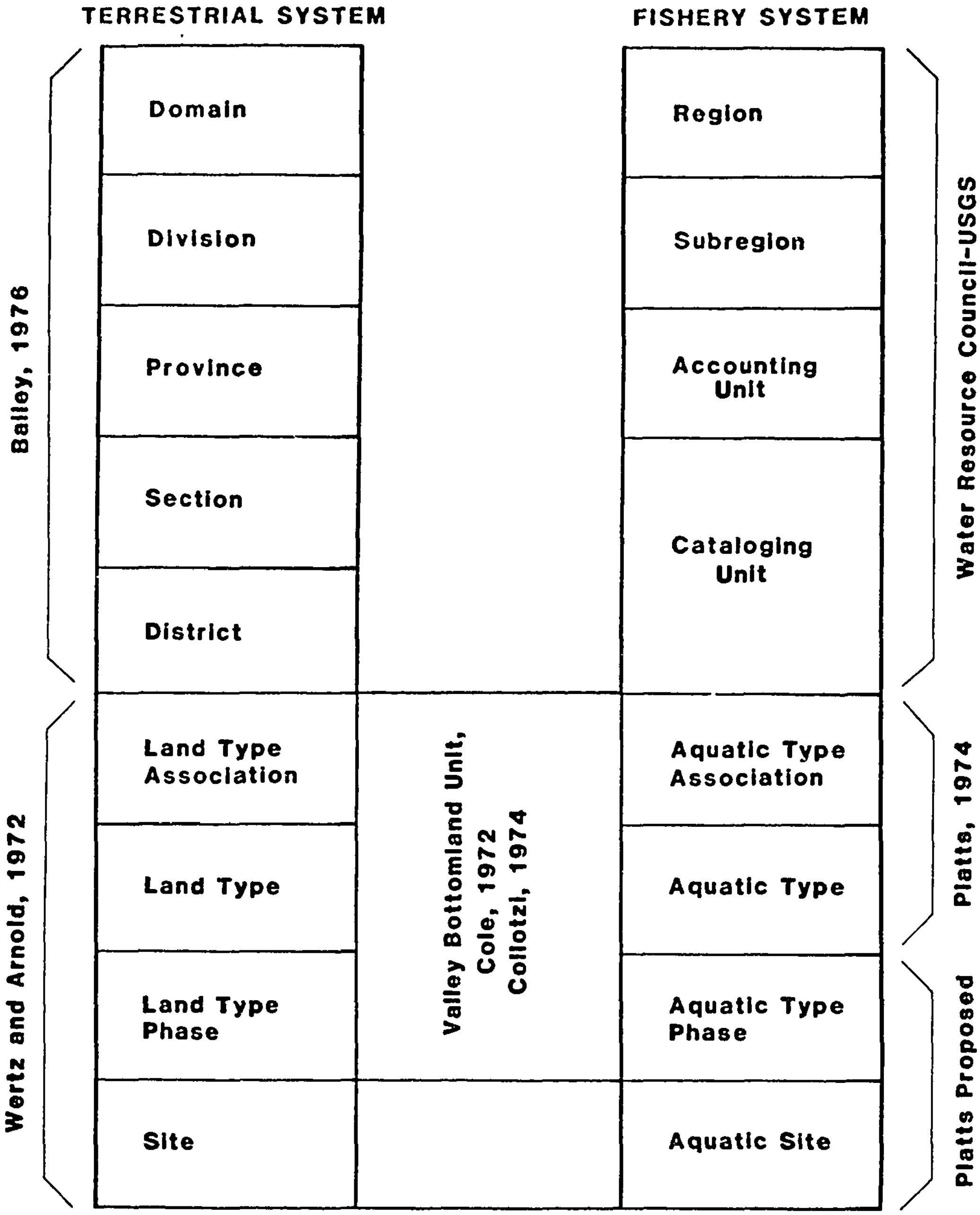


Figure 3. A proposed integration of the terrestrial and fishery ecosystems. (Platts, 1980)

classification, each at its own level of hierarchy. ECOCLASS was the prototype system and was expanded into ECOSYM. The components used in ECOSYM were soil, climate, geology, land-form, and vegetation. In this system the components are selected and integrated through a series of land overlays to classify the landscape or its resources. ECOSYM fails to allow for an interpretation of the structure, function, and process of the ecological system.

Biological classifications exists on continental, national and statewide scales. Dice (1943) characterized the biotic provinces of North America based on peculiarities in climate, physiography, soil, and biota. He considered biotic provinces as having imprecise boundaries and acting as centers for dispersal and differentiation. Kuchler (1964) developed a map of the United States in which the theoretic potential natural vegetation was designated based on historical and climatic conditions. Bailey (1976, 1978) utilized the work of both to develop a more refined map of hierarchial ecoregions. This map is the most complete and widely accepted by natural classification workers to date (Lotspeich and Platts, 1982; Hughes and Omernik, 1981). His classification is based to a large extent on macro-climate as expressed by potential vegetation. He states,

> Animals are dependent directly or indirectly upon plants for food and often for shelter and breeding places. Even where plants do not control the distribution of animals, they often indicate the characters of the climate and soil upon which animals are dependent. Accordingly, for the present, vegetation offers the most satisfactory basis for distinguishing the major ecologic communities of the country.

The primary emphasis in these studies is the terrestrial ecology.

Statewide classifications exist for Oklahoma based on much more detailed study than the national scale maps. Bruner (1931) provided a detailed description of the vegetation of Oklahoma which segmented the state into imprecise vegetational regions. He does not discuss how these regions were developed. Blair and Hubbell (1938) developed biotic districts for Oklahoma based on the distribution of mammals and orthropterans. This study was less precise and the districts were based largely upon the geographic description of Oklahoma presented by Snider (1917). Rice and Penfound (1959) described the forestlands of Oklahoma and Webb (1970) selected six faunal regions in his description of the reptiles of Oklahoma. No information is given on the basis of selection for these regions.

In summary, many regional classification schemes have been used to divide the earth's surface into general or specific natural areas about which man can begin to increase his understanding of the complexity of nature. Although many studies have included the State of Oklahoma, few have included detailed descriptions and those have largely dealt with vegetative features of the state. However, these descriptive studies may serve as an effective standard against which an aquatic regional scheme may be compared.

CHAPTER V

DEVELOPMENT OF LOTIC ECOREGIONS

Prior to the development of aquatic ecoregions for Oklahoma it is important to understand any previous stream classification efforts and to evaluate their use for Oklahoma. This chapter is a compilation of the philosophy, techniques, and results of the known efforts.

May systems have been presented for classifying aquatic environments within ecosystems. However, they generally pertain to special aquatic types or are too broad to be of use on specific streams. These systems vary as to the factors used to describe the various aquatic types. Physical, chemical, biological, climatological, areal and developmental properties have been used as criteria for classification. Until recent years, few of these systems received general acceptance for usage.

In a study of western European streams, Huet (1959) developed a classification system based on "slope-rule." He postulated that: 1) the slope or gradient of the stream bed is usually directly related to the fish fauna; and 2) in nearby rivers of comparable size, stretches with similar gradient have similar fish fauna. Therefore, his "slope-rule" states, "In given biogeographical area, rivers or stretches of rivers of like breadth, depth and slope have nearly identical biological characteristics and very similar fish populations." From this theory he developed four zones for fish fauna and postulated all western European streams would exhibit these zones. He named the: 1) trout zone; 2) grayling zone; 3) barbel zone; and 4) bream zone. Each zone would have a characteristic assemblage of fish species.

Kuehne (1962) studied the Buckhorn Creek watershed of eastern Kentucky and developed a classification system based on Horton's (1945) stream order system. Samples of the fish population supported the branching system showing a progressive increase in average numbers of species as stream order increased. Within stream order, species composition, gradients and food chains were comparable.

Pennak (1971) discarded the reliance on taxonomic biological criteria for classifying streams. He suggested more emphasis be placed on a group of physical and chemical parameters which can be universally and easily determined, with the knowledge that widely separated streams and rivers having very similar non-biological features will usually have parallel and ecologically similar fauna. He found it necessary to use thirteen parameters to classify streams (Table 2). This classification resulted in a very large number of groups and the author did not recommend a technique for reducing this number to a manageable size.

Platts (1974) examined the relationship between physical stream structure and fish populations in a mountainous region in Idaho. He based this study on a perceived watershed-stream association. He felt streams are controlled by the watershed they help build, and each one

Table 2. Criteria proposed by Pennak (1971) for classifying streams accoring to physical habitat.

1.	mean width (m) during 10 months	1	1-5	5-20	20-50	50-200	200
2.	flow	temporary	permanent				
3.	mean current (km/hr) during 10 lowest months	0.5	0.5-2.5	2.5-5.0	5-10	10	
4.	dominant substrate	rubble and boulders	gravel	sand	organic or inorganic silt	course organic debris	hardpan
5.	summer maximum temperautre, °C	30	20-30	10-20	5-10	5	
6.	winter minimum temperature	20	10-20	5-10	0-5		
7.	mean turbidity for 10 clearest months (ppm Fuller's earth)	exceptionally clear (10)	clear (10-50)	slightly turbid (50-100)	turbid (100-500)	highly turbid (500)	
8.	total dissolved inorganic content (mg. per liter)	very small (30)	small (30-100)	medium (100-300)	large (300)		
9.	total dissolved organic content (mg. per liter)	very small (30)	small (30-100)	medium (100-300)	large (300)		
10.	water hardness (ppm bound CO2)	soft (10-10)	medium (10-40)	hard (40-100)	very hard (100)		
11.	organic pollution (mean annual daytime dissolved oxygen, % saturation)	absent (95%)	slight (80-95%)	moderate (50-80%)	heavy (10-50%)	severe (10%)	
12.	maximum rooted aquatic cover	absent or negligible	restricted (10%)	moderate (10-50%)	dense (50%)		
13.	dominant streamside vegetation	absent or negligible	herbs and grasses	brush with some herbs and grasses	woodland; more or less forested, with ground cover		

reflects the geology, geomorphology, biology, climate, and hydrology of its drainage basin. The watershed exercises its control over the stream by dictating or influencing physical and chemical conditions, which in turn help determine the character of the aquatic environment. Watershed and stream variables can be described, measured and quantified (Table 3).

These variables allow identification and description of both the stream and its surroundings. He concluded aquatic environments can be described, classified, and worked into an ecosystem classification methodology based on the geologic formations in the Idaho batholith.

Warren (1979) believed that a watershed/stream classification must integrate climate, geology, biota, and culture, as opposed to considering them separately. He also stated the integration and classification should be hierarchial and be determined from the potentials of the land and water of interest, rather than from their existing condition. Streams within his proposed classification would have increasingly similar ecological potentials as one moved down through the hierarchy to ever smaller watersheds or ecological regions.

Lotspeich (1980) conducted a thorough philosophical discussion on watersheds as the basic ecosystem. He stated, "Any classification of streams should be included in a classification of watersheds as ecosystems because they are an integrated product of the watershed." He referred to Cooper (1969) for a description of this relationship by definition. This definition of a watershed is: "a specific segment of the earth's surface, set off from adjacent segments by more or less discrete boundaries, and occupied by a particular group of plants and

Table 3. Dimensions employed by Platts (1974) in his classification of streams of Idaho batholith.

1. Stream, pool, and riffle widths to the nearest foot.
2. Four stream depths at equal intervals across the stream to the nearest inch.
3. Ratings, locations, and features of pools.
4. Stream channel surface material classifications.
5. Cover, conditions, and types of streambanks.
6. Channel elevations and gradients.
7. Geologic process groups and geomorphic types.
8. Stream order.

animals." This is very close to the classical definition of ecosystem. He feels watersheds have physiographic boundaries that prevent most interaction with adjacent watersheds except for migrations of certain mobile biotic populations and occasionally transfers of groundwater along porous subsurface strata. Within such a basin, the ecosystem consists of streams, vegetation, soils, and associated biota, forming a mosaic of characteristics in response to local climates and physiography within the individual basin. These mosaics will tend to repeat in nearby basins of similar physical environment. Streams flow as a linear continuum and stream quality is the product of the watershed functioning as an ecosystem.

Watershed classification can be the result of many single or multiple sets of characteristics of the watershed. The selection of these factors will greatly impact the resulting classification. Lotspeich breaks the factors into three categories. "State" factors which are essential to and control all biological-physical interactions within a system. Geology and climate were chosen as "State" factors that form the basis for classifying watersheds. "Transactional" factors initially interact in such a way as to condition the development and productivity of the system. Soil and vegetation, as conditioned by the microclimate, were selected as "transactional" factors. The stream itself then becomes the "integrative" factor because it has a passive role in the day-to-day functioning of the system. Thus a system is described with a controlling force consisting of two elements (climate and geology), a reacting force (soil and vegetation) that responds by circular conditioning to controlling forces, and at the lowest level, the stream which responds to all factors of the living system within its watershed.

Lotspeich and Platts (1982) developed this system further by proposing an integrated land-aquatic classification system. Their basic objective was to develop a simple system based on causes of differences between land classes, the absence of a specialized nomenclature, and the integration of the riverine system with the terrestrial features as the basic ecological system. They believed that classification of an ecosystem should describe the processes that give form and productivity to that ecosystem, not by describing each element constituting the system. Therefore, they recommended the use of geology and climate to classify first order watersheds. As a result, their ecoregions tend to be quite large with broad demarcation zones.

Hughes and Omernik (1981) developed a synoptic approach on the basic premise that stream characteristics reflect watershed characteristics, that detectable spatial patterns in watershed attributes exist, and that streams in similar watersheds generally have similar physical and biological characteristics. Their objectives were to: 1) demonstrate a method to select similar watersheds based on attributes they believe to be responsible for certain stream characteristics; 2) demonstrate how those characteristics of stream channels conform to the regional patterns of the responsible watershed attributes; and 3) show how fish communities conform to the regional patterns in watershed attributes and characteristics of stream channels. They feel this information would be useful to management agencies in five ways: 1) it should aid in the determination of regional and ecologically meaningful management units rather than site-specific or political units; 2) it should improve the mechanism for classifying and evaluating the attainability of stream uses; 3) it should allow an ecological means to rank the priority of stream improvements; 4) it should be useful for determining regional criteria and standards for naturally-occurring pollutants; and 5) it should help select regional index streams in relatively homogeneous areas, against which environmental changes can be assessed.

Omernik, et al. (1981) suggests two variations of the approach that is based on potentials and capabilities of the environment relative to terrestrial, as well as aquatic ecosystems. The first defines the most typical area(s) of designated ecoregions. This is useful for comparing or determining between region differences or similarities. The other defines homogeneous areas significantly different from one another within an ecoregion which is useful in studying within region differences and similarities. Maps of land-surface forms, soil suborders, land use and potential natural vegetation are overlain and compared for regional similarities and differences. The addition of precipitation, temperature, and lithology are suggested if major differences in these factors are suspected. The process then proceeds stepwise as follows:

(1) An area is selected along with stream characteristics of interest. In many cases the area of interest will be a state, but wherever major landscape features or watersheds do not coincide with state borders, states may find it useful

and economical to work cooperatively and incorporate portions of neighboring states. Stream characteristics of interest may include fish and macroinvertebrate assemblages or various aspects of the chemical and physical environment affecting those assemblages.

(2) Select the watershed size of interest. These may be small intermittent streams, large rivers, lakes and reservoirs of various sizes, or all the above.

(3) Select watershed features most likely to control the stream characteristics of interest. Features to consider are climate (especially mean annual precipitation and summer and winter temperature extremes), land-surface form (types of plains, hills, or mountains), surficial geology (types of bedrock or alluvial deposits), soils (whether wet or dry, hot or cold, shallow or deep, or low or high in nutrients), potential natural vegetation (grassland, shrubland, or forestland, and dominant species), major river basins (especially important in unglaciated areas for limiting fish and mollusk distribution), and land use (especially cropland, grazing land, forest, or various mixes of these). National maps of most of these features are available from the U.S. Department of Interior-Geological Survey (1970), but often, larger scale state maps can be obtained from state agencies or university departments.

(4) Examine the maps of selected features for classes of those features that occur in regional patterns. When original maps

differ in scale or when finer resolution is required, a mechanical enlarger or slide projector can be used to produce equal-scale maps or to enlarge the map. Select those classes of features that best distinguish among ecological regions.

(5) Overlay the selected features mapped at the same scale and draw lines that separate ecological regions. The maps are examined in combination on a light table and lines separating the ecological regions are drawn on a sheet of transparent paper (e.g., albanene). Finally, the regional lines are transferred to a base map of the area of interest. Most of this work can be done using map scales of 1:500,000 to 1:7,500,000. The base map should now be circulated among knowledgeable professionals to evaluate the significance of the ecological regions as drawn.

(6) Map the areas in each ecological region where all the predominant classes of features in that region are present. These can be considered as most-typical areas because they contain all the classes of features that were used to determine that ecological region. For example, if the predominant classes of land use, potential natural vegetation and land-surface form in an ecological region are cropland, grassland, and plains, respectively, only the portion of that region where cropland, grassland, and plains all occur together would be most-typical.

In testing this technique in the midwest, Hughes and Omernik (1981) found few significant differences in stream ecosystems, but severely distrubed streams throughout the region of study. Additional testing of reference reaches is prescribed and is currently being conducted in Ohio and Arkansas (Giese, personal communication).

Several researchers have studied the impact of stream size on the resulting biota and/or chemical state (Cushing, et al., 1980; Moeller, et al., 1979; Odum, et al., 1960; Sheldon, 1968; and Vannote, et al, 1980). The general concensus is that watershed area, average depth and efficient use of energy is maximized in mid-order streams, i.e., greatest species diversity, most desirable chemistry, is in streams of uniform flow of moderate size. Hughes and Omernik (1983) recommend a new stream classification system based on watershed area and discharge characteristics. In a comparison of 71 streams with Bailey's ecoregions (1976) they found stream order designation according to Horton (1945) to be inconsistent within ecoregions. Strahler (1957) describes several dimensionless factors of watersheds that could be used for classification. In Oklahoma, Harrel, et al. (1967) found good correlation between species diversity and stream order. Pflieger (1975) designated fish population regions in Missouri based on fish collection data.

In summary, a great deal of variation exists in the techniques of aquatic classification. A general concensus for the best technique does not exist. However, the selection of appropriate factors to develop a classification seem to depend on the use to be made of the classification and the availability of data.

CHAPTER VI

SELECTION OF APPROPRIATE FACTORS

The previous chapters summarized the efforts of other researchers to classify natural systems. This chapter is intended to evaluate all these efforts as they apply to the task of developing a system for the development of aquatic ecoregions for Oklahoma.

Many factors influence the resulting ecology of a water body. The amount of influence a single factor exerts varies with its association with all other factors and the potential extremes within the factor which may have overriding impact. For example: vegetative cover will exert an influence on a stream which may vary with its association with climate, soils, and land form. This influence can range from minor to great depending on the impact of other factors. However, the total removal (extreme case) of vegetation would result in severe and overriding impacts on the streams even if the effects of other factors were acceptable.

The selection of an optimum set of factors is a critical step in an ecoregion development study. The selection of a single factor (physiography), as used by Fenneman (1916), would be the simplest but would have the least chance of predicting resulting stream quality. The factors used by Bailey (1976) have been accurate for terrestrial biota but the work of Omernik, et al. (1981) indicates other factors which tend to integrate several basic factors work well as a predictive tool. All factors should be considered as they relate to Oklahoma and a selection made.

Environmental factors of watersheds can be divided into two primary groups. The factors are:

Macroscale factors have an influence over all or a large part of a designated watershed.

(1) Climate

(2) Land form/topography

(3) Soil type

(4) Vegetation

(5) Land use

(6) Lithology

(7) Hydrology

Microscale microscale includes those factors which occur instream and either directly influence the stream ecology or are a result of the stream ecology.

Aquatic Organisms

Fish

Periphyton

Macroinvertebrates

Substrate

Man Induced Zones

Environmental/Water Quality Indices

Generally, data to evaluate the macroscale factors are readily available. Items such as climate, topography, soil type, land use, and lithology are available from public agencies and in most cases have been geographically depicted on a statewide basis. The microscale factors are less readily available in a geographic format. However, site specific information is available for some areas and could potentially be used to evaluate ecoregion boundaries developed using the macroscale factors. A general analysis of factor availability, accuracy and importance is shown in Table 4.

Macroscale factors can be further subdivided as to their association with a watershed. Lotspeich (1980) separates these into "state" factors (those essential to, and which control, all biological-physical interactions within a system) and "transactional" factors (those which interact in such a way as to condition the development and productivity of the system). Four elements, ecoclimate, soil, vegetation and streams are chosen as "secondary" factors which are controlled by, and respond to, macroclimate and geology.

He further states that "soil texture (the pattern, distribution and size of soil particles within a soil profile) is probably the single most important property to ecosystem functioning." Soil development is a function of five elements: climate; parent material; topography; time; and vegetation. Soil texture is primarily derived from the parent material through the soil forming process.

Vegetation makes watersheds and ecoregions productive units through their photosynthetic capabilities. Terrestrial vegetation has

Table 4. Analysis of environmental factors in ecoregion development.

ENVIRONMENTAL FACTOR	AVAILABLE	ACCURATE	IMPORTANCE TO LOCAL AQUATIC ENVIRONMENT
Macroclimate	Yes	Low	Low
Precipitation	Yes	High	High
Runoff	Yes	High	High
Evaporation	Yes	High	Low
Evapotranspiration	Yes	Moderate	High
Temperature	Yes	High	Moderate
Water Temperatures	Yes	Low	High
Groundwater Recharge Rate	Yes	Low	High
Geology (generalized)	Yes	Low	High
Local Geology	Partial		
Lithology	No	-	High
Minerals	Yes	Moderate	Low
Geomorphology	Yes	Moderate	High
Soils (statewide)	Yes	Low	High
Soils (countywide)	Yes	Moderate	High
Soils (local)	Yes	High	Low
Land Use	Yes	High*	High
Vegetation (natural)	Yes	Low	Moderate
Topography	Yes	Yes	High
Stream Substrate	No	No	High
Biological (stream)	Limited	High	High
Physical	Varies	Varies	Varies

*Land use data varies with time and its use assumes a point in time.

received the attention of plant ecologists and foresters who have devised many classifcation schemes and ecoregion designations. Most of the schemes (Krajina, 1965; Bailey, 1976; Daubenmire, 1956; Hills, 1976) recognize the impact of climate on the resultant vegetation.

Lotspeich concludes that climate and geology are the preferred factors for ecoregion development because they are the "causative factors for all development. However, Lotspeich (1980) and Lotspeich and Platts (1982) have not developed ecoregion maps for testing and analysis.

Hughes and Omernik (1981) have developed ecoregion maps and have conducted preliminary tests to determine their suitability. Their factor selection followed that of Bailey's (1976, 1978) in that factors of soil, climate, physiography and vegetation are as important to aquatic ecosystems as they are in the development of terrestrial ecosystems. This further enabled them to comply with the need for a hierarchial classification system and to utilize readily available maps of each factor to develop their aquatic ecoregions. The philosophy expressed for factor selection is that regionalizing land/water interrelationships should be based on factors that integrate the sum of all elements of the environment as opposed to the factors termed "drivers" which have an overall impact on the system. In this way a more detailed analysis can be achieved which can provide a key to more subtle differences than those identified using only climate and geology.

Other researchers (Trautman, 1981; Warren, 1979; Pflieger, 1981; Dice, 1943) have proposed the use of varying groups of factors for specified uses. The selection of factors for use in developing aquatic ecoregions for Oklahoma should draw on their recommendations, but also consider availability, accuracy and importance to the aquatic environment. Each factor recommended by previous researchers and their component parts will be considered in this selection process.

Climate has an overriding effect on all biological and physical processes. Climatic factors that establish the hydrologic features of a region are the amount and distribution of precipitation; the occurence of snow and ice; and the effects of wind, temperature, and humidity on evapotranspiration and snowmelt (Linsley, et al., 1958). A worldwide system of climatic regions has been developed by Koppen (1931) and used in other classification schemes (Dice, 1943; Bailey, 1976; Crowley, 1967; Kuchler, 1964). Koppen's classification is available but its scale is too large to separate small substate areas and its variability within classes very large.

Geology has a basic role in forming the earth as we know it (Hammond, 1963; Lobeck, 1939). Oklahoma has a very complex geological history with many localized areas of uplift and folding. Maps of the state are available which include a wide range of detail and accuracy. Geology imparts a character on the soil it produces and the resulting slope. Both of these factors have a major influence on the resulting stream types. Since the geology of Oklahoma expresses itself in soil type and slope these factors may be a more accurate measure of the total geological effect.

Information on soil type, which is a result of the interaction of geology, climate, biota and time, is available at almost any level of detail desired. There are over 4,000 types and associations in Oklahoma. Maps exist for the state, by counties and by farm ownership. The erodibility of the soils of the state have been analyzed by the USDA Soil Conservation Service.

Land use impacts the resulting streams in a variety of ways and at varying levels. In Oklahoma 95% of all land is placed in some form of agricultural endeavor (Oklahoma Conservation Commission, 1978). These uses have been mapped in a variety of detail and can be used for almost any level of study. The accuracy varies with the level of detail and is for a point in time. Landowners vary their usage annually, therefore, any land use information is a point estimate. There is no current provision to update this data on a statewide basis.

Potential natural vegetation maps have been developed by Kuchler (1964) for the United States. His maps were based on biotic studies which were compiled from historical summaries of areas of the United States. The Oklahoma portion of this map is quite detailed due to the availability of vegetative information. This map projects an estimate of the vegetation that would exist in the state in the absence of anthropogenic activities. The use of this information minimizes the acceptance of the detrimental activities of man on the land and in the streams. This provides a measure of potential and capacity for the area rather than acceptance of the current status of an area.

Topography information is available at any level of detail desired. The United States Geological Survey has produced quadrangle maps of the state showing topography at several levels. A basic part of soil classification is the slope of the land. This is quite detailed and would be a useful tool in quantifying the topography of a watershed.

Stream substrate was recommended by Warren (1979) as a useful tool in classifying streams. The availability of this information for Oklahoma streams is almost nonexistent and available only as observations rather than objective and quantified measurements. The substrate does have major impact on the resulting biota of the stream.

Biological data for streams have been collected in a variety of forms for many years. There has been no statewide attempt to collect an adequate amount of data to evaluate Oklahoma's streams. A monitoring program was conducted sporadically in the late 1970's. Mr. Jim Pigg (personal communication) has continued fish collections on many of these sites to date. Aquatic macroinvertebrate data is available for a few streams for only a short period of record. Adequate data probably exists to develop biotic indices only for the fish biota.

Physical factors of watersheds can be developed from information collected for other purposes. Several researchers have examined physical factors of watersheds which could serve to classify them. Strahler (1957) summarized a group of dimensions which could be used to describe watersheds. He listed two classes of descriptive terms as: 1) linear scale measurements, whereby geometrically analogous units of topography can be compared as to size; and 2) dimensionless numbers, usually angles or ratios of length measures, whereby the shapes of analogous units can be compared irrespective of scale. Linear scale measurements include length of stream channels of given order, drainage density, constant of channel maintenance, basin perimeter, and relief.

Dimensionless properties include stream order numbers, stream length and bifurcation ratios, junction angles, maximum valley-side slopes, mean slopes of watershed surfaces, channel gradients, relief ratios, and hypsometric analysis and integrals (relation of horizontal cross-sectional drainage basin area to elevation) (Langbein, et al., 1947). Horton's (1945) stream order system is well accepted. Hughes and Omernik (1983) studied 71 streams in the United States and concluded Horton's classification was not accurate on a national scale due to differences in map specifications. They suggest the use of mean annual discharge per unit area and watershed area to quantify stream and watershed size. Data for this analysis is normally available only for the larger streams in Oklahoma.

In reviewing the literature on the development of aquatic ecoregions it becomes clear that two specific groups of researchers have developed techniques which could be of value in developing aquatic ecoregions for Oklahoma. Lotspeich (1980), Platts (1974, 1980), and Lotspeich and Platts (1982) have developed a philosophical approach which has a great deal of credibility. They believe that classification of an ecosystem should describe the processes that give form and productivity to that ecosystem, not by describing each element constituting the system. With a differing viewpoint Hughes and Omernik (1981) utilized existing information in a synoptic fashion to develop ecoregions in several areas of the country. Their technique is still being tested but preliminary work in Oklahoma seems quite adequate for general usage.

Regional geography is science with strong leanings toward art. Regional development without basic knowledge and training is "doodling" (James, 1952). Since the author is not a trained geographer and since he has a background in engineering and the natural sciences there is a strong tendency toward quantification of natural systems. The team of Larsen, Omernik, Hughes and Shirazi, of EPA's Corvallis Research Laboratory, does include geographic training. In addition, they have developed a technique for assigning ecoregions which has been applied to Oklahoma along with several other states. These maps are developed in a stepwise process as described in a previous section.

This process results in ecoregion designation which is being tested in Arkansas and Ohio. In the future it will also be tested in Oklahoma. The test procedure calls for the selection of natural streams (unimpacted by man) and an intensive program of data collection which will be evaluated for extrapolation of characteristics to other streams in the region.

Based upon the evaluation in this chapter the author proposes to utilize eight characteristics (land use, soils, land-surface form, potential natural vegetation, watershed area, rainfall, runoff, and evapotranspiration) in a numerical fashion to develop ecoregions for Oklahoma. This will then be tested with an environmental variable for the same area to determine significant difference between the ecoregions assigned to Oklahoma. If significant differences exist a quantifiable method will have been developed for proper assignation of watersheds. This would also enable the drawing of ecoregion boundary lines at Conservation Needs Inventory (CNI) watershed boundaries (SCS, 1971, Figure 4) which would have utility in the water quality standards process. This map will become the base for the development of ecoregions in Oklahoma.

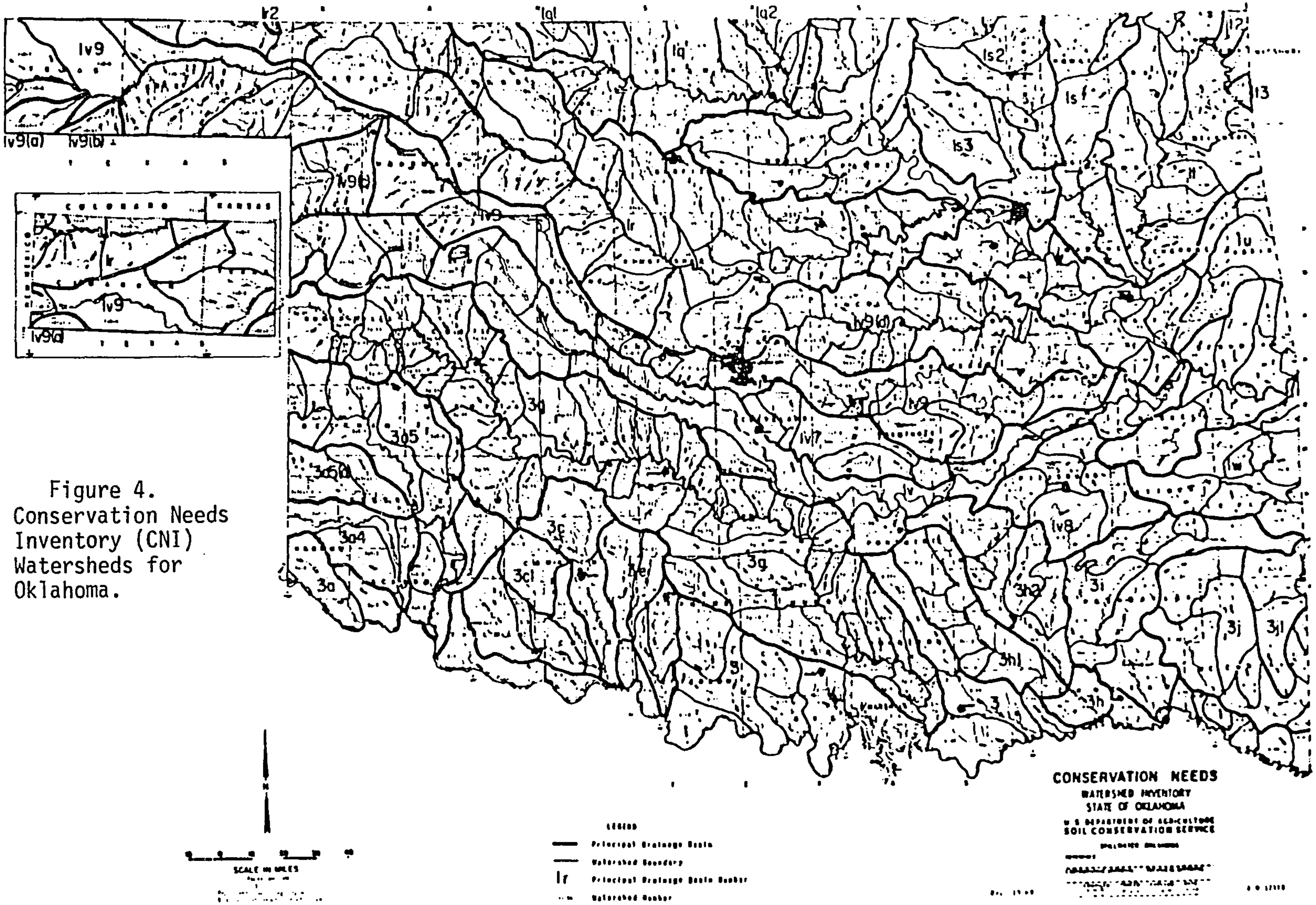


Figure 4.
Conservation Needs
Inventory (CNI)
Watersheds for
Oklahoma.

CHAPTER VII

SELECTION OF EVALUATION FACTORS

Of equal importance with selection of factors to develop ecoregions is the selection of appropriate data to evaluate the accuracy of ecoregion development. Several suitable parameters may exist or a combination of factors may be preferable. This chapter will evaluate the needs of this study and select the most appropriate. Areas to consider in this selection process are: 1) is it indicative of the relative "health" of the stream; 2) does it have a logical cause/effect relationship; 3) will it be accepted by water officials as accurate; 4) is it available on a statewide basis; and 5) in the range of values acceptable for Oklahoma waters.

Water Quality Indices

Water quality data is available from records of both the U.S. Geological Survey and the Oklahoma State Department of Health. Table 5 (OSDH, 1984) lists the parameters available for the majority of sampling stations in the state. The period of record varies greatly from station to station and must be considered in data selection. Another problem area is the selection of stations for use. Most stations are located in large watershed areas which would require a compilation of CNI watersheds above this point.

Table 5. Water quality parameters reported in Oklahoma's Trend Monitoring program.

Core and Regular Monthly Stations

Parameter	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Chloride	X	X	X	X	X	X	X	X	X	X	X	X
COD	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Oxygen	X	X	X	X	X	X	X	X	X	X	X	X
Fecal Coliform*	X	X	X	X	X	X	X	X	X	X	X	X
Fluoride	X	X	X	X	X	X	X	X	X	X	X	X
Kjeldahl Nitrogen	X	X	X	X	X	X	X	X	X	X	X	X
Nitrate/ Nitrite	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X
Spec. Cond.	X	X	X	X	X	X	X	X	X	X	X	X
Sulfates	X	X	X	X	X	X	X	X	X	X	X	X
Susp. Solids	X	X	X	X	X	X	X	X	X	X	X	X
Temperature	X	X	X	X	X	X	X	X	X	X	X	X
TOC	X	X	X	X	X	X	X	X	X	X	X	X
Total Nitrogen	X	X	X	X	X	X	X	X	X	X	X	X
Total Phosphorus	X	X	X	X	X	X	X	X	X	X	X	X
Calcium	X		X		X		X		X		X	
Iron	X		X		X		X		X		X	
Manganese	X		X		X		X		X		X	
Magnesium	X		X		X		X		X		X	
Potassium	X		X		X		X		X		X	
Sodium	X		X		X		X		X		X	
Arsenic					X						X	
Cadmium					X						X	
Chromium					X						X	
Copper					X						X	
Lead					X						X	
Mercury					X						X	
Nickel					X						X	
Selenium					X						X	
Silver					X						X	
Zinc					X						X	

* = Core sites only

Table 5. Cont.

Core and Rotating Toxics Stations

The following toxics analyses are performed once annually on all core and rotating toxic stations in fish tissue, sediment, and water:

Aldrin	Total Chlordane	Methoxychlor
Arsenic	(cis isomer)	Total DDT
Cadmium	(trans isomer)	o,p DDD
Chromium	Nonachlor	o,p DDE
Copper	(cis isomer)	o,p DDT
Dieldrin	(trans isomer)	p,p DDD
Lead	Endrin	p,p DDE
Mercury	Hexachlorobenzene	p,p DDT
PCBs	Hexachlorocyclohexane	
% lipid content	(alpha BHC isomer)	
	(gamma BHC isomer)	

It is unlikely that a single physical, chemical or biological parameter could be used to evaluate the ecoregions developed. Many water quality indices have been developed. Ott (1978) and Inhaber (1976) have conducted extensive reviews of the literature for physical and chemical indices. Lomnitz (1983) conducted a thorough review of biological indices as they relate to water quality management.

Ott (1978) lists 21 characteristics which an ideal water quality index should possess (Table 6). He did not expect any single index to meet all 21 criteria. Each criterion varies in terms of its relative importance and the significance that it should receive when indices are being evaluated. Dunnette (1976) evaluated 12 water quality indices according to the U.S. Council of Environmental Quality (CEQ) guidelines. The guidelines from the 1974 CEQ Annual Report (1974) are: 1) facilitate improved communication of environmental quality information to the public; 2) be readily derived from available monitoring data; 3) strike a balance between oversimplification and complex technical conceptualizations; 4) impart an understanding of the significance of the data they represent; and 5) be objectively designed but amenable to comparison with expert judgement in order that their validity can be assessed. Only two of the twelve indices met all criteria (Table 7). These are the National Science Foundation's Water Quality Index (NSFWQI) (Brown, et al., 1970) and the Harkins index (Harkins, 1974). Ott found, through a survey in 1977, the most commonly used index, by public water pollution control agencies, is the NSFWQI, followed by the Harkins' index. He also stated that Oklahoma had used the Harkins' index in the development of its 305(b) report.

Table 6. Desirable characteristics of an ideal water quality index (Ott, 1978).

1. be developed from a logical scientific rationale or procedure
2. strike a reasonable balance between oversimplification and technical complexity
3. be sensitive to small changes in water quality
4. avoid eclipsing
5. avoid ambiguity
6. avoid nonlinearity in the aggregation process
7. be dimensionless
8. employ a clearly defined range
9. impart an understanding of the significance of the data
10. be relatively easy to apply
11. easily accommodate new variables
12. permit probabilistic interpretations to be made
13. include variables that are widely and routinely measured
14. include toxic substances
15. include variables that have clear effects on aquatic life, recreational use, or both
16. be tested in a number of geographical areas
17. show reasonable agreement with expert opinion
18. show reasonable agreement with biological measures of water quality
19. be compatible with water quality standards
20. include guidance on how to handle missing values
21. clearly document the limitations

Table 7. Evaluation by Dunnette of 12 water quality indices according to CEQ criteria.

Proposed Indices	Criterion 1	2	3	4	5
Region X	X	X	O	X	O
Truett	X	X	X	O	O
NSF WQI	X	X	X	X	X
Nemerow	X	O	X	X	O
Harkins	X	X	X	X	X
Dee	X	O	O	X	O
McDuffie	X	X	O	O	O
Inhaber	X	O	O	X	O
Dinius	X	X	X	X	O
Prati	X	O	X	X	O
Walski	X	O	O	O	O
Horton	X	O	O	O	O

Key to criteria: X = met; O = not met. The criteria, from the 1974 CEQ Annual Report, are as follows: (1) facilitate improved communication of environmental quality information to he public; (2) be readily derived from available monitoring data; (3) strike a balance between oversimplication and complex technical conceptualizations; (4) impart an understanding of he significance of he data they represent; and (5) be objectively designed but amenable to comparison with expert judgement in order that their validity can be assessed.

Harkins' index is a statistical approach for analyzing water quality data which is based on the rank order of observations. Harkins' index can be developed using any number of parameters. The scale of the index is from 0 to 100 with higher numbers indicating poorer quality. The limitation in Harkins' method is that different streams cannot be compared unless the data set is the same. This is difficult to achieve on a statewide basis.

Biological Indices

Lomnitz (1983) separated biological evaluations into: 1) habitat suitability indices; 2) diversity indices and measures of community structure; 3) recovery indices; 4) intolerant species analyses; and 5) omnivore-carnivore comparisons.

Habitat suitability indices have been developed by the U.S. Fish and Wildlife Service (1982) to provide a detailed analysis of the quantity and quality of habitat in a specified stream. The analysis is thorough but very data dependent. A great deal of field work is necessary to develop an index.

Diversity indices and measures of community structure have been in use since 1912. Lomnitz lists 15 separate diversity indices and 12 measures of community comparison. He also introduces three special indices which incorporate the concept of diversity. He summarized this analysis by stating, "The ability of a water resource to sustain a balanced biotic community is one of the best indicators of its potential for beneficial use." He feels no single measure will adequately assess biological health, but quantification requires a mix of assessment methods, and the index of diversity is an integral part of that mix.

A recovery index developed by Cairns (1975) was developed as a measure of the ability of an ecosystem to recover from displacement due to pollutional stress in order to evaluate the potential uses of a water body. This index is not suitable for use in a natural stream classification system. Intolerant species analysis is also a measure of pollutional impacts and is not suitable for a natural classification system (Cairns, 1974).

Omnivore-carnivore analysis examines the trophic structure of a waterbody. The biological operations of an ecosystem can be viewed as a series of compartments which are described by three general categories: producers; consumers; and decomposers. The consumers are generally divided into herbivores and carnivores. However, a class exists between these two groups which feed equally on plants and animals. Water quality and habitat affect the availability of food types, resulting in changes in the structure and function of the aquatic community.

Community structure indices are commonly computed as a biological tool to evaluate the status of a natural system. They may be used in both aquatic and terrestrial communities. Generally, the reasons for selecting this analysis is either one or a combination of: 1) investigating a community structure or function; 2) establishing a relationship with other community properties such as productivity and stability; 3) establishing its relationship to environmental conditions; 4) comparing between biotic communities; 5) evaluating the biotic health of the community; 6) assessing the effects of pollutant discharges; and 7) monitoring water quality by biological rather than physical-chemical means.

Community structure studies can be conducted with any group of the biotic realm. However, strong differences in sampling technique limit the comparability between groups of the community found in a particular location. Generally, aquatic studies are conducted with algae, periphyton, macroinvertebrates or fish. The algal and periphyton techniques require very specialized studies with detailed analysis to yield useful data. Most fresh water aquatic studies are conducted with either fish or macroinvertebrates. Several advantages and disadvantages have been shown for each of these groups as shown in Table 8 (Cairns and Dickson, 1971; Karr, 1981).

A survey of the reasons for conducting community structure studies show that reasons (2), (4) and (7) directly address the needs of this study. Since it has been established that streams are a product of the environmental factors in their watersheds it is expected that water quality will reflect differences in the factors between sets of watersheds. The establishment of water quality characteristics in a single watershed requires a great deal of study and many observations due to the inherent variability of the many water quality parameters, both spatially and temporally.

Aquatic organisms tend to act as individual water quality monitors. Since they are present in the stream at all times, the nature of their community will reflect the extremes of the characteristics imparted to the streams by their watersheds. Accurate determination of this

Table 8. Advantages and disadvantages of using macroinvertebrates and fish in evaluation of the biotic integrity of freshwater aquatic communities (Cairns and Dickson, 1971; Karr, 1981).

Advantages	Disadvantages
MACROINVERTEBRATES	
°Fish that are highly valued by humans are dependent on bottom fauna as a food source. °Many species are extremely sensitive to pollution and respond quickly to it. °Bottom fauna usually have a complex life cycle of a year or more, and if at any time during their life cycle environmental conditions are outside their tolerance limits, they die. °Many have an attached or sessile mode of life and are not subject to rapid migrations, therefore, they serve as natural monitors of water quality.	°They require specialized taxonomic expertise for identification, which is also time-consuming. °Background life-history information is lacking for many species and groups. °Results are difficult to translate into values meaningful to the general public.
FISH	
°Life history information is extensive for most species. °Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and utilize foods of both aquatic and terrestial origin. Their position a the top of the aquatic food web also helps provide an integrated view of the watershed environment. °Fish are relatively easy to identify. Most samples can be sorted and identified in the field, and then released. °The general public can relate to statements about conditions of the fish community. °Both acute toxicity (missing taxa) and stress effects (depressed growth and reproductive success) can be evaluated. Careful examination of recruitment and growth dynamics among years can help pinpoint periods of unusual stress.	°Sampling fish communities is selective in nature. °Fish are highly mobile. This can cause sampling difficulties and also creates situations of preference and avoidance. Fish also undergo movements on diel and seasonal time scales. °There is a high requirement for manpower and equipment for field sampling.

community structure will enable an accurate evaluation of the general nature of the stream.

An evaluation of Table 8 in regards to the availability of information for Oklahoma and analysis by Hughes, et al. (1981) strongly favors the selection of the fish community to compare streams. The state has been largely surveyed by Mr. Jim Pigg (personal communication) in a uniform manner over a period of years. The disadvantages of intensive manpower and equipment requirements and selectivity in sampling have been eliminated since a single researcher has completed this survey with comparable techniques and level of effort. Therefore, the use of analysis for the fish communities in the streams of Oklahoma is strongly favored as a measure of expected biota.

Many indices have been developed which are suitable for use with fish species. Lomnitz (1983) lists 15 diversity indices and 12 community comparison indices. With the growth in computer technology aquatic researchers have expanded their use of diversities by calculating many indices for a data set. This has resulted in the expanded use of special indices which are a function of multiple characteristics of the communities (Beck, 1955; Gammon, 1976; Karr, 1981; Hughes, et al., 1981). Karr developed an index of biological integrity of fish communities for use in classifying water resources. A trophic state analysis is conducted with relatively simple data collection programs. The presence or absence of carnivores and insectivorous fish species indicate high quality waters whereas, large numbers of omnivores indicate the aquatic system does not favor high quality fish species. This well thought out index uses 12 criteria

(Table 9), objectively developed, which are assigned subjective numerical designations. The sum of his evaluation is an arbitrary class of biotic integrity. The index has been applied to the streams in Illinois with good success and may be useful in evaluating ecoregions for Oklahoma.

Of more recent development is a similar system, developed by Pigg (personal communication) for use in Oklahoma. This system uses 16 criteria for a community which are developed objectively and values are assigned subjectively to create an index of the nature of the streams fish community (Table 10). This index may be used to compare sites on a single stream, compare temporal changes on a single stream or compare between streams. The index relies on a comparable data set with a uniform level of effort and sampling techniques. Its use should be a good basis of comparability of streams throughout Oklahoma.

Based on the considerations shown on page 71, the most appropriate evaluation factor for this study is the use of fish population information coupled with the many indices available to compare fish communities. Fish populations are indicative of the relative "health" of a stream; exhibit cause/effect relationships with stream quality; are generally acceptable as accurate by water officials; to a lesser extent available statewide; and exhibit applicability in Oklahoma waters.

Table 9. Parameters used in assessment of fish communities (Karr, 1981).

Species Composition and Richness	
	Number of species
	Presence of Intolerant Species
	Species Richness and Composition of Darters
	Species Richness and Composition of Suckers
	Species Richness and Composition of Sunfish (except Green Sunfish)
	Proportion of Green Sunfish
	Proportion of Hybrid Individuals
Ecological Factors	
	Number of Individuals in Sample
	Proportion of Omnivores (Individuals)
	Proportion of Insectivorous Cyprinids
	Proportion of Top Carnivores
	Proportion with Disease, Tumors, Fin Damage, and Other Anomalies

TABLE 10. STREAM FISHERIES COMMUNITY RATING FORM (Pigg, Pers. Comm.)

STREAM____________ REACH LOCATION____________ SCORE/RATING________ CLASSIFICATION____________

COUNTY____________ LEGAL DESCRIPTION SEC____TS____RANGE____EVALUATOR__________

	RATING ITEM	CATEGORY									
		Excellent		Good		Fair		Poor		Very poor	
1.	Number of Species per Sample (Attempted)	> 20/sample	0	15-20/sample	3	10-14/sample	6	5-9/sample	9	< 5/sample	12
2.	Accumulated Species per Sampling Period	> 40/site	0	30-40/site	6	20-29/site	12	10-19/site	18	< 10/site	24
3.	Species Diversity based on Number of Fish *(Wilhm, 1976)	> 2.75	4	2.25-2.75	8	1.75-2.24	12	1.25-1.74	16	< 1.25	20
4.	Species Diversity based on Biomass of Fish *(Wilhm, 1976)	> 3.00	6	2.25-3.00	9	1.50-2.24	12	0.75-1.49	15	< 0.75	18
5.	Proportion Biomass/ Number of Fish	> 1.0	8	0.75-1.0	10	0.50-0.74	12	0.25-0.49	14	< 0.25	16
6.	Number of Darter Species	≥ 4 species	0	3 species	2	2 species	4	1 species	6	0 species	8
7.	Number of Sunfish Species	≥ 4 species	2	3 species	4	2 species	6	1 species	8	0 species	10
8.	Number of Sucker Species	≥ 4 species	0	3 species	2	2 species	4	1 species	6	0 species	8

Table 10. Continued.

	RATING ITEM	CATEGORY									
		Excellent		Good		Fair		Poor		Very poor	
9.	Intolerant Species	≥ 4 species	0	3 species	4	2 species	8	1 species	12	0 species	16
10.	Percentage of Green Sunfish/ to Other Sunfish	< 10%	4	10-29%	8	30-49%	12	50-80%	16	> 80%	20
11.	Proportion of Fish to Species in Sample	< 50	6	50-249	9	250-449	12	450-650	15	> 650	18
12.	Proportion of Omnivorous (individual) Cyprinids	< 10%	4	10-24%	8	25-49%	12	50-75%	16	> 75%	20
13.	Proportion of Insectivorous (individual) Cyprinids	> 75%	0	50-75%	3	25-49%	6	10-24%	9	< 10%	12
14.	Number of Top Carnivores	> 10	0	8-10	3	5-7	6	3-4	9	< 3	12
15.	Number of Species making up 75% of population	≥ 5	4	4 species	8	3 species	12	2 species	16	1 specie	20
16.	Percentage of Rough Fish	< 5%	8	5-9%	10	10-14%	12	15-20%	14	> 20%	16

* Wilhm, 1976 $d = (ni/n)\log_2(ni/n)$

Column Total =

Add Column Scores E_____ + G_____ + F_____ + P_____ + VP_____ = Reach Score___________

46-71=Excellent; 74-122=Good; 123-173=Fair; 174-201=Poor; 202-290=Very Poor

CHAPTER VIII

STREAMS AS A CONTINUUM

Because of the factors selected to develop aquatic ecoregions for Oklahoma it is imparative to recognize the special nature of the major streams in the state as they relate to the characteristics of their basins. This chapter evaluates the general nature of stream systems as they apply to stream classification.

Streams and rivers change along their length in respect to the many factors which form the character of the stream (Beckinsale, 1971). This continual change has an overriding impact on the resulting biota in the stream. Hynes (1970) reviewed the voluminous amount of literature on attempts to classify streams by longitudinal zonation. He states these attempts are only useful as long as they do not become articles of faith which tend to stifle further inquiry. It must be realized that designated zones are not discrete and their sequential arrangement is often masked by impacts of the local geography.

That biota tend to associate into general groupings is an accepted principle. Huet (1959) classified streams in western Europe by biotic groupings. This study concluded the zonation was mostly the result of stream gradient which affected both stream temperature and velocity. This concept was termed "slope-rule" and oversimplified the complexity of natural systems. Cushing, et al. (1980) evaluated 15 physical-chemical characteristics in 34 streams in North America and Europe. They found positive correlation with watershed area, phosphate concentration, total dissolved solids, solar radiation, temperature fluctuation, nitrate concentration and summer base flow. They concluded a classification system must include biological data to be useful.

Kuehne (1962) found successional changes in the fish population in Buckhorn Creek, Kentucky. When analyzed by Horton's stream order classification he was able to group the fish communities according to the size of stream in which they were found. The small headwater streams (order one) were found to have a low species diversity and a similar fish population throughout the large watershed. Species diversity increased in higher order streams with the maximum diversity in order 3. Again the fish communities were similar in all streams of like order. Harrel, et al. (1967) found a very similar situation in an intermittent stream in Oklahoma. The fish species diversity exhibited a high correlation to stream order although the diversity was lower than the eastern Kentucky stream as reported by Kuehne.

Total community diversity is greatest in medium-sized (third to fifth order) streams where temperature variations tend to be maximized (Vannote, et al., 1980). Habitat structure becomes reduced in most large streams along with increased autotrophic production. As stream size increases, the reduced importance of terrestrial organic input coincides with enhanced significance of autochthonous primary production and organic transport from upstream. The ability to predict resulting stream quality through watershed characteristics is greatly hampered by this set of circumstances.

Therefore, this study will not be adequate to classify those streams in Oklahoma which are characterized by significant autochthonous production. Since the characteristics of watersheds are used as the sole basis of classification it is important to apply the results of the study to those streams which reflect the terrestrial organic input and the riparian character of the stream. It is recommended individual studies be conducted on these streams to more accurately characterize and classify their nature. The designation given to watersheds which comprise the mainstem of a deleted stream will apply only to those streams originating in the designated watershed.

CHAPTER IX

METHODS

The accuracy of any research is directly related to the accuracy of the data used in the study. This chapter describes the methods of data collection and handling to inform the reader of the scope and scale of the data set.

The perception of aquatic ecoregions necessitates a fundamental principle that:

$$E = f\,[X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots\ldots + X_n]$$

Where E is the overall quality of the aquatic system and X is a factor in the watershed which has some impact on the stream. A discussion of potential influencing factors were given in Chapter VI. The factors chosen for use in this study are:

1. Rainfall
2. Runoff
3. Watershed Area
4. Soil Type
5. Land Use
6. Potential Natural Vegetation
7. Evapotranspiration
8. Slope

Data were collected from varying sources as discussed below. Priority was given to the acquisition of data readily available in a format consistent with CNI watershed separation. In some cases it was necessary to utilize some type of numeric weight to transform the data into a digital form consistent with aquatic impact. When this was necessary the weight chosen was from standard practices and conformed to those found in the literature. A summary of data acquisition and preparation follows.

Rainfall

The average annual rainfall for each individual watershed was not available from the National Weather Service. The method selected was deemed the most accurate for a data set on a statewide basis. Rainfall records for 164 stations were collected for the period from 1960 to 1982. These data were entered into the OWRB computer and transformed into a graphic display by the SYMAP program (Dudnik, 1971). This enabled the development of a state map portraying isolines of one inch increments of average annual rainfall (Figure 5). An overlay was prepared of the state depicting individual CNI watersheds. Because the SYMAP program produces individual data points it was then possible to summarize the average annual rainfall for a watershed by averaging the level of data points within that watershed. An example for CNI watershed lv9-25 follows:

Inches/Year of Rainfall Between:	Data points in CNI watershed:		Average Rainfall:		
34 and 35	2	X	34.5	=	69
35 and 36	64	X	35.5	=	2,272
36 and 37	21	X	36.5	=	766.5
Total	87				3,107.5

3,107.5 ÷ 87 = 35.7 inches/year

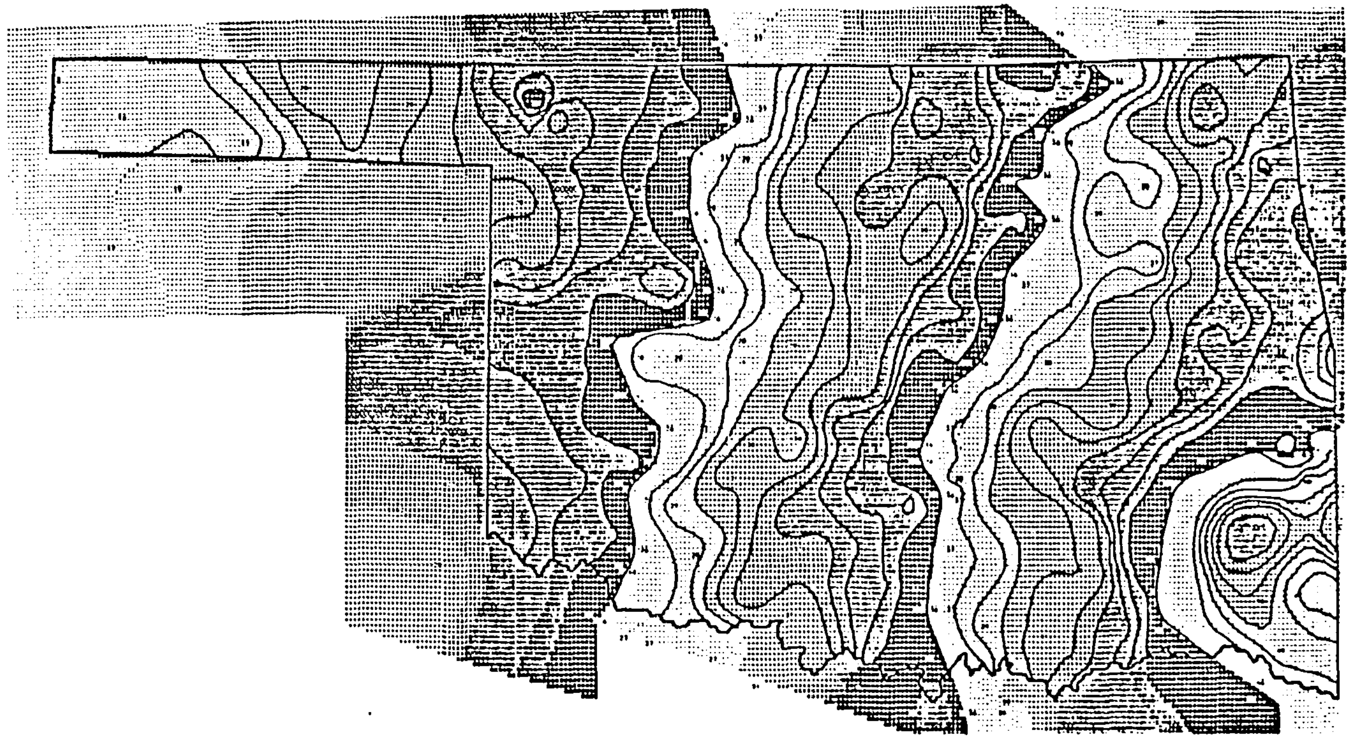


Figure 5. SYMAP of average annual precipitation for Oklahoma, 1960 - 1982.

Average annual rainfall was not multiplied by any factor since, in general, the greater the rainfall, the more stable the aquatic system.

Runoff

The amount of rainfall which is not evaporated, transpired, removed from the system, or stored is runoff. Runoff is measured as stream flow and generally a complete and accurate record exists for major streams in Oklahoma. However, runoff from small streams and individual watersheds must be interpolated from the nearest stream flow monitoring site. Stream flow records from 35 stations for the period from 1960 to 1982 were collected and entered into the OWRB computer. A SYMAP program was applied as in the above and average annual runoff calculated in the same manner (Figure 6). However, due to the reduced number of adequate stations the map produced exhibited abberations from the expected pattern. As data becomes available for additional stream flow stations the data base should be updated to improve its accuracy.

No weight factors were used for this watershed factor since the greater the average annual runoff the more desirable the aquatic habitat.

Evapotranspiration

It is difficult to measure the amount of water transpired by plants and evaporated from soil. Other workers (Pettyjohn, et al., 1983) have subtracted the average annual stream flow from the average annual rainfall on the assumption the difference is evapotranspiration. Therefore, the difference in rainfall and runoff were calculated for each CNI watershed from factors (1) and (2) above.

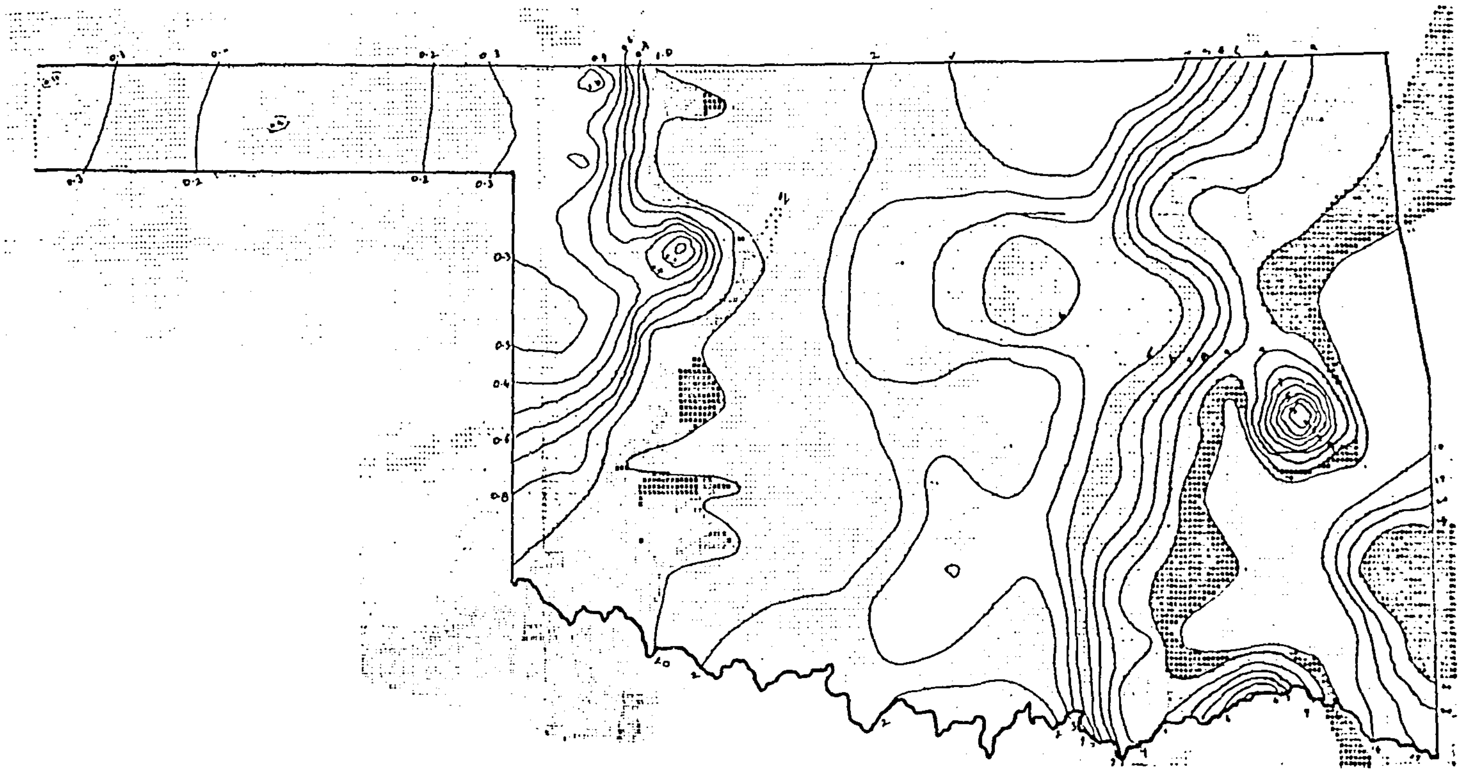


Figure 6. SYMAP of average annual runoff for Oklahoma, 1960 - 1982.

Watershed Area

This factor was determined from the USDA publication, "WRC Hydrologic Unit Boundaries Correlated with Oklahoma CNI Watersheds and Other Sub-State Resource Unit Delineations" (USDA, 1971). It is used for comparative purposes between watersheds since, in general, the greater the total area the greater the amount of water available in the stream system. No weight factor was used for this variable.

Soil Type

Soil is the long-term product of geological and climatological factors and exerts a great impact on the natural vegetation, the land use and the resulting stream quality.

Broad differences exist for soil types in Oklahoma. In the eastern part of the state soils are developed in humid conditions, often under a vegetative canopy, with considerable leaching. This produces soils depauperate in nutrients (particularly phosphorus and potassium) and moderately to strongly acid in nature. These are generally classified as podzolic or lithosolic. In western Oklahoma the soils are generally formed under grassland canopy, with comparatively little rainfall, and often transported by wind action. They are often reddish in color and higher in nutrients due to the low rainfalls. Detailed soil surveys are not yet complete for the state. Approximately one-half of the counties have delineated soil types on a CNI watershed basis. Efforts to use county by county soil surveys to determine proportions of soil type by watershed proved to be beyond the scope of this study and fraught with technical difficulties. This is primarily due to the temporal variations in survey preparation and soil classification terminology in different counties. Efforts to join these county soil maps into CNI watershed maps failed primarily because of changes in terminology between soil reports from different counties, the large variation in the year completedand the inability to match many soil types at county lines.

Soil associations have been prepared for the state (OWRB, 1980) from data prepared at Oklahoma State University. Soil associations occur naturally in a defined proportional pattern on a unique type of landscape. The associations are comprised of several series whose characteristics, such as climate, parent material, and vegetation, are similar. Figure 7 depicts the thirty-nine soil associations used in this study and their locations in the state. The legend describes the general properties of each group of associations.

To determine the proportion of each soil association in a CNI watershed required a mapping technique. Watershed maps of major stream basins were prepared at 1:75,000 scale. The statewide soil association map was projected on the basin maps and their boundaries drawn. A LASICO digital planimeter was used to determine the proportional area of each soil association in each watershed. These proportions were converted to percentages for each watershed area.

Since soil associations have no numeric value, a decision was made to select a quantifiable characteristic of each soil type as a measure of impact on resulting stream quality. The USDA, Soil Conservation Service, Stillwater, has prepared an unpublished work book entitled, "Estimating Soil Loss Resulting from Water and Wind Erosion." This

High Plains and Breaks — **Reddish Chestnuts Lithosols and Regosols***

Dark-colored loams and clay loams with moderately clayey subsoils on loess, unconsolidated loams, silts, and caliche. Developed under mid and short grasses.

- PM — Potter Mansker
- Richfield Dalhart Portales
- PK — Pullman Richfield

Loamy sands with heavier subsoils and with loose deep sand. Developed under tall grasses and sand sage.

- Vona Dalhart Tivoli

Brown loamy soils on sandstone escarpments, basaltic mesas and associated footslopes (breaks) developed under mid and short grasses.

- TBS — Travessilla Berthoud Rough stony land

Central Reddish Prairies — **Southern Brunizems and Regosols***

Dark soils with clayey subsoils developed under tall grass mostly in clayey Red Beds.

- RZV — Renfrow Zaneis Vernon
- BTK — Bethany Tabler Kirkland

Loamy soils with loamy subsoils developed under tall grass in loamy Red Beds or alluvium.

- Grant Pond Creek Nash
- CQ — Cobb Quinlan
- Vanoss Minco Yahola

Grand Prairies — **Southern Brunizems Lithosols and Grumusols***

Dark loams and clayey soils with clay subsoils developed in marine clay and limestones under tall grasses.

- DST — Durant San Saba Tarrant
- T — Tarrant
- Tarrant Newtonia

Eastern (Cherokee) Prairies — **Brunizems Planosols, Lithosols***

Dark-colored soils mostly with clayey subsoils developed on shales, sandstones, and limestones under tall grasses.

- LSS — Labette-Summit-Sogn
- SS — Sogn-Summit
- PDB — Parsons-Dennis-Bates

Western (Rolling Red) Plains — **Reddish Chestnuts and Regosols***

Dark or reddish soils with clay subsoils developed in clayey Red Beds under mid and short grasses.

- TV — Tillman Vernon
- FHT — Foard Hollister Tillman
- RBV — Rough broken land Vernon

Reddish or dark soils with loam subsoils developed in loamy Red Beds.

- RBQ — Rough broken land Quinlan
- WCQ — Woodward Carey Quinlan
- CS — Carey St. Paul
- WDQ — Woodward Dill Quinlan

Brown and light brown loams and sands with clay loam to sandy subsoils or unconsolidated sands and loamy deposits developed under grasses, scrub oaks, shinnery oak and sage.

- PT — Pratt Tivoli
- NBM — Nobscot Brownfield Miles
- Enterprise Tipton Yahola

Cross Timbers — **Red-Yellow Podzolics Lithosols***

Light colored sandy soils with reddish subsoils on various sandy materials developed under oak hickory forests with prairie openings (Savannah).

- DS — Darnell Stephenville
- WC — Windthorst Chigley
- DTY — Dougherty Teller Yahola

Ozark Highlands — **Red-Yellow Podzolics***

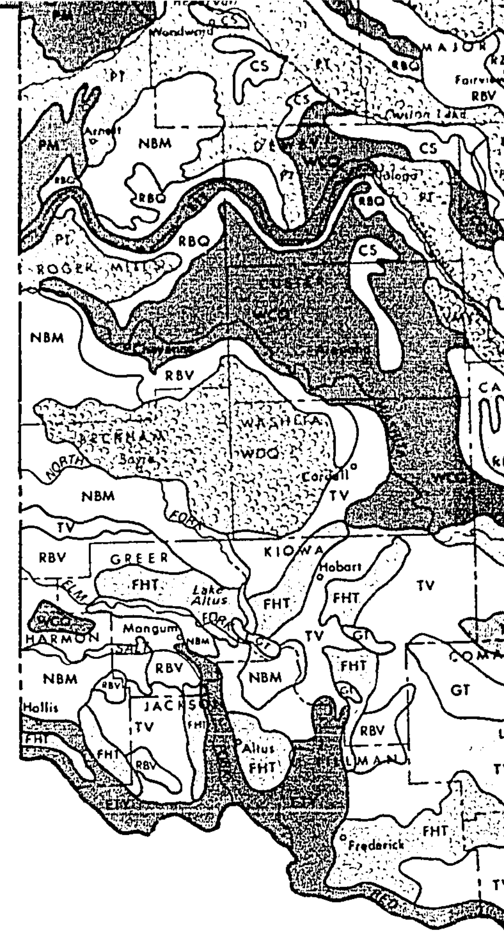
Brown and light brown silty soils with reddish clay loam subsoils on cherty limestone developed under oak-hickory-pine forests and tall grasses.

- Bodine-Baxter

Bottomlands — **Alluvial Soils***

Nearly level, deep sandy to clayey bottomland soils. Some areas flood frequently, most flood occasionally, and some rarely. Soils are developed under lowland hardwoods which decrease in density from east to west.

- MYT — Miller-Yahola-Teller
- APY — Atkins-Pope
- VO — Verdigris-Osage
- YPR — Yahola-Port-Reinach



Forested Coastal Plain — **Red-Yellow Podzolics***

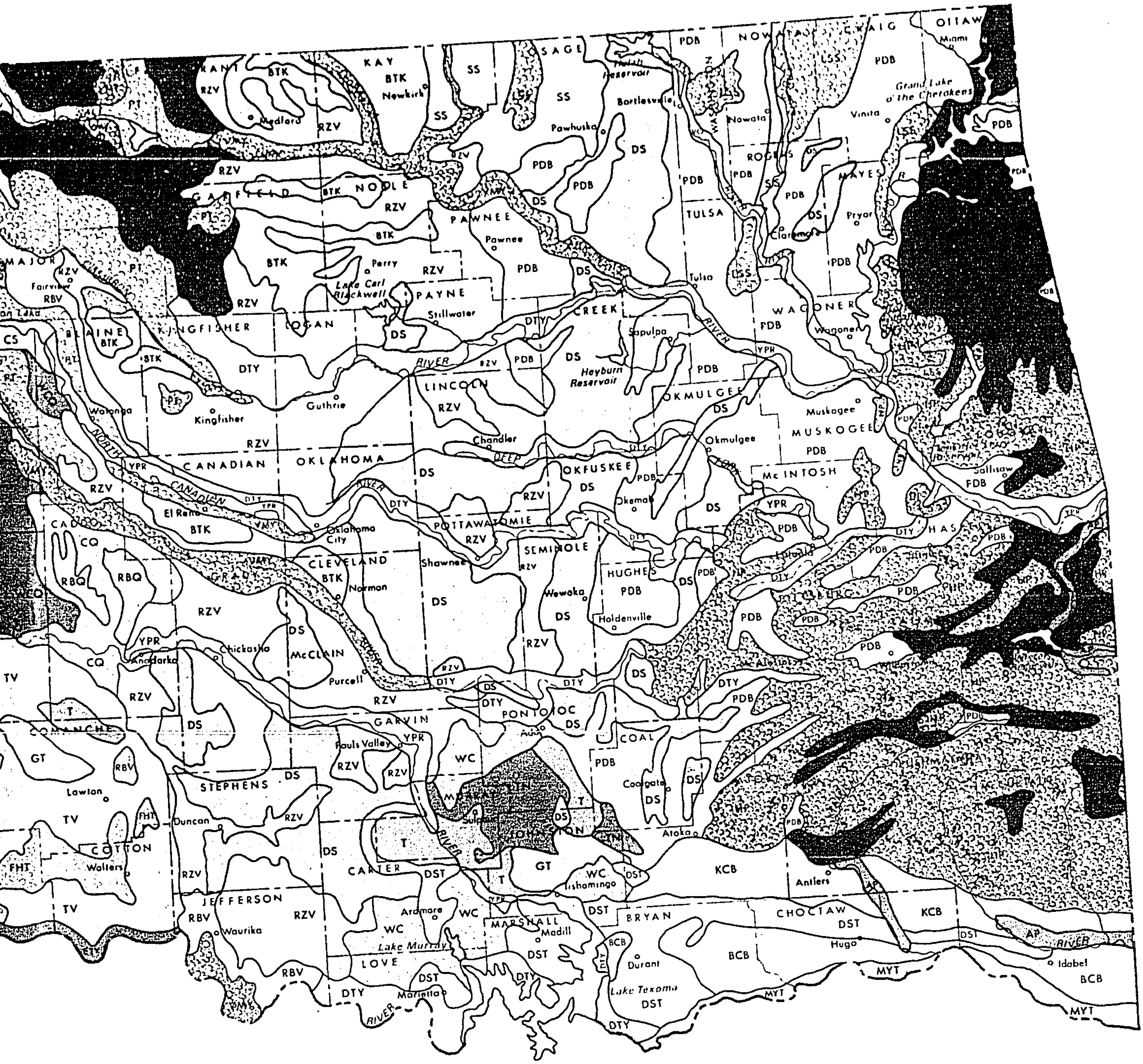
Light-colored acid sandy soils with sandy clay loams to clay subsoils developed in Coastal Plain sediments under forest (pine-oak in eastern part, oak-hickory in western).

- KCB — Kirvin-Cuthbert-Bowie
- BCB — Bowie-Caddo-Boswell

Granitic Soils — **Lithosols***

Granitic Mountain area and brown, thin stony granitic soils developed under mid grasses, cedars and shrubs.

- GT — Granitic Mountains-Tishomingo soils



Podzolics*

clay loams to
diments under
in western

sols*

stony granitic
nd shrubs

ingo soils

Ouachita Highlands — **Red-Yellow Podzolics and Lithosols***

Light-colored acid sandy to loamy soils with heavier subsoils and shallow soils developed on sandstones and shales under oak-hickory-pine forests

- HP — Hector-Pottsville
- Enders-Conway-Hector

*Dominant Great Soil Group(s) of the area

FIGURE 7
SOIL ASSOCIATIONS

Data—Oklahoma State University
Mapping—Oklahoma Water Resources Board

work book includes state specific techniques to aid in estimating soil loss by the universal soil loss equation. One factor in this calculation is the soil-erodibility factor (K). It is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9 percent slope 72.6 feet long.

Soil properties that influence erodibility are those which affect the infiltration rate, permeability and total water capacity, and those that resist the dispersion, splashing, abrasion, and transporting forces of rainfall and runoff. Individual K factors are designated for each named soil type in the state. The factors range from 0.17 (low erodibility) to 0.49 (high erodibility).

To determine an overall soil factor in a CNI watershed involved the following steps:

(1) Determine the average "K" factor of the soil association. This was done by calculating the mean of all soil types and profiles in the soil association.

(2) Determine the percentage of a specific soil association in a specific CNI watershed.

(3) Multiply the percent of the soil association by the inverse of the appropriate average "K" factor.

(4) Sum the resulting scores for all soil associations in the watershed. The result is the watershed's soil factor.

The inverse of the soil associations "K" factor was necessary in step 3 to assure that low erosibility which is expected to produce good stream quality would result in a greater numerical value than the higher "K" factors for more erosible soils.

Land Use

Factors such as climate, soil and availability of water greatly influence the use of land by man. But man's use of the land may often have a profound influence on the stream environment which eminates from the area. Man's use of land in Oklahoma is predominantly agricultural (OWRB, 1980), however, large units of urban, forest and reservoirs exist which have effects which vary greatly. The Oklahoma Conservation Commission report number 540 lists land use by C.N.I. watershed for the entire state for 1976. This was the most recent data available on a statewide basis. This data was collected and summarized by CNI watershed into five categories as follows:

(1) Total watershed area;

(2) Total crop area;

(3) Total forest area;

(4) Total pasture area; and

(5) Total range area.

Information on the land area used for urban development, military installations, parks, reservoirs, etc. were not included. Since each of these miscellaneous categories have quite different influence on a stream system they were handled in the data set according to the following. Major parks and refuges were treated as forest area and added to that category. Reservoir area was deleted from the data set entirely and the remaining categories computed as an "other" category. Those uses in this category generally have a strong negative influence on stream quality. To determine the area of "other" the sum of categories (2) through (5) was subtracted from (1). In some cases this produced erroneous areal estimates. The estimates for each watershed were examined to determine if the calculation did not represent the expected range, or if unduly large or small areal estimates could be explained for the particular watershed. Twenty-one of 380 watersheds required corrections. These included transposed numbers, incorrect total area and land use estimates based on a portion of the watershed leaving the majority of the watershed in the "other" category.

The impact of various land uses on stream quality vary greatly. Studies in localized areas have shown a general trend for large negative impacts by cropland usage (Burton and Turner, 1975; Morrison, 1981; Harms, et al., 1974; EPA, 1973; Wanielista, 1977). Lesser negative impacts are found from livestock, and urban usage. The least negative impact is by forest lands. The "4th Annual Report of the Council on Environmental Quality" listed the following quantitative factors for the land use categories in this study:

	L	$\frac{1}{L}$
Crop	0.08	12.5
Pasture and Range	0.01	100.0
Forest	0.005	200.0
Urban	0.01	100.0

The inverse of these values were used to produce a CNI watershed land use factor by multiplying the percent of each land use by the appropriate impact factor and summing the values for the watershed.

Potential Natural Vegetation

Vegetation results from the sum of natural processes which exists in a geographic area. It is influenced by the geology, topography, soil, climate and natural selection. Man greatly influences vegetation by manipulation for man's benefit. Since vegetation is the result of natural biological processes it continually strives to return to its "climax" state. If anthropogenic activities were removed from a geographic area the natural vegetation would return to climax given adequate time. Potential natural vegetation is a measure of the direction of this natural tendency.

A. W. Kuchler (1964) developed a detailed map of this tendency for the coterminous United States. The Oklahoma portion of the map is quite detailed due to the availability of information from Bruner (1931), Duck and Fletcher (1943), Kelting and Penfound (1953) and Rice and Penfound (1959). Kuchler designated fourteen vegetative types for Oklahoma (Table 11).

The Oklahoma portion of the map was projected on a 30 by 54 inch map of CNI watersheds. Each boundary was traced on the map and the proper vegetative designation shown. A LASICO digital planimeter was used to determine the areal proportions of each vegetative type in each watershed. The percentage of each vegetative type was then calculated. Determining the impact of each vegetative type on stream quality was not as straight forward as other data sets.

The "C" factor of the Universal Soil Loss Equation is a plant cover factor which is the ratio of soil loss from an area with specific plant cover to that from the fallow condition. It measures the combined effect of all the interrelated cover, management variables plus the growth stage and vegetative cover at the time of the rain.

Table 11. Vegetative types employed by Kuchler(1964) which occur in Oklahoma.

Veg.	Title	Kuchler's Designation	C	$\frac{1}{\text{"C"}}$
A	GBG	Grama-Buffalo Grass	0.042	23.81
B	SBP	Sandsage-Bluestem Prairie	0.038	26.32
C	JPW	Juniper-Pinyon Woodland	0.033	30.30
D	MBG	Mequite-Buffalo Grass	0.031	31.77
E	BGP	Bluestem-Grama Prairie	0.064	15.63
F	SHN	Shinnery	0.035	28.57
G	CTM	Cross Timbers	0.031	32.26
H	BSP	Bluestem Prairie	0.06	16.67
I	NFF	Northern Floodplain Forest	0.001	1000
J	BLP	Blackland Prairie	0.06	16.67
K	MOS	Mosaic of Bluestem Prairie and Oak Hickory Forest	0.02	50
L	OHF	Oak-Hickory Forest	0.001	1000
M	OHP	Oak-Hickory-Pine Forest	0.001	1000
N	SFF	Southern Floodplain Forest	0.001	1000

The "C" factor is developed by considering aspects of; canopy, mulch, subsurface vegetation, and ground cover. Woodlands are calculated separately from rangelands and are ignored when the proportion of tree canopy is less than twenty percent.

Bruner (1931) and Woodin and Lindsey (1954) were used to determine relative percentages of tree canopy and forest litter. Bruner includes a detailed description of many vegetative areas of the state. The estimated percent of ground cover and canopy for grassland regions came from a variety of sources (Rice and Penfound, 1959; Kelting, 1954; Ray, 1959; Johnson and Risser, 1975; Smith, 1940; Carpenter, 1940; Rice, 1952; Rice and Penfound, 1954; and Crockett, personal communication).

This produces a single "C" factor for each vegetative type. The inverse of this factor was used as the impact factor for multiplication by the percent of each vegetative type in a watershed. The products were summed for a watershed vegetative factor.

Slope

Several techniques exist for the expression of slope. Strahler (1957) lists many techniques which may be used. Schumm, 1956, evaluated the use of relief ratio (an index of the average ground slope within a basin) as a rapid and useful expression of slope. He found it to be an accurate tool to compare between-basin similarities if comparable techniques were used. Abrahams (1980) found that relief ratio correlated highly with source-area slope in exterior basins (1st and 2nd order streams). Source-area slope is determined by dividing the difference in altitude between the highest and lowest points in the source area by the straight line distance (measured in the same units) from the channel head to the farthest point on the perimeter of the source area. This is a simple and rapid technique which can be utilized to develop a comparative slope index to compare CNI watersheds. The overall accuracy of this slope estimation technique is not adequate for individual watershed evaluation. It was deemed acceptable for this study because of the large scale (statewide) and the need for a "comparative" slope factor as opposed to actual slope dimensions.

To determine source-area slope required the use of cartographic techniques. The OWRB drafting section utilized USGS quadrangle maps of 15 minute angle to develop a statewide map in which CNI watersheds were overlain and corrected where necessary. Then the highest and lowest points in the basin were determined in mean feet above sea level. In some watersheds aberrent physical features existed which were deleted to prevent an inaccurate slope factor from being developed. The difference in elevation was divided by the longest distance in the watershed to the channel mouth. The resulting slope factor was calculated for all CNI watersheds in Oklahoma.

Slope has multiple impacts on resulting stream quality. The more gentle the slope the less erosion will occur and the less natural dissolved oxygen will be available. Although erosion rates increase with slope the level of dissolved oxygen increases and the riffle habitat increases. In general terms the greater the slope the more desirable the overall stream quality. Accordingly, the slope factor was used in this study without modifications.

This compilation of data produced a matrix of environmental factors on each CNI watershed in the state. The level of accuracy varies with each factor. This will be discussed in a later section. However, the level of accuracy chosen was optimized in light of the statewide scale of this study. Future studies would do well to improve the accuracy of the data base for most factors.

CHAPTER X

SUMMARY STATISTICS

The data collection phase of the project produced a large matrix with ratio-level measurements (Appendix A). The first step in the data analysis was the preparation of descriptive statistics to enhance the researcher's understanding of the scope and scale of the data set. Table 12 lists summary statistics for the environmental variables in the study. This chapter is composed of a description of the statistics computed followed by a narrative description of each variable in the data set:

(1) Mean - the measure of central tendency in the data set. It is the sum of each record divided by the number of records.

(2) Median - is the value of the record lying exactly in the middle when all records are ordered from highest to lowest.

(3) Standard Deviation - is a measure of dispersion about the mean in the same units as individual records.

(4) Minimum - is the lowest value for a recorded in the data set.

(5) Maximum - is the highst value for a record in the data set.

(6) Skewness - is a measure of deviation from the symmetry of a normal distribution. The value is zero when the distribution is a symmetric bell-shaped curve. A positive value indicates

Table 12. Summary statistics for environmental variables.

VARIABLE	MEAN	MEDIAN	STD	MIN.	MAX.	SKEWNESS	KURTOSIS
1. Rainfall (inches/year)	33.9	33.8	8.4	15.5	51.5	0.02	0.80
2. Slope factor (dimensionless)	.0451	.0331	.0462	.0080	.4282	5.15	32.93
3. Runoff (inches/year)	3.1	2.5	2.7	.01	9.98	1.08	0.15
4. Watershed area (square miles)	171.4	137.4	132.1	0.2	716.0	0.92	0.42
5. Soil factor [% soil type X (1/K)]	333.7	331.9	60.0	18.5	588.2	0.93	4.79
6. Land use factor [%use X (L)]	9325.2	9076.3	3842.9	920	19,950	0.37	-0.22
7. Vegetation factor [% veg X (1/C)]	3850.7	3226.0	2902.0	1000	10,001	1.18	0.06
8. Evapo-transpiration (inches/year)	28.9	30.0	4.8	15.15	40.0	-0.6	-0.03

clustering to the left of the mean with most of the extreme values to the right. A negative value indicates clustering to the right.

(7) Kurtosis - is a measure of the relative peakedness or flatness of the curve defined by the data set. A normal distribution will have a value of zero. A positive value indicates the curve is more peaked than a normal distribution, while a negative value indicates the curve is flatter.

The following is a variable by variable analysis of the summary statistics:

(1) Rainfall - The average rainfall in a watershed in Oklahoma is 33.9 inches/year and ranges from 15.5 to 51.5 inches/year. The standard deviation is 8.4 inches/year. The distribution of values is centered well but the curve is slightly flatter than normal. Rainfall extreme exists in the far west (low) and the southeast (high).

(2) Runoff - This factor is very small compared to the average annual rainfall. The mean is 3.1 inches/year with a standard deviation of 2.7. The range is from 0.01 to 9.98 inches/year. The curve is skewed somewhat to the left with a near normal peak. This is due to a greater number of CNI watersheds in western Oklahoma with attendent low runoff.

(3) Evapotranspiration - This factor, a function of rainfall and runoff, averaged 28.9 inches/year. It ranged from 15.15 to 40.0 inches/year and the standard deviation was 4.8 inches/year. The distribution curve was near normal.

(4) Watershed Area - The average CNI watershed is 171.4 square miles with a standard deviation of 132.1 square miles. Watersheds used in the study range from 0.2 to 716.0 square miles. The distribution is skewed somewhat to the left (smaller) but the peak is only slightly elevated.

(5) Soil Factor - The soil factors (% soil type x 1/K) have a mean of 333.7 and a standard deviation of only 60.0. The range of values is from 18.5 to 588.2. The distribution curve is skewed to the left and very peaked. This is due to a large number of watersheds having similar values. The small standard deviation supports this analysis.

(6) Land Use Factor - The land use factors (% of land use x 1/L) ranged from 920 to 19,950 with a mean of 9,325 and a standard deviation of 3,843. The curve of value is very close to normal distribution.

(7) Vegetation Factor - This factor (% vegetation type x 1/C) resulted in values ranging from 1,000 to 10,001 with a mean of 3,851 and a standard deviation of 2,902. The curve is somewhat skewed to the left but near normal height.

(8) Slope Factor - The average slope factor (source-area slope) is 0.0451 for Oklahoma. Values range from 0.008 to 0.4282 and the standard deviation is larger than the mean. Skewness and kurtosis indicate the curve is far left (low value) of the mean and extremely peaked. This is due to watersheds of large land area predominately of relatively gentle terrain with few very steep areas of mountains.

The summary statistics indicate a good range of values was collected in most cases. Care is needed in the use of statistical analyses which have stringent requirements for a normal data set. However, the data set was judged adequate for many statistical techniques.

CHAPTER XI

PATTERN ANALYSIS

The matrix produced by the data collection procedure was quite large and consisted primarily of continuous measurements of the variables. This large size encouraged the use of sophisticated multivariate techniques in describing the tendencies of the data set. This improves the objectivity of the evaluation and assures consistency throughout the study. An analysis is presented of similar studies followed by a description of the techniques used and the resulting ecoregion designations. A large array of powerful software packages are available for data analysis. Aside from the SYMAP package discussed previously the software of the Statistical Analysis System (SAS Institute) of Cary, North Carolina (SAS, 1982) was used. To determine the patterns that existed in the data set required some of these advanced statistical techniques.

Approaches to pattern analysis in the natural sciences include:

(1) placing the entities of interest into discrete groups (classification), or

(2) ordering them along some environmental gradient (ordination).

If community variation is discontinuous, classification is a natural framework for conceptualizing communities; if communities variation is continuous, ordination is more natural. According to "Multivariate Analysis in Community Ecology," (Gaugh, 1982) the current thinking is the complementary use of ordination and classification which recognizes the utility of classification for many practical purposes even when rather arbitrary dissections must be imposed on continuous community variation.

Environmental interpretation is usually provisional to some degree. Often the verification of the interpretation by experimental tests may not be possible. Three approaches serve to increase confidence in these interpretations: 1) the plausibility of the interpretation may be considered in terms of the known values for a subset; 2) several random subsets of the data can be ordinated to see if basic patterns remain stable; 3) new samples not included in the original ordination may be used to see if community composition can be predicted.

In general the usefulness of classification increases with data set size. The reason for this is that most multivariate procedures give equal emphasis to all data in the matrix. The basic purposes of multivariate analyses are: 1) summarizing large complex data sets; 2) aiding the interpretation of and hypothesis generation about community variation; and 3) refining models of community structure.

Sneath and Sokal (1973), and Mello and Buzas (1978) concluded that good reasons exist for the application of classification techniques to a large data set first and then investigation of the general pattern of the community through ordination. They base this on the reasoning that classification should be based on the full data set and ordination tends to reduce the data set to only its strongest factors. Data structures that are strongly clustered in nature are rare and community variation is relatively continuous. Therefore, any classification scheme is to some extent imposed. The process of classification and the choice of techniques tend to be more complex and subjective than ordination techniques.

Faced with a large array of techniques available and with the relative ease of access through SAS the author selected several techniques for application.

Virtually all multivariate techniques require a standardized data base unless the units of measure for all variables are essentially similar. The SAS Proc Standard procedure was used to create a data set for each variable with a mean of zero and a standard deviation of one. This allows each variable to have equal weight in the analysis.

The next step in data preparation is the development of a correlation matrix. This is the basic tool of many multivariate techniques. The SAS procedure Proc Corr was used to develop Pearson product-moment correlations. This correlation matrix was examined to determine if data sets were highly correlated. Of the sixty-four correlations in the data matrix eight exhibited r^2 values above 0.5 (Table 13). None of these were negative correlations (inverse relationship) and they ranged from 0.85 for precipitation and runoff to 0.52 for evapotranspiration and land use factor. Precipitation and the land use factor each had four high correlation values. Vegetation factor and runoff each had three and evapotranspiration had two values of r^2 above 0.5.

The central purpose of a Cluster Analysis (CA) is to provide a method to classify variables into groups of observations which have some greater relationship with members of the group in which they are classified than with members of another group. The class in which an observation is assigned may be an arbitrary group or a natural group. The cluster analyses utilized in this study summarize very large data sets. The usefulness of the classification increases with data set size. The computer then becomes a tool to increase the objectivity of the classification. Even so, the properties of community classification partly reflect community structure and partly reflect the thoughts and opinions of the researcher.

The process of classification, in CA, is essentially the summarization for each sample of information on each variable into a single number. For this process equal emphasis is given to all variables in the data set. This produces objectively general classes and can produce variations in the perspective given to the analysis. A summary of the great variety of CA techniques is given by Blashfield and Aldenderfer (1978). An increasing amount of interest in these techniques has occurred during the past twenty years. This is primarily due to the availability of large computers to process the great amount of data involved. Additional interest has been as a result of many workers becoming familiar with its use and the pragmatic nature of this otherwise complex multivariate technique.

Sneath and Sokal (1973) lists eight aspects of clustering methods. Each individual field within this group has many devotees. The selection of techniques used in this study were made of the basis of

Table 13. Pearson Product-Moment Correlation Values exceeding 0.5 for Environmental Factors in CNI watersheds.

R2	Ordinate Factor	Abcissa Factor
0.85684	Precipitation	Runoff
0.83990	Precipitation	Evapotranspiration
0.80701	Runoff	Vegetation Factor
0.71973	Precipitation	Land Use Factor
0.70191	Precipitation	Vegetation Factor
0.70084	Runoff	Land Use Factor
0.60066	Vegetation Factor	Land Use Factor
0.51591	Evapotranspiration	Land Use Factor

availability through SAS rather than a detailed study based on desirable traits of a single method. The SAS program (SAS, 1982) is oriented toward hierarchical clusters from a multivariate data matrix. Proc Cluster produces hierarchical clustering of observations by the user's choice of the centroid method (Fowler, 1967), Ward's method (Ward, 1963) or average linkage on squared Euclidean distances (Sokal and Michener, 1958). ProcFastclus is for use on large data sets and produces disjoint (discreet) clusters which are not part of another cluster. ProcVarclus is more complex in that it uses component analysis to produce the clusters from the data matrix.

The data matrix produced from the data collection process previously described was submitted for analysis by ProcFastclus since the number of observations (CNI watersheds) exceeded 100. This procedure requires the selection of an arbitrary number of clusters to be produced. Subsequent analysis indicates the eight clusters chosen to be too large for this particular data set. A general trend corresponding to the authors knowledge of the state was produced. From this inspection it was determined a more thorough hierarchical analysis would produce sufficient information to select a proper number of clusters. The three techniques available in the ProcCluster procedure were applied to the data set (Centroid, Ward's, Average Linkage). These correspond to three of the four major groups listed by Blashfield and Aldenderfer (1978). The ProcTree procedure was used to produce dendograms of the clusters. To determine the geographic extent of the clusters required the transfer of the results to an 11-inch x 14-inch map of Oklahoma depicting CNI watersheds. A color was selected for each branch of the tree and the corresponding CNI watersheds colored appropriately. It was found the most revealing technique of transfer was to start at the root of the tree and prepare a map with only two clusters. When completed, a new map was prepared by moving one step up the tree and showing three clusters. This continued sequentially until the geographic pattern began to be fragmented.

It is important to note that the first branch indicates the greatest difference in the data set from the other branch of the tree. Each succeeding step is of less significance or of smaller and smaller clusters. Each of the methods in ProcCluster use a standard agglomerative hierachical algorithm which pulls in greatly different clusters in the final steps. The maps for each cluster method are included as Figures 8, 9, and 10, at the author's preferred level of numbers of clusters.

Each observation begins in a cluster by itself. On the first pass the two closest clusters are merged to form a cluster replacing the two old clusters. This continues until the entire data set is one cluster. The three methods differ only in how the distances between the clusters is computed. Therefore, each algorithm pulls in more and more distant clusters from the data set. The centroid method determines the distances between the centroids (means) of the clusters, Ward's uses the sum of squares between the clusters added up over all the variables and average linkage measures the average distance between successive pairs of observations, one in each cluster.

There are no satisfactory methods for determining the number of clusters for any types of cluster analysis (SAS, 1982). The number of

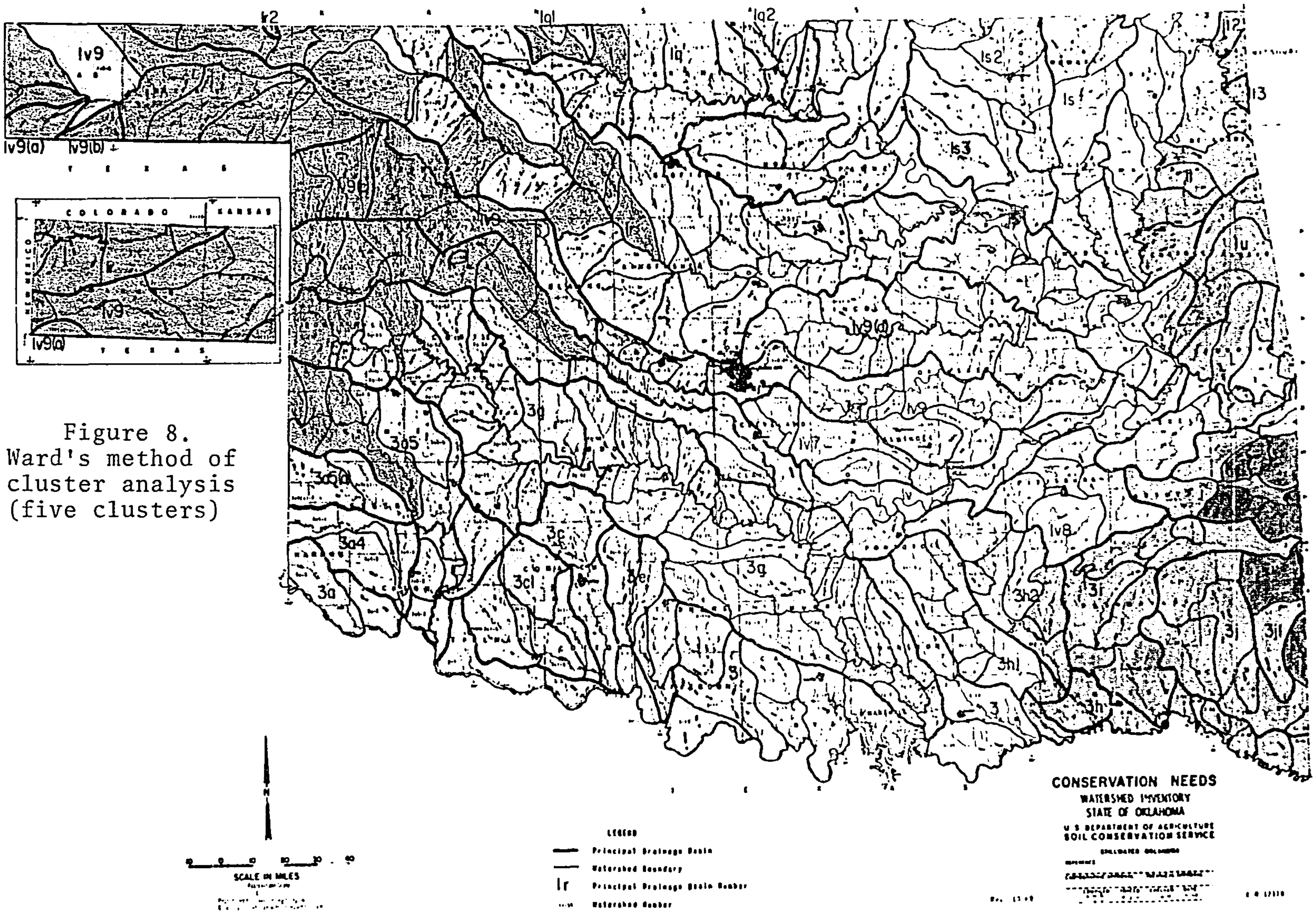


Figure 8.
Ward's method of
cluster analysis
(five clusters)

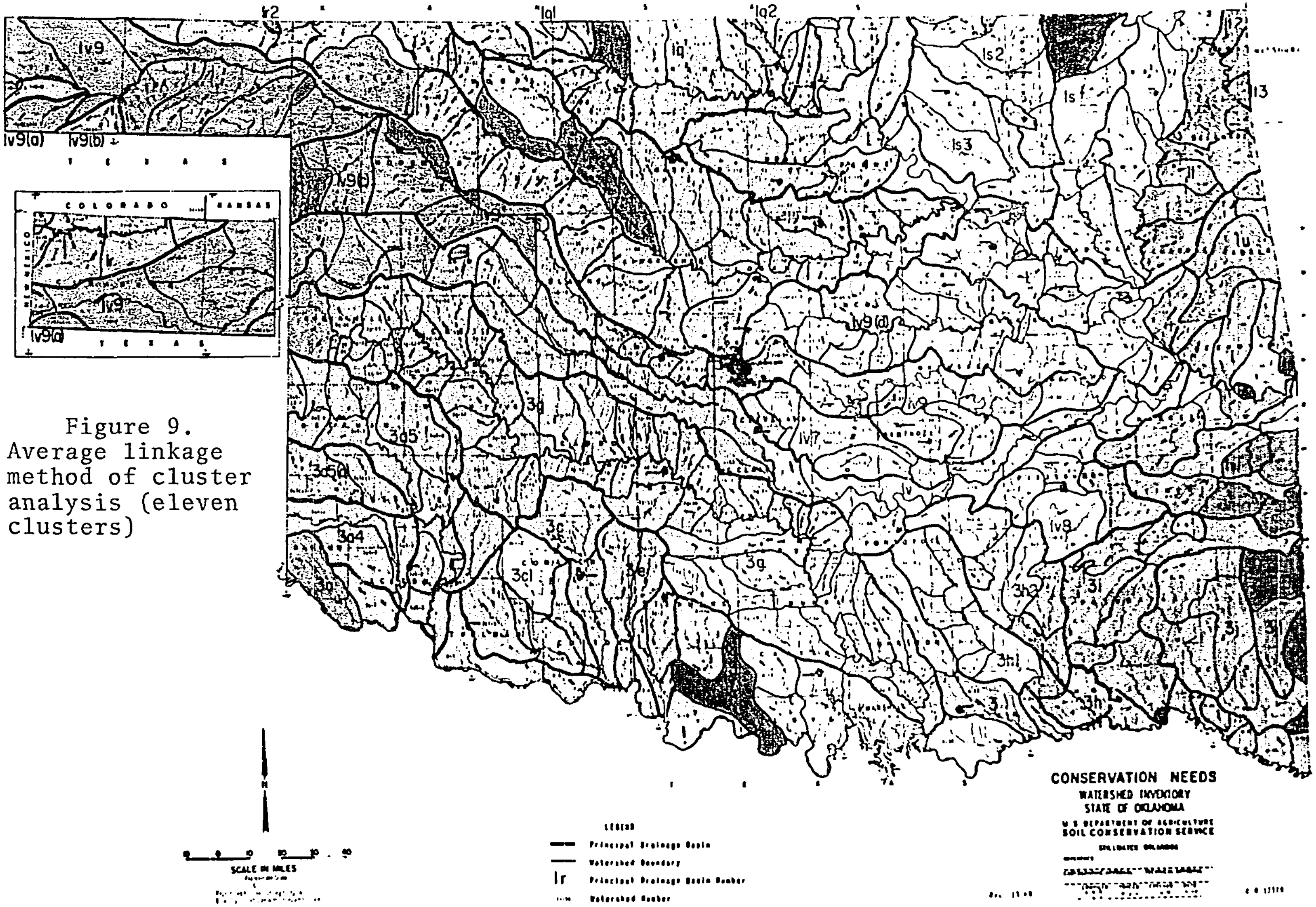


Figure 9.
Average linkage
method of cluster
analysis (eleven
clusters)

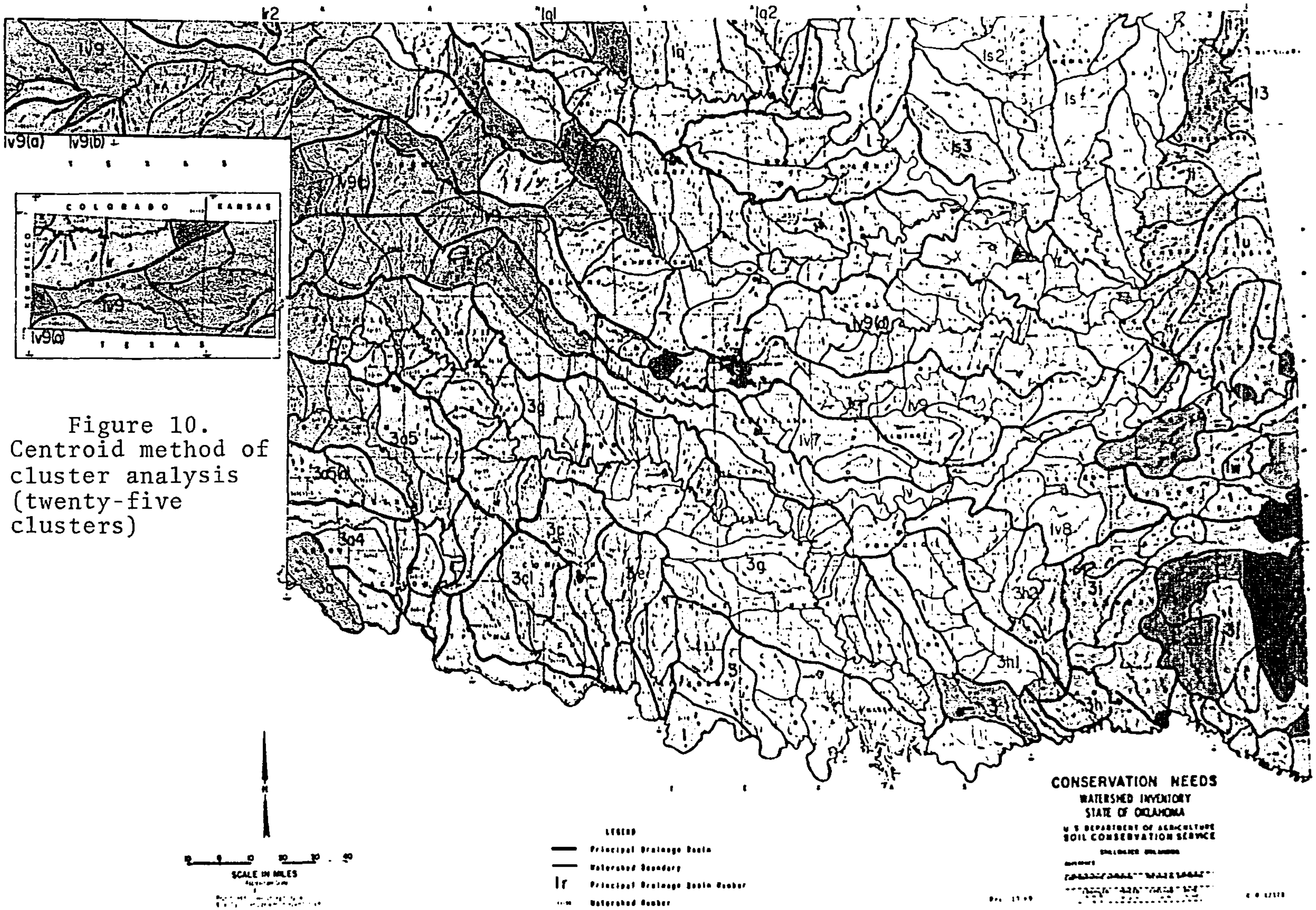


Figure 10.
Centroid method of
cluster analysis
(twenty-five
clusters)

clusters extracted must be evaluated against the needs of the study and the purpose for which the classification is to be used. Gaugh (1982) advises if the data are naturally clustered most clustering techniques readily recover the clusters correctly. If the data are continuous there is no natural number of clusters and no natural boundaries to the clusters. In this case, boundaries are imposed on the data by the clustering technique. Data structures that are naturally strongly clustered are rare in nature. Variation is usually relatively continuous and consequently most classifications are imposed.

Cluster analysis has been widely used in aquatic systems (Hocutt, et al., 1974; Cushing, et al., 1980; Cairns and Kaesler, 1971) and for terrestrial regionalization (Hagmeier, 1966; Kikkawa and Pearse, 1969).

Inspection of the colored maps from each CA method produced a pattern of geographic relationships. In all methods the mountainous eastern part of Oklahoma consisted of a wider variety of watershed types and in the Centroid and Average Linkage methods exhibited the greatest diversity by clustering last. This was especially true for the Poteau River drainage basin.

Second in distance from the major cluster was the Mountain Fork and Kiamichi drainage basins. This is a continuation of the mountainous region of southeastern Oklahoma. The next separate cluster produced is a group of large watersheds in the Oklahoma panhandle. This is an area of flat terrain, high crop usage and low rainfall. By the sixth cluster level some of the large drainage basins of northwest Oklahoma had been separated from the major cluster. These are characterized by extensive rangeland, moderate rainfall, and rolling prairie terrain. The seventh cluster was comprised of two widely separated watersheds (1S.22 and 3.11A). However, they are both in the areas designated as true prairie by Bruner (1938) and Duck and Fletcher (1943). The eighth cluster was a division of the mountainous group of eastern Oklahoma. The lower Mountain Fork River (3J.11) was the entire cluster. The ninth cluster was a portion of the Poteau River drainage (1W.4, 1W.6, 1W.7).

The first major geographic break occurred on the tenth cluster. Roughly one-half of the state was separated from the heretofore main cluster. The jagged demarcation between east and west roughly corresponded to that of Duck and Fletcher (1943), Kuchler (1964), and Bailey (1976). Several watersheds existed as islands in the geographic pattern indicating a gradual change rather than an abrupt demarcation.

Subsequent clustering further subdivided the eastern portion of the state. By the thirteenth cluster the northeastern hardwood forest and the southeastern pine forest areas became clearly demarcated from the eastern area termed woods by the author.

The fifteenth cluster further subdivided eastern Oklahoma and did not greatly impact the integrity of the major boundaries established at higher levels. By the twentieth cluster the character of western Oklahoma clusters began to change. However, major subregions did not materialize in the CA. The division in the west exhibited an alternating pattern rather than grouping at some identifiable geographic locality. The author attributes this to the weakness in the clusters at this low level. The CA will force a division even when a natural division may not exist. By the twentieth cluster the division is being made on very small differences in attributes. Since the computer does not "see" the data set on a geographic basis it makes the division objectively. Therefore, no geographic pattern is produced from the data set. As mentioned previously several "islands" of watershed existed from the CA used. In an effort to determine if this was due to some attribute of the watershed, some error in the data base, or some mathmatical oddity of the CA it was decided to apply a discriminant analysis (DA) to the data base to determine if the watersheds were correctly classified.

Discriminant analysis is a multivariate technique closely related to multiple regression and factor analysis. The researcher is able to use this technique to calculate the effect of a collection of variables on a non-integer dependent variable (Class). Linear combinations of independent variables that best distinguish between cases in the categories of the dependent variable are found. Cushing, et al. (1980), used this technique to classify thirty-four streams in North America and Europe based on physical and chemical variables. This is suggested by Sneath and Sokal (1933), Gaugh (1982), and Cooley and Lohnes (1971), as a technique to aid in the understanding of the data set.

Discriminant Analysis is available through SAS in a variety of choices. They indicate that classificatory discriminant analysis is used to classify observations into two or more known groups on the basis of one of more numeric variables. These can be conducted through ProcDiscrim or ProcNeighbor. ProcNeighbor should be used when the classes have non-normal distribution. Since some variables in the data set have non-normal distribution (slope, soil factor) it was decided to use ProcNeighbor for the analysis.

Each watershed received a class designation based on its grouping in the three cluster techniques. This was determined by the author grouping clusters based on an arbitrary perception of the geographic pattern produced by the cluster analysis. If a watershed was designated to a class in two or more out of the three techniques it was placed in that class (Figure 11). The classes were:

F = Plains, for that portion of far western Oklahoma with special characteristics.

P = Prairie, chosen for watersheds comprising the bulk of western Oklahoma.

W = Cross Timbers, chosen for watersheds in eastern and central Oklahoma including cross timbers and hardwood prairie mosaic areas.

U = Upland, that area of eastern Oklahoma generally in the Ozarkian Uplift.

M = Mountains, chosen for watersheds in the limited eastern portion of the state.

The linear combination developed by the DA for use with the data set indicated the variable "evapotranspiration" was not useful for analysis. Therefore, the DA was conducted with only seven variables.

Although discriminant analysis is a complex multivariate statistical technique the output from ProcNeighbor is very straightforward. It simply lists the classification results and indicates where watersheds had been misclassified. The results of this

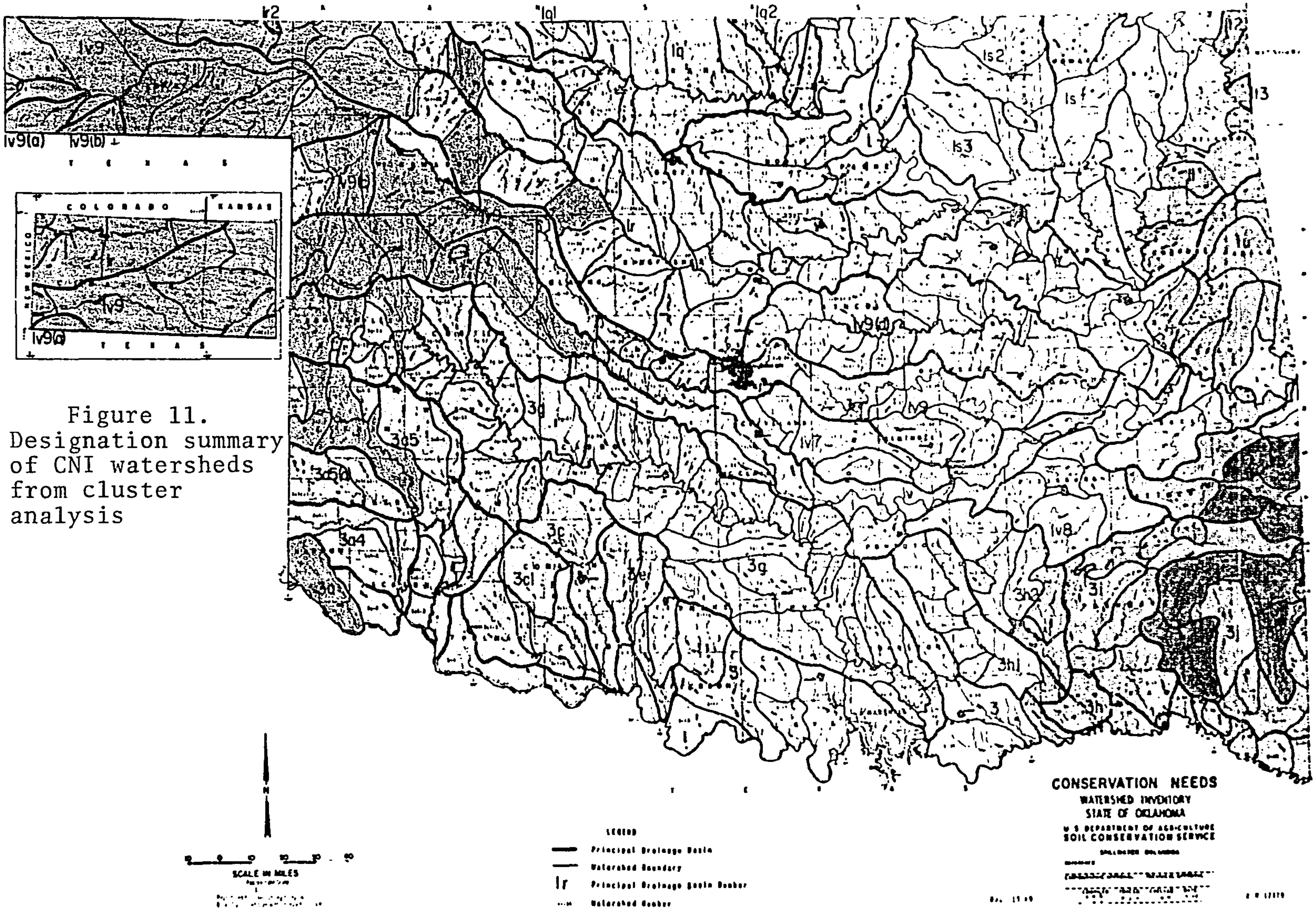


Figure 11.
Designation summary of CNI watersheds from cluster analysis

analysis is shown in Figure 12. This map is proposed for designation as the aquatic ecoregion map of Oklahoma. At present only the five ecoregions shown above are proposed. This varies somewhat with the ecoregions proposed by the EPA research team in Corvallis, Oregon. The map shown is similar to that submitted to the OWRB by Omernik and Hughes. However, it is not as detailed in subregional designation but is more detailed as to exact watershed boundaries. As the data set is improved the classificatory power should be improved. For the present the proposed ecoregions can provide a framework for more detailed analysis.

The assignment of watersheds to a specific ecoregion required an element of subjectivity since the CA techniques varied somewhat in cluster assignments. In addition, the DA reassigned some watershed even when all three cluster techniques concurred on class assignment. This indicates a data set for these watersheds which is transitional in nature to the designated ecoregions. These watersheds are shown in Figure 13 and must receive further evaluation prior to final classification into an ecoregion. It is envisioned this will probably require some kind of field evaluation and/or additional watershed factors to recommend final placement into an ecoregion.

The CA methods did not concur on the assignment of 73 of 381 watersheds. The DA reclassified 35 of 381 watersheds. Of the 35 watersheds 12 were not unanimously designated to a particular class by the CA methods and 23 were reclassified in spite of unanimity. This produces a total of 96 watersheds in the transitional group (Figure 13). An examination of Figure 14 indicates many of the 95 watersheds

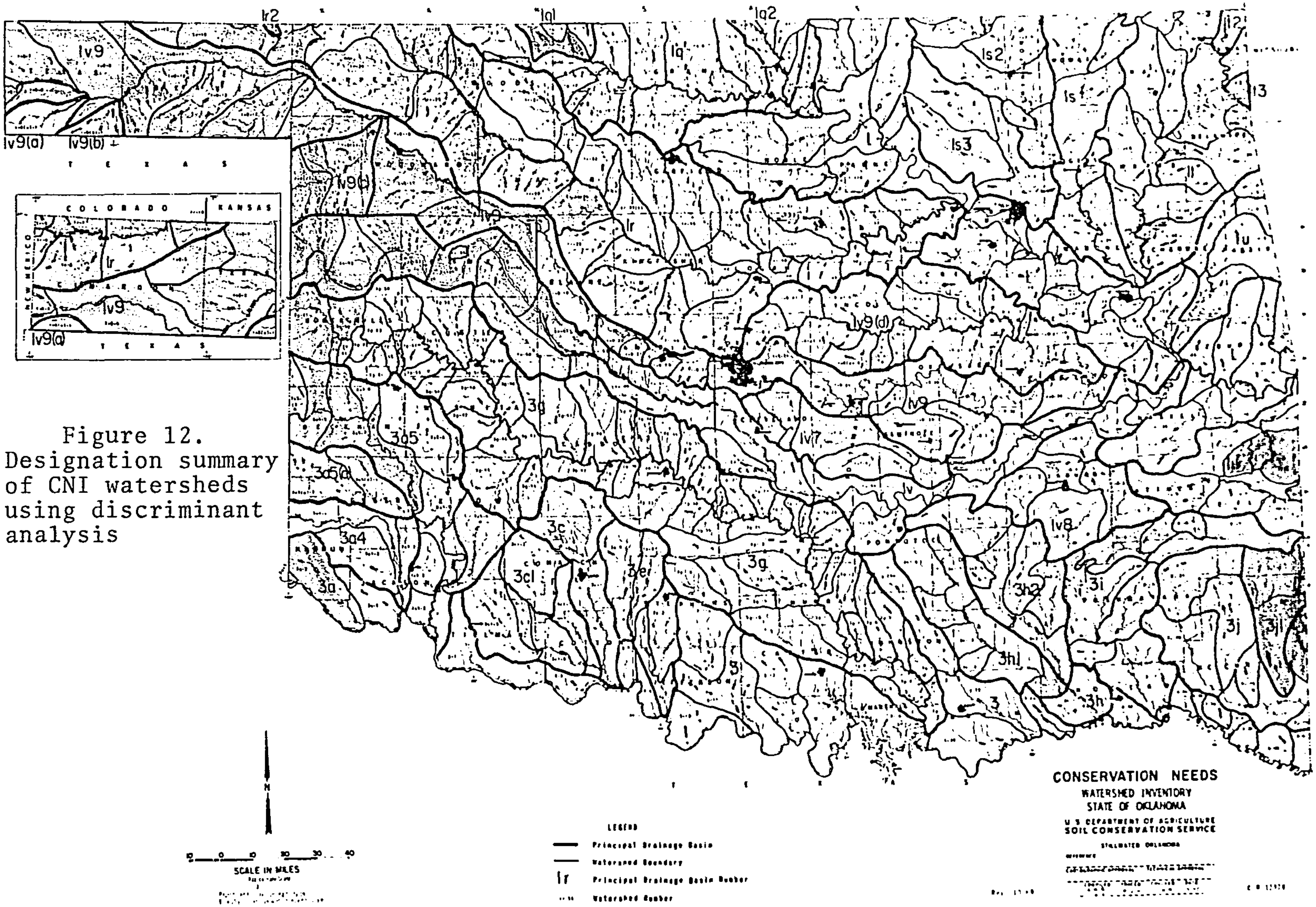


Figure 12. Designation summary of CNI watersheds using discriminant analysis

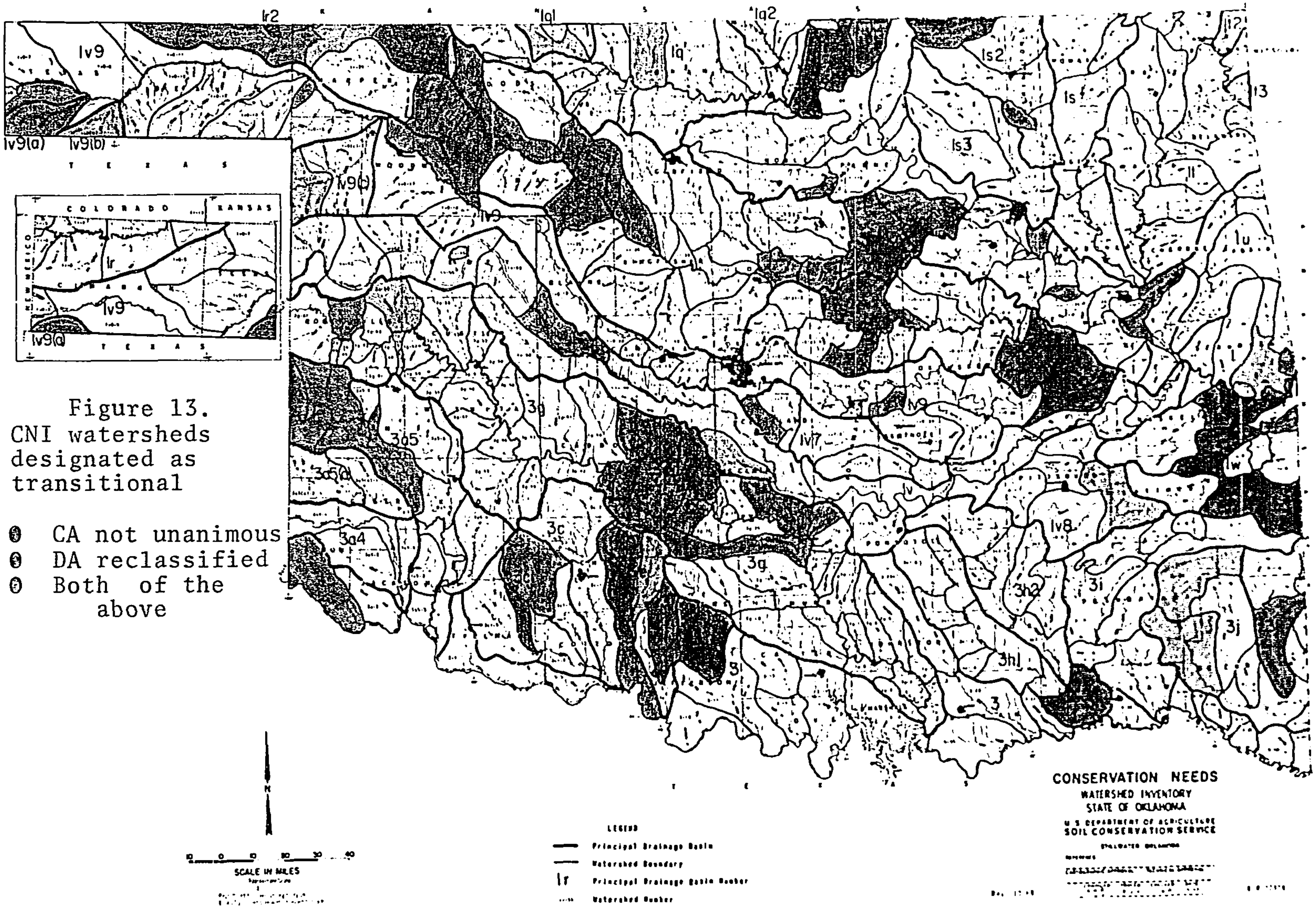


Figure 13.
CNI watersheds
designated as
transitional

- CA not unanimous
- DA reclassified
- Both of the above

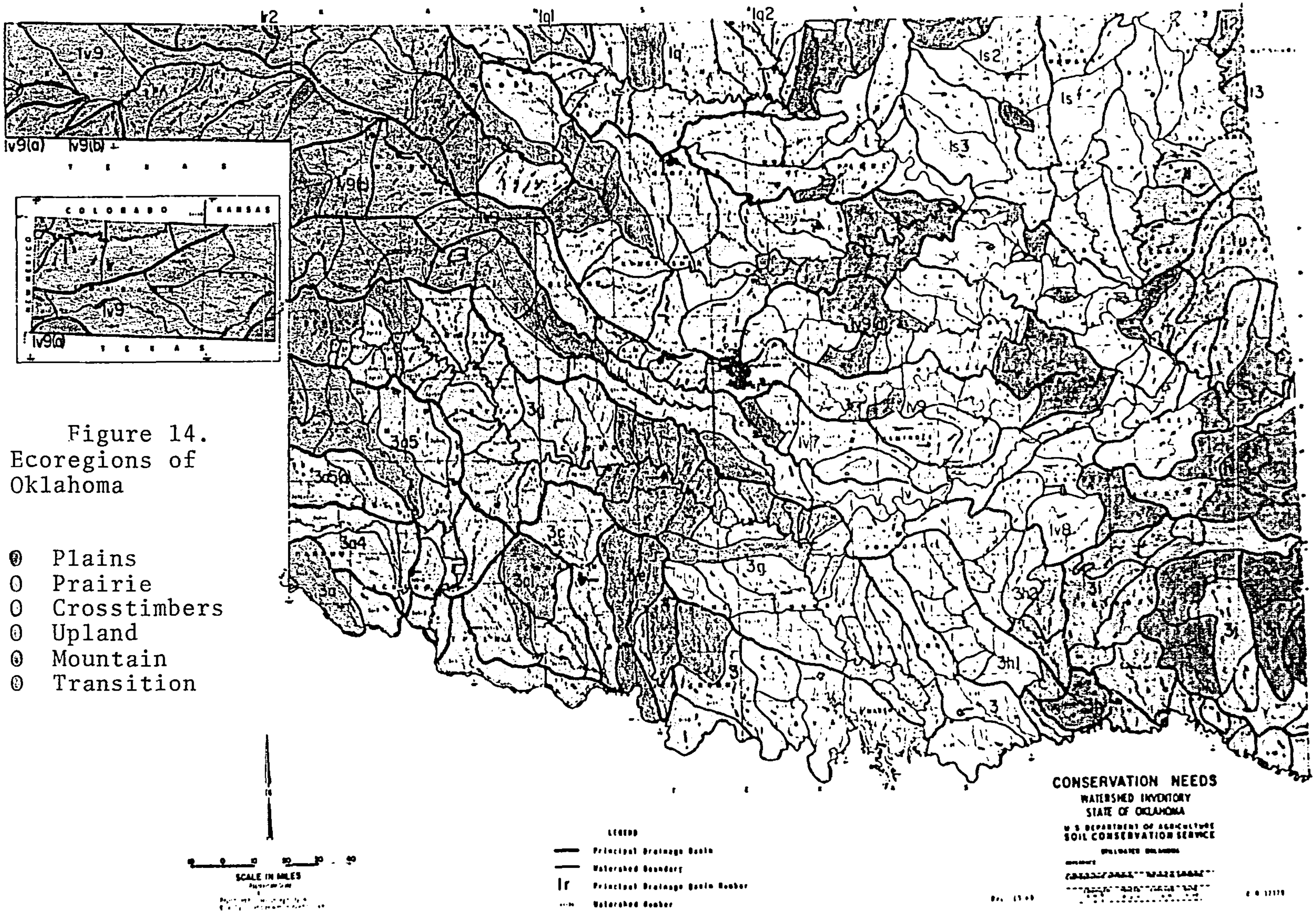


Figure 14.
Ecoregions of Oklahoma

- Plains
- Prairie
- Crosstimbers
- Upland
- Mountain
- Transition

lie on the demarcation line between ecoregions. This configuration supports the EPA Corvallis Laboratory team's ecoregion development technique of assigning "most typical" and "generally typical" to ecoregion. However, the data set utilized in this study minimizes the transitional areas as compared to the EPA method. Table 14 lists the watersheds by ecoregion and separates those transitional watersheds into appropriate groups as indicated by an asterisk. The geographic pattern produced by the above methods is very similar to those found in previous studies (Snider, 1917; Bruner, 1931; Duck and Fletcher, 1943; Omernik and Hughes, Personal Communication). This tends to support its credibility as a predictive tool for overall stream quality.

Table 14. CNI watershed occurrence by ecoregion.+

PLAINS

1Q1.6*	1R.24	1V9.4	1V9.17
1R.5	1R.27*	1V9.5	1V9.18
1R.6	1R.28*	1V9.6	1V9C.1*
1R.7	1R.34*	1V9.7	1V9C.2
1R.8	1V.41	1V9.8*	3A.3*
1R.9	1V.42	1V9.9	3A.5*
1R.11	1V.43	1V9.10	3A5.7*
1R.12*	1V.44	1V9.11	3A5.9*
1R.16	1V.46	1V9.12	3A5.10*
1R.22*	1V.47*	1V9.13	3G.64*
1R.23*	1V9.3	1V9.15	3G.67

PRAIRIE

1.105	1R.31	1V9.20	3E.1
1.107	1R.32*	1V9.21	3E.3*
1.109	1R.33*	1V9.22	3G.40
1.110	1R.33A*	1V9.23	3G.41
1.111	1R.33B*	1V9.24	3F.42
1.112	1R.35	1V9A.1*	3G.43
1.114	1R.36	1V9B.1*	3G.44
1.118	1R.37	1V9D.5*	3G.45
1Q.3	1R.38	1V9D.14*	3G.46
1Q.7*	1R.39	3.1	3G.47
1Q.8	1R.40	3.3	3G.48
1Q.9	1R.42	3.10	3G.49
1Q.10	1R.43	3.11	3G.50
1Q.11	1R.44*	3A.2	3G.51
1Q.12	1R.45*	3A4.1	3G.52
1Q.13	1R.46	3A4.2	3G.53
1Q.14	1R.47	3A4.3	3G.54
1Q.15	1R.48*	3A5.2	3G.55
1Q.16	1R.51	3A5.3	3G.56
1Q.17	1R.53*	3A5.4	3G.57
1Q1.4	1R2.3*	3A5.5	3G.58*
1Q1.5	1S.21	3A5.6	3G.59
1Q2.5	1V.45	3A5.8	3G.60
1Q2.6	1V.48	3A5A.1	3G.61
1Q2.7	1V.49	3A5A.2	3G.62
1Q2.8	1V.50*	3C.1	3G.63
1Q2.9	1V.51	3C.2	3G.65
1R.18*	1V.52	3CL.1	3G.66
1R.25*	1V9.14*	3CL.2*	
1R.29*	1V9.16*	3CL.3	
1R.30	1V9.19	3CL.5	

+ Numbers correspond to SCS designation (SCS, 1971).
* Transitional watersheds designated for further study.

Table 14. Cont.

CROSS TIMBERS

1.106*	1S2.11*	1V9D.3	3G.11
1.108*	1S2.12	1V9D.4*	3G.12
1.113*	1S3.1	1V9D.6	3G.13
1.115	1S3.2	1V9D.7	3G.14
1.116	1S3.3	1V9D.8	3G.15
1.117	1T.26	1V9D.9	3G.16
1.119*	1T.28	1V9D.10	3G.17
1.120	1T.29	1V9D.11	3G.18*
1.121	1T.30	1V9D.12	3G.19
1.122*	1T.34	1V9D.13	3G.20*
1.123	1T.35	1W.2*	3G.21*
1.124	1T.37	1W.3*	3G.22*
1.125	1T.39	1W.4*	3G.23*
1.126	1T.41	1W.9*	3G.24*
1.127	1V.53*	1W.10*	3G.25
1.128*	1V.54	1W.11	3G.26
1.130*	1V.55	3.4*	3G.27
1.131	1V.56	3.6*	3G.28
1.132	1V.57	3.11A*	3G.29
1.134	1V.58	3.12	3G.30*
1.135	1V.59	3.13	3G.31*
1.135A*	1V7.1*	3.14	3G.32
1.138*	1V7.2	3.16	3G.33*
1.140*	1V7.3	3.22	3G.34*
1Q.18*	1V7.4	3.23	3G.35*
1R.41*	1V7.5	3.23A	3G.36*
1R.49*	1V8.1	3CL.4*	3G.37*
1R.50*	1V8.2	3E.2*	3G.38*
1R.52*	1V8.4	3E.4*	3G.39*
1R.54*	1V8.5	3G.1	3H.1*
1S2.2	1V9.25	3G.2	3H1.2
1S2.3	1V9.26	3G.3	3H1.3
1S2.4	1V9.27*	3G.4	3H1.4
1S2.5	1V9.28	3G.5	3H1.5
1S2.6	1V9.29	3G.6	3H1.6
1S2.6*	1V9.30	3G.7	3H2.3
1S2.7*	1V9.31	3G.8	3H2.4
1S2.9	1V9D.1	3G.9	3H2.5
1S2.10	1V9D.2	3G.10	3H2.6

UPLAND

1.129	1T.42	3.35	3I.4
1.133	1T2.18	3.36	3I.5
1.136	1U.4	3.37	3I.6
1.137	1U.5	3.39	3I.7
1.139*	1U.6	3.40	3I.8
1.141	1U.8	3.41	3I.9

Table 14. Cont.

1.142	1U.9	3H1.1	3J.14
1T.32	1V8.3*	3H2.1	3J.17
1T.33	1V9.32*	3H2.2	3J.18
1T.36	1W.5	3I.1	3J.19
1T.38	3.26	3I.2	3J.20*
1T.40	3.32	3I.3	3J.21*

MOUNTAIN

1W.1*	1W.8	3J1.1*	3J1.3
1W.6	3J.15	3J1.2	3J1.4
1W.7	3J.16		

CHAPTER XII

ECOREGION DESCRIPTION

The ecoregions described in the previous chapter are geographically similar to the body of literature on the spatial characteristics of the State of Oklahoma. Although developed by an objective numerical technique the strength of the classification variables was adequate to produce, in general terms, the familiar geographic pattern. The purpose of this chapter is to provide a description of each ecoregion in terms of the variables selected to produce the classification. Table 15 lists the summary statistics for the eight variables utilized in this study. Table 16 is a separate listing of the summary statistics for land use by ecoregions. Table 17 is a listing of fish species anticipated by Miller and Robinson (1973) for each ecoregion. The fish species analysis is extremely cursory. It is based on a review of only one publication. Further study is needed to refine this listing to more accurately depict the fish species which inhabit each ecoregion. However, the list can be used as a starting point in this evaluation. The following is a brief description of each ecoregion.

TABLE 15. SUMMARY STATISTICS OF WATERSHED VARIABLES BY ECOREGION

ECOREGION		N	MEAN	STD	MIN	MAX	RANGE
PLAINS	AREA (SQ/MI)	44	251.42	160.29	13.21	557.39	544.18
	SLOPE	44	386.89	138.09	80.00	722.00	642.00
	RAINFALL (IN/YR)	44	21.18	3.41	15.50	27.50	12.00
	RUNOFF (IN/YR)	44	0.50	0.38	0.15	1.50	1.35
	EVAPOTRANSPIRA-TION (IN/YR)	44	20.68	3.17	15.15	26.07	10.92
	NATURAL VEGETATION	44	2506.77	340.51	1773.27	3177.00	1403.73
	SOIL TYPE	44	394.07	51.71	276.21	505.09	228.88
	LAND USE	44	6931.73	2200.79	2648.75	12422.50	9773.75
PRAIRIE	AREA (SQ/MI)	122	188.38	143.12	5.17	716.02	710.84
	SLOPE	122	338.31	191.37	82.00	1047.00	965.00
	RAINFALL (IN/YR)	122	28.12	3.68	18.00	39.50	21.50
	RUNOFF (IN/YR)	122	1.79	1.25	0.15	7.88	7.73
	EVAPOTRANSPIRA-TION (IN/YR)	122	26.33	2.78	17.85	32.63	14.78
	NATURAL VEGETATION	122	3390.54	5337.66	1563.00	42800.87	41237.87
	SOIL TYPE	122	320.85	71.01	199.80	588.24	388.44
	LAND USE	122	6247.25	2181.97	920.00	12012.50	11092.50
WOOD	AREA (SQ/MI)	156	150.22	112.36	0.24	457.15	456.90
	SLOPE	156	403.88	333.24	125.00	2872.00	2747.00
	RAINFALL (IN/YR)	156	37.47	4.06	27.50	48.20	20.70
	RUNOFF (IN/YR)	156	5.57	3.46	1.50	22.32	20.82
	EVAPOTRANSPIRA-TION (IN/YR)	156	31.89	2.23	25.88	38.17	12.29

(CONTINUED)

TABLE 15. SUMMARY STATISTICS OF WATERSHED VARIABLES BY ECOREGION

ECOREGION		N	MEAN	STD	MIN	MAX	RANGE
WOOD	NATURAL VEGETATION	156	11799.62	20097.83	1563.00	100000.00	98437.00
	SOIL TYPE	156	325.87	47.00	256.41	477.46	221.05
	LAND USE	156	10716.47	2228.15	6381.25	18440.00	12058.75
UPLAND	AREA (SQ/MI)	49	143.30	105.32	14.33	422.00	407.67
	SLOPE	49	568.18	325.47	177.00	1813.00	1636.00
	RAINFALL (IN/YR)	49	45.60	2.64	40.20	51.50	11.30
	RUNOFF (IN/YR)	49	11.95	2.76	5.90	20.10	14.20
	EVAPOTRANSPIRATION (IN/YR)	49	33.65	2.27	29.60	40.00	10.40
	NATURAL VEGETATION	49	94221.88	12623.91	37299.80	100010.00	62710.20
	SOIL TYPE	49	342.09	13.52	300.26	357.14	56.88
	LAND USE	49	13913.42	3474.06	2737.50	19260.00	16522.50
MOUNTAIN	AREA (SQ/MI)	10	101.02	97.05	16.30	320.78	304.48
	SLOPE	10	2295.70	1350.51	509.00	4282.00	3773.00
	RAINFALL (IN/YR)	10	47.75	2.39	45.30	51.50	6.20
	RUNOFF (IN/YR)	10	20.84	5.84	12.50	25.50	13.00
	EVAPOTRANSPIRATION (IN/YR)	10	26.91	4.32	21.00	32.90	11.90
	NATURAL VEGETATION	10	85162.61	31645.20	5993.74	100000.00	94006.26
	SOIL TYPE	10	345.79	11.39	326.55	357.14	30.59
	LAND USE	10	16409.00	3072.65	10371.25	19950.00	9578.75

TABLE 16. SUMMARY STATISTICS FOR LAND USE BY ECOREGION

ECOREGION		N	MEAN	STD	MIN	MAX	RANGE
PLAINS	% CROP	44	42.05	20.25	2.60	83.[illegible]0	81.30
	% PASTURE	44	1.15	1.97	0.00	7.10	7.10
	% FOREST	44	6.12	12.49	0.00	58.70	58.70
	% RANGE	44	45.80	23.37	0.00	96.20	96.20
	% OTHER	44	4.87	6.89	0.00	27.10	27.10
PRAIRIE	% CROP	122	44.90	21.48	0.00	89.50	89.50
	% PASTURE	122	7.16	8.87	0.00	39.50	39.50
	% FOREST	122	3.33	4.78	0.00	26.70	26.70
	% RANGE	122	38.17	20.41	0.00	91.60	91.60
	% OTHER	122	4.87	6.13	0.00	42.00	42.00
WOOD	% CROP	156	13.56	11.58	0.00	55.00	55.00
	% PASTURE	156	26.18	15.46	0.00	74.40	74.40
	% FOREST	156	19.04	15.58	0.00	84.40	84.40
	% RANGE	156	34.07	19.23	0.00	79.50	79.50
	% OTHER	156	7.14	8.13	0.00	38.90	38.90
UPLAND	% CROP	49	7.33	16.30	0.00	83.00	83.00
	% PASTURE	49	35.54	17.46	1.90	82.30	80.40
	% FOREST	49	45.57	24.91	0.00	92.60	92.60
	% RANGE	49	5.56	8.44	0.00	31.80	31.80
	% OTHER	49	5.98	7.45	0.00	38.50	38.50
MOUNTAIN	% CROP	10	0.32	0.80	0.00	2.50	2.50
	% PASTURE	10	23.22	21.74	0.50	64.20	63.70
	% FOREST	10	64.38	30.21	5.90	99.50	93.60
	% RANGE	10	8.45	13.07	0.00	34.20	34.20
	% OTHER	10	3.62	5.14	0.00	14.40	14.40

Table 17. Occurrence of fish species by ecoregion (Miller and Robinson, 1973).

SPECIES	COMMON NAME	PLAINS	PRAIRIE	CROSS TIMBERS	UPLAND	MOUNTAIN
Ichthyomyzon castaneus	Chestnut Lamprey			P	C	C
Ichthyomyzon gagei	Southern brook lamprey				C	C
Scaphirhycus platorynchus	Shovelnose sturgeon			P	P	
Polydon spathula	Paddlefish			P	P	
Lepisosteus Oculatus	Spotted gar		P	P	C	C
Lepisosteus Osseus	Longnose gar		P	P	C	C
Lepisosteus Platostomus	Shortnose gar		P	C	C	C
Lepisosteus Spatula	Alligator gar			P	P	P
Amia calva	Bowfin				P	C
Anguilla rostrata	American eel			P	P	P
Alosa alabamae	Alabama shad				P	
Alosa chrysochloris	Skipjack herring			P	P	C
Dorosoma cepedianum	Gizzard shad	P	C	C	C	C
Dorosoma petense	Threadfin shad			P	P	
Hiodon alosoides	Goldeye		P	P	P	C
Hiodon tergisus	Mooneye				P	
Salmo gairdner:	Rainbow trout			P	P	
Esox americanus	Grass pickerel				P	C
Esox lucius	Northern pike	P		P		
Esox niger	Chain pickerel			P	P	
Astynax mexicanus	Mexican tetra			P		
Campostoma anonalum	Stoneroller		P	P	C	C
Carrassius auratus	Goldfish			P	P	
Cyprinus carpio	Carp	P	C	C	C	C
Dionda nubila	Ozark minnow				P	
Hybognathus hayi						
Hybognathus nuchalis	Silvery minnow			P	P	C
Hybognathus placitus	Plains minnow	C	C	C	C	C
Hybopsis aestivalis	Speckled chub	P	P	P	P	
Hybopsis amblops	Bigeye chub				P	
Hybopsis gracilis	Flathead chub	P	P			
Hybopsis storeriana	Silver chub		P	P	P	
Hybopsis x-punctatau	Gravel chub				P	
Nocomis asper	Redspot chub			P	P	
Notemigonus crysoleucas	Golden shiner		P	C	C	C
Notropis amnis	Pallid shiner			P	P	C
Notropis atherinoides	Emerald shiner	C	C	C	C	C
Notropis atrocaudalis	Blackspot shiner				P	
Notropis bairdi	Red river shiner	P	P	P	P	
Notropis blennius	River shiner		P	P	P	
Notropis boops	Bigeye shiner		P	P	C	C
Notropis buchanani	Ghost shiner		P	C	C	C
Notropis camurus	Blunt face shiner		P	P	P	
Notropis chalybaeus	Ironcolor shiner					P
Notropis cornutus	Common shiner			P	P	P
Notropis emiliae	Pubnose minnow				P	C
Notropis fumeus	Ribbon shiner			P	P	P

Table 17. Cont.

SPECIES	COMMON NAME	PLAINS	PRAIRIE	CROSS TIMBERS	UPLAND	MOUNTAIN
Notropis girardi	Arkansas River shiner	P	P	P		
Notropis greenei	Wedgespot shiner				P	
Notropis lutrensis	Red shiner	C	C	C	C	C
Notropis maculatus	Taillight shiner				P	
Notropis ortenburgeri	Kiamichi shiner			P	P	C
Notropis perpallidus	Colorless shiner				P	
Notropis pilsbryi	Duskystripe shiner				P	
Notropis potteri	Chub shiner	P	P	P	P	
Notropis rubellus	Rosyface shiner			P	C	C
Notropis shumardi	Silverband shiner			P	P	
Notropis spilopterus	Spotfin shiner				P	
Notropis stramineus	Sand shiner	P	P	P	P	
Notropis umbratilis	Redfin shiner			P	C	C
Notropis venustus	Blacktail shiner		P	P	P	P
Notropis volucellus	Mimic shiner			P	C	C
Notropis whipplei	Steelcolor shiner			P	C	C
Phenocobius mirabilis	Suckermouth minnow	C	C	C	C	C
Phoxinus erythrogaster	Southern red-bellied dace		P	P	P	
Pimephales notatus	Bluntnose minnow		P	C	C	C
Pimephales promelas	Fathead minnow	C	P	P	P	
Pimephales tenellus	Slim minnow		P	P	P	
Pimephales vigilax	Bullhead minnow	P	C	C	C	C
Semotilus atromaculatus	Creek chub				P	P
Carpiodes carpio	River carpsucker	C	C	C	C	C
Carpiodes cyprinus	Quillback carpsucker		P			
Carpiodes velifer	Highfin carpsucker		P	P	P	
Catostomus commerson	White sucker				P	
Cycleptus elongatus	Blue sucker			P		
Erimyzon oblongus	Creek chubsucker				P	C
Hypentelium nigricaus	Northern hogsucker				P	
Ictobus bubalus	Smallmouth buffalo		P	P	C	C
Ictobus cyprinellus	Bigmouth buffalo		P	C	C	C
Ictobus niger	Black buffalo		P	P	P	
Minytrema melanops	Spotted sucker			P	C	C
Moxostoma carinatum	River redhorse				P	C
Moxostoma duguesnei	Black redhorse		P	P	P	C
Moxostoma erythrurum	Golden redhorse		P	P	C	C
Moxostoma macrolepidotum	Shorthead redhorse		P	P	P	
Ictalurus furcatus	Blue catfish			P	P	
Ictalurus melas	Black bullhead	C	C	C	C	C
Ictalurus natalis	Yellow bullhead	P	C	C	C	C
Ictalurus nebulosus	Brown bullhead				P	
Ictalurus punctatus	Channel catfish	P	C	C	C	C
Noturus eleutherus	Mountain madtom				P	P
Noturus exilis	Slender madtom				P	P
Noturus flavus	Stonecat			P	P	
Noturus gyrinus	Tadpole madtom		P	P	P	C

Table 17. Cont.

SPECIES	COMMON NAME	PLAINS	PRAIRIE	CROSS TIMBERS	UPLAND	MOUNTAIN
Noturus miurus	Brindled madtom			P	P	
Noturus nocturnus	Freckled madtom			P	C	C
Noturus placidus	Neosho madtom				P	
Pylodictis olivaris	Flathead catfish		P	C	C	C
Amblyopsis rosae	Ozark cavefish				P	
Typhlicthys subterraneus	Southern cavefish				P	
Aphredoderus sayanus	Pirate perch				P	
Cyprinodon rubrofluviatilus	Red River pupfish	P	P			
Fundulus catenatus	Northern studfish				P	
Fundulus kansae	Plains killifish	C	C	P		
Fundulus notti	Starhead topminnow				P	P
Fundulus notatus	Blackstripe topminnow		P	P	C	C
Fundulus olivaceous	Blackspotted topminnow			P	C	C
Fundulus sciadicus	Plains topminnow			P		
Gambusia affinis	Mosquitofish	P	P	P	C	C
Labidesthes sicculus	Brook silversides		P	C	C	C
Menidia audens	Mississippi silversides			P	P	
Cottus carolinae	Banded sculpin				P	
Morone chrysops	White bass		P	P	P	
Morone mississippiensis	Yellow bass				P	
Morone saxatilis	Striped bass			P	P	
Elassoma zonatum	Banded pygmy sunfish				P	
Ambloplites rupestris	Rock bass				P	
Centrarchus macropterus	Flier				P	
Lepomis auritus	Redbreast sunfish				P	
Lepomis cyanellus	Green sunfish	C	C	C	C	C
Lepomis gulosus	Warmouth		P	C	C	C
Lepomis humilis	Orangespotted sunfish	C	C	C	C	C
Lepomis macrochirus	Bluegill	C	C	C	C	C
Lepomis marginatus	Dollar sunfish				P	
Lepomis megalotis	Longear sunfish	P	C	C	C	C
Lepomis microlophus	Redear sunfish	P	C	C	C	C
Lepomis punctatus	Spotted sunfish				P	
Lepomis symmetricus	Bantam sunfish				P	
Micropterus dolomieui	Smallmouth bass			P	C	C
Micropterus punctulatus	Spotted bass		P	C	C	C
Micropterus salmoides	Largemouth bass	C	C	C	C	C
Pomoxis annularis	White crappie		P	C	C	C
Pomoxis nigromaculatus	Black crappie		P	P	C	C
Ammocrypta clara	Western sand darter			P	P	
Ammocrypta vivax	Scaly sand darter			P	P	C
Crystallaria asprella	Crystal darter				P	
Etheostoma asprigene	Mud darter				P	
Etheostoma blennioides	Greenside darter				P	P
Etheostoma fusiforme	Swamp darter				P	
Etheostoma chlorosomum	Bluntnose darter			P	C	C
Etheostoma cragini	Arkansas darter				P	

Table 17. Cont.

SPECIES	COMMON NAME	PLAINS	PRAIRIE	CROSS TIMBERS	UPLAND	MOUNTAIN
Etheostoma flabellare	Fantail darter				P	
Etheostoma gracile	Slough darter			P	C	C
Etheostoma histrio	Harlequin darter					C
Etheostoma microperca	Least darter			P	P	
Etheostoma nigrum	Johnny darter				P	C
Etheostoma parvipinne	Goldstripe darter				P	P
Etheostoma proeliare	Cypress darter			P	P	C
Etheostoma punctulatum	Stippled darter				P	
Etheostoma radiosum	Orangebelly darter				P	P
Etheostoma spectabile	Orangethroat darter		P	P	C	C
Etheostoma stigmaeum	Speckled darter				P	
Etheostoma whipplei	Redfin darter			P	P	
Etheostoma zonale	Banded darter				P	
Perca flavescens	Yellow perch			P		
Percina caprodes	Log perch		P	P	C	C
*Percina copl*andi	Channel darter			P	C	
Percina maculata	Blackside darter				P	C
Percina nasuta	Longnose darter				P	P
Percina pantherina	Leopard darter				P	P
Percina phoxocephala	Slenderhead darter			P	C	C
Percina sciera	Dusky darter			P	P	C
Percina shumardi	River darter			P	P	
Stizostedion canadense	Sauger			P	P	P
Stizostedion vitreum	Walleye		P	P	P	
Aplodinotus grunniens	Drum	P	P	C	C	C
Mugil cephalus	Striped mullet			P	P	
	Summary	P = 17 C=12 T=29	P=44 C=18 T=62	P=80 C=28 T=108	P=101 C=53 T=154	P=17 C=70 T=87

Plains

The plains ecoregion is characterized by low rainfall, little runoff, flat terrain, heavy crop production, and large watersheds. The soils are dark colored loams and clay loams with moderately clayey subsoils which are developed largely under short grasses. Because the area is largely sedimentary and the precipitation rate is low the soil retains large amounts of nutrients. The streams of this region are heavily impacted by the harsh climate.

The average watershed size is 251 square miles with a large standard deviation of 160 square miles. The range is from 13.21 to 557.39 square miles. Slope is moderate with an average slope-area ratio of 387 units. This ranges from 80 to 722 with few areas of great relief.

Climatic conditions greatly impact this region. The average annual rainfall is 21.18 inches/year and varies from 15.5 to 27.5 inches/year. Annual runoff ranges from an almost nonexistent 0.15 inches/year to a small 1.5 inches/year and averages 0.5.

The potential natural vegetation is largely short grass prairie species. The western edge of the region is represented with Juniper-Pinyon woodland and the eastern portion becomes mixed grass prairie with sagebrush in the sandy areas.

The soils in the western portion of the region occur on sandstone escarpments and basaltic mesas, and are brown loamy mixed with large stones. In the eastern portions of the region the soils tend to be sandy and unconsolidated. Portions of the red beds begin to outcrop in this area. The "K" factor computation produced a soil type factor which was higher than any other ecoregion. This is an indication of both soils with low erodibility and flat slope.

Man's use of the land in this ecoregion is split between two predominant types. Crop use is great where groundwater is available. Rangeland predominates where water is not available. They average 42.0 and 45.8 percent, respectively.

The streams of this ecoregion reflect the severe nature of the climatic conditions of this part of the state. Flows are seasonal and, except during flash flows, meander across a broad streambed comprised largely of sand. Waters are heavily mineralized but are low in sediment and exhibit extreme temperatures. Miller and Robinson (1973) indicate only 12 fish species are found throughout this area and only 17 fish species are found in a portion of the ecoregion.

Prairie

This ecoregion does not show the unity through CA of some of the other regions. This is probably indicative of the variable nature of this transitional region. In general, the variety of stream types is great due to a combination of geologic and climatic conditions.

Physically, the watersheds are moderately large (188 sq/mi) and flat with a slope-area ratio of 338 units. This variability is shown by the range from 5.17 to 716.02 square miles in area and the slope-area ratio from 82 to 1,047 units. The standard deviations of 143 square miles in area and 191 units of slope attest to this variability.

Climatically the variation is not as great as other ecoregions. Rainfall averages 28.12 inches/year but the standard deviation is only 3.68 inches/year. However, the range is quite large, ranging from 18 to 39.5 inches/year. Runoff remains quite low (1.79 inches/year average) with a range from 0.15 to 7.88 inches/year.

The natural vegetation of this ecoregion is, again, quite variable. Both tall grass prairie and mixed grass prairie are major grassland types. Many areas have large amounts of riparian forestland, although the mesquite prairie biome comprises a portion of this ecoregion . The occurrence of woody vegetation is largely controlled by subsurface water availability. The vegetation factor averaged 3,390 with a standard deviation greater than the mean (5,337). The range was from 1,563 to 43,800 indicating the variable nature of this ecoregion.

The soils of this ecoregion are representative of the variable nature of the ecoregion. In the northern portion are the central Reddish Prairies which are generally loamy to clay loam. However, most river bottoms have large deposits of sand. In the southern portion are the Rolling Red Plains which are greater in clay content. In the eastern portion of the ecoregion the soils tend to be sandier in nature. The soils are largely erosible and this ecoregion had the lowest average soil factor (320.85) with a large standard deviation (71).

The land use percentages indicate a heavy crop use (44.9%) with the bulk of the remaining use as rangeland (38.2%). This produced the lowest average land use factor of any ecoregion. However, the factors ranged from 920 to 12,012 which is indicative of the variety of this ecoregion.

The streams of this ecoregion vary greatly as could be deduced from the description above. Many of the poorest streams in the state occur in this ecoregion. However, some very fine streams can also be found. The streams of the Wichita Mountains are clear and cool and the fish communities are quite diverse. The streams of the canyon country in Canadian, Caddo, and Blaine Counties are very desirable. However, the presence of adequate flow is a determining factor of the ability of streams in the ecoregion to produce adequate fish communities. Sixty-two fish species are anticipated for this region while only eighteen are expected throughout the region.

Cross Timbers

This large area of east-central Oklahoma is quite varied and can be considered a transition zone between the woodlands to the east and the prairies to the west. This ecoregion exhibits features of both yet has a unique character of its own. Historically the fire resistant woodlands provided a firebreak for major prairie fires. Human usage has greatly impacted this ecoregion.

This ecoregion contains more watersheds than any other region (156). However, they are intermediate in size (150 square miles) but range from 0.24 to 457 square miles. The slope-area ratio is greater than the two previous ecoregions (404 average) and are both flat (125) and very steep (2872).

Average annual rainfall varies from 27.5 to 48.2 inches/year and averages 37.47 inches/year. Runoff is 5.57 inches/year average but ranges from 1.5 to 22.32 inches/year. The climatic conditions produce more stable stream flow and a greater impact by man as a result of water development.

The natural vegetation of the bulk of this ecoregion ranged from forestland through a savannah climax to a prairie system. Vegetation factors varied accordingly from 1,563 to the maximum of 100,000. The average was 11,800.

Soils are predominantly light colored sandy soils in the wooded portions and dark colored clayey soils in the grassland portions. These soils are not as nutrient rich as soils to the west nor as leached as soils to the east. The soils are generally well drained.

The use of the land by man is well balanced in this ecoregion. Only 13.56% is in cropland while pasture and rangeland, at 26.18 and 34.07%, respectively, comprise over half the total use of land. Forestland is almost 20% and "other" is the greatest of any ecoregion at 7.14%. This produces land use factors averaging 10,716.

Streams of this ecoregion are both varied and variable. Suitable conditions for biota vary greatly between streams and also within a stream system. The fish community is varied (108 species expected) with 28 species found throughout the region while 80 can be found in some portion.

Upland

The upland ecoregion of Oklahoma includes some of the best streams in the state. The region is characterized by adequate rainfall, hilly terrain, expansive forests and savannahs. Geologic influences are increased and climatic conditions are more stable. Forestlands predominate and man's impact is decreased.

The watersheds are moderate in size (143.3 square miles average) and slope is increased (568). This produces streams of sustained flow and high reaeration properties.

The soils are light colored and often acid and sandy. The soils are shallow with a rocky substrate. These are formed under oak-hickory forest in the north and oak-hickory-pine in the south. Soils exhibit low erodibility (342 average) and often occur in small areas in and around rock outcroppings.

Rainfall is great (45.6 inches/year average) and fairly uniform throughout the region (40.2 minimum to 51.5 maximum inches/year). Runoff is large, averaging almost 12 inches/year. This produces very stable flows and adequate subsurface moisture for forests.

The natural vegetation is predominantly forests and varies in type only in the species mix. The vegetation factors produced averaged 94,220 and ranged from 12,624 to 100,000. This is the highest of any ecoregion.

The land use factors averaged 13,913 and ranged from 2,738 to 19,260. This was primarily due to a high forestland percentage of 45.57. Crop usage has a 7.33% average.

Streams of this ecoregion are naturally clear and cool in the steeper gradients. They usually have good fish populations. Some streams are heavily impacted by man's usage but may recover quickly if corrective action is taken. The complex fish community may have 154 species represented. Fifty-three of these are found throughout the region.

Mountain

This ecoregion only has ten watersheds but has the best overall stream quality of any ecoregion. It is separated from the upland ecoregion primarily by its much greater slope factor and greater rainfall and runoff. This area includes some of the most scenic areas in Oklahoma.

Physically the watersheds are small (101 square miles average) but extremely steep (2,296 slope average). This produces a high stream gradient with excellent reaeration properties.

The rainfall for this ecoregion averages 47.75 inches/year with very little variation. Runoff averages almost double that of any other ecoregion (20.84 inches/year). This coupled with the physical features of the watersheds produce excellent quality streams.

The natural vegetation for this ecoregion is almost entirely oak-hickory-pine forests. This produces very large vegetation factors averaging 85,162.

Soils are shallow, sandy and not erosible. Rock outcroppings are common. These conditions produced the largest soil type factors of and ecoregion, averaging 346.

Land use is predominantly forestland (64.38%) with pasture being second at 23.22%. This produced large land use factors averaging 16,409.

Streams of this ecoregion are clear, cool, and rocky with sustained flow, excellent reaeration and habitat. The fish populations are the most desirable, sensitive, and diverse in the state. Eighty-seven species are expected with 70 of those found throughout the region.

It is apparent from the separate ecoregion descriptions tha CA and DA produced from the watershed variables offer excellent intuitive results. Not only does the geographic pattern generally correspond with previous studies but it is also possible to describe these objectively determined "regions" with some degree of confidence.

CHAPTER XIII

EVALUATION

As proposed in Chapter I and discussed in Chapter VII, it is desirable to evaluate the ecoregions produced from watershed variables by measuring with a separate and "dependent" evaluation variable. As concluded in Chapter VII, an appropriate media for the evaluation of ecoregion development is by the analysis of the fish populations existing in discrete stream units. For this study, it was desirable to consider several criteria in the selection of fish populations to perform the evaluation. These criteria, in order of relative importance, are as follows:

(1) The entire watershed area should be located within a single designated ecoregion;

(2) The geographic pattern should include most of the state;

(3) All of the watershed area should be within the limits of the data set (Oklahoma);

(4) Fish collections should be thorough, using multiple collection techniques if possible;

(5) Major sources of anthropogenic pollution should not exist in the immediate area;

(6) Several collection sites should be included for each stream;

(7) Adequate collection size was arbitrarily selected to be 1,000 individuals;

(8) Proper species identification is required;

(9) Quantitative information is required, to species, enabling evaluation by biological indices; and

(10) Publication, in some format, is desirable.

Considering the above factors, a total of nineteen streams were selected for the data set (Table 18). These collections are from: Pigg (1977); Pigg and Hill (1974); Cook (1979); Benderim (1977); Jenkins and Finnell (1957); and Harrel, et al. (1967). Unpublished collections were from Pigg (personal communication) and OWRB agency files. Of significant variance from the selection criteria were: (1) the North Canadian River at Woodward (1V9.16); (2) Oak Creek near Elk City (3G.55); and Big Cabin Creek near Nowata (1S.22). These streams remained in the data set because of their geographic location in the state.

A data matrix was prepared for use in a variety of analyses. The matrix contained 100 species collected from the nineteen streams (Appendix B). These ranged from 15 in Oak Creek (3G.55) to 57 in the Upper Muddy Boggy River (3H2.1). Total individuals per stream ranged from 820 in Oak Creek (3G.55) to 20,771 in Mill Creek (3G.6). Sampling methods were predominately by seine but also included electrofishing, traps, gill nets, chemicals and sportfishing. This produced a total of 93,183 fish or 4,904 fish per stream.

Since the collection criteria and methodology varied immensely in the data set, it would be very difficult to perform comparative

Table 18. Stream fish collection summary used for evaluation of ecoregion designation.

CNI WATERSHED	STREAM NAME	ECOREGION	COLLECTOR	YEAR	METHODS
1R.46	Otter Creek	Prairie	Harrel	1965	Seine
1S.22	Big Creek	Cross Timbers	Finnel	1952	Various
1S3.1	Bird Creek	Cross Timbers	OWRB	1983	Seine/ Electro.
1V7.1	Little River	Cross Timbers	Wade	1963	Various
1V9.16	N. Canadian River	Prairie	OWRB	1983	Seine/ Electro.
1W.5	Fourche Maline Cr.	Upland	Pigg	1977	Seine/ Electro.
1W.9	Brazil Creek	Upland	Pigg	1979	Seine/ Electro.
3.23A	Blue River	Cross Timbers	Pigg	1979/ 1980	Seine
3C.2	West Cache Creek	Prairie	Cook	1977	Seine/ Electro.
3CL.2	East Cache Creek	Prairie	Pigg	1977	Seine/ Electro.
3G.5	Pennington Creek	Cross Timbers	Pigg	1975 1976	Seine/ Electro.
3G.6	Mill Creek	Cross Timbers	Benderim	1975	Various
3G.55	Oak Creek	Prairie	OWRB	1983	Seine
3H1.2	Clear Boggy Creek	Cross Timbers	Pigg	1975	Various
3H2.1	Muddy Boggy Creek	Upland	Pigg	1975	Various
3I.7	Kiamichi River	Upland	Pigg/ Echelle	1972 1973	Seine Electro.
3I.9	Buffalo Creek	Upland	Pigg/ Echelle	1973	Seine
3J.21	Little River	Upland	Pigg	1978	Various

statistics on a stream by stream basis. Additionally, the distribution and variance of the population is unknown, the sample size is small (19 of 380 watersheds), and the complex nature of stream processes precluded most available statistical techniques. As discussed in Chapter VII, many stream indices exist to reduce a complex fish collection to comparative terms. To perform the index calculations all separate collection sites for a particular stream were combined and a single group of indices determined. This enabled large sample sizes and a method of gross comparisons between streams. To further simplify the comparability of the data set, the streams were grouped according to the ecoregion for which they were designated in Chapter XII. The results of these calculations are shown in Table 19. To further aid in comparison the arithmetic mean, the standard deviation and the range are shown in Table 20. It can clearly be seen that variation exists between the ecoregions as designated. Note that only three ecoregions are represented in the fish data set.

Inspection of this summary does not reveal whether statistically significant differences occur in the indices between ecoregions. Several statistical tests have been developed to measure the differences between two means. The most common test is the student's t distribution (Gosset, 1908). However, this test requires that the sample must be drawn from a population with normal distribution. Although moderate departures from this requirement can be tolerated, most researchers feel at least a mound shape population distribution must exist (Daniel, 1976). The author is unwilling to assume a normal distribution exists for any of the biological indices for all streams within an ecoregion, therefore, that test is not applicable.

Table 20. Summary statistics for fish population indices by ecoregion.

ECOREGION	KARR	PIGG	MARGELEF	MENHENICK	SHANNON-WEINER	BRILLOUIN	REDUNDANCY
				<u>Mean</u>			
Prairie	21.8	105.8	2.64	0.43	2.56	2.52	0.428
Cross Timbers	29.7	70.4	4.16	0.59	3.43	3.39	0.336
Upland	31.3	74.3	4.23	0.67	3.11	3.07	0.389
				<u>Standard Deviation</u>			
Prairie	4.82	22.73	0.61	0.15	0.53	0.54	0.124
Cross Timbers	6.95	21.01	0.95	0.36	0.52	0.53	0.102
Upland	5.59	14.22	1.30	0.17	0.48	0.48	0.085
				<u>Range</u>			
Prairie	12	53	1.52	0.37	1.30	1.34	0.277
Cross Timbers	18	61	2.60	0.88	1.55	1.56	0.285
Upland	12	43	3.83	0.50	1.13	1.11	0.207

Table 19. Indices of fish populations for nineteen streams in Oklahoma.

ECOREGION	CNI WATERSHED	KARR	PIGG	MARGELEF	MENHENICK	SHANNON-WEINER	BRILLOUIN	REDUNDANCY
Prairie	1R.46	19	105	2.15	0.24	3.04	3.03	0.297
	3C.2	27	83	3.61	0.44	2.31	2.30	0.543
	3CL.2*	25	85	2.72	0.61	2.81	2.75	0.355
	3G.55	23	120	2.09	0.52	1.74	1.69	0.574
	1V9.16*	15	136	2.61	0.34	2.88	2.85	0.366
Cross Timbers	1S.22	33	66	3.99	0.33	4.36	4.35	0.179
	1V7.1*	17	110	2.85	0.28	3.26	3.25	0.315
	1S3.1	35	57	5.45	1.16	3.54	3.45	0.337
	3.23A	32	75	3.53	0.55	3.67	3.63	0.243
	3G.5	23	82	3.54	0.45	2.81	2.79	0.436
	3G.6	35	54	4.52	0.32	3.44	3.43	0.378
	3H1.2	33	49	5.22	1.03	2.91	2.84	0.464
Upland	1W.5	33	74	4.54	0.76	3.65	3.60	0.306
	1W.9*	31	76	4.47	0.72	3.72	3.68	0.281
	3H2.1	39	46	6.67	0.85	3.42	3.39	0.419
	3I.7	27	89	2.99	0.35	2.59	2.57	0.458
	3I.9	27	72	2.84	0.62	3.01	2.96	0.316
	3J.21*	35	75	4.53	0.59	2.76	2.73	0.488

Statistical tests do exist for data sets from populations with unknown distributions. The non-parametric equivalent of the t-test for equality of means is the Wilcoxen Test for Two Independent Samples (Wilcoxon and Wilcox, 1964). This test is performed by arranging the observations of both groups in question in order of their magnitude and then assigning ranks. Two test statistics are then computed from the sum of the ranks and the number of observations. The null hypothesis for the test is the two means are equal. If either of the two test statistics are less than or equal to the critical value then the null hypothesis can be rejected. Critical values are obtained from standard tables in statistical tests (Sanders, 1980). Comparisons of the means between three ecoregions by this technique are shown in Table 21. The only null hypothesis that can be rejected at the 95% confidence level by this test is in the comparison of the prairie ecoregion with the upland streams. The comparisons of the cross timbers ecoregion with both prairie and upland are not significantly different at the 95% confidence level although the prairie and cross timbers comparison was so close that statistical significance would occur at any lower confidence limit.

Another useful statistical test for significant differences between two or more sets of sample data is by analysis of variance. Sets of data can be compared to see if they can be considered to have the same mean at given levels of significance. The null hypothesis is tested to determine if the ratio of variance due to environmental variation divided by variance due to error is different from unity. An "F" statistic is calculated from the data set using the sum of squares

Table 21. Wilcoxon test for statistical difference of population means.

Prairie	Cross Timbers	Upland
15	15	27
19	23	27
23	32	27
25	33	31
27	33	33
	35	35
	35	39

$H_o = \overline{X}_p = \overline{X}_w$

15	1	12
17	2	11
19	1	10
23	1	9
23	2	8
25	1	7
27	1	6
32	2	5
33	2	4
33	2	3
35	2	2
35	2	1

$R_i = 44$
$R_i' = 5(5+7+1)-44 = 21$
Critical value = 20 @ 95% confidence
H_o not rejected at 95% confidence

$H_o = \overline{X}_p = \overline{X}_u$

39	2	1
35	2	2
33	2	3
31	2	4
27	2	5
27	2	6
27	2	7
27	1	8
25	1	9
23	1	10
19	1	11
15	1	12

$R_i = 50$
$R_i' = 5(13)-50 = 15$
Critical value = 20
H_o rejected

$H_o = \overline{X}_w = \overline{X}_u$

39	2	1
35	2	2
35	1	3
35	1	4
33	2	5
33	1	6
33	1	7
32	1	8
31	2	9
27	2	10
27	2	11
27	2	12
23	1	13
17	1	14

$R_i = 50$ or 55
$R_i' = 7(15)-55 = 50$ or 55
Critical value = 36
H_o not rejected

technique. If the calculated F is larger than the F value taken from standard tables the null hypothesis can be rejected. Table 22 gives the ANOVA table for calculation of the F statistic for the Karr index means in the prairie, cross timbers, and upland ecoregions. Since the calculated F is 4.48 and the tabular F (95% confidence interval and two and eighteen degrees of freedom) is 3.55, the null hypothesis cannot be rejected.

Both statistical tests above fail to show that significant differences (at 95% confidence interval) exist between sample means for the three ecoregions designated when Karr's index is the observation of choice. An inspection of Table 20 indicates this analysis would likely hold for other indices as well.

Community comparison indices have been developed to measure the degree of similarity or dissimilarity between biotic communities (Lomnitz, 1983). Two basic types of comparisons have been developed. Qualitative indices use presence or absence data and are usually only reliable when comparing a variety of organism groups. When data on species abundance are available, quantitative similarity indices can be used. These indices are considered more powerful for community comparisons.

One community comparison index of each of the two major types was chosen for application with the data set. The Dice index (Czekanowski, 1913) was used because it places more emphasis on common attributes and is better at discriminating between dissimilar collections. The formula for the Dice index is:

Table 22. Analysis of variance in Karr index means by ecoregion.

$H_o = M_p = M_w = M_u$

	Prairie	Cross Timbers	Upland
	19	17	33
		35	31
	27	32	39
	25	23	27
	23	35	27
	15	33	35
		33	27
$\overline{X}$	21.8	29.7	31.3
n_i	5	7	7
6 Xij 1	109.0	207.9	219.1
6 (Xij)2/n 1	2,376.2	6,174.6	6,857.8

u 6
(Xij)2/n=15,408.6
p 1

w
(Xij)2/n=15,922
p

u 6
(Xij)2/n=536.0
p 1

u 6
C=[(Xij)]2/n=15,120.8
p 1

w
TSS = Total Sum of Squares = (Xij2/n)-C=15,193.0-14395.7=801.2
p

u 6
GSS = Group Sum of Squares = [(Xij)2/n]-C=14,610.9-14,395.7=287.8
p 1

ESS = Error Sum of Squares = TSS-GSS=801.2-287.8=513.4

Total Degrees of Freedom = N-1=18

Groups Degrees of Freedom = 3-1=2

Error Degrees of Freedom = 18-2=16

Mean squared deviations from the mean =

Groups = 215.2 2=143.9 Error = 32.09

Table 22. Cont.

	SS	df	MS
Total	801.2	18	
Groups	287.8	2	143.9
Error	513.4	16	32.09

F = 143.9 32.09=4.48

$F_{0.05(1),2,17}=3.55$

H_o not rejected since computed F is smaller than tabular F

$$S = \frac{2a}{2a+b+c}$$

where a, b, and c are defined as shown in Figure 15.

The quantitative index chosen was the percentage similarity of community modification of the Bray-Curtiss Similarity Coefficient (Whittaker, 1952). This index is developed by standardizing proportions of the collections and comparing those proportions in a pair-wise manner. The formula for this index is:

$$Sab = \min(P_{ia}, P_{ib})$$

where P_{ia} and P_{ib} is the relative abundance of species i at station a or b. This results in a percentage expression of similarity between a pair of sites.

In general terms, if this percentage is above 60 the sites are essentially similar. If the index is below 40 the sites are very dissimilar. From 40 to 60 is an area of lesser confidence in stating the similarity or dissimilarity.

Fish data from the nineteen selected streams were entered into the OWRB computer terminal. Programs had previously been developed to calculate both the Dice and Bray-Curtiss indices with biological data. The results of these comparisons are shown in Table 23. The qualitative index shows little variation from region to region. The prairie and cross timbers ecoregions are very similar with a comparison index of 80.31. The cross timbers and upland ecoregions are nearly as similar with a 77.71 comparison index. The most dissimilar (69.57) were the prairie and upland ecoregions.

		COLLECTION A	
		present	absent
COLLECTION B	present	a number of species common to both collections	b number of species present in B but not in A
	absent	c number of species present in A but not in B	d number of spcies not represented in either collection

Figure 15. Definition of variables in the Dice community comparison index.

Table 23. Comparison of ecoregion populations by community comparison techniques.

SITES	SIMILARITY INDEX	%SIMILARITY
A & B	80.31496	48.21012
A & C	69.56522	36.72808
B & C	77.70701	52.86027

The quantitative index exhibited a similar pattern with comparisons of cross timbers with both prairie and upland in the inconclusive range (48.21 and 52.86, respectively). However, the percent of community similarity of prairie with upland was statistically dissimilar (36.73).

It is apparent from the statistical analysis of the fish collection information that trends do exist from the prairie to the cross timbers and then to the upland ecoregions. Most of the indices calculated follow this general trend (Table 20). However, statistical tests fail to show, at the 95% confidence level, that differences exist between the three ecoregions with multiple fish collections. Several explanations are possible for this occurrence. A few of these are:

(1) Inadequate biological variation exists between designated regions to enable quantification of unique regions.

(2) Watershed characteristics vary at a greater magnitude than stream fish communities.

(3) The sample size was inadequate to provide a statistically reliable test.

(4) Variations in fish collection technique have masked actual variation in the fish community.

(5) Ecoregions designated have minor transitions and the woodland ecoregion is actually a transition zone.

Based on an inspection of the data presented in this chapter the most probable conclusion is that insufficient fish data are available to perform an accurate test of ecoregion integrity. Additional fish collections are needed to determine conclusively. The needed collections are beyond the scope of this study. When adequate fish data are available, sufficient statistical tools are available to accurately determine regional differences.

In summary, the evaluation procedure revealed ecoregion trends to support the intuitive evaluations in earlier chapters, but was not successful in the application of stringent statistical tests due to minimal data size. Additional data are needed to conclusively support or reject the ecoregion designations.

CHAPTER XIV

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine if a technique could be developed for assigning aquatic ecoregions to streams in Oklahoma. It was determined that watershed attributes, generally available on a statewide basis, can be used to develop a conceptual framework on which to manage and protect the waters of the state. Broad scale geographic properties were used to define watershed differences which could be spatially represented as regions. These "regions" were then compared with fish collections from a broadly scattered pattern. The resulting analysis tends to support the regions developed by objective multivariate techniques. Statistical validity was evaluated but hampered by the small size of the evaluation data set.

The data matrix produced for this study came from a variety of sources. The time required to produce the basic data was nominal when compared to the geographic scale. This matrix is on file at the Oklahoma State University computer. Further data improvements will increase the accuracy of the regions designated.

Multivariate statistical procedures can be very helpful in organizing and summarizing large data sets of continual nature. These procedures are easily available, powerful in illuminating the tendencies in the data, objective and easily misinterpreted. They should be used much more often in the management of natural resources but always with caution. The use of cluster analysis to group the data to produce major clusters followed by discriminant analysis to test the resulting classification produces useful and objective groups from a large data set.

Policy Implications

The results of this study can have important and long lasting impact on the management of Oklahoma's water resources. If accepted through the rule making process of the state the following benefits could result:

(1) high quality waters of the upland and mountain ecoregions could be protected by the application of stringent criteria established to protect the numerous sensitive aquatic organisms found in many of the cool clear streams of these regions.

(2) The waters of the plains and prairie ecoregions could be protected to their highest level by the establishment of criteria which are not violated on a routine basis by natural conditions in their watersheds.

(3) The diversity of the waters in the cross timbers ecoregion could be recognized and criteria established to protect the desired waters from adverse conditions created by man's activities.

(4) Municipal wastewater treatment facilities could be designed to protect receiving streams to a more precise level and not be penalized or rewarded by the town's location within the state.

(5) Industrial dischargers could plan for waste treatment technology and plant expansion on an informed basis to protect the state's water, yet continue to operate.

(6) Nonpoint source pollution programs could be improved by the ability to recognize and separate natural and man-induced impacts on streams.

However, these potential gains in water quality management can only be achieved by completing the remaining steps in the establishment of aquatic ecoregions. The following recommendations are provided to aid in completing the required steps:

(1) The map produced (and attendent CNI classifications) should be used as a first step in establishing aquatic ecoregions for use in the management and protection of Oklahoma waters.

(2) An effort is needed to adjust the CNI watershed boundaries to more closely correlate to natural watershed boundaries.

(3) Certain portions of the data set need to be improved to increase the reliability of the classification process. They are:

   (a) Slope factor - a more detailed study of much greater magnitude or an innovative technical alternative is needed, although the statewide scale must be maintained.

(b) Vegetation factor - detailed field measurements are needed on "natural" plots to determine their relative impact on the quality of downstream waters.

(c) Soil factor - more detailed soil maps are available for most of the state. Their use presented technical and economic problems which extended beyond the scope of this study.

(d) Land use - several errors were discovered in the data set. Inspection of the data should solve most of these discrepancies.

(e) Biotic collections need to be made at representative streams in each region. These need to be "unimpacted" and will provide a target for water quality programs in the future.

(f) Field evaluation of the transitional watersheds to evaluate the data set used in this study is needed to support assignment of the watersheds into an ecoregion.

(4) Additional data should be collected for other watershed varibles. These should be tested and the ecoregions modified as desired.

(5) Additional multivariate analyses may improve our understanding of watersheds and their characteristics. Regression analysis, factor analysis, canonical discriminant analysis and further cluster analysis would be useful.

(6) Evaluation of additional data sets may be needed for the 95 watersheds designated as transitional. This will enable a

final placement into an ecoregion and the application of appropriate criteria for protection.

(7) Detailed studies of physical, chemical, and biological properties of each ecoregion are needed to provide the water quality standards setting process with adequate data to establish protective criteria for each ecoregion. The stream sites selected must be as "unimpacted" by man's activities as possible.

This project is felt to be a significant step in the effort to improve the waters of Oklahoma. Since it serves to provide technical support to Oklahoma's Water Quality Standards setting process it can be an important step. The author feels the project did provide insight into the variation of the waters of Oklahoma. However, many additional watershed characteristics could, and should be used to improve this classification. The purposes of this project have been met by the production of an objective, reasonable and economical grouping of Oklahoma's water for use in the protection and management for future generations.

BIBLIOGRAPHY

Anderson, J. R., E. E. Hardy and J. T. Roach, "A Land-Use Classification System for Use with Remote Sensor Data," USGS Cir. 671, 1972, Remote Sensing Committee of the Assoc. of Amer. Geog.

Anderson, J. R., E. E. Hardy, J. T. Roach and R. E. Witmer, "A Land-Use and Land Cover Classification System for Use with Remote Sensor Data," USGS Prof. Paper 964, 1976.

Atwood, W. W., "The Physiographic Provinces of North America," Boston, Given and Co., 1940.

Bailey, R. G., R. D. Pfister and J. A. Henderson, "Nature of Land and Resource Classification - A Review," Journ. of Forestry, Vol. 76, 1978, pp. 650-655.

Bailey, R. G., "Ecoregions of the U.S.," Map 1:7,500,000, USDA Forest Service, Intermoun. Reg. Ogden, UT, 1976.

Bailey, R. G., "Description of the Ecoregions of the U.S.," USDA Forest Service, Intermoun. Reg. Ogden, UT, 1978.

Bailey, R. G., "Ecoregions of the U.S. After the Classification of J. M. Crowley," USGS Nat'l Mapping Div., 1981.

Beck, W. M., Jr., "Suggested Methods for Reporting Biotic Data," Sewage Ind. Wastes. Vol. 27, 1955, p. 78.

Beckinsale, R. P., "River Regimes," Introduction to Physical Hydrology, R. J. Chorley, ed., Methven and Co., London, 1971, pp. 176-192.

Benderim, G. E., "Fishes of Mill Creek, A Tributary of the Washita River, Johnson and Murray Counties, Oklahoma," Proc. Okla. Acad. Sci., Vol. 57, 1977, p. 114.

Blair, W. F. and T. H. Hubbell, "The Biotic Districts of Oklahoma," Amer. Midl. Nat., Vol. 20, No. 2, 1938, pp. 425-454.

Blashfield, R. K. and M. S. Aldenderfer, "The Literature on Cluster Analysis," Multivariate Behavioral Research, Vol. 13, 1978, pp. 271-295.

Brillouin, L., Science and Information Theory, 2nd ed., Academic Press Inc. NY, 1960.

Brown, R. M., N. I. McClelland, R. A. Deininger and R. G. Tozer, "A Water Quality Index - Do We Dare?" Water Sewage Works, 1970, pp. 339-343.

Bruner, W. E., "The Vegetation of Oklahoma," Ecol. Monog., Vol. 1, 1931, pp. 99-188.

Burton, T. M. and R. R. Turner, "The Effects of Land Use on Stormwater Quality and Nutrient and Suspended Solids Exports from Three North Florida Watersheds," Proc. Stormwater Management Workshop, Florida Technological University, Orlando, FL, 1975.

Cairns, J., Jr., "Indicator Species vs. the Concept of Community Structure as an Index of Pollution," Water Resources Bull. Vol. 10, 1974, pp. 338-347.

Cairns, J., Jr., "Biological Integrity - A Quantitative Determination," The Integrity of Water (R. K. Ballentine and L. J. Guarraia, editors), 055-001-01068-1, 1975, U.S. Govt. Printing Office, Wash. D.C.

Cairns, J., Jr. and K. L. Dickson, "A Simple Method for the Biological Assessment of the Effects of Waste Discharges on Aquatic Bottom-Dwelling Organisms," Jour. Water Poll. Control Fed., Vol. 43, 1971, p. 755.

Carpenter, J. R., "The Grassland Biome.," Ecol. Monog., Vol. 10, 1940, pp. 617-684.

Cook, K. D., "Fish Population Study of West Cache Creek with Emphasis on Search for the Wichita Spotted Bass, Micropterus punctulatus Wichitae," Proc. Okla. Acad. Sci., Vol. 59, 1979, p. 13.

Cooley, W. W. and Lohnes, P. R., Multivariate Data Analysis, Wiley and Son, Inc., New York, 1971, pp. 1-364.

Cooper, Charles F., Ecosystem Concept in Natural Resource Management, George M. VanDyne (Editor), Academic Press, New York, 1969, pp. 309-324.

Corliss, J. C. and R. D. Pfister., "ECOCLASS - A Method for Classifying Ecosystems," 1973, USDA Forest Service, For. Sci. Lab., Missoula, Mont.

Council on Environmental Quality, Fourth Annual Report to the President, 1973, Govt. Print. Off., Wash. D.C.

Council on Environmental Quality, Environmental Quality: The Fifth Annual Report, 1974, Govt. Printing Office, Wash., D.C.

Cowardin, Lewis M., "Wetland Classification in the United States," Journ. of Forestry, Vol. 76, 1978, pp. 666-668.

Crockett, J. D., Personal communication, Oklahoma State University, June 15, 1984.

Crowley, J. M., "Biogeography," Canadian Geog. Vol. 11, 1967, pp. 312-326.

Cushing, C. E., C. D. McIntire, J. R. Sedell, K. W. Cummins, G. W. Minshall, R. C. Peterson and R. L. Vannote, "Comparative Study of Physical-Chemical Variables of Streams Using Multi-variate Analysis," Arch. Hydrobiol., Vol. 89, 1980, pp. 343-352.

Czekanowski, J., "Zarys Method Statystycznych," Die Grundzuge der Statischen Metoden, Warsaw, 1913.

Daniel, W. W., Biostatistics:A Foundation for Analysis in the Health Sciences. 2nd ed., John Wiley and Sons, NY, 1976, p. 502.

Daubenmire, R., "Climate as a Determinant of Vegetation Distribution in Eastern Washington and Northern Idaho," Ecol. Monog., Vol. 20, 1956, pp. 131-154.

Davis, L. S. and J. H. Henderson, "ECOSYM - A Classification and Information System for Management of Wildland Ecosystems," Utah State Univ., 1976, Logan, Utah.

Dice, L. R., The Biotic Provinces of North America, Univ. of Mich. Press, Ann Arbor, 1943.

Dickinson, R. E., Germany, 2nd ed., 1964, Methuen.

Duck, L. G. and J. B. Fletcher, "A Game Type Map of Oklahoma," 1943, Division of Wildlife Restoration, Oklahoma Game and Fish Department, Oklahoma City, Okla.

Dudnik, E. E., "SYMAP - User's Reference Manual for Synagraphic Computer Mapping," Rep. NO. 71-1, 1971, Univ. of Ill. at Chicago Circle, Chicago, Ill.

Dunnette, David A., "Water Quality Index Development and Application for the Willamette Basin, Oregan," Unpublished report, 1976, Dept. of Env. Qual., Portland, Oregon.

Echelle, A. A. and G. D. Schnell, "Factor Analysis of Species Associations Among Fishes of the Kiamichi River, Oklahoma," Trans. Amer. Fish Soc., Vol. 105, No. 1, 1976, pp. 17-31.

Felley, J. D. and L. G. Hill, "Multivariate Assessment of Environmental Preferences of Cyprinid Fishes of the Illinois River, Oklahoma," Amer. Midl. Naturalist, Vol. 109, No. 2, 1983, pp. 209-221.

Fenneman, N. M., "Physiographic Divisions of the U.S." Annals Assoc. of Amer. Geog., Vol. 18, 1928, pp. 61-353.

Frayer, W. E., L. S. Davis and P. G. Risser, "Uses of Land Classification," Journ. of Forestry, Vol. 76, 1978, pp. 647-649.

Gauch, Hugh G., Multivariate Analysis of Community Ecology, 1982.

Gammon, J. R., "The Fish Populations of the Middle 340 km of the Wabash River," Technical Report No. 86, 1976, Purdue Univ. Water Resources Research Center, West Fayette, IN.

Giese, John, Jr., Personal Communication, Jan., 1984.

Gosset, W. S., "The Probable Error of a Mean," Biometrika, Vol. 6, 1908, pp. 1-25.

Gower, J. C., "A Comparison of Some Methods of Cluster Analysis," Biometrics, Vol. 23, 1967, pp. 623-637.

Hagmeier, E. M., and C. S. Stults, "A Numerical Analysis of the Distribution Patterns of North American Mammals," Systematic Zool., Vol. 13, 1964, pp. 125-155.

Hammond, E. H., "Classes of Land Surface Form in the 48 States," Annals Assoc. Amer. Geog., Vol. 54, 1963, Map. Supp. No. 4. 1:500,000.

Harkins, Ralph D., "An Objective Water Quality Index," J. Water Poll. Cont. Fed., Vol. 46, No. 3, 1974, pp. 558-591.

Harms, L. L., J. N. Dornbush and J. R. Anderson, "Physical and Chemical Quality of Agricultural Land Runoff," J. Water Poll. Cont. Fed., Vol. 46, 1974, p. 2460.

Harrel, R. C., D. J. Davis and T. C. Dorris, "Stream Order and Species Diversity of Fishes in an Intermittent Oklahoma Stream," Amer. Midl. Nat., Vol. 72, No. 2, 1967, pp. 428-436.

Hart, J. F., "The Highest Form of Geographical Art," Annals of Assoc. of Amer. Geog., Vol. 72, 1981, pp. 1-30.

Herbertson, A. J., "The Major Natural Regions," Geographical Journal Vol. 25, 1905.

Hills, A. G., "An Integrated Iterative Holistic Approach to Ecosystem Classification," Proc. of the First Meeting, Canadian Committee on Ecological (Biophysical) Land Classification, Petawawa, Ontario, Canada, 1976.

Hocutt, C. H., R. L. Kaesler, M. T. Masnik, and J. Cairns, Jr., "Biological Assessment of Water Quality in a Large River System:An Evaluation of a Method for Fishes," Arch. Hydrobiol., Vol. 74, No. 4, 1974, pp. 448-462.

Horton, R. E., "Erosional Development of Streams and Their Drainage Basins:Hydrophysical Approach to Quantitative Morphology," Bull. Geol. Soc. Amer., Vol. 56, 1945, pp. 275-370.

Huet, M., "Profiles and Biology of Western European Streams as Related to Fish Management," Trans. Amer. Fish. Soc., Vol. 88, No. 1, 1959, pp. 155-163.

Hughes, R. M., J. H. Gakstatter, M. A. Shirazi and J. M. Omerinik, "An Approach for Determining Biological Integrity in Flowing Waters," In Place Resource Inventories:Principles and Practices. A National Workshop, Univ. of Me., 1981.

Hughes, R. M. and J. M. Omerinik, "A Proposed Approach to Determine Regional Patterns in Aquatic Ecosystems," Symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information, Portland, Oregon, 1981.

Hughes, R. M. and J. M. Omerinik, "An Alternative for Characterizing Stream Size," From:"Dynamics of Lotic Ecosystems", Ann Arbor Science Press, 1983.

Huntzinger, T. L., "Low-Flow Characteristics of Oklahoma Streams," USGS, Open-File Report 78-166 pp.93. 1978.

Hynes, H. B. N., The Ecology of Running Waters, Liverpool Univ. Press, 1970.

Inhaber, Herbert, Environmental Indices, John Wiley and Sons publ., New York, N.Y., 1976, p. 178.

James, Preston E., "Toward a Further Understanding of the Regional Concept," Annals Assoc. Amer. Geog., Vol. 42, 1952, pp.195-222.

Jenkins, R. M. and J. C. Finnell, "The Fishery Resources of the Verdigris River in Oklahoma," Report No:59, 1957, Okla. Fish. Res. Lab., Norman, Okla.

Joerg, W. L. G., "The Subdivision of North America into Natural Regions:A Preliminary Inquiry," Annals of Assoc. Amer. Geog., Vol. 4, 1914, pp. 55-83.

Johnson, F. L., and P. G. Risser, "A Quantitative Comparison Between an Oak Forest and an Oak Savannah in Central Oklahoma," Southwestern Nat., Vol. 20, NO. 1, 1975, pp. 75-84.

Karr, J. R., "Assessment of Biotic Integrity Using Fish Communities," Fisheries, Vol. 6, No. 6, 1981, pp. 21-27.

Kelting, R. W., "Effects of Moderate Grazing on the Composition and Plant Production of a Native Tall-Grass Prairie in Central Oklahoma," Proc. Okla. Acad. Sci., Vol. 34, 1954, pp. 126-135.

Kelting, R. W. and W. T. Penfound, "Literature on the Vegetation of Oklahoma," Proc. Okla. Acad. Sci., Vol. 34, 1953, pp. 126-135.

Kikkawa, J., and K. Pearse, "Geographical Distribution of Land Birds in Australia - A Numerical Analysis," Aust. J. Zool., Vol. 17, 1969, pp. 821-840.

Koppen, W., Gundris des Klimakunde, Walter de Gruyter Co., Berlin, Germany, 1931.

Krajina, V. J., "Biogeoclimatic Zones and Classification of British Columbia," Ecology of Western North America, V. J. Krajina, ed. Vancouver, Univ. British Columbia, 1965, pp. 1-17.

Kuchler, A. W., "Potential Natural Vegetation of the Conterminous United States," Amer Geog. Soc., Spec. Pub. 36, 1964, New York.

Kuchler, A. W., Vegetation Mapping, New York, 1967.

Kuehne, R. A., "A Classification of Streams:Illustrated by Fish Distribution in Eastern Kent County," Ecology, Vol. 43, No. 4, 1962, pp. 608-614.

Lambou, V. W., C. R. Gasaway, M. G. Bross, and A. Ming, "Oklahoma Fishing Waters - A Preliminary Inventory," Bull. No. 2, 1965, Okla. Fish Res. Lab., Norman, Okla.

Langbein, W. B., et al., "Topographic Characteristics of Drainage Basins," USGS Water Supply Paper 968-C, 1947, p. 157.

Linsley, R. K., Jr., M. A. Kohler, and J. L. H. Paulhus, Hydrology for Engineers, McGraw-Hill, New York, 1958.

Lobeck, A. K., Geomorphology, McGraw-Hill, NY, 1939.

Lomnitz, Elliot, "Technical Support Manual:Waterbody Surveys and Assessments for Conducting Use Attainability Analyses, 1983, U.S.EPA manual.

Lotspeich, F. B. and William S. Platts, "An Integrated Land-Aquatic Classification System," N. Amer. Journ. Fish. Mgmt., Vol. 2, 1982, pp. 138-149.

Lotspeich, F. B., "Watersheds as a Basic Ecosystem," Water Resources Bull., Vol. 16, 1980, pp. 581-586.

Mello, J. F., and M. A. Buzas, "An Application of Cluster Analysis as a Method of Determining Biofacies," J. Paleontol., Vol. 42, 1968, pp. 747-748.

Miller, J. M. and H. W. Robison, Fishes of Oklahoma, OSU Press, 1973.

Minshull, Roger M., Regional Geography:Theory and Practice, London, 1967.

Mize, L. O., "Statistical Summaries of Streamflow Records, Oklahoma Through 1974," 1975, USGS Open-file Report.

Moeller, J. R., G. W. Minshull, R. W. Cummins, R. C. Peterson, C. E. Cushing, J. R. Sedell, R. A. Larson and R. L. Vannote, "Transport of Diss. Org. Carbon in Streams of Differing Physiographic Characteristics," Organ. Geoshem., Vol. 1, 1979, pp. 139-150.

Morrison, J., "Environmental Impact of Land Use on Water Quality," Final Report on the Black Creek Project Phase II, 1981, U.S.EPA, Chicago, Il.

Nice, M. M. and L. B. Nice, The Birds of Oklahoma, New series No. 20, 1924, University of Oklahoma Bulletin.

Odum, H. T., J. E. Cantlon, and L. S. Kornicker, "An Organization Hierarchy Postulate for the Interpretation of Species-Individual Distributions, Species Entropy, Ecosystem Evaluation, and the Meaning of a Species Variety Index," Ecology, Vol. 41, 1960, pp. 395-399.

Oklahoma Conservation Commission, "Nonpoint Source Loadings Forecast Methodology," Statewide 208 report, 1978.

Oklahoma State Department of Health, "Oklahoma Surface Water Quality Report - Water Years 1978-83," 1984.

Oklahoma Water Resources Board, "Oklahoma Comprehensive Water Plan," OWRB publ. No. 94, 1980, Oklahoma City, Oklahoma.

Omernik, J. M., M. A. Shirazi and R. M. Hughes, "A Synoptic Approach for Regionalizing Aquatic Ecosystems," Inplace Resource Inventories - Principles and Practices. A Nat'l Workshop. Univ. of Me., 1981.

Ott, W. R., "Environmental Indices:Theory and Practice," Ann Arbor Science Press, Ann Arbor, 1978.

Pennak, R. W., "Toward a Classification of Lotic Habitats," Hydrobiologia, Vol. 38, No. 2, 1971, pp. 321-334.

Pettyjohn, W. A., H. White and S. Dunn, Water Atlas of Oklahoma, Publ. of Univ. Cent. for Water Res., 1983, Okla. State Univ., Stillwater, Okla.

Pflieger, W., Fishes of Missouri, Mo. Dept. of Nat. Res., 1975.

Pflieger, W. L., M. A. Schene, Jr., and P. S. Haverland, "Techniques for the Classification of Stream Habitats with Examples of Their Application in Defining the Stream Habitats of Missouri. In:Acquisition and Utilization of Aquatic Habitat Inventory Information, Amer. Fish. Soc., Bethesda, MD, 1981.

Pigg, J., L. G. Hill, "Fishes of the Kiamichi River, Oklahoma," Proc. Okla. Acad. Sci., Vol. 54, 1974, pp. 121-130.

Pigg, J., "A Survey of the Fishes of the Muddy Boggy River in South Central Oklahoma," Proc. Okla. Acad. Sci., Vol. 57, 1977, pp. 68-82.

Pigg, J., Personal communication, June 1984.

Pimentel, R. A., Morphometrics, Kendall-Hunt Publ. Co., 1979.

Platt, Robt. S., "A Review of Regional Geography," Annals of Assoc. Amer. Geog., Vol. 47, 1957, pp. 187-190.

Platts, W. S., "Geomorphic and Aquatic Conditions Influencing Salmoids and Stream Classification - With Application to Ecosystem Classification," Intermoun. Forest and Range Exper. Sta., USDA Forest Service, Boise, 1974.

Platts, W. S., "A Plea for Fishery Habitat Classification," Fisheries, Vol. 5, No. 1, 1980, pp. 2-6.

Ray, R. R., "A Phytosociological Analysis of the Tall-Grass Prairie in Northeastern Oklahoma," Ecol., Vol. 40, 1959, pp. 255-261.

Rice, E. L., "Phytosociological Analysis of a Tall Grass Prairie in Marshall County, Oklahoma," Ecol., Vol. 33, No. 1, 1952, pp. 112-116.

Rice, E. L. and W. T. Penfound, "The Upland Forests of Oklahoma," Ecol., Vol. 40, No. 4, 1959, pp. 593-608.

SAS Institute, Inc., SAS User's Guide:Statistics, 1982 Edition, SAS Institute, Cary, 1982.

Sanders, T. G., Principles of Network Design for Water Quality Monitoring, Colorado State University, Ft. Collins, 1980.

Shannon, C. E. and W. Weaver, The Mathematical Theory of Communication, Univ. of Ill. Press, Urbana, 1963.

Sheldon, A. L., "Species Diversity and Longitudinal Succession in Stream Fishes," Ecology, Vol. 49, No. 2, 1968, pp. 193-198.

Smith, C. C., "Biotic and Physiographic Succession on Abandoned Eroded Farmlands," Ecol. Monog., Vol. 10, 1940, pp. 421-484.

Snider, L. C., "Geography of Oklahoma," Okla. Geol. Surv., Bull., Vol. 27, 1917, pp. 23-325.

Sokal, R. R. and C. D. Michener, "A Statistical Method for Evaluating Systematic Relationships," Univ. Kansas Sci. Bull., Vol. 38, 1958, pp. 1409-1438.

Sokal, R. R. and P. H. A. Sneath, Principles of Numerical Taxonomy, W. H. Freeman, San Francisco, 1973.

Stevenson, M. M., G. D. Schnell and R. Black, "Factor Analysis of Fish Distribution Patterns in Western and Central Oklahoma," Syst. Zool., Vol. 23, 1974, pp. 202-218.

Stoddert, D. R., "Geography and the Ecological Approach - The Ecosystems as a Geographical Principle and Method," Geography, Vol. 50, 1965, pp. 242-251.

Strahler, A. N., "Quantitative Analysis of Watershed Geomorphology," Trans. Amer. Geophys. Union, Vol. 38, 1957, pp. 913-920.

Sutton, G. M., Fifty Common Birds of Oklahoma, University of Oklahoma Press, 1977.

Terrell, J. W., et al., "Habitat Suitability Index Models," FWS/OBS-82/10.A, 1982, U.S. Fish and Wildlife Service, Ft. Collins, CO.

Trautman, M. G., The Fishes of Ohio, Ohio State Univ. Press, 1981.

U.S. Department of Agriculture, "National Inventory of Soil and Water Conservation Needs," Statistical Bull. 461, 1967, Conservation Needs Inventory Committee, 1971.

U.S. Department of Agriculture, Soil Conservation Service, Estimating Soil Loss Resulting from Water and Wind Erosion, Soil Conservation Service Stillwater, Oklahoma, Undated.

U.S. Environmental Protection Agency, "Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants," EPA-430/9-73-014, 1973, Govt. Printing Office, Wash. D.C.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell and C. E. Cushing, "The River Continuum Concept," Can. Journ. of Fish. and Aquatic Sciences, Vol. 37, 1980, pp. 130-137.

Vidal de la Blache, P., Principles of Human Geography, DeMartonne, E. ed., New York, NY, 1926.

Wanielista, M. P., Y. A. Yousef and N. M. McLellon, "Nonpoint Source Effects on Water Quality," J. Water Pol. Cont. Fed., 1977, pp. 441-451.

Ward, J. H., Jr., "Hierarchical Grouping to Optimize an Objective Function," Amer. Stat. Assoc. Journ., Vol. 58, 1963, pp. 236-244.

Warren, C. E., "Toward Classification and Rationale for Watershed Protection," EPA-600/3-79-059, 1979, U.S. EPA Corvallis, Ore.

Water Resources Council, "The Nation's Water Resources - A First National Assessment of the Water Resources Council," Parts 1-7, 1968, U.S. Govt. Print. Off., Wash., D.C.

Webb, R. G., Reptiles of Oklahoma, Univ. of Okla. Press, 1970.

Wertz, W. A. and J. F. Arnold, "Land Systems Inventory," 1972, USDA For. Serv., Intermountain Region, Ogden, Utah.

Whittaker, R. H., "A Study of Summer Foliage Insect Communities in the Great Smoky Mountains," Ecological Monographs, Vol. 22, 1952, p. 6.

Whittlesey, Derwent, "The Regional Concept and the Regional Method," American Geography:Inventory and Prospect, Syracuse Univ. Press, Syracuse, NY, 1954.

Wiener, N., Cybernetics, John Wiley and Sons, Inc., N.Y., 1948.

Wilcoxon, F. and R. Wilcox, Some Rapid Approximate Statistical Procedures, Lederle Laboratories, 1964.

Wilson, A. G., Geography and the Environment:Systems Analytical Methods, J. Wiley and Sons, N.Y., 1981.

Witmer, Richard E., "U.S. Geological Survey Land-Use and Land-Cover Classification System," Journ. of Forestry, Vol. 76, 1978, pp. 661-668.

Woodin, H. E. and A. L. Lindsey, "Juniper-Pinyon East of the Continental Divide, as Analyzed by the Line-Strip Method," Ecol., Vol. 35, No. 4, 1954, pp. 473-489.

Appendix A. CNI watershed variables used in cluster analysis.

15.51 TUESDAY, JULY 17, 1984 1

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
1	1.105	38.79	24825	75.8	0.0	12.1	11.3	0.8	31.5	1.50	30.00	292
2	1.106	142.26	91045	10.4	7.3	9.3	66.5	6.6	32.0	1.50	30.50	304
3	1.107	299.48	191667	37.6	8.8	39.5	0.0	14.1	33.6	1.50	32.10	345
4	1.108	206.83	132371	34.4	0.1	10.6	39.3	15.6	31.7	1.50	30.20	234
5	1.109	394.87	252715	31.8	7.0	25.6	24.9	10.7	31.6	1.81	29.79	287
6	1.110	307.48	196786	25.9	1.1	1.1	71.9	0.0	30.8	1.50	29.30	224
7	1.111	182.16	116582	45.2	2.9	3.8	45.7	2.4	31.5	2.47	29.03	163
8	1.112	377.41	241541	23.6	1.8	4.5	63.8	6.2	31.1	3.21	27.89	164
9	1.113	44.00	28159	24.8	1.0	27.8	45.2	1.2	31.0	4.32	26.68	500
10	1.114	246.36	157673	23.6	1.9	11.0	61.4	2.0	32.1	3.57	28.53	228
11	1.115	324.68	207795	7.3	21.5	15.8	41.2	14.3	35.7	3.16	32.54	249
12	1.116	195.16	124901	6.6	42.4	22.8	11.8	16.3	37.7	6.56	31.14	288
13	1.117	368.35	235743	5.2	52.4	25.3	10.9	6.2	36.7	4.75	31.95	182
14	1.118	5.92	3788	6.9	2.5	3.3	5.7	1.6	37.5	5.17	32.33	537
15	1.119	38.86	24870	23.0	0.8	41.8	8.1	26.3	38.3	6.86	31.44	250
16	1.120	181.91	116421	11.4	25.1	36.8	24.8	1.8	38.0	4.84	33.16	484
17	1.121	117.15	74976	40.5	4.0	46.3	0.1	9.1	38.7	7.97	30.73	144
18	1.122	15.94	10200	45.7	5.4	40.6	0.0	8.4	37.5	6.50	31.00	529
19	1.123	76.35	48863	21.3	26.2	41.3	4.9	6.3	38.4	6.28	32.12	360
20	1.124	42.42	27148	30.9	2.8	48.4	17.4	0.5	39.2	6.60	32.60	451
21	1.125	158.99	101753	21.1	2.5	26.6	49.1	0.6	39.6	7.23	32.37	318
22	1.126	100.05	64032	14.9	6.7	32.2	32.6	13.5	41.1	9.17	31.93	365
23	1.127	58.30	37312	4.4	5.1	6.3	48.0	36.2	41.5	9.50	32.00	234
24	1.128	92.28	59058	13.1	31.3	44.5	7.6	3.6	42.2	10.50	31.70	652
25	1.129	173.90	111294	6.6	45.0	18.9	22.1	7.3	42.8	10.04	32.76	466
26	1.130	51.70	33088	4.0	14.4	50.2	23.8	7.7	42.4	9.17	33.23	681
27	1.131	235.67	150828	8.8	12.9	56.7	19.5	2.1	41.3	8.11	33.19	305
28	1.132	41.27	26412	1.9	10.0	63.9	21.6	2.6	42.7	7.33	35.37	396
29	1.133	115.56	73958	6.4	49.1	31.5	1.0	12.0	43.5	10.66	32.84	613
30	1.134	65.01	41606	0.4	28.0	48.2	0.7	22.7	43.8	7.38	36.42	298
31	1.135A	77.89	49849	0.0	23.5	49.2	2.2	25.0	44.0	8.80	35.20	636
32	1.135	340.78	218097	0.1	60.8	7.1	3.0	29.0	44.3	8.40	35.90	597
33	1.136	285.05	182432	0.2	46.4	45.4	0.7	7.2	44.5	12.24	32.26	699
34	1.137	19.60	12544	74.3	11.3	1.9	3.5	9.0	44.5	12.50	32.00	1022
35	1.138	119.01	76166	17.5	19.0	40.8	11.6	10.9	44.7	11.96	32.74	264
36	1.139	181.99	116473	10.8	28.5	51.7	0.7	8.2	43.1	12.50	30.60	861
37	1.140	32.65	20896	29.2	32.1	27.7	0.0	11.0	41.5	12.50	29.00	1233
38	1.141	118.19	75640	0.7	78.1	18.3	0.2	2.6	44.5	12.50	32.00	1345
39	1.142	69.29	44344	0.0	74.4	24.7	0.9	0.0	43.8	12.50	31.30	557
40	1Q1.4	77.46	49575	36.9	0.4	2.1	57.3	3.3	26.4	1.50	24.90	82
41	1Q1.5	5.17	3312	73.2	0.0	0.5	24.8	1.4	25.5	1.50	24.00	323
42	1Q1.6	93.10	59584	36.9	0.4	2.1	57.3	3.3	25.7	1.50	24.20	126
43	1Q.10	155.35	99423	35.4	0.8	3.4	59.0	1.3	26.5	2.50	24.00	124
44	1Q.11	65.69	42041	39.6	0.0	0.0	60.4	0.0	24.5	1.23	23.27	553
45	1Q.12	51.06	32678	89.5	0.0	1.2	6.7	2.5	25.7	1.50	24.26	296
46	1Q.13	11.70	7488	76.3	0.0	0.2	23.5	0.0	26.5	1.50	25.00	304
47	1Q.14	196.80	125952	64.4	1.2	0.9	18.0	15.6	26.8	1.50	25.30	250
48	1Q.15	29.92	19151	76.5	0.0	0.0	13.8	9.6	27.7	1.50	26.20	301
49	1Q.16	406.40	260095	88.6	0.0	0.4	9.6	1.4	30.2	1.73	28.47	167
50	1Q.17	35.54	22744	60.0	2.8	0.4	36.0	0.8	32.5	2.50	30.00	135
51	1Q.18	41.76	26726	42.4	7.6	17.9	29.2	2.8	32.4	1.74	30.66	237
52	1Q2.5	58.84	37657	72.1	0.0	0.0	27.7	0.2	30.5	2.50	28.00	139
53	1Q2.6	48.22	30861	64.7	2.6	4.7	23.2	4.8	31.0	2.50	28.50	121
54	1Q2.7	65.50	41920	64.7	2.6	4.7	23.2	4.8	31.7	1.75	29.95	104
55	1Q2.8	43.00	27520	64.7	2.6	4.7	23.2	4.8	32.2	2.36	29.84	303
56	1Q2.9	425.81	272520	64.7	2.6	4.7	23.2	4.8	32.5	2.21	30.29	193

Appendix A. Continued.

SAS 15:51 TUESDAY, JULY 17, 1984 2

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
57	1Q.3	313.61	200710	38.3	0.0	0.8	55.6	5.3	31.0	1.24	29.76	330
58	1Q.7	230.15	147296	75.0	0.0	0.8	3.3	0.9	31.7	1.50	30.20	195
59	1Q.8	397.13	254163	76.0	0.0	0.5	22.9	0.7	32.2	2.24	29.96	130
60	1Q.9	108.74	69592	84.0	0.0	0.4	0.0	15.5	32.5	2.50	30.00	169
61	1R.11	74.40	47615	43.8	0.0	0.0	56.2	0.0	16.6	0.25	16.35	288
62	1R.12	69.44	44441	47.7	7.5	0.0	44.8	0.0	18.7	0.15	18.55	375
63	1R.16	199.82	127885	61.8	16.8	0.0	0.0	21.3	20.8	0.23	20.57	317
64	1R.18	156.82	100364	6.7	0.9	0.0	91.6	0.7	24.0	0.34	23.66	267
65	1R.22	141.19	90361	51.4	1.0	0.0	44.1	3.6	23.1	0.34	22.76	576
66	1R.2.3	14.67	9389	56.5	8.9	0.0	22.1	12.5	22.5	0.25	22.25	304
67	1R.23	103.96	66532	4.1	0.0	0.1	89.7	6.1	22.5	0.73	21.77	304
68	1R.24	469.41	300422	2.6	0.3	0.0	96.2	0.9	23.2	0.42	22.78	80
69	1R.25	8.38	5363	0.8	0.0	0.0	9.1	0.0	23.7	1.00	22.70	537
70	1R.26	27.83	17811	42.1	0.0	0.1	57.8	0.0	23.5	0.95	22.55	541
71	1R.27	153.05	97952	20.7	0.0	0.8	78.0	0.6	24.0	1.17	22.83	469
72	1R.28	67.21	43014	28.5	0.7	1.1	67.8	1.9	24.8	1.23	23.57	524
73	1R.29	236.14	151128	16.9	0.0	3.3	77.5	2.3	25.6	1.50	24.10	237
74	1R.30	311.80	199552	27.2	2.0	3.7	65.3	1.8	26.1	1.25	24.85	368
75	1R.31	374.62	239756	60.9	0.0	0.0	39.8	0.2	25.4	1.46	23.94	317
76	1R.32	138.31	88518	64.2	0.0	6.5	28.0	1.3	27.1	1.50	25.60	136
77	1R.33B	31.25	20000	34.5	4.0	37.5	23.8	0.1	29.4	1.76	27.64	147
78	1R.33A	67.59	43257	41.6	8.0	33.8	14.3	2.3	28.6	1.50	27.10	259
79	1R.33	227.07	145325	28.7	7.7	12.3	36.0	15.3	27.6	1.50	26.10	200
80	1R.34	212.34	135897	51.4	1.8	5.9	40.8	0.0	27.5	1.43	26.07	430
81	1R.35	193.22	123660	59.2	0.9	2.8	33.8	3.2	27.6	1.47	26.13	447
82	1R.36	159.40	102015	64.9	3.2	3.0	28.9	0.0	28.9	1.90	27.00	305
83	1R.37	420.88	269365	41.6	1.0	1.5	54.0	1.9	30.1	1.97	28.13	139
84	1R.38	332.38	212723	63.4	0.7	1.8	33.5	0.6	28.3	1.80	26.50	332
85	1R.39	60.47	38700	57.4	5.2	8.0	28.4	1.0	29.6	3.50	26.10	440
86	1R.40	155.60	99583	58.2	0.0	6.1	33.4	2.2	29.5	3.25	26.25	321
87	1R.41	70.64	45209	38.0	0.0	2.1	42.7	17.2	30.5	3.50	27.00	285
88	1R.42	96.43	61715	47.2	2.9	23.2	22.8	3.9	31.1	3.50	27.60	321
89	1R.43	378.86	242470	32.3	0.2	9.0	41.4	17.2	31.0	3.60	27.40	305
90	1R.44	163.97	104940	48.7	0.3	11.8	35.9	3.3	31.5	4.50	27.00	728
91	1R.45	287.55	184031	19.6	0.2	1.2	64.3	14.6	30.7	3.17	27.53	212
92	1R.46	204.40	130817	34.8	1.7	7.9	48.9	6.7	31.6	3.50	28.10	169
93	1R.47	312.60	200066	33.5	7.7	17.6	34.5	6.7	31.4	4.49	26.91	222
94	1R.48	54.85	35104	46.0	0.0	23.3	24.9	5.8	31.5	4.50	27.00	740
95	1R.49	87.36	55910	12.5	0.2	7.4	78.8	1.0	32.5	5.20	27.30	376
96	1R.5	46.20	29568	77.1	0.0	0.0	22.9	0.0	15.5	0.35	15.15	653
97	1R.50	117.14	74968	23.4	0.0	14.2	62.5	0.0	34.1	5.50	28.60	344
98	1R.51	482.24	308632	19.8	3.8	8.1	66.2	2.0	31.2	4.72	26.48	293
99	1R.52	177.16	113382	27.8	2.0	24.2	46.0	0.0	33.0	5.26	27.74	247
100	1R.53	371.69	237880	12.4	19.9	28.9	32.0	6.7	35.5	5.11	30.39	244
101	1R.54	146.10	93505	5.7	14.3	7.4	62.9	9.8	34.9	4.50	30.40	239
102	1R.6	49.83	31891	47.1	2.9	0.0	34.6	15.4	15.5	0.35	15.15	722
103	1R.7	81.33	52051	66.0	0.0	0.0	34.0	0.1	15.5	0.35	15.15	613
104	1R.8	242.56	155238	48.8	0.0	0.1	47.7	3.3	15.8	0.35	15.45	499
105	1R.9	21.16	13541	75.8	0.0	0.0	23.5	0.7	15.9	0.27	15.63	373
106	1S2.6	163.16	104423	11.4	17.7	26.3	33.2	11.4	35.4	7.50	27.90	501
107	1S2.11	47.27	30253	15.3	6.9	30.0	30.0	17.8	37.5	6.81	30.69	617
108	1S2.12	187.31	119879	17.9	8.7	43.8	29.6	0.0	38.1	8.43	29.67	277
109	1S2.10	186.21	119176	17.3	8.2	36.0	23.4	15.1	41.0	2.83	38.17	308
110	1S.21	605.77	387696	11.6	7.6	33.6	44.0	3.2	38.0	5.37	32.63	307
111	1S.22	268.92	172107	10.2	1.3	39.8	39.9	8.8	40.5	7.26	33.24	276
112	1S.23	457.15	292575	9.1	5.1	27.5	43.2	15.0	39.0	8.18	30.82	158

SAS 15:51 TUESDAY, JULY 17, 1984 3

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
113	1S.24	127.83	81811	1.5	17.0	35.3	38.3	7.9	38.2	9.29	28.91	289
114	1S.25	199.01	127365	29.3	3.3	23.3	27.2	16.9	39.4	9.65	29.75	199
115	1S.26	402.87	257835	21.0	25.3	25.3	22.0	6.4	38.3	8.69	29.61	161
116	1S2.7	33.57	21484	3.3	14.2	0.0	56.4	26.1	34.7	1.50	33.20	521
117	1S2.9	192.03	122901	5.4	27.2	16.6	43.2	7.6	35.5	2.17	33.33	328
118	1S3.1	369.09	236217	5.1	6.5	18.3	65.5	4.7	35.6	2.76	32.84	280
119	1S3.2	2.72	1740	3.2	22.3	74.4	0.0	0.1	36.2	4.35	31.85	232
120	1S3.3	239.04	152984	10.3	3.8	9.8	38.0	38.1	38.1	7.95	30.15	239
121	1T.26	0.24	156	15.4	46.2	6.4	32.1	0.0	40.6	7.50	33.10	274
122	1T.28	5.57	3566	32.2	7.5	29.1	31.1	0.1	41.5	8.58	32.92	331
123	1T2.18	43.15	27616	24.6	14.3	32.0	12.8	16.3	41.5	9.50	32.00	379
124	1T.29	141.88	90802	55.0	12.5	6.3	0.4	25.8	41.1	9.50	31.60	199
125	1T.30	402.29	257466	12.9	21.1	44.2	6.3	15.5	42.2	9.50	32.70	274
126	1T.32	94.52	60492	5.9	9.3	45.6	31.8	7.5	42.4	9.50	32.90	423
127	1T.33	66.96	42854	0.6	4.9	55.1	0.8	38.5	43.4	9.29	34.11	434
128	1T.34	54.09	34620	18.8	10.3	51.7	16.5	2.6	41.4	9.45	31.95	183
129	1T.35	312.42	199950	5.4	20.1	61.7	10.0	2.8	41.9	8.72	33.18	177
130	1T.36	335.01	214406	2.5	40.6	40.0	1.4	15.4	43.5	10.19	33.31	389
131	1T.37	107.73	68945	15.0	5.2	57.6	9.7	12.6	40.6	9.43	31.17	125
132	1T.38	78.12	49996	0.0	57.9	41.9	0.0	0.2	42.6	10.05	32.55	557
133	1T.39	350.61	224393	13.7	13.2	50.5	17.6	5.0	39.8	9.11	30.69	219
134	1T.40	227.76	145765	1.5	49.4	48.6	0.5	0.0	42.6	10.27	32.33	405
135	1T.41	215.26	137766	11.3	40.9	28.5	11.2	8.1	40.3	10.01	30.29	247
136	1T.42	260.85	166943	0.5	52.2	40.8	0.1	6.6	42.7	10.50	32.20	451
137	1U.4	76.34	48857	0.0	49.9	48.4	0.0	1.8	45.0	12.25	32.75	629
138	1U.5	56.84	36377	13.2	31.7	46.8	0.0	8.3	44.7	10.50	34.20	607
139	1U.6	170.30	108991	0.8	60.6	35.9	0.1	2.6	44.5	11.63	32.87	461
140	1U.8	256.52	164176	0.1	17.0	82.3	0.0	0.6	44.5	12.50	32.00	682
141	1U.9	170.00	108798	2.6	53.3	16.0	0.3	27.9	43.5	11.82	31.68	569
142	1V.41	324.41	207620	25.2	2.9	0.0	68.4	3.5	21.9	0.30	21.60	576
143	1V.42	289.97	185580	10.5	6.4	0.5	72.5	10.2	22.4	0.31	22.09	517
144	1V.43	297.54	190426	17.8	2.7	0.2	77.4	2.0	23.4	0.48	22.92	456
145	1V.44	211.56	135398	19.8	2.5	0.1	50.5	27.1	24.4	0.58	23.82	377
146	1V.45	44.94	28761	46.4	0.0	0.0	51.2	2.4	24.5	0.37	24.13	589
147	1V.46	255.52	163534	46.0	16.1	0.0	37.8	0.0	24.3	0.87	23.43	336
148	1V.47	224.92	143949	44.1	6.1	7.1	40.9	1.8	26.4	1.50	24.90	286
149	1V.48	544.01	348165	68.2	1.7	2.4	26.6	1.0	26.3	1.37	24.93	252
150	1V.49	238.59	152699	49.3	9.8	13.6	22.4	4.8	29.8	1.74	28.06	123
151	1V.50	13.83	8851	34.9	14.1	10.5	37.9	2.7	28.5	1.50	27.08	819
152	1V.51	175.80	112512	55.7	1.1	11.8	25.0	6.5	29.8	1.70	28.10	214
153	1V.52	336.40	215295	24.1	2.9	26.2	35.2	11.5	33.9	2.96	30.94	148
154	1V.53	181.84	116380	20.6	6.1	19.0	53.5	0.8	33.6	2.70	30.90	262
155	1V.54	394.38	252400	5.1	8.9	7.8	47.8	30.4	38.0	3.85	34.15	207
156	1V.55	219.65	140576	4.7	0.8	40.1	50.0	4.3	38.1	3.77	34.33	334
157	1V.56	125.09	80056	10.8	39.8	26.3	19.4	3.7	41.4	6.62	34.78	248
158	1V.57	147.81	94596	8.1	38.4	23.6	23.4	6.5	40.5	7.17	33.33	269
159	1V.58	212.50	135999	2.2	50.5	20.1	24.6	2.5	41.5	9.98	31.52	313
160	1V.59	186.12	119115	5.6	28.8	48.3	7.8	9.5	41.0	4.45	36.55	398
161	1V7.1	130.75	83680	12.8	13.9	25.9	37.2	10.2	33.5	2.50	31.08	395
162	1V7.2	121.38	77682	1.4	39.6	15.6	16.1	27.2	34.7	2.50	32.20	304
163	1V7.3	337.20	215807	5.0	31.5	25.2	38.2	0.1	36.4	2.68	33.72	176
164	1V7.4	237.50	152000	1.9	20.8	35.0	40.5	1.8	37.5	2.97	34.53	253
165	1V7.5	133.41	85380	3.5	24.3	35.7	28.5	8.0	40.7	5.18	35.52	536
166	1V8.1	162.76	104164	0.5	44.0	6.0	35.4	14.2	42.1	9.06	33.04	403
167	1V8.2	332.67	212912	0.1	54.3	5.8	36.2	3.5	44.1	11.38	32.72	366
168	1V8.3	375.98	240630	0.0	66.0	14.3	14.2	5.5	45.2	12.50	32.70	446

Appendix A. Continued.

SAS 15:51 TUESDAY, JULY 17, 1984 4

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
169	1V8.4	117.47	75181	1.8	49.0	12.3	27.2	9.7	43.2	10.99	32.21	240
170	1V8.5	141.15	90336	0.5	42.5	11.7	26.7	18.7	41.1	11.55	29.55	221
171	1V9.14	24.90	15936	7.2	0.0	0.0	89.6	3.2	22.5	0.35	22.15	605
172	1V9.18	400.62	256396	33.2	6.3	6.8	36.9	16.9	24.8	0.58	24.22	292
173	1V9.19	325.02	208012	33.7	5.2	3.4	15.8	42.0	26.5	1.29	25.21	114
174	1V9.17	441.18	282355	23.6	2.4	1.7	68.1	4.2	23.1	0.72	22.38	358
175	1V9.16	250.07	160045	23.6	2.4	1.7	68.1	4.2	23.5	0.74	22.76	191
176	1V9.15	401.58	257011	18.4	0.1	0.0	76.0	5.5	22.3	0.35	21.95	352
177	1V9.13	302.65	193695	31.6	33.6	0.1	34.5	0.2	21.3	0.27	21.03	181
178	1V9.12	425.68	272435	39.4	58.7	0.0	1.8	0.1	20.4	0.22	20.18	264
179	1V9.11	456.53	292179	38.0	29.9	0.1	15.0	17.0	20.4	0.19	20.21	185
180	1V9.10	320.73	205266	52.9	45.2	0.1	0.9	1.0	19.7	0.15	19.55	339
181	1V9.27	54.00	34560	24.4	6.1	29.5	40.0	0.0	36.7	2.49	34.21	230
182	1V9.26	25.20	16128	23.3	3.9	42.2	26.6	4.0	36.5	2.50	34.03	255
183	1V9.28	240.44	153881	5.7	21.9	36.3	33.2	2.9	37.6	4.28	33.32	246
184	1V9.29	243.47	155819	8.7	21.2	29.8	34.3	6.0	40.0	6.99	33.01	307
185	1V9.25	347.31	222277	24.0	25.4	15.4	32.2	3.1	35.9	2.53	33.37	198
186	1V9.24	54.05	34592	57.4	1.5	5.9	12.5	22.8	32.3	2.79	29.51	190
187	1V9.22	172.80	110592	65.1	2.8	7.7	21.2	3.2	30.4	2.81	27.59	152
188	1V9.23	24.00	15360	63.3	2.0	7.3	9.2	18.2	23.5	3.04	20.46	210
189	1V9.21	41.08	26291	78.8	4.4	3.8	11.4	1.7	29.2	1.50	27.70	233
190	1V9.20	74.40	47615	71.0	7.7	12.3	8.8	0.2	28.4	1.50	26.90	156
191	1V9.31	191.32	122444	18.3	36.1	4.7	38.1	2.7	40.1	6.27	33.83	327
192	1V9.30	269.57	172524	4.4	21.1	36.4	31.3	6.8	39.3	4.42	34.88	200
193	1V9.3	62.67	40108	64.7	0.0	1.0	29.2	5.1	15.5	0.35	15.15	354
194	1V9.4	528.08	337971	49.3	0.0	0.1	50.6	0.0	16.6	0.27	16.33	421
195	1V9.5	422.45	270367	32.3	0.0	0.0	67.5	0.1	16.7	0.23	16.47	336
196	1V9.6	557.39	356729	63.3	0.0	0.0	36.5	0.2	16.8	0.18	16.62	405
197	1V9.7	546.20	349568	83.9	0.0	0.1	15.2	0.7	18.9	0.15	18.75	402
198	1V9.8	145.14	92889	37.3	0.0	5.7	56.4	0.6	18.8	0.15	18.65	346
199	1V9.9	364.36	233190	83.9	0.0	0.1	15.2	0.7	20.4	0.15	20.25	327
200	1V9A.1	249.96	159974	63.3	0.0	0.0	36.5	0.2	18.0	0.15	17.85	384
201	1V9B.1	115.07	73644	11.4	0.0	23.3	56.4	8.9	19.9	0.15	19.75	338
202	1V9C.1	181.37	116076	30.7	2.4	0.1	65.5	1.3	20.8	0.35	20.45	277
203	1V9C.2	344.14	220249	37.6	2.5	0.3	59.3	0.3	21.7	0.39	21.31	268
204	1V9D.1	204.02	130576	6.0	19.1	35.4	28.6	10.9	31.8	3.50	28.30	232
205	1V9D.14	263.84	168860	13.5	22.5	25.0	33.7	5.2	39.5	7.88	31.62	263
206	1V9D.6	62.96	40294	9.0	0.0	25.8	59.5	5.7	35.6	3.00	32.60	463
207	1V9D.5	154.00	98559	11.9	1.0	15.8	68.1	3.2	34.6	2.71	31.89	276
208	1V9D.3	264.89	169529	15.3	1.2	21.4	59.4	2.6	34.2	3.34	30.86	188
209	1V9D.2	35.00	22400	28.6	0.0	8.9	61.0	1.5	36.5	4.40	32.10	357
210	1V9D.13	22.64	14490	8.3	33.1	28.2	27.9	2.5	39.5	5.50	34.00	330
211	1V9D.12	148.90	95296	8.3	33.1	28.2	27.9	2.5	38.5	4.63	33.87	420
212	1V9D.11	253.50	162240	5.0	47.7	21.3	23.3	2.8	36.5	4.64	31.86	237
213	1V9D.10	314.96	201574	3.4	37.1	29.7	29.7	0.0	37.8	4.73	33.07	172
214	1V9D.9	78.32	50124	6.1	45.7	15.0	32.6	0.7	36.1	4.50	31.60	380
215	1V9D.8	114.11	73029	5.7	38.5	24.3	30.5	1.0	36.8	4.80	32.00	325
216	1V9D.7	74.75	47839	6.4	11.3	37.7	39.3	5.3	36.3	3.62	32.68	508
217	1V9D.4	253.09	161976	10.5	6.3	21.3	58.4	3.5	34.7	4.97	29.73	225
218	1W.1	17.70	11328	0.0	45.6	29.7	24.2	0.5	46.1	18.50	27.60	3114
219	1W.10	52.41	33542	0.7	48.4	12.4	34.2	4.2	44.6	12.50	32.10	568
220	1W.11	91.42	58509	19.3	23.5	31.8	19.8	5.7	43.9	12.50	31.40	327
221	1W.2	258.03	165139	1.2	33.1	24.2	21.6	19.8	45.6	14.82	30.78	1167
222	1W.3	134.57	86125	0.0	45.6	29.7	24.2	0.5	48.2	22.32	25.88	2721
223	1W.4	258.03	165139	0.0	84.4	5.6	8.3	1.7	46.3	14.63	31.67	2872
224	1W.5	274.00	175360	0.0	58.2	23.2	1.3	17.2	45.8	12.50	33.30	693

Appendix A. Continued.

SAS 15:51 TUESDAY, JULY 17, 1984 5

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
225	1W.6	74.77	47853	0.0	31.6	64.2	4.2	0.0	45.3	12.50	32.80	3845
226	1W.7	192.74	123354	2.5	5.9	55.3	21.9	14.4	45.4	12.50	32.90	4282
227	1W.8	153.20	98048	0.7	48.4	12.4	34.2	4.2	45.9	13.97	31.93	3858
228	1W.9	237.66	152102	0.5	53.3	30.8	15.4	0.0	45.5	11.29	34.21	1336
229	3.1	291.44	186521	0.0	7.0	15.4	56.4	21.3	26.6	1.72	24.88	251
230	3.10	211.24	135192	48.9	12.3	19.7	14.3	4.8	31.0	2.35	20.65	165
231	3.11	716.02	458252	7.4	26.7	25.1	35.8	4.9	33.4	2.43	30.97	157
232	3.11A	267.68	171318	8.5	5.1	12.3	64.7	9.4	32.2	3.30	28.90	310
233	3.12	18.11	11589	0.1	18.1	65.2	8.9	7.7	34.6	2.87	31.73	249
234	3.13	149.20	95488	9.7	36.4	22.9	27.8	3.2	35.3	1.73	33.57	331
235	3.14	364.78	233460	6.9	21.1	15.8	49.3	6.9	35.9	1.90	34.00	331
236	3.16	397.83	254611	9.5	36.3	13.1	27.8	13.2	37.6	2.31	35.29	278
237	3.22	286.93	183635	35.3	15.8	41.4	2.8	4.6	41.0	7.42	33.58	215
238	3.23	376.64	241050	33.8	39.4	19.4	0.5	6.9	41.1	8.94	32.16	159
239	3.23A	13.28	8499	32.6	14.8	47.4	0.0	5.3	38.7	5.03	33.67	159
240	3.26	103.03	65939	10.2	40.3	42.8	3.1	3.6	43.1	8.67	34.43	338
241	3.3	91.50	58560	46.4	1.4	9.3	28.8	14.1	29.6	2.50	27.10	238
242	3.32	95.04	60825	1.4	20.5	66.1	0.0	11.9	45.9	5.90	40.00	178
243	3.34	56.04	35866	1.8	37.0	42.6	14.5	4.0	47.6	9.83	37.77	264
244	3.35	41.27	26413	13.8	8.2	44.4	27.0	6.6	47.9	10.50	37.40	473
245	3.36	46.21	29574	16.0	6.1	62.7	13.7	1.6	48.2	12.28	35.92	253
246	3.37	38.48	24627	8.7	5.1	65.9	12.8	7.6	48.2	13.00	35.20	337
247	3.39	67.80	43392	29.3	5.5	55.4	0.0	9.7	48.0	13.57	34.43	436
248	3.4	72.51	46406	42.5	1.1	9.0	43.3	4.0	31.0	2.50	28.50	318
249	3.40	89.32	57165	15.8	44.4	39.1	0.0	0.7	48.1	16.34	31.76	177
250	3.41	73.65	47136	11.3	54.0	31.6	0.0	3.0	48.1	18.50	29.60	192
251	3.6	52.11	33350	26.0	3.0	6.4	56.4	8.2	30.5	2.50	28.00	446
252	3A.2	149.39	95609	54.2	0.1	0.1	39.3	6.2	23.1	0.95	22.15	250
253	3A.3	335.56	214758	78.0	0.2	3.2	16.3	2.3	22.8	0.93	21.87	314
254	3A4.1	283.45	181408	47.1	1.3	3.6	43.0	4.9	23.3	0.92	22.38	254
255	3A4.2	306.88	196403	65.5	0.6	1.6	31.9	0.5	23.6	0.95	22.65	364
256	3A4.3	109.43	70035	76.0	2.4	1.6	17.8	2.2	24.4	0.95	23.45	311
257	3A.5	13.21	8454	52.4	0.8	3.7	42.7	0.4	22.5	0.95	21.55	300
258	3A5.10	90.80	58112	33.2	2.5	3.6	45.4	15.3	23.9	0.47	23.43	397
259	3A5.2	350.11	224070	44.4	0.8	9.9	29.1	15.7	25.2	0.95	24.25	326
260	3A5.3	116.74	74712	77.6	0.3	2.9	12.4	6.8	24.9	0.95	23.95	312
261	3A5.4	286.54	183388	54.9	3.3	4.3	35.9	1.7	26.6	0.97	25.63	417
262	3A5.5	265.16	169703	71.0	1.2	1.1	19.3	7.4	24.7	1.01	23.69	240
263	3A5.6	391.04	250266	68.0	1.4	2.0	26.6	2.0	25.2	0.95	24.25	374
264	3A5.7	525.21	336134	43.7	3.9	3.3	41.4	7.6	24.3	0.65	23.65	341
265	3A5.8	65.03	41619	46.8	1.4	1.0	48.7	2.2	24.5	0.63	23.87	427
266	3A5.9	200.64	128410	42.2	3.0	1.0	32.8	20.8	23.9	0.54	23.36	547
267	3A5A.2	306.67	196268	24.6	0.6	1.0	73.3	0.5	23.5	0.79	22.71	347
268	3A5A.1	256.25	164000	45.7	0.7	3.5	49.1	0.9	23.8	0.87	22.93	362
269	3C.1	373.60	239106	37.4	3.4	4.4	46.0	8.8	30.0	2.02	27.98	379
270	3CL.1	208.79	133628	49.3	4.0	6.6	40.0	0.0	29.8	2.03	27.77	363
271	3CL.2	274.23	175508	16.1	12.8	5.2	63.8	2.1	31.4	1.34	30.06	888
272	3CL.3	182.89	117048	48.2	1.3	10.5	38.8	1.2	29.2	2.28	26.92	196
273	3CL.4	73.96	47333	4.8	1.6	16.1	77.4	0.1	27.5	1.50	26.00	249
274	3CL.5	291.70	186688	16.1	12.8	5.2	63.8	2.1	26.9	1.49	25.41	286
275	3C.2	453.97	290543	27.7	7.3	10.1	52.0	2.9	29.9	1.50	28.40	946
276	3E.1	173.43	110996	28.3	3.3	8.2	58.7	1.4	30.9	2.50	28.40	100
277	3E.2	193.23	123667	17.7	5.5	23.0	43.0	10.9	31.3	2.50	28.80	259
278	3E.3	183.85	117665	24.8	3.8	19.8	45.3	6.1	32.1	1.78	30.32	222
279	3F.4	276.12	176717	32.1	4.2	8.4	54.0	1.3	31.3	1.64	29.66	301
280	3G.1	59.47	38061	5.6	26.6	7.5	21.4	38.9	40.0	5.93	34.07	233

Appendix A. Continued.

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
281	3G.11	414.76	265448	7.0	18.1	21.7	53.2	0.0	36.0	2.78	33.22	689
282	3G.12	335.06	214441	7.3	20.1	23.1	42.4	7.1	36.5	3.12	33.38	588
283	3G.13	43.05	27549	11.9	9.9	28.3	45.8	4.0	36.0	3.50	32.50	631
284	3G.14	255.52	163532	8.1	14.6	19.6	56.0	1.7	34.4	3.54	30.86	328
285	3G.15	138.02	88331	14.8	16.3	19.4	41.1	8.4	33.5	3.31	30.19	245
286	3G.16	149.58	95731	15.4	13.8	20.3	41.2	9.3	32.4	2.56	29.84	328
287	3G.17	61.01	39047	19.3	8.8	30.4	37.9	3.7	35.3	3.50	31.80	489
288	3G.18	108.61	69511	18.4	8.2	11.7	60.2	1.4	33.8	2.66	31.14	252
289	3G.19	49.50	31677	6.7	6.2	12.3	71.4	3.3	36.1	3.50	32.60	543
290	3G.2	57.86	37031	4.4	7.2	17.0	47.7	23.7	39.1	4.07	35.03	257
291	3G.20	56.73	36308	22.8	11.3	18.2	44.4	3.3	36.0	3.50	32.50	239
292	3G.21	42.75	27357	5.7	1.9	12.5	79.5	0.3	35.5	3.50	32.00	464
293	3G.22	34.85	22301	11.9	0.3	11.9	73.8	2.1	35.4	3.50	31.90	405
294	3G.23	32.50	20800	24.4	0.8	19.4	54.5	1.0	35.4	3.50	31.90	387
295	3G.24	85.80	54912	23.1	1.0	17.4	58.0	0.5	34.6	3.38	31.22	434
296	3G.25	58.95	37725	39.5	1.4	15.9	41.9	1.4	34.5	3.17	31.33	285
297	3G.26	14.02	8976	19.6	9.7	21.6	47.5	1.5	33.8	2.50	31.30	738
298	3G.27	76.97	49259	21.6	3.2	13.5	59.3	2.4	34.2	2.58	31.62	447
299	3G.28	19.99	12795	22.8	5.0	10.0	61.7	0.5	34.5	2.50	32.00	713
300	3G.29	23.14	14810	18.5	10.6	14.3	55.1	1.5	33.8	2.90	30.90	634
301	3G.30	106.24	67994	18.5	10.6	14.3	55.1	1.5	32.7	1.50	31.20	533
302	3G.3	97.01	62086	3.1	9.2	16.5	55.4	15.8	38.8	3.15	35.65	332
303	3G.31	9.49	6074	6.5	20.4	14.7	58.4	0.0	33.1	2.58	30.52	330
304	3G.32	84.69	54199	22.2	16.9	14.0	44.1	2.9	30.8	1.50	29.30	341
305	3G.33	6.10	3904	40.7	8.1	5.4	41.5	4.4	29.6	1.50	28.10	224
306	3G.34	114.44	73242	27.6	13.5	12.5	44.2	2.2	31.8	1.50	30.30	379
307	3G.35	98.85	63264	27.6	13.5	12.5	44.2	2.2	30.6	1.50	29.10	399
308	3G.36	13.25	8480	26.2	19.8	8.3	45.7	0.0	29.8	1.50	28.30	462
309	3G.37	83.59	53498	21.7	22.2	21.2	33.3	1.6	29.5	1.50	28.00	444
310	3G.38	56.77	36330	20.5	23.6	26.7	28.7	0.4	30.7	1.50	29.20	491
311	3G.39	47.88	30643	31.4	15.0	23.3	24.0	6.2	30.5	1.50	29.00	571
312	3G.4	62.69	40122	3.6	17.7	37.7	30.3	10.7	39.0	4.85	34.15	424
313	3G.40	294.71	188617	29.5	23.2	20.9	26.4	0.0	29.0	1.50	27.50	338
314	3G.41	325.89	208570	51.6	5.8	17.1	23.4	2.1	27.7	1.48	26.22	316
315	3G.42	129.68	82998	35.9	8.3	18.0	37.2	0.6	28.8	1.50	27.30	246
316	3G.43	127.94	81881	59.0	4.9	8.4	27.7	0.0	26.7	1.50	25.20	249
317	3G.44	111.53	71379	37.0	2.1	1.9	59.1	0.0	27.1	1.33	25.77	462
318	3G.45	329.60	210945	57.5	2.4	2.3	36.4	1.3	26.2	1.18	25.02	583
319	3G.46	70.99	45435	54.6	1.7	4.2	39.3	0.2	26.5	1.50	25.00	576
320	3G.47	110.66	70822	83.8	1.2	8.1	3.9	3.0	26.5	1.16	25.34	402
321	3G.48	115.69	74042	61.4	1.6	1.9	32.7	2.3	26.3	0.95	25.35	566
322	3G.49	112.95	72289	75.2	1.6	3.0	19.8	0.5	27.8	1.07	26.73	336
323	3G.5	126.94	81242	1.6	20.2	19.5	58.7	0.0	37.7	3.27	34.43	448
324	3G.50	107.49	68792	58.1	1.9	11.1	28.9	0.0	27.4	0.95	26.45	346
325	3G.51	71.60	45823	55.0	1.9	3.6	34.8	4.7	27.3	0.95	26.35	320
326	3G.52	73.56	47079	51.9	1.0	0.2	46.0	1.0	26.1	0.95	25.15	295
327	3G.53	261.80	167549	38.6	0.0	0.2	50.3	10.9	25.4	0.83	24.57	282
328	3G.54	80.08	51252	58.6	0.9	2.2	31.4	6.8	25.8	0.93	24.87	585
329	3G.55	74.14	47448	38.7	0.6	2.0	54.6	4.0	25.7	0.83	24.87	476
330	3G.56	83.53	53459	46.2	0.2	0.6	44.5	8.5	25.8	0.81	24.99	285
331	3G.57	59.56	38119	34.1	0.4	1.8	58.5	5.3	25.3	0.67	24.63	427
332	3G.58	200.58	128372	30.3	0.8	0.3	67.3	1.2	24.6	0.44	24.16	538
333	3G.59	27.69	17723	38.0	2.0	1.1	40.4	18.5	24.5	0.41	24.09	416
334	3G.6	120.85	77344	3.9	27.9	7.4	41.1	19.7	37.2	2.63	34.57	475
335	3G.60	40.50	25920	37.3	4.0	1.3	53.8	3.6	24.5	0.51	23.99	600
336	3G.61	101.58	65011	16.6	3.7	1.3	67.7	10.7	24.5	0.48	24.02	631

Appendix A. Continued.

Appendix A. Continued.

SAS 15:51 TUESDAY, JULY 17, 1984 7

OBS	CNI	SQ_MI	AREA	PCNT_CRP	PCNT_FOR	PCNT_PAS	PCNT_RAN	PCNT_OTH	PRECIP	RUNOFF	EVAP	SLOPE
337	3G.62	43.16	27622	18.8	5.6	0.6	74.6	0.4	24.5	0.35	24.75	716
338	3G.63	84.87	54317	18.4	2.7	0.4	76.3	2.2	24.5	0.36	24.14	703
339	3G.64	101.35	64864	23.9	5.2	0.7	64.0	6.1	24.2	0.27	23.93	617
340	3G.65	30.76	19686	24.8	4.5	1.1	56.8	12.8	24.5	0.25	24.25	884
341	3G.66	16.44	10522	16.3	5.2	1.3	77.2	0.0	24.5	0.25	24.25	1047
342	3G.67	266.08	170291	29.5	4.5	0.9	58.9	6.1	24.2	0.29	23.91	503
343	3G.7	63.69	40762	5.8	23.3	26.5	43.2	1.2	36.8	2.50	34.30	745
344	3G.8	87.60	56064	11.3	22.9	22.4	42.2	1.2	37.7	2.50	35.20	644
345	3G.9	38.58	24691	19.9	16.7	23.7	38.3	1.4	36.5	2.50	34.00	794
346	3H.1	227.36	145510	1.7	39.9	56.9	0.0	1.4	44.7	8.16	36.54	231
347	3H1.1	71.83	45972	1.5	39.4	57.7	0.0	1.4	43.6	10.35	33.25	305
348	3H1.2	365.82	234126	4.8	26.1	56.5	12.4	0.2	40.6	9.66	30.94	259
349	3H1.3	40.95	26209	5.7	24.8	61.8	7.1	0.6	40.5	8.50	32.00	375
350	3H1.4	17.15	10976	5.9	11.4	38.3	35.9	8.4	39.3	6.97	32.33	716
351	3H1.5	141.28	90417	6.9	14.5	61.1	16.7	0.7	39.5	7.60	31.90	306
352	3H1.6	249.00	159360	1.4	5.6	30.8	57.6	4.5	39.3	5.88	33.42	625
353	3H2.1	231.27	148013	1.7	42.7	37.5	3.2	14.9	42.7	11.54	31.16	406
354	3H2.2	181.29	116025	0.0	80.0	9.1	10.8	0.1	44.1	11.07	33.03	459
355	3H2.3	237.79	152186	0.5	43.9	30.7	15.5	9.3	41.9	10.42	31.48	304
356	3H2.4	170.99	109434	0.3	29.0	37.9	30.1	2.7	40.4	9.55	30.85	238
357	3H2.5	36.80	23552	0.0	31.0	43.7	20.9	4.5	39.6	9.00	30.60	491
358	3H2.6	136.67	87470	4.6	33.6	52.1	5.2	4.5	42.0	7.04	34.96	315
359	3I.1	146.88	94003	0.0	66.8	28.1	0.6	4.5	45.9	9.93	35.97	436
360	3I.2	14.33	9171	1.6	28.8	54.3	7.3	8.0	46.5	7.50	39.00	288
361	3I.3	199.86	127910	0.0	69.3	19.1	10.9	0.7	47.1	12.50	34.60	864
362	3I.4	56.20	35968	2.4	36.6	51.1	7.1	2.8	45.8	12.50	33.30	302
363	3I.5	366.84	234778	0.1	72.7	17.7	8.2	1.3	45.8	11.98	33.82	727
364	3I.6	134.69	86204	0.0	53.3	27.2	19.3	0.2	46.1	12.36	33.74	843
365	3I.7	115.68	74035	0.4	64.7	30.2	2.7	2.0	48.7	12.31	36.39	726
366	3I.8	59.37	37997	0.1	85.3	14.5	0.0	0.2	47.5	13.13	34.37	1813
367	3I.9	15.65	10013	0.0	70.6	28.7	0.7	0.0	46.8	12.50	34.30	1412
368	3J1.1	320.78	205299	0.0	85.8	7.3	0.0	6.9	47.7	23.43	24.27	509
369	3J1.2	102.68	65715	0.0	85.3	14.5	0.0	0.2	50.5	25.50	25.00	1649
370	3J1.3	24.39	15610	0.0	69.2	30.8	0.0	0.0	51.5	25.50	26.00	1657
371	3J1.4	16.30	10432	0.0	85.3	14.5	0.0	0.2	51.0	25.50	25.50	1721
372	3J.14	52.67	33709	83.0	0.0	16.7	0.2	0.1	51.0	20.10	30.90	286
373	3J.15	63.79	40826	0.0	87.2	3.0	0.0	9.8	46.5	25.50	21.00	1293
374	3J.16	43.84	28058	0.0	99.5	0.5	0.0	0.0	47.6	25.50	22.10	1029
375	3J.17	255.13	163283	0.0	51.0	39.3	6.9	2.8	48.2	17.86	30.34	318
376	3J.18	99.10	63424	0.0	71.2	28.7	0.0	0.2	48.2	16.40	31.80	718
377	3J.19	29.41	18821	0.4	77.2	19.8	0.0	2.6	51.3	16.54	34.76	786
378	3J.20	422.00	270080	0.1	80.1	16.7	0.4	2.6	49.9	12.40	37.50	526
379	3J.21	268.54	171866	0.0	92.6	6.1	0.5	0.8	51.5	13.75	37.75	965
380	1V9.32	240.00	153600	8.1	31.4	25.0	30.0	4.6	40.2	6.44	33.76	323
381	3G.10	285.85	182944	9.3	17.3	21.0	48.2	4.2	35.1	3.20	31.90	463

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
1	1.105	275.535	38477	3367.5
2	1.106	293.915	2345	9830.0
3	1.107	290.457	1667	7590.0
4	1.108	291.791	50554	7000.0
5	1.109	274.960	42801	7917.5
6	1.110	257.199	1563	7843.7
7	1.111	266.815	19134	6335.0
8	1.112	257.496	1563	8105.0
9	1.113	283.513	1974	7930.0
10	1.114	261.239	5127	8115.0
11	1.115	342.035	3042	11521.2
12	1.116	310.394	3420	13652.5
13	1.117	346.410	3226	14785.0
14	1.118	263.762	3226	1646.2
15	1.119	266.256	4799	8067.5
16	1.120	289.350	3883	11502.5
17	1.121	275.937	4892	6856.2
18	1.122	263.603	5000	6551.2
19	1.123	336.723	3507	10756.2
20	1.124	269.471	4222	7576.2
21	1.125	259.663	4658	8393.7
22	1.126	263.312	4480	9356.2
23	1.127	263.975	24238	10125.0
24	1.128	335.657	56603	11993.7
25	1.129	332.281	70658	13912.5
26	1.130	284.505	59698	11100.0
27	1.131	274.572	9005	10520.0
28	1.132	307.159	4378	10833.7
29	1.133	320.724	74674	14350.0
30	1.134	268.811	37871	12765.0
31	1.135A	332.876	44142	12340.0
32	1.135	338.003	48468	16071.2
33	1.136	331.997	72594	14612.5
34	1.137	322.581	100000	4628.7
35	1.138	320.108	68752	10348.7
36	1.139	319.875	37300	11895.0
37	1.140	331.861	90090	10655.0
38	1.141	357.143	100000	17738.7
39	1.142	357.143	99052	17440.0
40	1Q1.4	316.361	2509	6811.2
41	1Q1.5	277.778	1563	3585.0
42	1Q1.6	450.061	1773	6811.2
43	1Q.10	539.780	2520	6972.5
44	1Q.11	313.273	1855	6535.0
45	1Q.12	289.633	1806	2158.7
46	1Q.13	277.778	1563	3323.7
47	1Q.14	332.163	1868	4495.0
48	1Q.15	327.265	1853	3296.2
49	1Q.16	276.791	1676	2247.5
50	1Q.17	278.973	1563	5030.0
51	1Q.18	270.251	1563	7040.0
52	1Q2.5	295.312	1563	3691.2
53	1Q2.6	200.000	1563	4598.7
54	1Q2.7	253.789	1563	4598.7
55	1Q2.8	258.710	1563	4598.7
56	1Q2.9	262.237	1563	4598.7

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
57	1Q.3	375.060	2159.82	6648.7
58	1Q.7	375.366	1941.00	1437.5
59	1Q.8	274.371	1603.62	3360.0
60	1Q.9	263.330	1563.00	2640.0
61	1R.11	490.433	2587.37	6167.5
62	1R.12	362.467	2381.00	6576.2
63	1R.16	383.912	2598.47	6262.5
64	1R.18	339.691	2422.39	9493.7
65	1R.22	437.475	2480.09	5612.5
66	1R.2.3	333.333	1919.31	5946.2
67	1R.23	276.206	1919.31	9641.2
68	1R.24	377.851	2237.82	9802.5
69	1R.25	373.887	1819.24	920.0
70	1R.26	334.898	1739.38	6316.2
71	1R.27	373.557	1905.83	8198.7
72	1R.28	413.103	1958.69	7576.2
73	1R.29	572.941	2622.70	8521.2
74	1R.30	360.948	2043.54	7820.0
75	1R.31	378.388	1762.58	4750.0
76	1R.32	588.235	2344.76	4382.5
77	1R.33B	549.325	3171.45	7371.2
78	1R.33A	549.428	2646.44	7160.0
79	1R.33	528.938	2634.27	8258.7
80	1R.34	394.730	2130.80	5672.5
81	1R.35	329.829	2134.74	4900.0
82	1R.36	324.327	1749.75	4641.2
83	1R.37	333.299	1708.85	6460.0
84	1R.38	304.138	1771.87	4522.5
85	1R.39	374.287	2879.10	5497.5
86	1R.40	284.944	1579.96	4897.5
87	1R.41	289.248	2281.08	6675.0
88	1R.42	366.361	3015.80	6160.0
89	1R.43	271.542	1957.63	7203.7
90	1R.44	289.517	3077.00	5768.7
91	1R.45	269.637	1570.48	8295.0
92	1R.46	283.821	1992.72	7125.0
93	1R.47	320.330	2218.89	7838.7
94	1R.48	269.119	2693.84	5975.0
95	1R.49	320.280	3226.00	8916.2
96	1R.5	333.333	3030.00	3253.7
97	1R.50	299.167	2455.70	7962.5
98	1R.51	292.163	2231.96	8637.5
99	1R.52	292.191	2039.29	7767.5
100	1R.53	343.006	2640.28	10895.0
101	1R.54	292.136	2835.47	10941.2
102	1R.6	333.333	3030.00	6168.7
103	1R.7	333.333	2926.72	4235.0
104	1R.8	408.233	2844.73	5720.0
105	1R.9	382.983	2613.42	3367.5
106	1S2.6	308.795	2492.02	10772.5
107	1S2.11	257.009	4332.62	9351.2
108	1S2.12	258.121	5000.00	9303.7
109	1S2.10	319.536	3706.66	9306.2
110	1S.21	269.536	4839.28	9745.0
111	1S.22	285.714	5000.00	9237.5
112	1S.23	271.054	4614.33	9703.7

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
113	1S.24	319.984	3434	11568.7
114	1S.25	257.150	4870	7766.2
115	1S.26	260.997	4010	10692.5
116	1S2.7	256.410	3468	11131.2
117	1S2.9	295.601	4064	12247.5
118	1S3.1	343.277	2881	10213.7
119	1S3.2	343.747	3132	11950.0
120	1S3.3	268.938	4297	9478.7
121	1T.26	285.714	5000	13282.5
122	1T.28	257.322	37110	7932.5
123	1T2.18	331.043	84125	9277.5
124	1T.29	256.410	27268	6437.5
125	1T.30	316.723	70229	10981.2
126	1T.32	348.873	100000	10423.7
127	1T.33	318.794	78400	10427.5
128	1T.34	268.337	18186	9375.0
129	1T.35	261.878	12288	11537.5
130	1T.36	339.817	100000	13831.2
131	1T.37	268.525	38977	9217.5
132	1T.38	353.476	100000	15790.0
133	1T.39	290.553	6280	10121.2
134	1T.40	347.513	91039	14808.7
135	1T.41	260.205	17889	13101.2
136	1T.42	346.836	99259	15196.2
137	1U.4	357.143	100000	15000.0
138	1U.5	357.143	100000	12015.0
139	1U.6	357.143	100000	15990.0
140	1U.8	357.143	100000	11691.2
141	1U.9	357.143	100000	15112.5
142	1V.41	413.978	2402	8085.0
143	1V.42	410.920	2955	9731.2
144	1V.43	425.134	2413	8722.5
145	1V.44	372.763	2330	8517.5
146	1V.45	318.578	1563	5940.0
147	1V.46	438.653	2330	7575.0
148	1V.47	398.517	2148	6751.2
149	1V.48	312.389	2312	4192.5
150	1V.49	324.854	2192	6656.2
151	1V.50	263.158	2243	8366.2
152	1V.51	276.556	1703	5246.2
153	1V.52	311.170	2143	8171.2
154	1V.53	343.051	2249	8807.5
155	1V.54	367.672	3230	10443.7
156	1V.55	357.004	2919	9658.7
157	1V.56	377.070	3318	13035.0
158	1V.57	366.787	9910	13131.2
159	1V.58	329.595	44636	14847.5
160	1V.59	311.720	16156	12390.0
161	1V7.1	299.621	2660	10270.0
162	1V7.2	397.939	3226	13827.5
163	1V7.3	408.607	3189	12712.5
164	1V7.4	367.544	3226	11913.7
165	1V7.5	416.657	3973	12123.7
166	1V8.1	338.747	3226	14366.2
167	1V8.2	333.640	6371	15411.2
168	1V8.3	346.777	60971	16600.0

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
169	1V8.4	297.560	26974	14742.5
170	1V8.5	323.603	44994	14216.2
171	1V9.14	554.333	2344	9370.0
172	1V9.18	395.566	2260	7735.0
173	1V9.19	340.657	2403	7581.2
174	1V9.17	491.654	2602	8175.0
175	1V9.16	572.655	2634	8175.0
176	1V9.15	423.571	2132	8400.0
177	1V9.13	388.601	2463	10595.0
178	1V9.12	362.208	2444	12422.5
179	1V9.11	402.252	2509	9665.0
180	1V9.10	359.003	2477	9901.2
181	1V9.27	277.700	2659	8475.0
182	1V9.26	335.918	3226	8351.2
183	1V9.28	377.110	3430	11691.2
184	1V9.29	336.612	22201	11358.7
185	1V9.25	350.235	3040	10450.0
186	1V9.24	258.103	2602	5137.5
187	1V9.22	296.001	1563	4583.7
188	1V9.23	199.796	1563	4661.2
189	1V9.21	292.235	1563	3555.0
190	1V9.20	311.586	1563	4557.5
191	1V9.31	285.482	3925	11998.7
192	1V9.30	336.471	3621	11725.0
193	1V9.3	450.133	2381	4338.7
194	1V9.4	439.650	2421	5686.2
195	1V9.5	349.783	2381	7163.7
196	1V9.6	328.919	2403	4461.2
197	1V9.7	334.967	2388	2648.7
198	1V9.8	302.319	2405	6736.2
199	1V9.9	371.255	2468	2648.7
200	1V9A.1	314.143	2387	4461.2
201	1V9B.1	324.339	2400	9002.5
202	1V9C.1	505.086	2456	7553.7
203	1V9C.2	470.983	2294	6960.0
204	1V9D.1	382.335	2818	11385.0
205	1V9D.14	311.304	19571	11058.7
206	1V9D.6	364.506	3113	9212.5
207	1V9D.5	376.540	3198	9058.7
208	1V9D.3	415.056	3226	8771.2
209	1V9D.2	411.724	3226	7497.5
210	1V9D.13	272.660	3642	12583.7
211	1V9D.12	295.144	3796	12583.7
212	1V9D.11	385.730	3275	14342.5
213	1V9D.10	344.391	3748	13402.5
214	1V9D.9	390.137	3226	14046.2
215	1V9D.8	377.634	3166	13351.2
216	1V9D.7	333.512	3226	10570.0
217	1V9D.4	309.003	2874	9711.2
218	1W.1	357.143	100000	14560.0
219	1W.10	337.370	3226	14768.7
220	1W.11	340.377	30574	10671.2
221	1W.2	335.894	66990	13195.0
222	1W.3	357.143	100000	14560.0
223	1W.4	352.028	100000	18440.0
224	1W.5	326.945	94813	15810.0

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
225	1W.6	326.552	94019	13160.0
226	1W.7	332.365	51613	10371.2
227	1W.8	334.705	5994	14768.7
228	1W.9	342.990	55571	15286.2
229	3.1	329.626	2233	10710.0
230	3.10	294.915	1808	6951.2
231	3.11	298.322	2504	12012.5
232	3.11A	310.592	2265	9766.2
233	3.12	369.423	3111	11801.2
234	3.13	365.790	3084	12791.2
235	3.14	353.495	2815	11506.2
236	3.16	354.034	8193	12788.7
237	3.22	323.290	25521	8481.2
238	3.23	337.670	56822	10982.5
239	3.23A	390.940	7391	8637.5
240	3.26	349.107	100000	13137.5
241	3.3	329.873	3177	6080.0
242	3.32	334.214	93913	11917.5
243	3.34	335.621	100000	13532.5
244	3.35	325.531	100000	9612.5
245	3.36	336.402	100000	9220.0
246	3.37	330.763	100000	9758.7
247	3.39	331.955	100000	7976.2
248	3.4	290.350	2962	6381.2
249	3.40	344.085	100000	13057.5
250	3.41	337.379	100000	14401.2
251	3.6	300.392	1686	8025.0
252	3A.2	294.982	3177	5257.5
253	3A.3	349.578	2904	3195.0
254	3A4.1	336.579	3117	5998.7
255	3A4.2	305.608	3106	4338.7
256	3A4.3	317.184	3105	3590.0
257	3A.5	310.150	3177	5495.0
258	3A5.10	430.769	2857	7345.0
259	3A5.2	343.569	2161	6185.0
260	3A5.3	303.539	2962	3240.0
261	3A5.4	308.436	3061	5536.2
262	3A5.5	301.048	3031	3907.5
263	3A5.6	343.411	2767	4190.0
264	3A5.7	383.313	3002	6556.2
265	3A5.8	357.143	3115	6055.0
266	3A5.9	404.199	2913	6587.5
267	3A5A.2	288.749	3159	7907.5
268	3A5A.1	291.990	3062	6061.2
269	3C.1	277.481	2765	7067.5
270	3CL.1	272.412	3181	6076.2
271	3CL.2	339.519	3205	9871.2
272	3CL.3	271.444	3177	5912.5
273	3CL.4	270.089	3177	9740.0
274	3CL.5	274.276	2980	9871.2
275	3C.2	297.264	2275	8306.2
276	3E.1	279.035	1782	7843.7
277	3E.2	320.227	2644	9011.2
278	3E.3	321.759	2699	8190.0
279	3E.4	287.049	1696	7611.2
280	3G.1	264.861	1667	12170.0

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
281	3G.11	438.536	3226.00	11197.5
282	3G.12	417.292	2663.51	11371.2
283	3G.13	367.857	3226.00	9938.7
284	3G.14	382.405	2922.34	10751.2
285	3G.15	378.304	3214.78	10335.0
286	3G.16	380.009	2892.40	10032.5
287	3G.17	326.317	3154.75	9201.2
288	3G.18	328.955	3206.38	9200.0
289	3G.19	332.130	2128.31	10023.7
290	3G.2	312.500	1918.93	10335.0
291	3G.20	278.283	3094.73	9135.0
292	3G.21	279.202	3226.00	9681.2
293	3G.22	284.437	3221.79	8988.7
294	3G.23	294.616	3178.40	7955.0
295	3G.24	282.055	3179.08	8078.7
296	3G.25	341.153	3177.17	6693.7
297	3G.26	375.353	3212.12	9245.0
298	3G.27	333.802	3204.63	8430.0
299	3G.28	322.581	3188.27	8505.0
300	3G.29	309.228	3226.00	9441.2
301	3G.30	291.805	3205.75	9441.2
302	3G.3	317.193	1799.05	10648.7
303	3G.31	365.132	3219.10	11471.2
304	3G.32	338.031	3199.68	9757.5
305	3G.33	319.988	3181.51	7258.7
306	3G.34	281.439	3178.69	8935.0
307	3G.35	269.302	3177.50	8935.0
308	3G.36	278.896	3201.37	9687.5
309	3G.37	328.536	3224.81	10321.2
310	3G.38	359.009	3224.27	10556.2
311	3G.39	300.647	3219.05	8742.5
312	3G.4	393.596	2527.88	11455.0
313	3G.40	349.045	3211.50	9738.7
314	3G.41	345.801	3028.80	6065.0
315	3G.42	351.505	1940.50	7688.7
316	3G.43	318.374	2560.13	5327.5
317	3G.44	292.900	3117.93	6982.5
318	3G.45	285.129	3070.48	5198.7
319	3G.46	290.381	2944.26	5392.5
320	3G.47	294.888	2686.34	2787.5
321	3G.48	304.906	3141.17	4777.5
322	3G.49	294.118	3177.00	3590.0
323	3G.5	419.072	2105.55	11880.0
324	3G.50	288.423	3177.00	5106.2
325	3G.51	289.506	3177.00	5377.5
326	3G.52	286.405	3177.00	5568.7
327	3G.53	293.913	3177.00	6622.5
328	3G.54	331.903	3177.00	4952.5
329	3G.55	332.183	3177.00	6663.7
330	3G.56	294.118	3177.00	5977.5
331	3G.57	306.285	3177.00	7066.2
332	3G.58	324.158	3130.60	7418.7
333	3G.59	320.030	3177.00	6875.0
334	3G.6	439.385	2274.23	12448.7
335	3G.60	301.044	3177.00	7136.2
336	3G.61	320.463	3130.82	8917.5

Appendix A. Continued.

SAS

OBS	CNI	SOIL_FAC	VEG_FAC	LAND_FAC
337	3G.62	287.836	3177	8915.0
338	3G.63	306.584	3155	8660.0
339	3G.64	440.504	2992	8418.7
340	3G.65	303.171	3143	8280.0
341	3G.66	323.190	3101	9093.7
342	3G.67	433.735	2973	7858.7
343	3G.7	477.457	1975	11822.5
344	3G.8	354.095	3226	11301.2
345	3G.9	419.981	2794	9928.7
346	3H.1	340.960	77580	13831.2
347	3H1.1	327.170	100000	13808.7
348	3H1.2	332.311	21237	12190.0
349	3H1.3	339.013	3134	11981.2
350	3H1.4	431.470	3148	10613.7
351	3H1.5	288.329	3066	10836.2
352	3H1.6	377.495	2774	10427.5
353	3H2.1	351.290	94290	14121.2
354	3H2.2	349.679	89771	18000.0
355	3H2.3	315.899	21090	14336.2
356	3H2.4	326.143	2846	12873.7
357	3H2.5	346.378	2953	13110.0
358	3H2.6	370.909	3226	12957.5
359	3I.1	349.531	100010	16680.0
360	3I.2	339.129	100000	12740.0
361	3I.3	344.956	100000	16930.0
362	3I.4	357.143	100000	13450.0
363	3I.5	345.425	100000	17261.2
364	3I.6	342.751	100000	15330.0
365	3I.7	334.725	100000	16435.0
366	3I.8	331.342	100000	18531.2
367	3I.9	340.218	100000	17060.0
368	3J1.1	351.271	100000	18580.0
369	3J1.2	346.705	100000	18530.0
370	3J1.3	341.434	100000	16920.0
371	3J1.4	353.441	100000	18530.0
372	3J.14	357.143	100000	2737.5
373	3J.15	357.143	100000	18720.0
374	3J.16	357.143	100000	19950.0
375	3J.17	355.589	100000	15100.0
376	3J.18	357.143	100000	17130.0
377	3J.19	352.259	100000	17685.0
378	3J.20	357.143	100000	17991.2
379	3J.21	357.143	100000	19260.0
380	1V9.32	300.261	76003	12341.2
381	3G.10	400.968	3226	10916.2

Appendix B. Fish population data for ecoregion evaluation.

SAS 16:27 MONDAY, JUNE 25, 1984 1

OBS	CNI	SPEC1	SPEC2	SPEC3	SPEC4	SPEC5	SPEC6	SPEC7	SPEC8	SPEC9	SPEC10	SPEC11	SPEC12	SPEC13	SPEC14	SPEC15	SPEC16	SPEC17	SPEC18	SPEC19	SPEC20	SPEC21	SPEC22	SPEC23	SPEC24	SPEC25	SPEC26	SPEC27	SPEC28	SPEC29	SPEC30	SPEC31	SPEC32	SPEC33
1	1.135	0	0	0	0	0	0	0	0	4	51	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1V7.1	0	0	4	0	0	1680	0	0	0	60	1	731	0	7	0	0	0	0	0	0	23	0	0	0	0	0	2340	0	0	0	0	0	543
3	1V9D.1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2841	0	0	0	0	0
4	1R.46	0	0	1	0	0	37	0	0	0	48	0	10	0	83	0	0	295	0	56	0	0	0	0	0	0	0	1573	0	0	0	0	0	0
5	1S.22	0	0	225	0	5	225	0	0	0	1250	0	5	0	0	0	0	30	0	0	0	0	0	0	0	0	0	1250	0	0	0	0	0	0
6	1S3.1	0	0	0	0	0	19	0	0	0	8	0	10	0	0	0	0	0	0	0	0	0	0	0	0	3	0	172	0	0	0	1	0	1
7	1T.35	0	0	0	0	0	15	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0
8	1T.39	0	0	0	0	0	27	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	0	0	0
9	1W.3	0	1	0	0	0	0	0	0	0	9	0	0	0	0	0	0	3	0	6	77	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1W.5	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	3	0	23	68	1	0	0	1	0	0	659	0	0	0	0	0	0

OBS	SPEC34	SPEC35	SPEC36	SPEC37	SPEC38	SPEC39	SPEC40	SPEC41	SPEC42	SPEC43	SPEC44	SPEC45	SPEC46	SPEC47	SPEC48	SPEC49	SPEC50	SPEC51	SPEC52	SPEC53	SPEC54	SPEC55	SPEC56	SPEC57	SPEC58	SPEC59	SPEC60	SPEC61	SPEC62	SPEC63	SPEC64	SPEC65	SPEC66
1	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	3	0	0	0	0	0	6	35
2	0	0	0	0	131	0	0	70	0	33	658	0	0	0	0	0	0	0	0	0	0	0	1273	43	508	0	0	0	0	8	71	0	0
3	33	0	0	0	0	0	0	0	14	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0
4	0	0	0	0	0	0	0	2175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	1	15	0	0	0	0	1	0	0	0
5	225	0	5	0	0	0	1250	225	30	0	30	0	0	0	5	225	30	750	0	0	750	0	1250	30	225	0	0	30	0	5	0	225	0
6	1	0	1	0	15	0	285	0	254	24	2	0	0	0	0	8	0	2	0	0	0	0	0	1	0	8	0	0	6	2	0	2	1
7	0	0	0	0	0	0	6	0	0	1	6	0	0	0	0	0	0	1	0	0	0	0	0	2	3	0	0	0	0	0	0	0	3
8	0	0	0	0	0	6	0	4	0	1	0	3	0	0	0	0	12	0	2	0	0	0	0	0	0	9	0	0	0	0	0	21	0
9	0	0	0	30	0	0	2	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	10
10	201	0	1	7	0	0	38	1	26	148	0	0	0	0	5	0	0	0	0	0	12	1	12	0	4	1	0	0	0	0	0	5	119

OBS	SPEC67	SPEC68	SPEC69	SPEC70	SPEC71	SPEC72	SPEC73	SPEC74	SPEC75	SPEC76	SPEC77	SPEC78	SPEC79	SPEC80	SPEC81	SPEC82	SPEC83	SPEC84	SPEC85	SPEC86	SPEC87	SPEC88	SPEC89	SPEC90	SPEC91	SPEC92	SPEC93	SPEC94	SPEC95	SPEC96	SPEC97	SPEC98	SPEC99	SPEC100	SPEC101
1	0	6	0	0	0	2	93	0	13	57	0	0	0	1	0	0	0	0	0	0	0	0	0	21	0	0	0	3	0	0	0	0	0	0	0
2	56	0	0	0	0	0	344	47	123	112	43	0	0	8	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
3	0	1344	0	0	0	0	0	9	1	54	15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	751	0	0	0	0	0	305	376	77	585	0	0	0	60	208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	250	225	0	0	0	30	750	750	30	750	0	0	30	750	225	0	0	0	0	0	0	0	0	0	0	1250	225	0	225	5	5	0	225	0	0
6	0	28	0	0	0	5	19	27	46	116	1	0	5	14	17	0	0	0	0	0	0	0	0	0	5	1	2	24	0	1	0	2	0	0	0
7	7	13	0	2	0	5	38	4	66	15	1	0	0	11	7	0	0	0	0	0	0	0	0	0	1	0	0	8	0	0	0	1	0	1	2
8	0	0	0	0	0	0	0	4	0	33	32	0	0	0	5	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9	2	119	0	0	0	0	1	0	1	5	0	0	9	1	16	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	295	61	0	0	0	5	118	21	48	56	2	0	46	4	29	0	0	0	0	0	0	0	0	0	19	34	0	4	0	1	0	0	12	0	0

Appendix B. Continued.

SAS 16:27 MONDAY, JUNE 25, 1984 2

OBS	CNI	SPEC1	SPEC2	SPEC3	SPEC4	SPEC5	SPEC6	SPEC7	SPEC8	SPEC9	SPEC10	SPEC11	SPEC12	SPEC13	SPEC14	SPEC15	SPEC16	SPEC17	SPEC18	SPEC19	SPEC20	SPEC21	SPEC22	SPEC23	SPEC24	SPEC25	SPEC26	SPEC27	SPEC28	SPEC29	SPEC30	SPEC31	SPEC32
11	1W.9	0	0	0	0	0	0	0	0	6	213	0	0	0	0	0	0	3	25	0	410	0	2	0	0	0	0	273	0	0	0	0	0
12	3.23A	0	0	0	0	0	0	0	0	0	460	0	0	0	0	0	100	15	0	0	136	0	381	0	0	0	0	3	0	0	0	74	0
13	3AS.6	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2014	0	0	0	0	0
14	3C.1&2	0	0	0	0	0	39	0	0	0	18	0	2	0	1	0	0	21	0	1	0	60	0	0	0	0	0	1768	0	0	0	0	0
15	3CL.2	0	0	0	0	0	4	0	0	0	4	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	3G.4	0	0	0	0	0	0	0	0	0	188	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	32	0	0	0	0	0
17	3G.5	0	0	0	0	0	4	10	0	0	156	1	0	0	0	0	0	2	0	0	1783	0	0	0	0	0	0	24	0	0	0	0	0
18	3G.8	0	19	4	3	0	299	12	0	0	555	0	118	0	0	5	0	138	0	0	6735	0	0	0	0	0	0	885	0	0	0	0	0
19	3G.55	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	553	0	0	0	0	0
20	3H1.2	0	0	2	0	0	3	0	0	0	40	0	3	0	0	0	0	1	0	33	13	0	0	0	0	0	0	188	0	0	0	25	0

OBS	SPEC33	SPEC34	SPEC35	SPEC36	SPEC37	SPEC38	SPEC39	SPEC40	SPEC41	SPEC42	SPEC43	SPEC44	SPEC45	SPEC46	SPEC47	SPEC48	SPEC49	SPEC50	SPEC51	SPEC52	SPEC53	SPEC54	SPEC55	SPEC56	SPEC57	SPEC58	SPEC59	SPEC60	SPEC61	SPEC62	SPEC63	SPEC64	SPEC65	SPEC66	SPEC67
11	0	553	0	6	1	0	0	73	0	41	0	0	0	19	0	0	0	0	0	0	0	0	0	1	13	0	25	0	0	4	0	0	0	153	38
12	34	517	2	0	0	0	3	95	1	0	26	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	252
13	88	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	12	2	0	0	0	0	0	0	0	0	291
14	157	0	38	0	0	2	0	1	8	0	90	0	0	9	0	0	0	0	0	0	0	0	0	6	4	3	0	0	0	0	0	0	0	0	2677
15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	6	0	21	5	4	0	0	0	0	0	0	0	0	21
16	248	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	38	0	0	163
17	30	0	1188	0	0	0	0	207	1	0	2	0	0	0	0	0	0	0	0	0	0	1	0	4	2	1	0	0	0	0	0	0	10	1	96
18	115	0	3710	857	0	0	401	790	1	0	116	7	0	0	0	3	0	0	0	0	0	54	0	20	8	30	0	0	0	0	7	0	29	0	1936
19	136	0	0	0	0	5	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	1	8	5	0	0	0	0	0	2	0	0	24
20	0	7	720	0	0	38	0	5	0	0	119	1	0	0	1	6	10	1	0	0	0	5	1	0	0	60	0	0	0	33	1	0	0	0	19

OBS	SPEC68	SPEC69	SPEC70	SPEC71	SPEC72	SPEC73	SPEC74	SPEC75	SPEC76	SPEC77	SPEC78	SPEC79	SPEC80	SPEC81	SPEC82	SPEC83	SPEC84	SPEC85	SPEC86	SPEC87	SPEC88	SPEC89	SPEC90	SPEC91	SPEC92	SPEC93	SPEC94	SPEC95	SPEC96	SPEC97	SPEC98	SPEC99	SPEC100	SPEC101
11	103	0	0	0	1	163	9	95	62	4	0	2	1	0	0	0	0	2	0	0	0	18	0	45	103	0	1	1	0	1	0	0	17	0
12	0	0	0	0	0	61	4	6	93	2	4	62	8	1	0	0	0	0	0	161	0	0	143	130	0	0	1	0	0	0	0	0	0	0
13	0	0	0	0	0	24	0	1	45	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	0	0	48	87	25	502	220	4	0	6	16	19	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	1
15	2	0	0	0	14	255	0	350	185	32	0	0	98	0	0	0	0	0	0	0	0	0	0	31	0	0	13	0	0	0	0	0	0	1
16	0	0	0	0	0	17	0	11	17	1	0	3	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0
17	198	0	0	0	0	169	9	127	189	30	2	18	13	0	0	0	0	0	0	0	0	0	0	430	0	0	3	0	0	0	0	0	1	0
18	267	4	2	0	12	309	24	454	1260	126	0	136	30	203	2	0	0	0	3	0	0	0	0	1004	0	0	52	0	0	0	0	4	0	14
19	0	0	0	0	0	0	5	4	14	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	2	0	0	0	0	1	1	1	23	0	0	2	2	5	1	0	0	0	0	0	0	0	32	0	0	0	2	0	0	0	14	23	0	1

OBS	CN	SPEC1	SPEC2	SPEC3	SPEC4	SPEC5	SPEC6	SPEC7	SPEC8	SPEC9	SPEC10	SPEC11	SPEC12	SPEC13	SPEC14	SPEC15	SPEC16	SPEC17	SPEC18	SPEC19	SPEC20	SPEC21	SPEC22	SPEC23	SPEC24	SPEC25	SPEC26	SPEC27	SPEC28	SPEC29	SPEC30	SPEC31
21	3H2.1	0	1	0	0	0	4	2	6	0	107	0	1	16	0	2	0	7	0	225	18	146	0	1	15	0	0	1917	0	3	20	56
22	3H2.2	0	0	0	0	0	0	0	0	5	2	0	0	0	0	0	0	4	0	13	314	12	0	1	0	0	0	1	6	0	0	0
23	3H2.6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	15	0	0	0	0
24	31.6	0	0	0	0	0	0	0	0	0	44	0	0	0	0	0	0	3	0	0	102	0	0	6	0	0	0	0	42	0	0	59
25	31.7	0	0	0	0	0	0	0	0	1	24	0	0	0	0	0	0	0	0	69	1681	0	0	4	0	0	0	0	885	0	0	0
26	31.9	0	0	0	0	0	0	0	0	2	40	0	0	0	0	0	0	1	0	0	308	0	0	0	0	0	0	0	204	0	0	0
27	3J.21	36	0	27	0	0	17	0	0	7	95	0	0	0	0	0	0	0	0	6	1562	0	0	0	0	0	0	0	20	76	0	16

OBS	SPEC32	SPEC33	SPEC34	SPEC35	SPEC36	SPEC37	SPEC38	SPEC39	SPEC40	SPEC41	SPEC42	SPEC43	SPEC44	SPEC45	SPEC46	SPEC47	SPEC48	SPEC49	SPEC50	SPEC51	SPEC52	SPEC53	SPEC54	SPEC55	SPEC56	SPEC57	SPEC58	SPEC59	SPEC60	SPEC61	SPEC62	SPEC63	SPEC64	SPEC65	SPEC66
21	20	0	5	246	6	303	4	0	40	0	0	283	5	2	1	0	4	1	3	0	0	0	4	1	0	1	225	0	0	0	211	60	0	0	0
22	1	0	277	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
23	0	0	13	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
24	0	0	77	0	11	61	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	25	2
25	0	0	1788	0	55	45	0	0	53	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	9	0	0	0	0	16	0	0	3	40
26	0	0	140	0	0	9	0	0	12	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	52	0
27	0	0	1379	0	0	142	0	0	8	0	0	0	0	0	3	0	0	0	1	1	1	1	3	0	5	15	11	0	0	0	4	12	0	0	9

OBS	SPEC67	SPEC68	SPEC69	SPEC70	SPEC71	SPEC72	SPEC73	SPEC74	SPEC75	SPEC76	SPEC77	SPEC78	SPEC79	SPEC80	SPEC81	SPEC82	SPEC83	SPEC84	SPEC85	SPEC86	SPEC87	SPEC88	SPEC89	SPEC90	SPEC91	SPEC92	SPEC93	SPEC94	SPEC95	SPEC96	SPEC97	SPEC98	SPEC99	SPEC100	SPEC101
21	322	1	12	1	3	0	15	2	16	63	4	0	1	0	10	0	0	0	0	0	0	0	0	35	1	0	0	0	23	0	0	31	16	0	37
22	352	17	0	0	0	9	31	7	39	27	7	0	0	2	0	0	0	0	2	2	0	0	3	6	0	0	0	0	0	0	0	0	0	0	0
23	5	0	0	0	0	0	9	0	54	10	0	0	0	0	0	0	0	0	1	0	0	0	0	29	0	0	0	0	0	0	0	0	1	0	0
24	13	26	0	0	0	0	6	0	4	20	0	0	3	0	0	0	0	0	0	0	0	0	0	93	0	0	0	0	3	0	0	4	14	0	0
25	53	1063	0	0	0	0	19	0	91	65	0	0	6	0	0	0	0	0	0	0	0	1	1	49	0	0	0	1	0	0	0	0	1	0	0
26	81	140	0	0	0	0	4	2	1	41	0	0	5	3	0	0	0	0	0	0	0	0	0	21	0	0	0	1	0	0	0	0	0	0	0
27	1	293	0	0	0	1	388	1	16	118	1	7	0	7	6	0	1	0	0	0	0	0	0	116	0	0	0	0	7	0	1	0	0	0	0

Appendix B. Continued.