

Illinois River Basin Water Quality Technical Assessment



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ILLINOIS RIVER BASIN WATER QUALITY TECHNICAL ASSESSMENT

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ILLINOIS RIVER BASIN WATER QUALITY TECHNICAL ASSESSMENT

1. INTRODUCTION

The Illinois Basin is home to productive forested and agricultural lands and has the distinction of containing streams with historically abundant salmonid fish populations. Valuable contributions from forestry, agriculture and fisheries in the Illinois Basin have prompted extensive data collection and study of the interactions between land use and water quality. The knowledge derived from these data collection efforts and academic study, some of which is presented in this document, will be used to design protective and enhancement strategies that address water quality issues.

Recently several agencies have been mandated to take proactive roles in developing management strategies in the Illinois Basin. In the near future water quality management plans will be developed for forested, agricultural and urban lands that address both nonpoint and point sources of pollution. It is imperative that these plans consider the relatively robust data that describe water quality, instream physical parameters and landscape features. The impending management efforts (see section 1.1 **Water Quality Programs**) demand that stakeholders, land managers, public servants and the general public become knowledgeable with water quality issues in the Illinois Basin.

The data review contained in this document summarizes the varied, yet extensive, data collection studies that have recently occurred in the Illinois Basin, with a focus on data collected by the Oregon Department of Environmental Quality (ODEQ). It is hoped that water quality programs operating in the basin will utilize this report to develop (and/or alter) water quality management efforts. In addition, this report should be used to track water quality, instream physical parameters and landscape conditions that currently exist. In the future it will be important to determine the adequacy of planned water quality improvements efforts: Through looking back at this report, written in August 1998, it will be possible to track the changes that have occurred in water quality, instream and landscape parameters that effect fish, as well as people, in the Illinois Basin.

1.1 Existing Water Quality Programs

The following programs, all of which focus on water quality or contain water quality components, currently exist in the state of Oregon. These programs will be the primary vehicles for implementing the improvements necessary to restore good water quality to the Illinois basin.

Oregon's Total Maximum Daily Load Program

The quality of Oregon's streams, lakes, estuaries and groundwater is monitored by the Department of Environmental Quality (DEQ). The information collected by DEQ is used to determine whether water quality standards are being violated and, consequently, whether the *beneficial uses* of the waters are being threatened. *Beneficial uses* include fisheries, aquatic life, drinking water, recreation, shellfish, irrigation, hydroelectric power, and navigation. Specific State and Federal plans and regulations are used to determine if violations have occurred: these regulations include the *Federal Clean Water Act of 1972* and its amendments *40 Codified Federal Regulations 131*, and *Oregon's Administrative Rules (OAR Chapter 340)* and *Oregon's Revised Statutes (ORS Chapter 468)*.

The term *water quality limited* is applied to streams and lakes where violations of State water quality standards occur. With a few exceptions, such as in cases where violations are due to natural causes, the State must establish a *Total Maximum Daily Load* or *TMDL* for any waterbody designated as water quality limited. A *TMDL* is the total amount of a **pollutant** (from all sources) that can enter a specific waterbody without violating the water quality standards.

The total permissible pollutant load is allocated to point, nonpoint, background, and future sources of pollution. *Wasteload Allocations* are portions of the total load that are allotted to point sources of pollution, such as sewage treatment plants or industries. The *Wasteload Allocations* are used to establish effluent limits in discharge permits. *Load Allocations* are portions of the *Total Maximum Daily Load* that are attributed to either natural background sources, such as soils, or from nonpoint sources, such as agriculture or forestry activities. Allocations can also be set aside in reserve for future uses.

The Northwest Forest Plan

In response to environmental concerns and litigation related to timber cutting and other operations on Federal Lands, the United States Forest Service (USFS) and the Bureau of Land Management (BLM) commissioned the Forest Ecosystem Management Team (FEMT) to formulate and assess the consequences of management options. The assessment emphasizes producing management alternatives that comply with existing laws and maintaining the highest contribution of economic and social well being. The “backbone” of ecosystem management is recognized as constructing a network of late-successional forests and an interim and long-term scheme that protects aquatic and associated riparian habitats adequate to provide for threatened species and “at risk” species. Biological objectives of the Northwest Forest Plan include assuring adequate habitat on Federal lands to aid the “recovery” of late-successional forest habitat-associated species listed as threatened under the Endangered Species Act and preventing species from being listed under the Endangered Species Act.

Oregon’s Forest Practices Act

The Oregon *Forest Practices Act* (FPA, 1994) contains regulatory provisions that include the following objectives: classify and protect water resources, reduce the impacts of clearcut harvesting, maintain soil and site productivity, ensure successful reforestation, reduce forest management impacts to anadromous fish, conserve and protect water quality and maintain fish and wildlife habitat, develop cooperative monitoring agreements, foster public participation, identify stream restoration projects, recognize the value of biodiversity and monitor/regulate the application of chemicals. Oregon’s Department of Forestry (ODF) has adopted *Forest Practice Administrative Rules* (1997) that clearly define allowable actions on State, County and private forest lands. *Forest Practice Administrative Rules* allow revisions and adjustments to the regulatory parameters it contains. Several revisions have been made in previous years and it is expected that the ODF, in conjunction with DEQ, will continue to monitor the success of the *Forest Practice Administrative Rules* and make appropriate revisions that address water quality concerns.

Coastal Nonpoint Pollution Control Program

The National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA) have developed guidance for State coastal nonpoint pollution control programs. Section 6217 of the Coastal Zone Act Reauthorization Amendments requires the State of Oregon to develop and submit to the NOAA and EPA coastal nonpoint pollution control

programs for approval (CZARA, 1990). *Coastal Nonpoint Pollution Control Programs* will be implemented under the provisions of the Clean Water Act (CWA, 1972) and the Coastal Zone Management Act (CZMA, 1972). The overriding purpose of Section 6217 of the CZARA is to enhance State and local efforts to manage land use activities that degrade coastal waters and habitats. All coastal nonpoint pollution control programs will closely coordinate with existing and future State and local water quality management plans. Specifically, a nonpoint pollution control program will achieve the following objectives: identify nonpoint source categories, identify management measure to be implemented and describe the process by which the State of Oregon will ensure the implementation of management measures.

Senate Bill 1010

Senate Bill 1010 allows the Oregon Department of Agriculture (ODA) to develop Water Quality Management Plans for agricultural lands where such actions are required by State or Federal Law, such as *TMDL* requirements. The Water Quality Management Plan should be crafted in such a way that landowners in the local area can prevent and control water pollution resulting from agricultural activities. Local stakeholders will be asked to take corrective action against identified problems such as soil erosion, nutrient transport to waterways and degraded riparian areas. It is the ODA's intent to establish Water Quality Management Plans on a voluntary basis. However, *Senate Bill 1010* allows the ODA to use civil penalties when necessary to enforce against agriculture activity that is found to transgress parameters of an approved Water Quality Management Plan. The ODA has expressed a desire to work with the local stakeholders and other State and Federal agencies to formulate and enforce approved Water Quality Management Plans.

Oregon Plan for Salmon and Watersheds

The State of Oregon has formed a partnership between Federal and State agencies, local groups and grassroots organizations, that recognizes the attributes of aquatic health and their connection to the health of salmon populations. Oregon's *Oregon Plan for Salmon and Watersheds* (formerly called the *Coastal Salmon Restoration Initiative*) considers the condition of salmon as a critical indicator of ecosystems (CSRI, 1997). The decline of salmon populations has been linked to impoverished ecosystem form and function. Clearly stated, the Oregon Plan has committed the State of Oregon to the following obligations: an ecosystem approach that requires consideration of the full range of attributes of aquatic health, focuses on reversing factors for decline by meeting objectives that address these factors, develops adaptive management and a comprehensive monitoring strategy, and relies on citizens and constituent groups in all parts of the restoration process.

The intent of the Oregon Plan is to conserve and restore functional elements of the ecosystem that supports fish, wildlife and people. In essence, the Oregon Plan is distinctly different from the traditional agency approach, and instead, depends on sustaining a local-state-federal partnership. Specifically, the CSRI is designed to build on existing State and Federal water quality programs, namely: *Coastal Nonpoint Pollution Control Program*, the *Northwest Forest Plan*, Oregon's *Forest Practices Act*, Oregon's *Senate Bill 1010* and Oregon's *Total Maximum Daily Load Program*

2. REGULATORY FRAMWORK

2.1 Beneficial Uses

The Oregon Environmental Quality Commission has adopted numeric and narrative water quality standards to protect designated beneficial uses. In practice water quality standards have been set at a level to protect the most sensitive uses and seasonal standards may be applied for uses that do not occur year round. Cold-water aquatic life such as salmon and trout are often the most sensitive uses in Rogue basin streams.

Oregon Administration Rules (**OAR Chapter 1, Division 41, Table 19**) lists the designated beneficial uses for which water is to be protected. The beneficial uses occurring in the Illinois Basin are presented in **Table 1**.

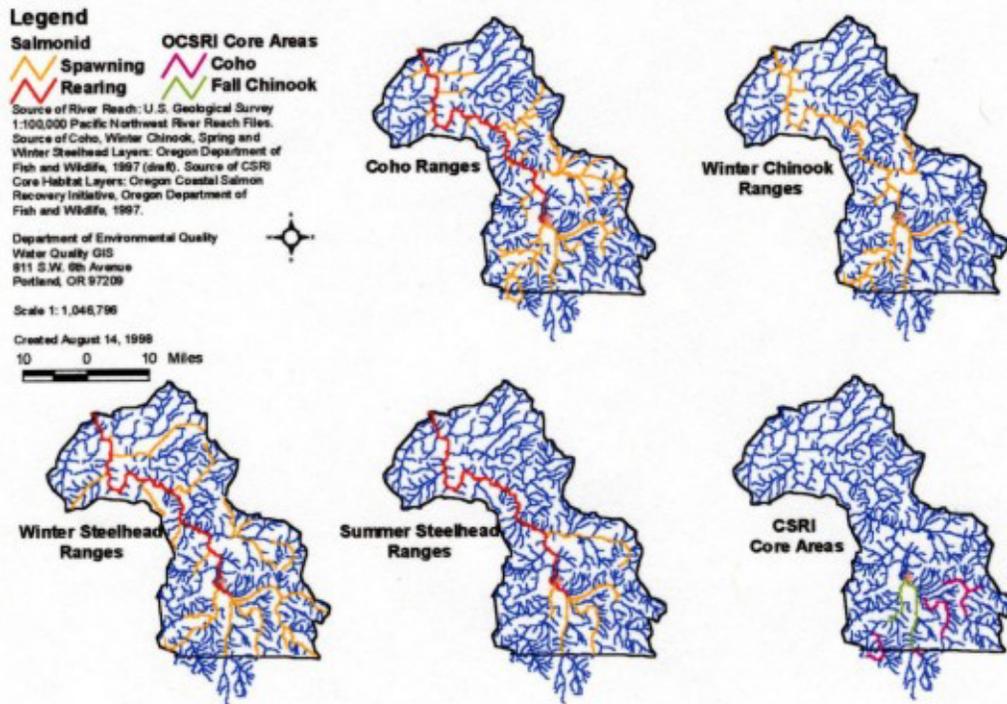
Table 1. Beneficial uses occurring in the Illinois Basin.

Beneficial Uses	All Tributaries to Rogue River
Public Domestic Water Supply	X
Private Domestic Water Supply	X
Industrial Water Supply	X
Irrigation	X
Livestock Watering	X
Anadromous Fish Passage	X
Salmonid Fish Rearing	X
Salmonid Fish Spawning	X
Wildlife and Hunting	X
Fishing	X
Boating	X
Water Contact Recreation	X
Aesthetic Quality	X
Hydro Power	X

Water supply beneficial use is with adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards

Numeric and narrative water quality standards are designed to protect the most sensitive uses. In the Illinois sub-basin, resident fish and aquatic life and salmonid spawning and rearing are designated the most sensitive beneficial uses. Locations of sensitive *beneficial uses* are presented in **Image 1**.

Image 1. Illinois Basin Coho, Chinook, and Steelhead Ranges, and CSRI Core Habitat Areas.



2.2 Water Quality Standards

Monitoring has shown that water quality in the Illinois often does not meet water quality standards. Numerous stream reaches in the Illinois River basin have been observed to be in violation of State of Oregon water quality standards for temperature. In addition, Sucker Creek and the East Fork Illinois River are listed for violating the Flow Modification Standard, and Grayback Creek is listed for violating Habitat Modification. Other streams within the sub-basin may also fail to meet standards, but data were insufficient to list the water body as Water Quality Limited (WQL). Water Quality Standards for the Illinois Basin are presented in **Appendix A**.

Section 303(d) of the Federal Clean Water Act (1972) requires that water bodies that violate water quality standards, thereby failing to fully protect *beneficial uses*, be identified and placed on a 303(d) list. Water quality management plan development (total maximum daily load – TMDL) will be implemented to restore water quality. In addition to watershed condition assessment and problem statements, water quality management plan (TMDL) requires that water quality goals and objectives be identified, responsible parties be designated, some measure of assurance that management plan (TMDL) activities will actually be implemented, and a monitoring of feedback loop (ODEQ 1997).

Temperature

A seven-day moving average of daily maximums (7-day statistic) was adopted as the statistical measure of the stream temperature standard. Absolute numeric criteria are deemed action levels and water quality standard compliance (**Table 2**). The numeric criteria adopted in Oregon's water temperature standard rely on the biological temperature limitations presented in **Table 3**. An extensive analysis of water temperature related to aquatic life and supporting documentation for the temperature standard can be found in the *1992-1994 Water Quality Standards Review Final Issue Papers* (DEQ, 1995).

Table 2. Water temperature action levels that apply to streams/ivers in the Illinois (Rogue) River basin.

Water Temperature Standard	7-Day Statistic
<i>Basic Absolute Criterion</i> – Applies year long in all streams in the basin, with the exception of those that qualify for the <i>salmonid spawning, egg incubation and fry emergence criterion</i> -or- <i>bull trout criterion</i> .	≤64°F (17.8°C)
<i>Salmonid Spawning, Egg Incubation and Fry Emergence Criterion</i> – Applies to stream segments designated as supporting native salmonid spawning, egg incubation and fry emergence for the specific times of the year when these uses occur.	≤55°F (12.8°C)
<i>Bull Trout Criterion</i> – Applies to waters determined by the Department to support or to be necessary to maintain the viability of Bull Trout in the basin.	≤50°F (10.0°C)

Table 3. Modes of thermally induced cold-water fish (salmon and trout species) mortality.

Modes of Thermally Induced Fish Mortality	Temperature Range	Time to Death
Instantaneous Lethal Limit – Denaturing of bodily enzyme systems	< 90°F < 32°C	Instantaneous
Incipient Lethal Limit – Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	74°F to 80°F 21°C to 27°C	Hours to Days
Sub-Lethal Limit – Conditions that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supply and increased competition from warm water tolerant species	64°F to 74°F 18°C to 21°C	Weeks to Months

Temperature Related to Aquatic Life

Aquatic life is the beneficial use of water in the Illinois Basin most sensitive to water temperature. Salmonid fishes, often referred to as cold water fish, and some amphibians appear to be highly sensitive to temperature. Oregon's water temperature standard employs logic that relies on using a few *indicator species*, which are the most sensitive. If temperatures are protective of these species, other species will share in this level of protection. Coho salmon (*Oncorhynchus kisutch*) were listed by the National Marine Fisheries Service (NMFS) as threatened (61FR24588), and NMFS has proposed to list steelhead trout (*Oncorhynchus mykiss*) as threatened (61FR41541) within the Illinois River basin. Fish species distribution ranges in the Illinois Basin are presented on **Image 1**.

If stream temperatures become too hot, fish die almost instantaneously due to denaturing of critical enzyme systems in their bodies (*Posser, 1967; Hogan, 1970*). The ultimate *instantaneous lethal limit* occurs in high temperature ranges (upper-90°F). Such warm temperature extremes are rare in the Illinois River basin.

More common and widespread, however, is the occurrence of temperatures in the mid- to high-70°F range (mid- to high-20°C range). These temperatures cause death of cold-water fish species during exposure times lasting a few hours to a day. The exact temperature at which a cold water fish succumbs to such a thermal stress depends on the temperature that the fish is acclimated and on particular development life-stages. This type of mortality, termed the *incipient lethal limit*, results from breakdown of physiological regulation of vital processes such as respiration and circulation (*Houston, 1971; Roberts, 1973; Heath and Hughes, 1973*). *Brett (1952)* reported an incipient lethal limit of 77°F (25°C) for spring chinook salmon. Similarly, *Bell (1984)* reported an incipient lethal limit for chinook salmon of 77°F (25°C). The Environmental Protection Agency (EPA) and National Marine Fisheries Service (NMFS) reported 50% mortality to adult salmon and steelhead trout with a constant water temperature of 70°F (21°C).

The most common and widespread cause of thermally induced fish mortality is attributed to interactive effects of decreased or lack of metabolic energy for feeding, growth or reproductive behavior, increased exposure to pathogens (viruses, bacteria and fungus), decreased food supply (impaired macroinvertebrate populations) and increased competition from warm water tolerant

species. This mode of thermally induced mortality, termed indirect or *sub-lethal*, is more delayed, and occurs weeks to months after the onset of elevated temperatures (mid-60°F to low-70°F).

* * *

State of Oregon Administrative Rules (Chapter 340) specify that, unless specifically allowed under a Department-approved surface water temperature management plan, no measurable surface water temperature increase resulting from anthropogenic activities is allowed (OAR 340-41-365):

- (i) In a basin for which salmonid fish rearing is a designated beneficial use, and in which surface water temperatures exceed 64.0°F (17.8°C);
- (ii) In waters and periods of the year determined by the Department to support native salmonid spawning, egg incubation, and fry emergence from the egg and from the gravels in a basin which exceeds 55.0°F (12.8°C);
- (iii) In waters determined by the Department to support or to be necessary to maintain the viability of native Oregon bull trout, when surface water temperatures exceed 50.0°F (10.0°C);
- (iv) In waters determined by the Department to be ecologically significant cold-water refugia;
- (v) In stream segments containing federally listed Threatened and Endangered species if the increase would impair the biological integrity of the Threatened and Endangered population;
- (vi) In Oregon waters when the dissolved oxygen (DO) levels are within 0.5 mg/L or 10 percent saturation of the water column or intergravel DO criterion for a given stream reach or subbasin;
- (vii) In natural lakes.

The Oregon Fish and Wildlife (ODFW) did not report the presence of Bull Trout in rivers of the Illinois Basin (ODFW 1997). Therefore, the temperature standard for bull trout habitat that is listed above does not apply to the Illinois Basin.

Habitat Modification

The criteria for Habitat Modification listing is a documentation that habitat conditions are a significant limitation to fish or other aquatic life as indicated by the following information:

- Beneficial uses are impaired. This documentation can consist of data on aquatic community status that shows aquatic communities (primarily macroinvertebrates) which are 60% or less of the expected reference community for both multimetric scores and multivariate model scores are considered impaired. Streams with either multimetric scores or multivariate scores between 61% and 75% of expected reference communities are considered as streams of concern. Streams greater than 75% of expected reference communities using either multimetric or multivariate models are considered unimpaired.

-or-

Where monitoring methods determined a Biotic Condition Index, Index of Biotic Integrity, or similar metric rating of poor or a significant departure from reference conditions utilizing a suggested EPA biomonitoring protocol or other technique acceptable to DEQ.

-or-

Fishery data on escapement, redd counts, population survey, etc. that show fish species have declined due to water quality conditions; and

- Habitat conditions that are a significant limitation to fish or other aquatic life as documented through a watershed analysis or other published report which summarizes the data and utilizes standard protocols, criteria and benchmarks (e.g. those currently used and accepted by Oregon Fish and Wildlife or Federal agencies (PACFISH)). Habitat conditions considered here are represented by data that relate to channel morphology or in-stream habitat such as Large Woody Material, Pool Frequency, Channel Width:Depth Ratio (other habitat factors are considered elsewhere - cobble embeddedness or percent fines would be considered under sedimentation, stream shading would be factored in under temperature, etc).

Grayback Creek is listed for Habitat Modification. Data used for listing was obtained from Grayback/Sucker Pilot Watershed Analysis (USFS, 1995). Specifically, it was reported within this watershed analysis that large wood, pool depth and frequency were below expected conditions. Coho and Winter Run Steelhead have been petitioned under the Endangered Species Act (ESA).

Flow Modification

The criteria for Flow Modification listing is a Documented flow conditions that are a significant limitation to fish or other aquatic life as indicated by the following information:

- Beneficial uses are impaired. This documentation can consist of data on aquatic community status that shows aquatic communities (primarily macroinvertebrates) which are 60% or less of the expected reference community for both multimetric scores and multivariate model scores are considered impaired. Streams with either multimetric scores or multivariate scores between 61% and 75% of expected reference communities are considered as streams of concern. Streams greater than 75% of expected reference communities using either multimetric or multivariate models are considered unimpaired.
-or-
Where monitoring methods determined a Biotic Condition Index, Index of Biotic Integrity, or similar metric rating of poor or a significant departure from reference conditions utilizing a suggested EPA biomonitoring protocol or other technique acceptable to DEQ.
-or-
Fishery data on escapement, redd counts, population survey, etc. that show fish species have declined due to water quality conditions; and
- an established or applied for Instream Water Right, and
- documentation that flows are not frequently being met such as through statistical summaries of stream flow based on actual flow measurements, and
- identification of human contribution to the reduction of instream flows below acceptable level indicated (e.g. evidence of water rights and diversions above or in the segment).

East Fork of the Illinois River is listed for Flow Modification: The Instream Water Right (IWR) #070979 was not met at the USGS gauge #14372500. In addition, Sucker Creek is listed for Flow Modification: IWR #62323 was not met at the USGS gauge #14375100. ODFW (1993) reported that low flows in these areas are due to water withdrawals. Coho populations are depressed within this region and are designated as a sensitive species. Winter Steelhead populations have been shown to be declining.

2.3 303(d) Listed Water Bodies in the Illinois Basin

River segments that violated the temperature-rearing standard (see Table 2) in the Illinois Basin are presented in Table 4 (i.e. These river segments are listed on the 1998 303(d) list for water temperature.). Salmonid rearing in the Rogue (Illinois) Basin occurs from June 1 through September 30. Salmonid Spawning (through Fry Emergence) periods occur from October 1 through May 31 or waterbody specified as identified by Oregon Department of Fish and Wildlife (ODFW) biologists. River segments listed as violating the habitat modification and flow modification standards in the Illinois Basin are listed in Table 5.

Table 4. 1998 303(d) Water Quality Limited (WQL) for Temperature during Salmon rearing periods in the Illinois basin.

Name	Segment Range
Dry Creek (South Fork Deer Creek)	Mouth to Headwaters
Silver Creek, South Fork	Mouth to Headwaters
Indigo Creek, North Fork	Mouth to Headwaters
Indigo Creek	Mouth to East Fork
Illinois River, West Fork	Mouth to California Border
Illinois River	Briggs Creek to East/West Fork Confluence
Illinois River, East Fork	Mouth to California Border
Fiddler Gulch	Mouth to Headwaters
Josephine Creek	Mouth to Headwaters
Klondike Creek	Mouth to Headwaters
Deer Creek, South Fork	Mouth to RM 2
Deer Creek	Mouth to North/South Fork Confluence
Collier Creek	Mouth to South Fork
Canyon Creek	Mouth to Headwaters
Briggs Creek	Mouth to Horse Creek
Bear Creek	Mouth to Headwaters
Elk Creek	Mouth to California Border
Sucker Creek	Mouth to Grayback Creek
Sixmile Creek	Mouth to Headwaters
Silver Creek, North Fork	Mouth to Hawk Creek
Silver Creek	Mouth to Todd Creek
Rough & Ready Creek	Mouth to North/South Confluence
Lawson Creek	Mouth to river mile 5
Rancherie Creek	Mouth to Headwaters
Lake Creek (Sucker Creek)	Mouth to diversion
Fall Creek	Mouth to Headwaters
Rough & Ready Creek, South Fork	Mouth to Headwaters
Althouse Creek	Mouth to river mile 7.5 (Tartar Gulch)
Soldier Creek	Mouth to Spalding Dam
Canyon Creek, South Fork	Mouth to headwaters
Free and Easy Creek	Mouth to Headwaters
Dunn Creek	Mouth to Headwaters
Illinois River	Mouth to Briggs Creek

Table 5. 1998 303(d) Water Quality Limited (WQL) for Habitat Modification and Flow Modification in the Illinois basin.

Name	Segment Range
Flow Modification	
Illinois River, West Fork	Mouth to California Border
Illinois River, East Fork	Mouth to California Border
Briggs Creek	Mouth to East/West Fork Confluence
Sucker Creek	Mouth to Bolan Creek
Habitat Modification	
Grayback Creek	Mouth to Headwaters
Sucker Creek	Mouth to Bolan Creek

3. AVAILABLE WATER QUALITY DATA SUMMARY

3.1 ODEQ Water Quality (Grab Samples) Data Summary

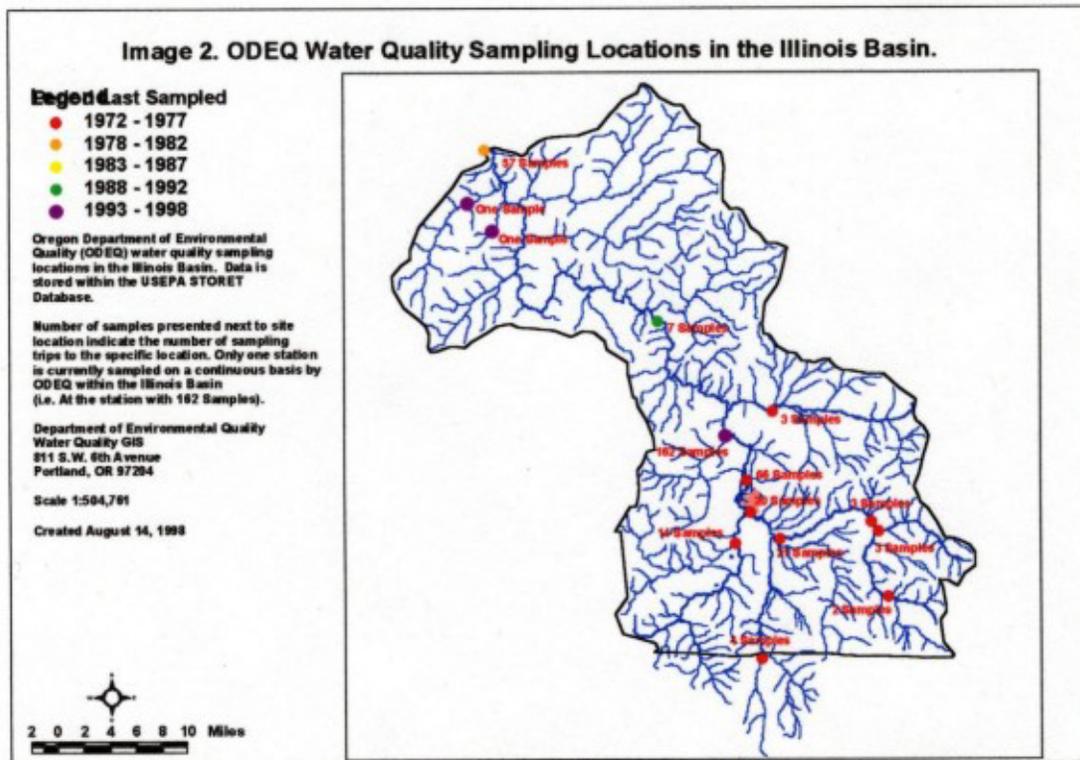
This report presents water quality chemistry data collected by the Oregon Department of Environmental Quality (ODEQ) in the Illinois River from 1980 to the present. ODEQ has been collecting water quality data sporadically throughout the Illinois sub-basin of the Rogue River basin since the early 1960's. Water Quality data collected at these stations is stored the U.S. Environmental Protection Agency's STORET database. DEQ monitoring stations located on the Illinois River, as well as tributary streams in the Illinois River sub-basin, are presented in **Table 6** and are illustrated in **Image 2**.

Table 6. DEQ Water Quality Monitoring Stations in the Illinois sub-basin.
[STORET, U.S. EPA database; a, only data from 1980 was included in analysis.]

Station Name	Station ID (STORET #)	Location (River Mile)	Number of Samples	Period of Record
Illinois River D/S Kerby	404161	48.4	162	1976 - Present ^a
Illinois River West of Selma	402278	33.5	7	June 1988 - Sept. 1990
Illinois River at Finch Bridge (Kerby)	402096	53.9	66	1960-1976
Illinois River at Mouth	402095	0.0	57	1966 - 1979
East Fork Illinois River At Hwy 199	402915	57.4	20	1973 - 1976
East Fork Illinois River At Road 415	402770	14.6	4	1971 - 1972
West Fork Illinois River At Hwy 199	402914	3.1	14	1975 - 1976
Horse Sign Creek D/S Pine Flat Creek	404818	3.1	1	July 1993
Lawsen Creek West Of USFS Trail #1173	404823	4.2	1	July 1993
Lake Creek at Hwy 46	402774	0.1	3	1971 - 1972
Sucker Creek at Bolan Creek Rd	402772	17.6	2	1971 - 1972
Sucker Creek at Takilma Rd	402916	0.4	21	1973 - 1976
Deer Creek at Hwy 199	402771	4.2	3	1971 - 1972
Grayback Creek at Hwy 46	402773	0.1	3	1971 - 1972

Most sites presented in **Table 6** were sampled for only a limited duration, however the water quality monitoring station located downstream of the City of Kerby (#404161) has been frequently sampled since 1970. Water quality parameters sampled at this site include chemical, biological, and physical parameters, which are collected in order to evaluate seasonal and annual water quality trends. Seasonal water quality trends (variability) in water temperature, dissolved oxygen, dissolved oxygen saturation, and the hydrogen ion activity (pH), as well as nutrient concentrations, observed at the Kerby station are presented below.

Results from "historical" water quality trending analysis for data collected at the Kerby sampling station is presented in **Appendix B**. Seasonal water quality trending analysis of data collected at this station for parameters other than listed above are also presented in **Appendix B**.



Seasonal Water Quality Variability

Data is presented in the form of seasonal box and whisker plots, which present the data temporally. The box plots will have month of analysis on the X-axis with the water quality parameter on the Y-axis. The box represents the data at the sampling sites for the specified period. Each box represents a summary of the data. The upper corner of each box is the 75th percentile (75 percent of the data are below that concentration), and the lower corner is the 25th percentile (25 percent of the data are below that concentration). The upper and lower tails are the 90th and 10th percentiles, respectively. Points above and below the tails represent data higher and lower than the 90th and 10th percentiles. The dashed line in the box is the median concentration for that site (half of the data fall above and below that concentration). An example of a box and whisker plot is shown in **Figure 1**

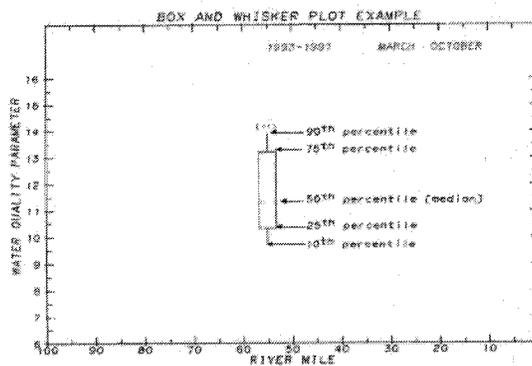


Figure 1. Example of box and whisker plot.

Seasonal Temperature Variability

Seasonal box plots of DEQ grab sample measurements of temperature in the Illinois River downstream of Kerby is presented in **Figure 2**. As shown, temperatures in the Illinois River frequently exceeded 17.8°C temperature standard during the summer period. Stream flows are at their minimum and available solar energy (for river heating) is near its annual maximum during the summer period. Winter water temperature levels decrease dramatically from summer values, as river flows increase and available solar energy is at an annual minimum. A much more extensive discussion of water temperature conditions in the Illinois River basin, as well as hydrologic flow statistic analysis, is presented in later chapters of this report.

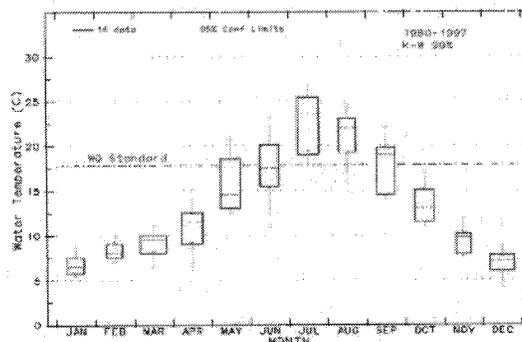
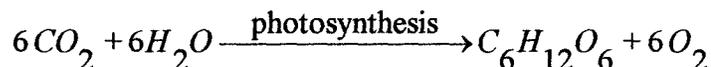


Figure 2. Seasonal temperature trend in the Illinois River downstream of Kerby.

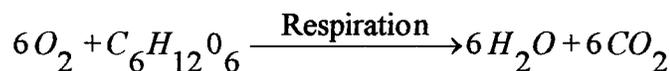
Seasonal Dissolved Oxygen Variability

The OAR specifies that for waterbodies identified by the Department as providing for cold-water aquatic life, the dissolved oxygen shall not be less than 8.0 mg/L as an absolute minimum (OAR 340-41-365). Where conditions of barometric pressure, altitude, and temperature preclude attainment of 8.0 mg/L, DO shall not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the DO shall not fall below 8.0 mg/L as a 30-day average, 6.5 mg/L as a 7-day rolling average of the daily minimums, and 6.0 mg/L as an absolute minimum. Water Quality standards for the Illinois (Rouge) basin are presented in Appendix A. Waterbodies identified as providing for cold-water aquatic life are bodies within which salmon, trout, cold-water invertebrates, and other native cold-water species exist throughout all or most of the year (OAR 340-41-455 Table 21) and within which juvenile anadromous salmonids may rear throughout the year. All reaches in the Illinois River Basin have been identified as providing for cold-water aquatic life.

Algal present in the river (either attached or free floating) use light energy for growth during daylight conditions. This process, called photosynthesis, produces oxygen (O₂) as a byproduct, and consumes carbon dioxide (CO₂):



In-stream dissolved oxygen concentration increase as a result of this process. Maximum daily dissolved oxygen concentrations occur in late afternoon, following a full day of oxygen production. Alternatively, dissolved oxygen is consumed and carbon dioxide is produced during nighttime conditions primarily through biological activity (Respiration):



Thus, minimum daily dissolved oxygen conditions occur just before sunrise, following a full night period of respiration. Dissolved Oxygen (and pH) can fluctuate widely in systems dominated by algae, both in the form of attached algae (periphyton) and suspended algae (phytoplankton). Therefore, the time of day of sampling strongly influences the measured DO and pH. Seasonal plots of DO and DO as a percent of saturation are presented in Figure 3.

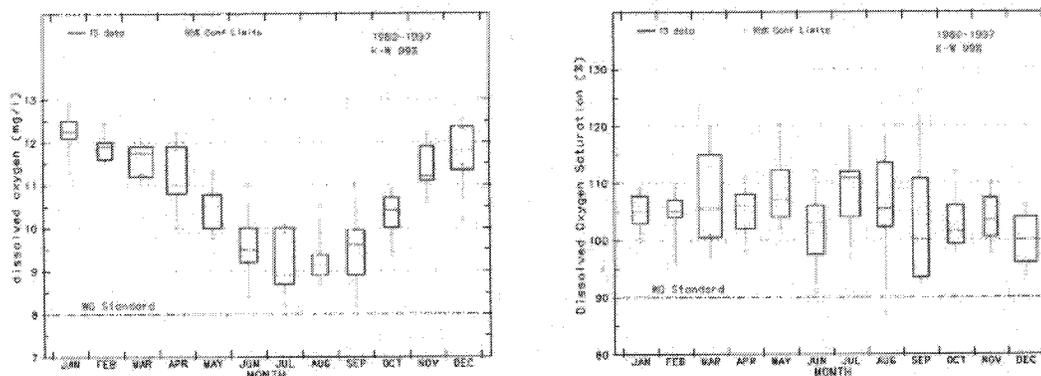


Figure 3. Dissolved Oxygen and Dissolved Oxygen Saturation in the Illinois River downstream of Kerby.

Dissolved Oxygen levels in grab samples collected in the Illinois River downstream of Kerby indicate that concentrations decrease during the summer period. However, calculated dissolved oxygen saturation levels at this DEQ water quality station are maintained primarily between 110 and 110 percent saturation. This level is above the respective winter and summer dissolved oxygen standard, 95 and 90%, respectively. These results indicate that the observed summer dissolved oxygen concentrations sag is partially resulting from decreased oxygen solubility at the elevated summer water temperatures (see **Figure 2**).

Oxygen produced during photosynthesis can result in in-stream concentrations greater than saturation. Saturation is defined as the maximum oxygen concentration anticipated at observed pressure and temperature. Super-saturation conditions can occur when oxygen produced during photosynthesis is at a rate greater than the gas transfer rate across the air/water interface. Similarly, under-saturation conditions can occur when oxygen consumed during respiration activity is at a rate greater than the gas transfer rate across the air/water interface. The relatively low saturation values measured in Illinois River indicate that algal production (both attached and free floating) is currently at low levels.

Seasonal pH (HYDROGEN ION ACTIVITY) Variability

The OAR specifies that the pH of streams in the Rogue Basin may not fall outside of the range 6.5-8.5 (see **Appendix A**).

Observed pH (hydrogen Ion Activity) trends in the Illinois River were similar to trends measured for dissolved oxygen. In addition to directly affecting dissolved oxygen cycling, the diurnal photosynthetic/respiration cycle affects the pH condition in the river through the consumption/production of carbon dioxide, respectively. Illinois River pH levels increase at reduced carbon dioxide levels, and decrease at increased carbon dioxide levels. Thus, river pH levels increase when photosynthesis consumes carbon dioxide, and decrease when respiration produces carbon dioxide. Accordingly, maximum daily pH conditions were greater during the mid/late summer period, when seasonal algal production is at an annual maximum (**Figure 4**).

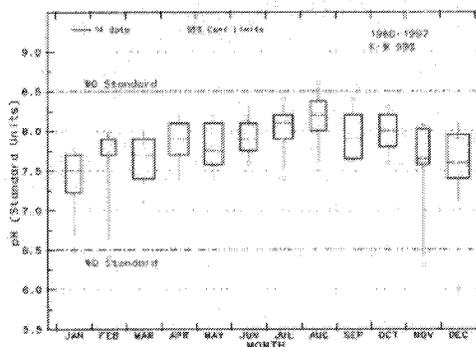


Figure 4. Seasonal pH trend in the Illinois River downstream of Kerby.

As discussed earlier, pH levels can fluctuate widely in rivers dominated by algae, with the daily maximum occurring during the late afternoon and the daily minimum occurring around dawn. A scattered plot of time-of-sampling and observed pH illustrates that late afternoon collection times were represented at this DEQ water monitoring station. Therefore, it can be assumed afternoon pH maximums are represented in this data (**Figure 5**).

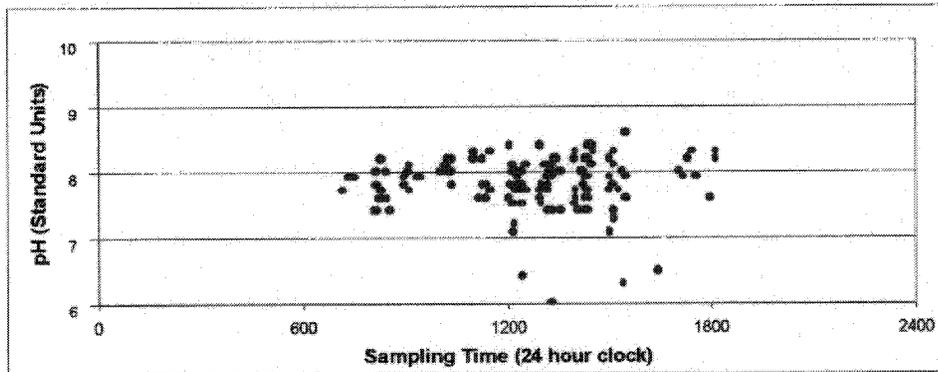


Figure 5. Sample time and observed pH at DEQ Water Quality monitoring site on the Illinois River downstream of the City of Kerby.

Seasonal Nutrient Concentration Variability

The rate of algal growth is limited by the availability of light, temperature and nutrients (Thomann and Mueller, 1987). If all of these are available in excess, then dense mats of periphyton (attached algae) will grow, and grazing by macro-invertebrates, grazer predation, substrate characteristics, and hydraulic sloughing will then regulate the algal mass.

Excessive algal growth can significantly degrade the health of a stream and cause aquatic toxicity problems related to excessive DO and pH fluctuations. During daylight hours, algae and other aquatic plants perform photosynthesis, which produces oxygen and utilizes carbon dioxide. This can result in dissolved oxygen levels well above saturation during the day as well as unacceptably high pH values. pH is affected because carbon dioxide in water forms carbonic acid. Waters high in CO_2 , therefore, will tend to have a low pH, while those low in CO_2 will have a high pH. Thus, as algae utilize CO_2 during the day, the pH of the water column will be increased. If excessive algae are present this can result in high afternoon pH levels which may result in toxicity to aquatic organisms. At night, photosynthesis ceases and respiration dominates the reaction. During respiration oxygen is utilized and CO_2 released, which results in declining DO and pH levels during the night.

Phosphorus and nitrogen are essential nutrients for algal growth. In freshwater systems not impacted by pollutant loads, one or both of these nutrients is generally in short supply relative to the needs of algae, thereby limiting algae growth. If point or non-point nutrient sources of the limiting nutrient are provided to the system, algal growth will occur until limited by some other factor. To gain insight into nutrient concentrations in the Illinois River and their influence on algal growth, total phosphorus and total nitrogen data is presented in **Figure 6**.

Nitrogen and phosphorus are present in several forms, not all of which are available for algal uptake. Phosphorus in the form of dissolved ortho-phosphate and nitrogen in the form of ammonia, nitrate, and nitrite (e.g. dissolved inorganic nitrogen) are readily available for algal uptake. Nutrients unavailable to algal uptake include phosphorus and nitrogen in particulate forms; such as inorganic matter, tightly bound to soil particles, and bound to dissolved organic matter. However, heterotrophic algae can utilize organically bound nutrients when dissolved inorganic nutrients are limiting growth.

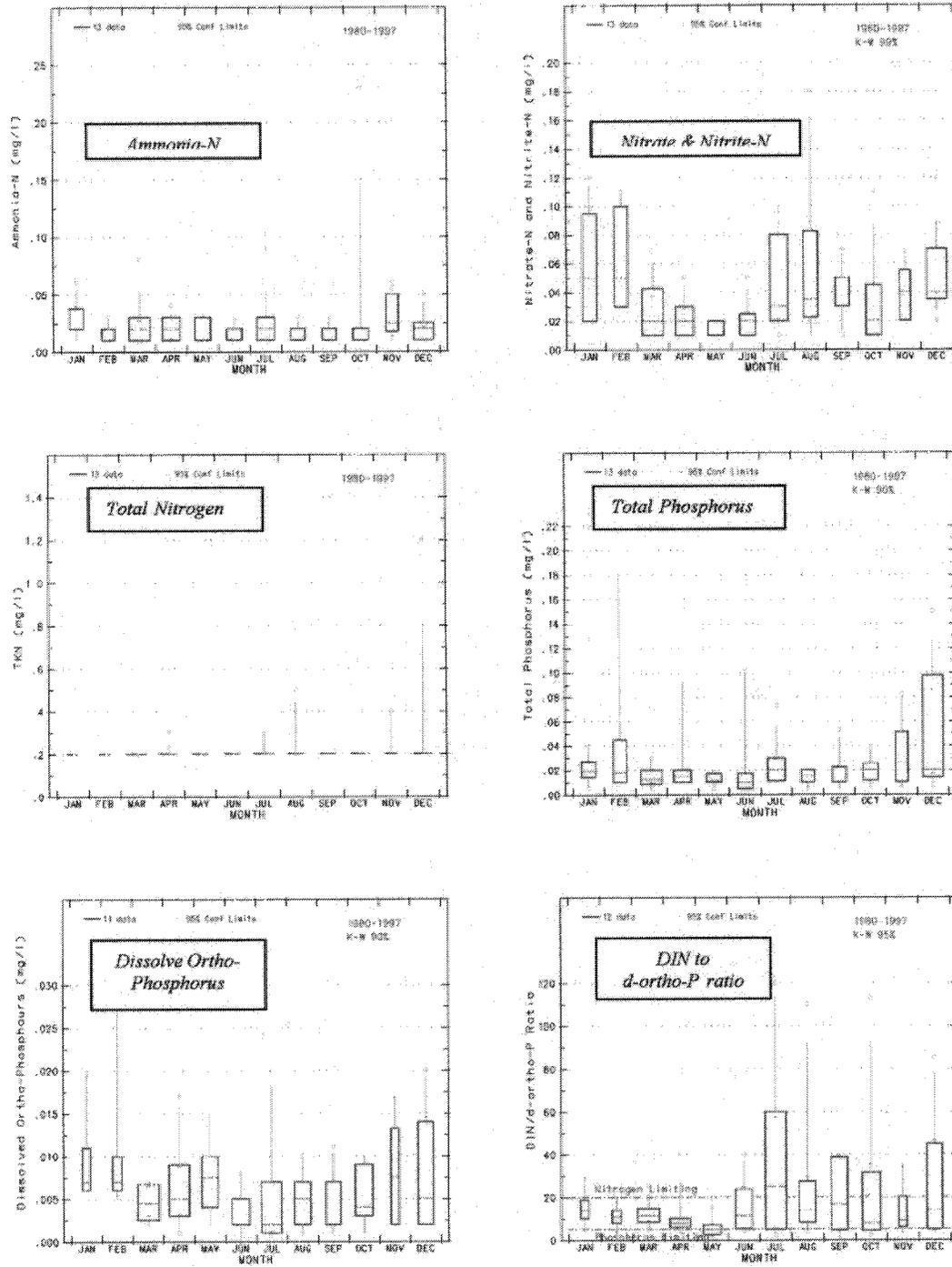


Figure 6. Seasonal Nitrogen and Phosphorus trends, as well as dissolved inorganic nitrogen (DIN) to dissolved ortho-phosphorus ratios, in the Illinois River downstream of Kerby.

The nutrient that limits growth is the nutrient in lowest supply relative to algal cell requirements. Under nutrient saturated conditions algal stoichiometry is generally well represented by the Redfield ratio that results in a mass basis ratio of dissolved inorganic nitrogen to dissolved ortho-phosphorus (N/P) of 7. The N/P ratio is a tool to determine the potential nutrient limiting algae growth. A N/P ratio less than 7 indicate that in-stream nitrogen is the limiting nutrient, and ratios greater than 7 indicate a phosphorus-limiting situation (Thomann and Mueller, 1987). Calculated dissolved inorganic nitrogen to dissolved ortho-phosphorus ratios is also included in Figure 6.

However, nutrients must not be present at or above saturating concentrations for the N/P ratio to be applied as a predictive tool. No nutrient limitation would occur, regardless of the N/P ratio, if in-stream nutrient concentrations are above saturation conditions. In those reaches, space, light, or water temperature may limit growth. Specifically, it has been observed that periphyton growth will **not** be limited by nitrogen or phosphorus if water column concentrations for the reactive forms of the nutrients are present in concentrations which exceed five times the respective Michaelis-Menten half-saturation constants (Thomann and Mueller, 1987). That is, if concentrations are high enough to satisfy algae growth requirements, growth will be limited factors other than nutrients. Typical half saturation constants reported in literature range from 0.004 to 0.008 for dissolved phosphorus and around 0.040 mg/l for dissolved nitrogen. Observed dissolved nutrient concentrations in the Illinois River downstream of Kerby are well below saturation conditions, and are often at or below the DEQ laboratory's minimum reporting limit (i.e. 0.005 mg/l for dissolved ortho-phosphorus, and 0.020 mg/l for both ammonia nitrogen and nitrate and nitrate nitrogen). Therefore, nutrient concentrations in the Illinois River at this location are below levels that would saturate algal growth requirements.

As mentioned earlier, dissolved oxygen and pH levels at the DEQ ambient water quality monitoring site downstream of Kerby (RM 48.4) are not listed as violating the respective standards on the Oregon 1998 303(d) List.

Additional Seasonal Variability Trends

The Department of Environmental Quality (DEQ) has collected water quality data from “other” rivers in the Illinois Basin (see Table 5), although much of this work was done during the 1970’s. It is difficult to assess *current* water quality conditions with data collected greater than ten ago because management activities that have occurred within the watershed since then can dramatically affect current water quality conditions. However, this data can be used to assess past water quality conditions, and to evaluate if conditions have changed over time.

Water quality data was collected by DEQ at: 1) the mouth of the Illinois River (1966 through 1979); 2) Sucker Creek at Takilma (1973 through 1976); and 3) East Fork Illinois River at Highway 199 (1973 through 1976). Water temperature, dissolved oxygen, dissolved oxygen percent saturation, and pH (Hydrogen Ion Saturation) data for these stations is presented in Figures 7 through 9, respectively. It is important to note that many of the standards illustrated on these figures were not applicable when the data was collected, and therefore they should only be used to as a reference towards current conditions (e.g. data collected at the d/s Kerby Station on the Illinois River – see Figures 2 through 6).

Similar seasonal temperature trends were observed at all locations, with annual minimum values occurring during the winter, and maximum values during the low flow summer months. Observed pH conditions were maintained within the current water quality Standard range of 8.5 to 6.5, indicating that algal growth (production) was not excessive. Observed summer pH levels were greater than winter values, which indicates increased biological productivity during the warm water summer months. Finally, observed dissolved oxygen concentrations and saturation levels were maintained above their respective current water quality Standards.

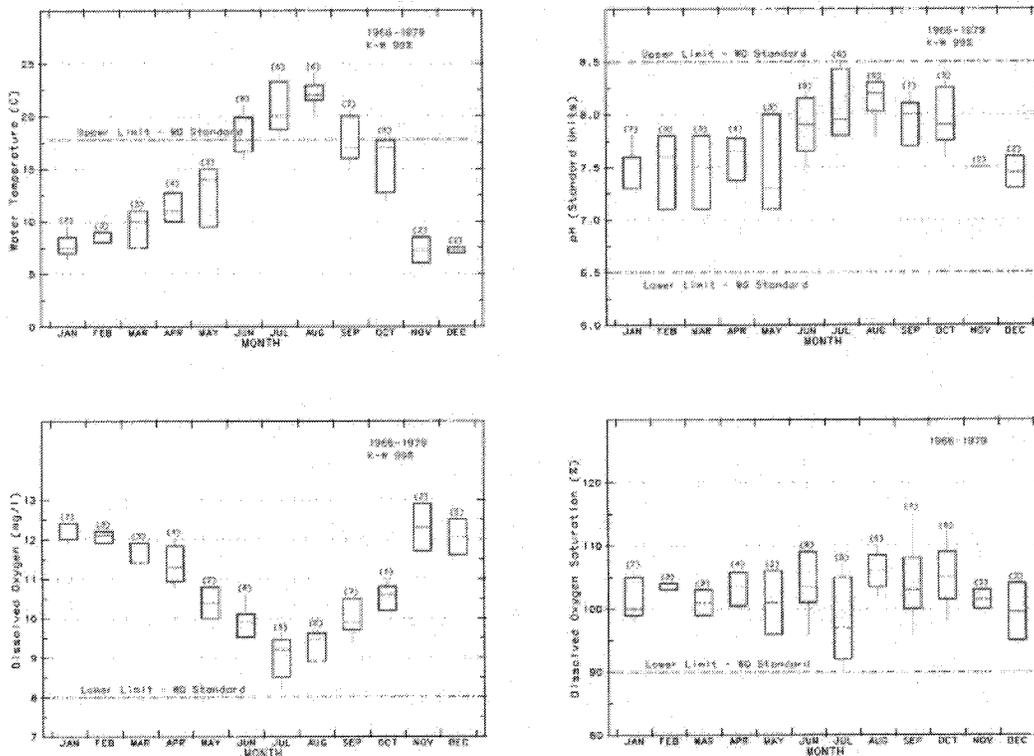


Figure 7. Water Quality Data collected on the Illinois River at the mouth – 1966 through 1979.

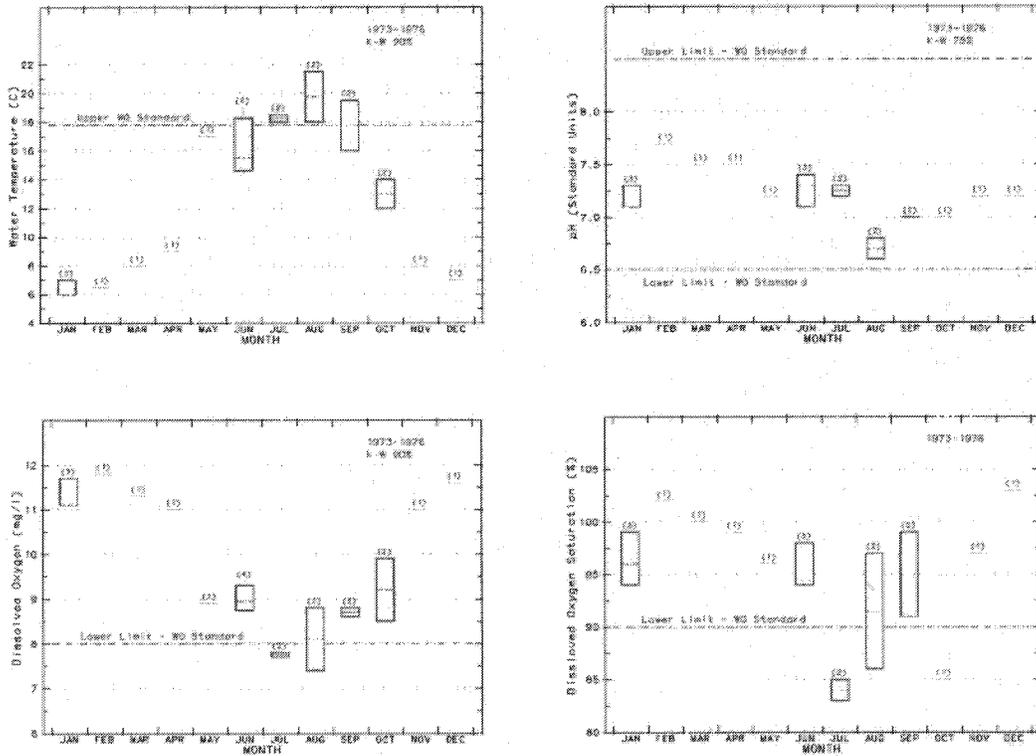


Figure 8. Water Quality Data collected on Sucker Creek near Takilma – 1973 through 1976.

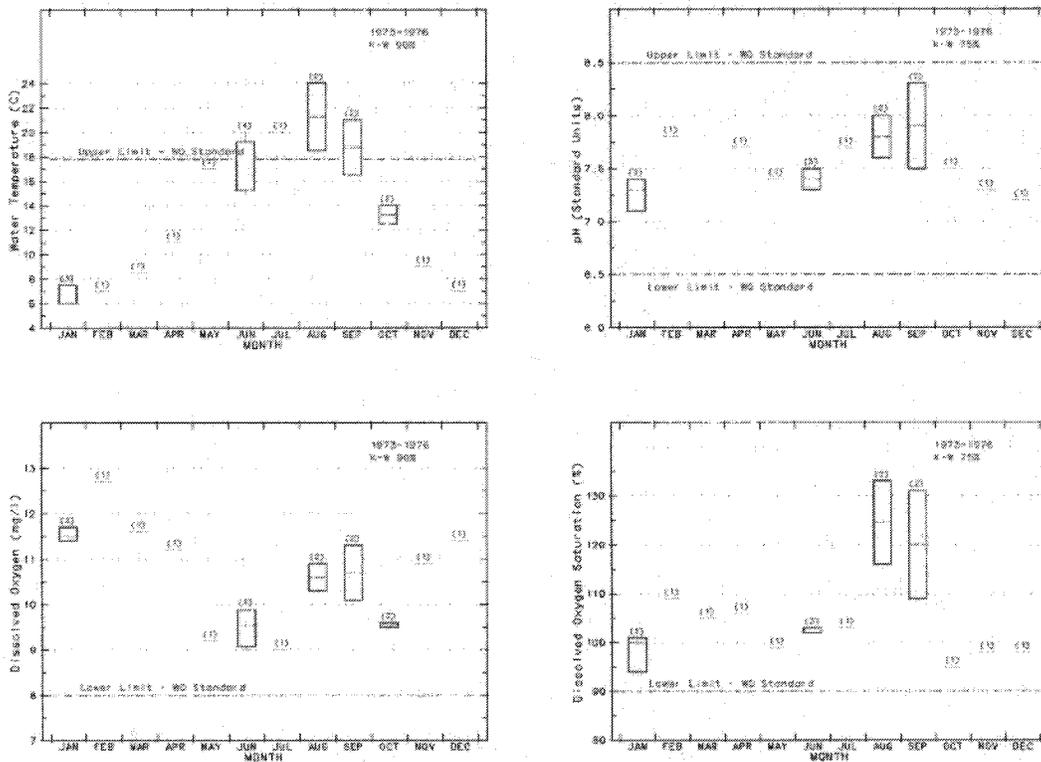


Figure 9. Water Quality Data collected on East Fork Illinois River – 1973 through 1976.

3.2 Continuous Temperature Data Summary

The Illinois River basin has been the focus of extensive continuous stream temperature monitoring since 1993. BLM and USFS have collected a total of 246 temperature data sets at 150 sites. The most recently measured 7-day statistic is presented in Table 7 along with applicable water temperature standards. It can be seen that over 45% of the most recently observed 7-Day temperature statistics are below the Basic Absolute Criteria of 64 °F.

Table 7. Most Recent 7-day statistics measured in the Illinois River basin.

Most Recent 7-Day Temperature Statistic	# of Sites	% of Total
Less than 58°F	17	11.3
58°F to 64°F	51	34.0
65°F to 71°F	38	25.3
72°F to 78°F	27	18.0
Greater than 78°F	17	11.3
Total	150	100%

Temperature standards violations generally occur within the mainstem portions of rivers and streams throughout the basin, however many violations were observed in upper reaches of forested tributaries. Image 3 displays a summary of the 7-day temperature statistics calculated from all of the continuous temperature data files in the Illinois River basin. Calculated 7-Day temperature values used in Image 3 are presented in Appendix C.

The warmest temperatures appear to occur between late July and early August (see Figure 2). The upper reaches of the West Fork and East Fork Illinois River, as well as valley portions of Sucker Creek, warm rapidly in the downstream direction to *sub-lethal* and *incipient lethal* levels for salmonids. Although there is some variability in the data between years, rapid water temperature changes occur within Illinois River Valley. River water temperatures in headwater forested areas of the Illinois River Basin are generally below the 64 °F temperature standard. However, water temperatures rapidly increase as rivers leave these forested areas and enter the Illinois River Valley (Figure 10).

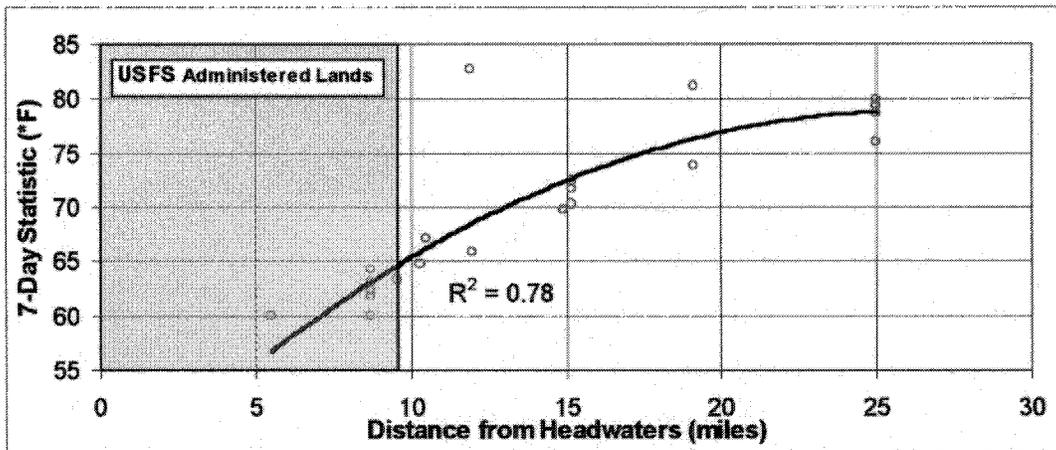
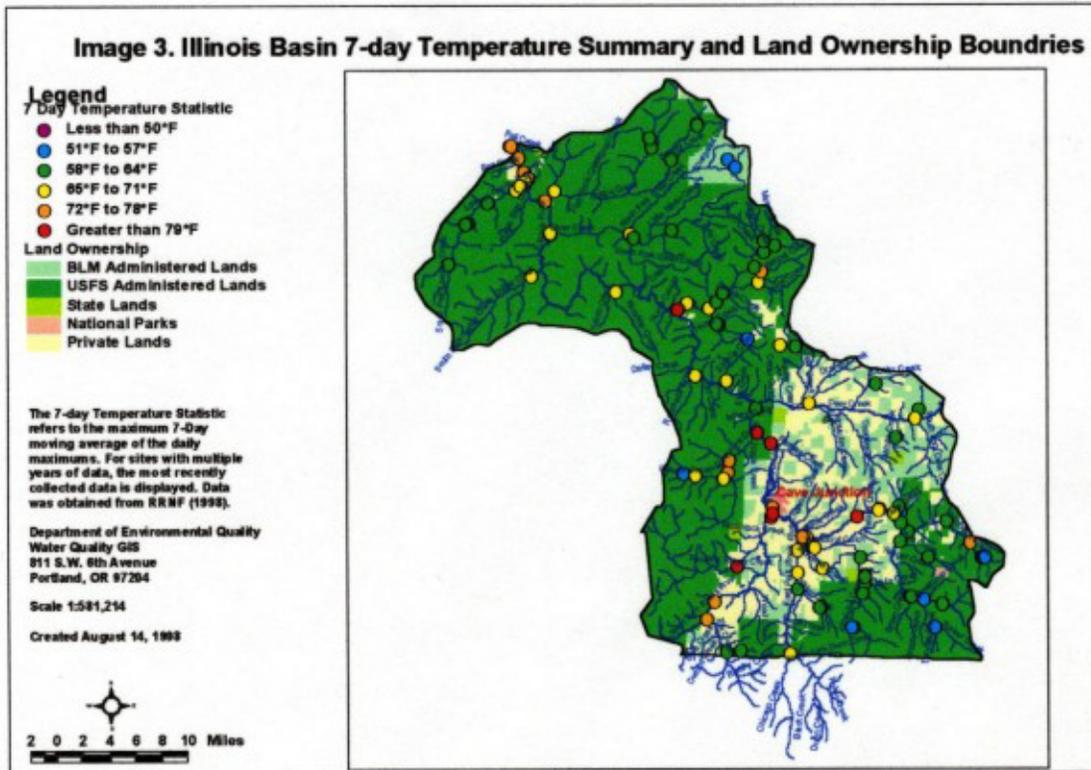


Figure 10. Observed 7-Day Temperature profile from the headwaters of Sucker Creek, through East Fork Illinois River, and the Illinois River below the City of Cave Junction.



Warm water temperatures are maintained throughout the entire downstream length of the mainstem Illinois River. However, some water temperature decrease was measured in the Illinois River near its confluence with the Rogue River (Figure 11). This observed temperature decrease could be due to several factors, including low water temperature tributary flows entering the Illinois River, natural climatological variability (i.e. data was collected over several years), and/or influences of groundwater. However, the precise proportions which these factors are influencing water temperature cannot be determined from the available data.

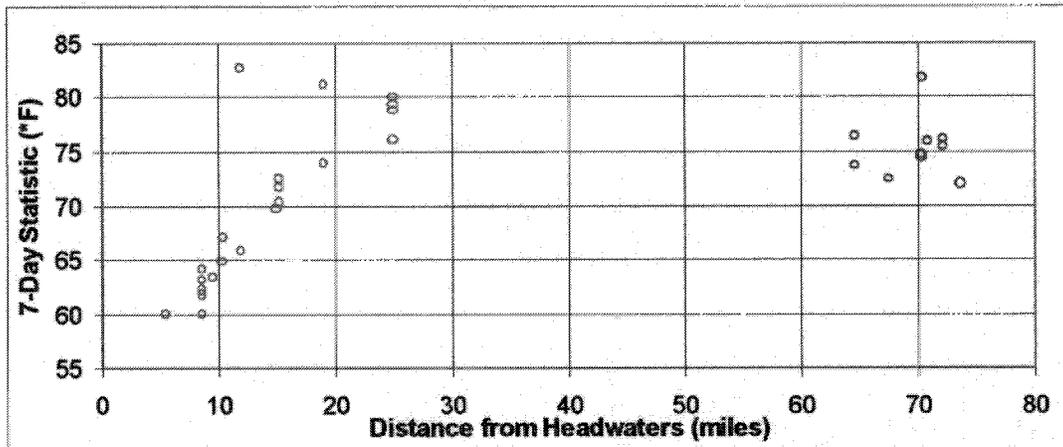


Figure 11. Observed 7-Day Temperature profile from the headwaters of Sucker Creek, through the Illinois River to its confluence with the Rogue River.

In addition to potentially cooling a river, tributary streams could possibly increase the water temperature of the receiving river. In addition to Sucker Creek, several other major tributaries drain directly into the Illinois River or into tributaries connecting with the Illinois. It was observed that the 7-Day temperature statistic increased as the water drains from their headwater regions, with temperatures above the standard at the mouth of each stream (Figure 12). In fact, no observed temperatures in the East and West Fork Illinois River were below the standard, and only one observed value below the standard in Deer Creek.

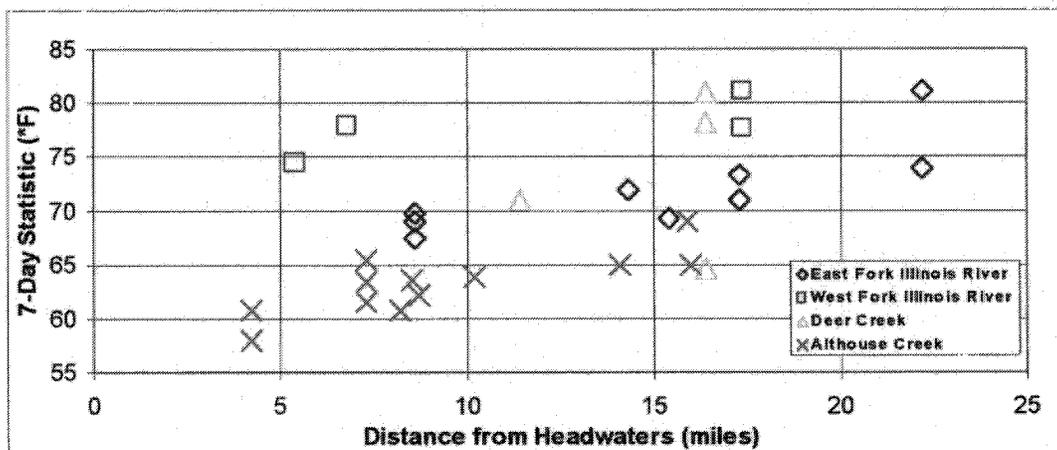


Figure 12. Water Temperature profile for tributaries of the Upper Illinois River.

Maximum 7-Day temperature statistics in the West and East Fork Illinois River and Deer Creek were shown to exceed 77°F (25°F). This temperature level can cause rapid mortality to salmonids. Recall that both Brett (1952) and Bell (1984) found the upper *incipient lethal limit* to be 77°F (25°F). The data show that vast reaches of these river systems located within the Illinois River Valley pose serious threats to salmon and trout populations. Present conditions in most of the basin exceed *sub-lethal* temperature ranges (mid-60°F to low-70°F).

In essence, the entire mainstem of the Illinois River, as well as many of the tributary streams which feed into the Illinois River mainstem, do not support summertime salmonid migrations, spawning and rearing. In much of this temperature limited section, river temperature are warm enough to cause rapid impairment of fish life sustaining biological processes for long periods of the summer.

Although water temperatures in the “headwater” regions of the basin are generally below the temperature standard of 64 °F, it is very important to note once again that temperatures increase in a downstream direction. This indicates that water-heating processes are occurring within these river reaches.

A technical assessment of water temperature related to stream 1) surface shade, 2) channel morphology, and 3) hydrology is presented in **Appendix D**.

3.3 Biological Data and Condition Assessment

In an effort to characterize “reference” river conditions in coastal regions of the State of Oregon, the Department of Environmental Quality (DEQ) collected macroinvertebrate, fish, habitat quality, and water quality samples at 34 river sites within the Oregon Coast Range during the 1992 and 1993 field season (DEQ 1994). Site locations were developed based on input from biologists and field staff from several government agencies, as well as reconnaissance surveys. Two reference sites for the California Coast Range Extension Sub-region were located within the Illinois Basin: Lawsen Creek and Horse Sign Creek. Both streams are located in forested areas of the basin. The watershed surface area of these two rivers occupy much less than ten percent of the entire Illinois basin surface area.

“Reference” condition is a qualitative rating of the watershed conditions based on our general knowledge of conditions in totally undisturbed watersheds. However, this is rarely the case, and the reference streams represent the best available streams in an area. Reference sites are sometimes located in highly modified watershed and may have considerable nonpoint source impairment. Therefore the DEQ used the following grading system for reference allocation:

- Grade A Ideal watershed and stream condition, a wilderness area or watershed with virtually no human disturbance.
- Grade B Good watershed and stream condition, some human disturbances but not widespread and/or best management practices are well implemented.
- Grade C Marginal watershed and stream condition for a reference site.

Both Lawson Creek and Horse Sign Creek were designated a Grade “A” condition, which indicates that these areas are not currently disturbed by human influences. It is important to point out that these streams were not randomly determined and therefore the Grade A designation for these two Illinois Basin rivers does not indicate that biological/habitat/chemical conditions throughout the Illinois basin are excellent. However, it does indicate that “undisturbed” portions of the Illinois basin do exist.

3.4 Flow Data and Condition Assessment

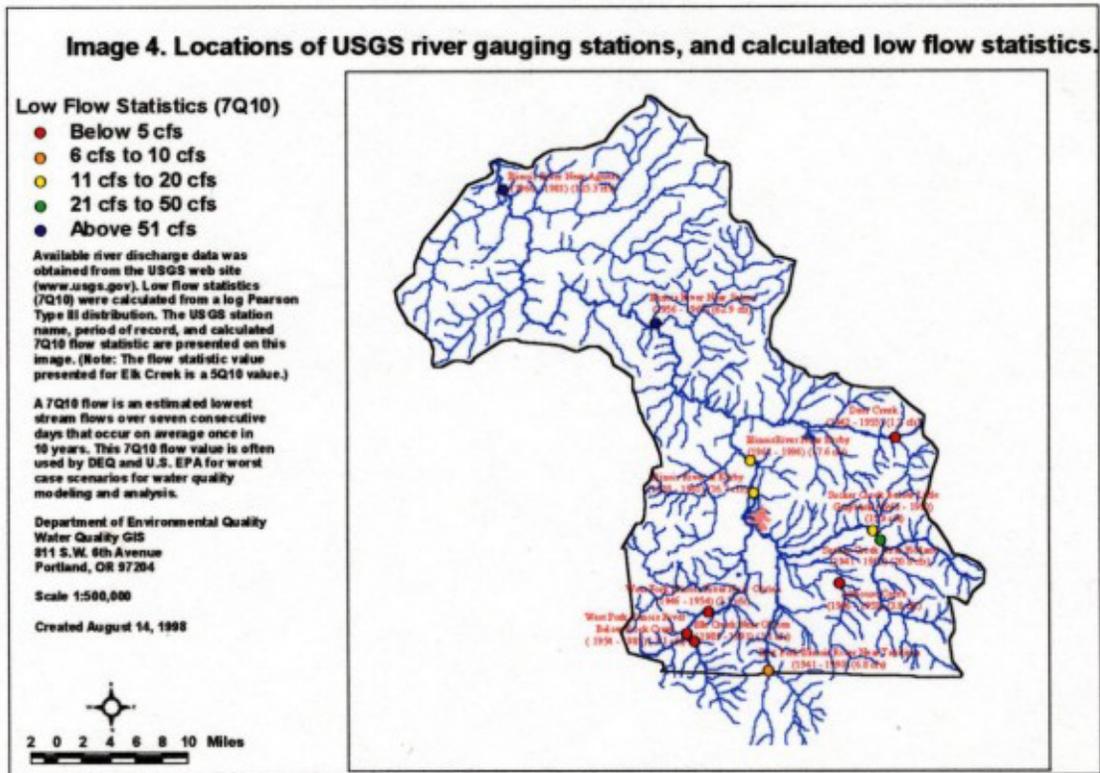
The form of precipitation in the basin affects the timing of flow in the Illinois River basin. When precipitation falls mostly as snow, peak flows are diminished, and flows remain higher into the late spring and summer. Rain on snow or other intense melting events result in high peak flows, with lower flows occurring earlier in the year. Low summer flows are common for many streams in the Illinois River basin due to low summer precipitation combined with extensive water withdrawals for irrigation (USFS 1995).

Perennial streams are those with flow throughout the year. *Intermittent* streams experience a period of time during the year without flow, or completely de-watered. It is an extreme event when a stream becomes intermittent in terms of aquatic life and water quality. Low flows are of particular concern within tributary streams of the Illinois River Valley, with many streams over appropriated (IVWC 1995), and thus insufficient flows exists to support anadromous and resident fish stocks or meet water quality standards (DEQ 1998).

Available daily stream flow data was obtained from the USGS web site (www.usgs.gov) and was processed to determine return periods for both high and low flow conditions. The duration periods for which flows were averaged were 1 day, 7 days, and 14 days. The return period was estimated using the Log Pearson Type III distribution for the following return periods: 2 years, 5 years, 25 years, and 50 years. Return flows are presented as xQy, where “x” represents the flow duration (days), “y” represents the return period (years) and “Q” represent river flow. For example, a 7Q10 would represent the 7-day average flow that occurs on average once every 10 years. Therefore, the probability that this flow condition will occur during any one year is 10%. ODEQ and USEPA often use the 7Q10 flow value for wastewater treatment plant design and worst case scenarios for water quality modeling and analysis. Table 8 lists USGS stream gauges stations which flow data was available. Station locations, as well as the calculated 7Q10 flow statistics for each station, are illustrated in Image 4. Calculated high and low flow statistic values are presented in Appendix E.

Table 8. USGS stream gauging stations which flow data was available for statistical analysis.

Site Name	Site Number	Location (River Mile)	Period of Record (Water Year)
Illinois River Near Agness	14378200	3.2	1960 – 1981
Illinois River Near Selma	14378000	32.0	1956 – 1967
Illinois River at Kerby	14377000	54.0	1928 – 1961
Illinois River Near Kerby	14377100	50.5	1961 – 1996
Sucker Creek Below Little Grayback	14375100	9.2	1965 – 1990
Sucker Creek Near Holland	14375000	9.7	1941 - 1964
Althouse Creek	14373500	2.0	1946 - 1952
Elk Creek	14375400	0.9	1985 - 1990
Deer Creek	14377500	13.5	1942 - 1955
East Fork Illinois River Near Takilma	14372500	13.9	1941 - 1990
West Fork Illinois River Below Rock Ck	14375500	12.9	1954 - 1984
West Fork Illinois River Near Obrien	14376500	9.7	1946 - 1953



Stream temperature is generally inversely related to flow volume; as flows decrease, stream temperature tends to increase, if energy processes remain unchanged (Boyd, 1996). Thus, the magnitude of the flow, both in the tributaries and mainstem, has implications on stream temperature. On average, the lowest mainstem flows occur in July, August and September (see Appendix E). It was shown in Figures 2, 7, 8, and 9 that stream temperatures in the Illinois Basin are at their annual maximum during this low flow period.

Figure 13 illustrates the relationship between drainage area of each gauging station within the Illinois Basin (see Image 4) and the calculated 7Q10 flow statistic observed at these stations. The deviation of a calculated flow statistic from this regression line illustrates whether flows are greater or less than expected from the calculated regression for the basin. It is important to note that this regression only takes into account the drainage area of the gauging stations, and other factors that may greatly influence flow conditions in a river are not accounted in this analysis (i.e. local precipitation patterns, soil type, different periods of data collection, etc.). However, a general relationship between expected and observed critical low flow conditions in the Illinois Basin can be evaluated (Image 5).

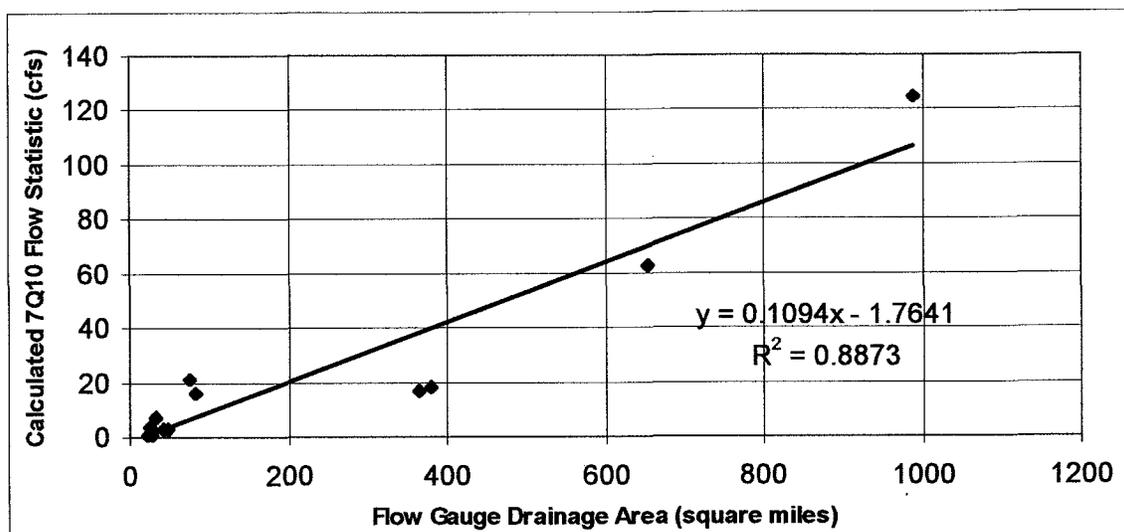


Figure 13. Regression between Gauge Drainage Area and calculated Critical Low Flow Statistics (7Q10) in the Illinois Basin.

It can be seen in Image 5 that calculated flow conditions at West Fork Illinois River flow gauging stations are similar to calculated flow values using the regression equation presented in Figure 13. Observed flows in East Fork Illinois River, Sucker Creek, and Althouse Creek are above values that would be expected with the regression equation. These four tributary systems drain together to form the Illinois River. Even though flows at these “upstream” locations are at (or above) expected values, flow conditions observed in the Illinois River downstream of the City of Cave Junction are well below expected values. Some of the highest observed water temperature readings for the Illinois Basin are also at this same location (see Image 3).

Flows conditions progressively increase in the Illinois River once again as it re-enters into U.S. Forest Service Administered Lands in the lower part of the Basin. Low flow statistics in the Illinois River mainstem approximately double between the USGS gauging station near Selma (RM 32) and

Image 5. Difference between expected and observed flows in the Illinois Basin.

Values presented on this image are intended to provide a rough estimate of the difference between expected and observed flows by taking into account the effects of drainage area.

Positive values indicate a site where flows are greater than expected, and negative values indicate areas where flow levels are below expected values.

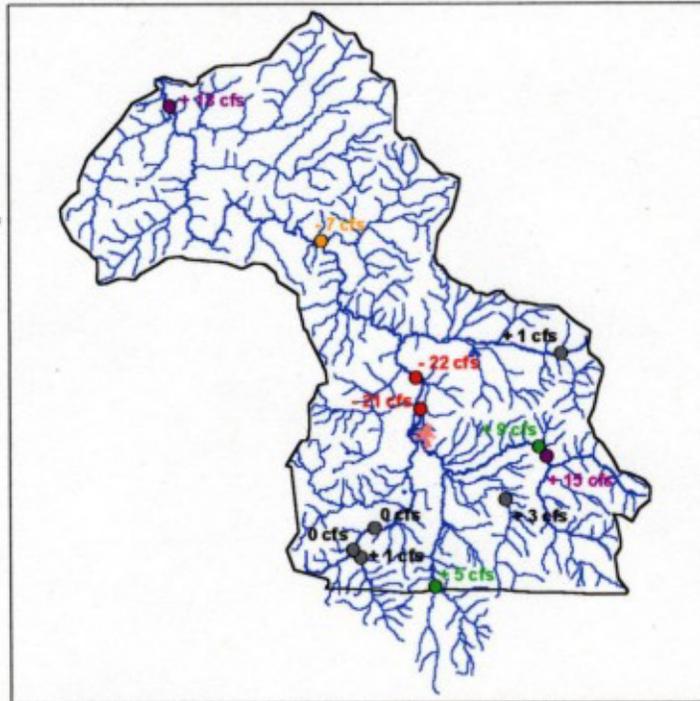
Expected flow values were calculated from a regression between observed 7Q10 flow and stream gauging station drainage area for stations located in the Illinois Basin.

Available river discharge data was obtained from the USGS web site (www.usgs.gov). Low flow statistics (7Q10) were calculated from a log Pearson Type III distribution. A 7Q10 flow is an estimated lowest stream flows over seven consecutive days that occur on average once in 10 years. This 7Q10 flow value is often used by DEQ and U.S. EPA for worst case scenarios for water quality modeling and analysis.

Department of Environmental Quality
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Portland, OR 97204

Scale 1:500,000

Created August 14, 1998



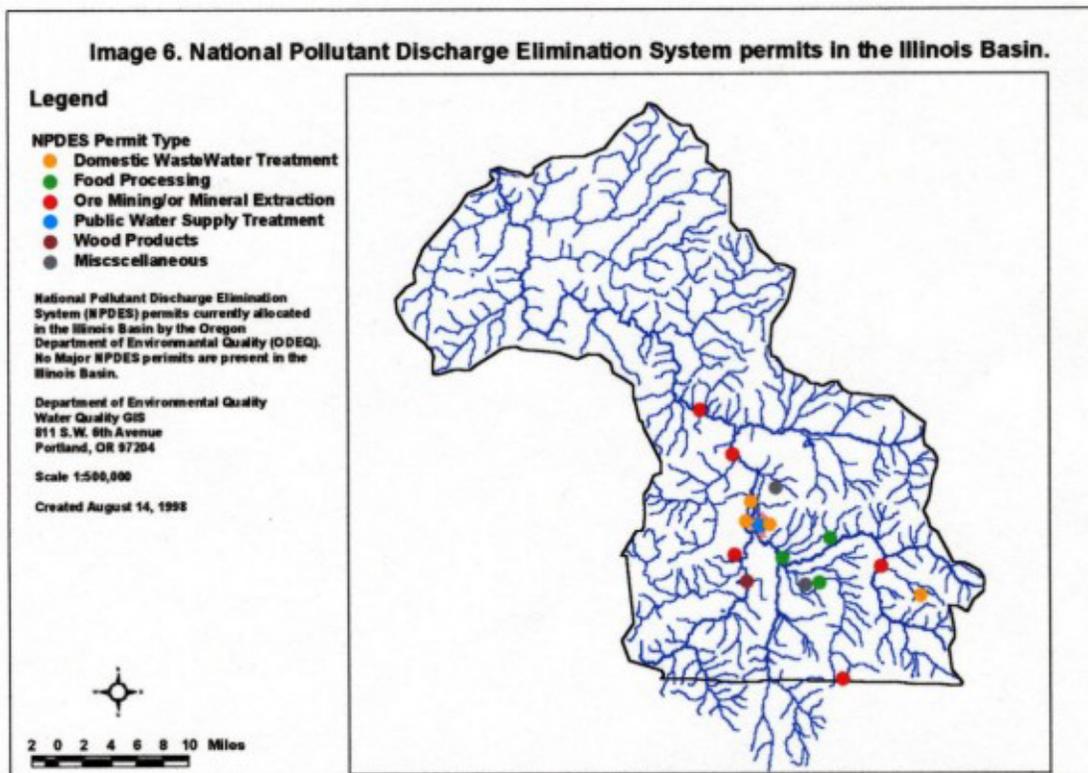
the USGS station near the mouth of the river (RM 3.2). Numerous tributary streams discharge into the Illinois River between these two stream gauging locations. However, long-term flow measurements for these streams are not available.

Calculated low flow statistics did not vary much between the 1, 7, and 14-day flow periods, as well as at most return periods (i.e. 2, 5, 10, 25, 50 years) (see **Appendix E**). This indicates that low flow events in the Illinois basin result from conditions occurring over extended periods of the summer (e.g. water withdrawals, low precipitation, etc.). The only exception was the calculated 1-year return period flow statistic, which was generally elevated and may indicate that much of the water produced during summer rain events is quickly transferred into the river. Therefore, it can be assumed that the "long-term" water storage is reduced proportionately by the amount of water entering the river during these quick response events.

Calculated high flow statistics indicate that the 1-Day flow events were much greater than for longer duration events (i.e. 7 and 14-Day). This indicates that much of the water produced during high intensity precipitation events enters the river quickly. In addition, this could also indicate rain-on-snow events within the basin (which can produce high flow conditions).

3.5 Locations of Permitted Discharges

Permitted point source locations in the Illinois basin are presented in **Image 6**. To be allowed to discharge wastes into the river, stream and lakes of the Illinois Valley, facilities presented in **Image 6** are required to adhere to discharge requirements presented on their respective NPDES (National Pollutant Elimination System) permits. The NPDES permit often requires that water quality monitoring of the waste stream be implemented by the facility. Copies of these NPDES permits and monitoring results are located at the respective facilities, as well as at the Oregon Department of Environmental Quality (ODEQ) office in Eugene.



4. POLLUTANT LOADING ANALYSIS - TEMPERATURE

4.1 Pollutant Identification

Temperature Defined: Temperature is an expression of Heat Energy per Unit Volume and is described in English Units as Btu per cubic feet:

$$\text{Temperature} = \frac{\text{Heat Energy}}{\text{Volume}} = \frac{\text{Btu}}{\text{ft}^3}$$

(Equation 1)

Pollutant Identification: Heat Energy

The pollutant of concern for water temperature is heat energy. The transfer processes that control stream temperature include solar radiation, longwave radiation, convection, evaporation and bed conduction (Wunderlich, 1972; Jobson and Keefer, 1979; Beschta and Weatherred, 1984; Sinokrot and Stefan, 1993). With the exception of solar radiation, which only delivers heat energy, these processes are capable of both introducing and removing heat from a stream. **Figure 14** displays heat energy process that solely control stream temperature.

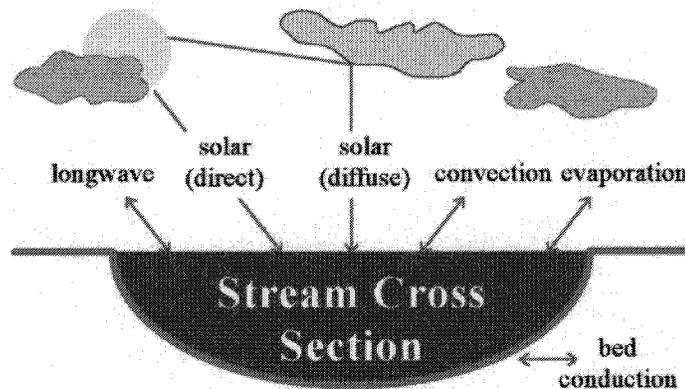


Figure 14. Thermodynamic (heat transfer) processes that heat or cool water.

When a stream surface is exposed to midday solar radiation, large quantities of heat will be delivered to the stream system (Brown 1969, Beschta et al. 1987). Some of the incoming solar radiation will reflect off the stream surface, depending on the elevation of the sun. All solar radiation outside the visible spectrum (0.36μ to 0.76μ) is absorbed in the first meter below the stream surface and only visible light penetrates to greater depths (Wunderlich, 1972). Sellers (1965) reported that 50% of solar energy passing through the stream surface is absorbed in the first 10 cm of the water column.

Both the atmosphere and vegetation along stream banks emit longwave radiation that when received by the stream surface has a warming influence. Water is nearly opaque to longwave radiation and complete absorption of all wavelengths greater than 1.2μ occurs in the first 5 cm below the surface (Wunderlich, 1972). Longwave radiation has a cooling influence when emitted from the stream surface. The net transfer of heat via longwave radiation usually balances so that the amount of heat entering is similar to the rate of heat leaving the stream (Beschta and Weatherred, 1984; Boyd, 1996).

Evaporation occurs in response to internal energy of the stream (molecular motion) that randomly expels water molecules into the overlying air mass. Evaporation is the most effective method of dissipating heat from water (Parker and Krenkel, 1969). As stream temperatures increase, so does the rate of evaporation. Air movement (wind) and low vapor pressures increase the rate of evaporation and accelerate stream cooling (Harbeck and Meyers, 1970).

Convection transfers heat between the stream and the air via molecular and turbulent conduction (Beschta and Weatherred, 1984). Heat is transferred in the direction of warmer to cooler. Air can have a warming influence on the stream when the stream is cooler. The opposite is also true. The amount of convective heat transfer between the stream and air is low (Parker and Krenkel, 1969; Brown, 1983).

Depending on streambed composition, shallow streams (less than 20 cm) may allow solar radiation to warm the streambed (Brown, 1969). Large cobble (> 25 cm diameter) dominated streambeds in shallow streams may store and conduct heat as long as the bed is warmer than the stream. Bed conduction may cause maximum stream temperatures to occur later in the day, possibly into the evening hours.

The instantaneous heat transfer rate experienced by the stream is the summation of the individual processes presented above:

$$\Phi_{\text{Total}} = \Phi_{\text{Solar}} + \Phi_{\text{Longwave}} + \Phi_{\text{Evaporation}} + \Phi_{\text{Convection}} + \Phi_{\text{Conduction}} \quad (\text{Equation 2})$$

Solar Radiation (Φ_{Solar}) is a function of the solar angle, solar azimuth, atmosphere, topography, location and riparian vegetation. Simulation is based on methodologies developed by Iqbal (1983) and Beschta and Weatherred (1984). *Longwave Radiation* (Φ_{Longwave}) is derived by the Stefan-Boltzmann Law and is a function of the emissivity of the body, the Stefan-Boltzmann constant and the temperature of the body (Wunderlich, 1972). *Evaporation* ($\Phi_{\text{Evaporation}}$) relies on a Dalton-type equation that utilizes an exchange coefficient, the latent heat of vaporization, wind speed, saturation vapor pressure and vapor pressure (Wunderlich, 1972). *Convection* ($\Phi_{\text{Convection}}$) is a function of Bowen's Ratio (1926) and terms include atmospheric pressure, and water and air temperatures. *Bed Conduction* ($\Phi_{\text{Conduction}}$) simulates the theoretical relationship ($\Phi_{\text{Conduction}} = K \cdot dT_b / dz$), where calculations are a function of thermal conductivity of the bed (K) and the temperature gradient of the bed (dT_b/dz) (Sinokrot and Stefan, 1993). Bed conduction is solved with empirical equations developed by Beschta and Weatherred (1984).

Flow volume is not included as a heat energy flux process presented in **Equation 2**. However, the amount of water in a river or stream does have a dramatic effect on water temperature (see **Equation 1**). That is, stream temperature is generally inversely related to flow volume; as flows decrease, stream temperature tends to increase, if energy processes remain unchanged (Boyd, 1996).

4.2 Existing Sources

Budgeting heat energy fluxes (transfer rates per area), presented **Equation 2**, can be used to determine existing sources of heat energy, as well distinguish between natural and anthropogenic sources of heat energy. Controlling variables for each of five components of heat energy fluxes present in waters of the Illinois Basin are presented in **Table 9**. Although not noted on **Table 9**, groundwater discharge can dramatically influence instream river temperature. Both "natural" and anthropogenic sources of energy will effect the temperature of groundwater.

Table 9. Existing Energy Sources for temperature change in the Illinois Basin.

Heat Energy Process	Controlling Variables	Anthropogenic Sources	Natural Sources
<i>Solar Radiation</i> (Φ_{Solar})	Solar Angle		✓
	Solar Azimuth		✓
	Cloud Cover		✓
	Topography		✓
	Latitude		✓
	Longitude		✓
	Riparian Height	✓	✓
	Riparian Width	✓	✓
	Riparian Density	✓	✓
	Stream Width/Depth Ratio	✓	✓
<i>Longwave Radiation</i> (Φ_{Longwave})	Emissivity		✓
	Riparian Height	✓	✓
	Riparian Width	✓	✓
	Riparian Density	✓	✓
	Air Temperature		✓
	Riparian Temperature		✓
	Stream Temperature	✓	✓
<i>Evaporation</i> ($\Phi_{\text{Evaporation}}$)	Latent Heat		✓
	Wind Speed		✓
	Relative Humidity		✓
	Air Temperature		✓
	Stream Temperature	✓	✓
<i>Convection</i> ($\Phi_{\text{Convection}}$)	Atmospheric Pressure		✓
	Relative Humidity		✓
	Air Temperature		✓
	Stream Temperature	✓	✓
<i>Bed Conduction</i> ($\Phi_{\text{Conduction}}$)	Bed Material	✓	✓
	Bed Temperature	✓	✓
	Stream Temperature	✓	✓

ITEMS 4.3 THROUGH 4.7 WILL BE DEVELOPED AS PART OF THE TMDL/WQMP FOR THE ILLINOIS RIVER SYSTEM. A TEMPERATURE TMDL/WQMP HAS BEEN APPROVED FOR THE HEADWATERS OF SUCKER CREEK AND ASSESSMENT WORK IS CURRENTLY UNDERWAY TO COMPLETE A TMDL/WQMP ON THE LOWER PORTION OF SUCKER CREEK. (SEE *Water Quality Management Plan-Rogue River Basin-Illinois Sub Basin-March 1, 1999*)

4.3 Targets

4.4 Loading Capacity

4.5 Loading Allocations

4.6 Water Quality Attainment

4.7 Margins of Safety

5. PUBLIC PARTICIPATION

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DEFINITION OF TERMINOLOGY

GENERAL TERMINOLOGY

- Active Bank Erosion:** Estimates from observation of the active stream bank erosion as a percentage (%) of the total reach length.
- Adaptive Management:** An iterative process where policy decisions that are implemented based on scientific experiments that tests the predictions and assumptions specified in a management plan. The results of the experiment are then used to guide policy changes for future management plans.
- Anadromous Fish:** Species of fish that spawn in fresh water, migrate to the ocean as juveniles, where they live most of their adult lives until returning to spawn in fresh water.
- At-Risk Stocks:** Anadromous fish species that are identified as requiring special management consideration due to low populations.
- Base Flow:** Groundwater fed summertime flows that occur in the long-term absence of precipitation.
- Bank Building Event:** A hydrologic event (usually high flow condition) that deposits sediments and organic debris in the flood plain and along stream banks.
- Beneficial Use:** Legislation that requires the reasonable use of water for the best interest of people, wildlife and aquatic species.
- Channel Complexity:** Implied high pool frequency of pools and large woody debris (instream roughness).
- Channel Simplification:** The loss (absence) of pools and large woody debris that is important for creating and maintaining channel features such as: substrate, stream banks and pool:riffle ratios.
- Clearcut Harvest:** Timber harvests that remove all trees are removed in a single entry from a designated area.
- Debris Flow:** A rapidly moving congregate of soil, rock fragments, water and trees, where over half of the material in transport has a particle size greater than that of sand.
- Decommission:** The removal of a road to improve hillslope drainage and stabilize slope hazards.
- Endangered Species:** A species that is declared by the Endangered Species Act (ESA) to be in danger of extinction throughout a significant portion of its range.
- Fire Regime:** The frequency, extent, intensity and severity of naturally occurring seasonal fires in an ecosystem.
- FLIR Thermal Imagery:** Forward looking infrared radiometer thermal imagery is a direct measure of the longer wavelengths emitted by all bodies. The process by which bodies emit longwave radiation is described by the Stefan-Boltzman 4th Order Radiation Law. FLIR monitoring produces spatially continuous stream and stream bank temperature information. Accuracy is limited to 0.5°C. FLIR thermal imagery often displays heating processes as they are occurring and is particularly good at displaying the thermal impacts of shade, channel morphology and groundwater mixing.
- Flood Plain:** Strips of land (of varying widths) bordering streams that become inundated with floodwaters. Land outside of the stream channel that is inside a perimeter of the maximum probable flood. A flood plain is built of sediment carried by the stream and deposited in the slower (slack waters) currents beyond the influence of the swiftest currents. Flood plains are termed "living" if it experiences inundation in times of high water. A "fossil" flood plain is one that is beyond the reach of the highest floodwaters.



Flood Plain Roughness: Reflects the ability of the flood plain to dissipate erosive flow energy during high flow events that over-top streams banks and inundate the flood plain.

Fluvial: Of, found in or produced by a river.

Gradient: Reach gradient estimated by valley gradient reported in percent (%) from 1:24,000 topography.

Groundwater: Subsurface water that completely fills the porous openings in soil and rocks.

Incipient Lethal Limit: Temperature levels that cause breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation.

Indicator Species: Used for development of Oregon's water temperature standard as sensitive species that if water temperatures are reduced to protective levels will protect all other aquatic species.

Instantaneous Lethal Limit: Temperature levels where denaturing of bodily enzymes occurs.

Instream Roughness: Refers to the substrate (both organic and inorganic) that is found in the active channel. Large woody debris provides instream roughness and is sensitive to human land use.

Large Woody Debris²: Pieces of woody debris located in the active channel at least 36 inches in diameter and 50 feet in length.

LWD per 100 m: A measure in instream roughness and large woody debris frequency. The number of pieces of woody debris with a minimum diameter of 24 inches and at least 50 in length divided by the primary channel length and multiplied by 100 meters.

Legacy Condition: Past land management and historical disturbance affect the conditions that are currently observed in a stream channel. Present conditions may reflect chronic or episodic events that no longer occur.

Mass Movement: The movement of soil due to gravity, such as: landslides, debris avalanches, rock falls and creep.

pH: A measure of the hydrogen ion concentration in aqueous solutions. Acidic solutions have a pH less than 7, neutral solutions have a pH of 7, and basic solutions have a pH that is greater than 7.

Peak Flow: The largest flow volume occurring in one year due to one storm event.

Pools: Number of pools reported in the survey reach.

Pools per 100 m: The frequency of pools observed in the survey reach per 100 meters of stream length. Calculated as the number of observed pools in the reach multiplied by 100 meters and divided by the primary channel length.

Primary Channel Length: Length of the primary channel located in the survey reach. Units are meters.

Primary Channel Width: Active channel width reported in meters.

Rate: A measurable occurrence over a specified time interval.

Reach: Survey reaches in the same stream were numbered for organization.

Redd: An anadromous fish nest made in the gravel substrate of a stream where a fish will dig a depression, lay eggs in the depression and cover it forming a mound of gravel.

Residual Pool Depth: Average pool depth reported in meters.

Riparian Area: A geographic area that contains the aquatic ecosystem and the upland areas that directly affect it. Also defined as 360 feet from a fish bearing stream and 180 feet from a non-fish bearing stream.

Sac Fry: Larval salmonid that has hatched, but has not fully absorbed the yolk sac and has not emerged from the redd.

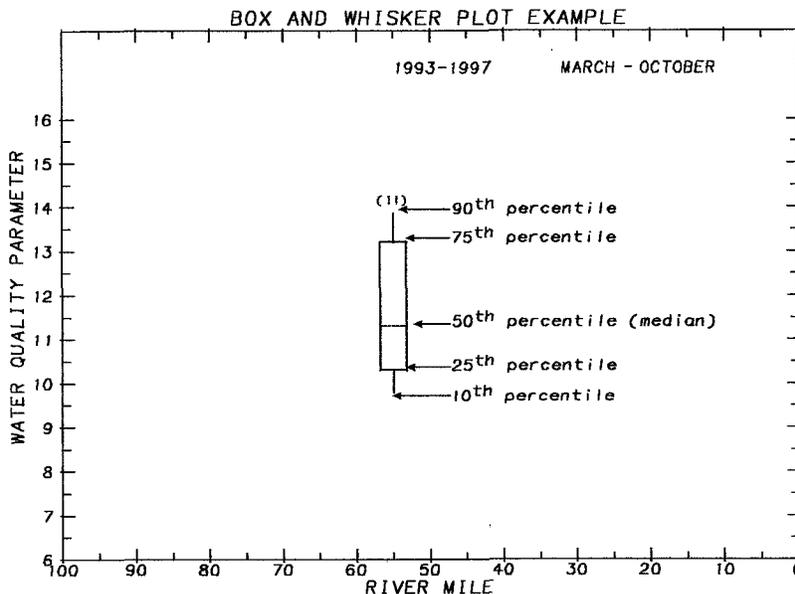
Sediment: Fragmented material that originates from the weathering of rocks and is transported by, suspended in, or deposited by water or air.

Seral Stage: Refers to the age and type of vegetation that develops from the stage of bare ground to the climax stage.

- Seral Stage - Early*: The period from bare ground to initial crown closure (grass, shrubs, forbs, brush).
- Seral Stage - Mid*: The period of a forest stand from crown closure to marketability (young stand of trees from 25 to 100 years of age, includes hardwood stands).
- Seral Stage - Late*: The period of a forest stand from marketability to the culmination of the mean annual increment (mature stands of conifers and old-growth).
- Smolt**: Juvenile salmonid one or two years old that has undergone physiological changes adapted for a marine environment. Generally, the seaward migrant stage of an anadromous fish species.
- Soil Compaction**: Activities/processes, vibration, loading, pressure, that decrease the porosity of soils by increasing the soil bulk density $\left(\frac{\text{Weight}}{\text{UnitVolume}} \right)$.
- Sub-Lethal Limit**: Temperature levels that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supplies, and increased competition from warm water tolerant species.
- Surface Erosion**: Detachment, entrainment, and transport of soil particles by wind and water.
- Threatened Species**: Species that are likely to become endangered through their normal range within the foreseeable future.
- Watershed**: A drainage basin that contributes water, organic material, dissolved nutrients, and sediment to streams, rivers, and lakes.
- Width:Depth Ratio**: The width of active channel divided by the average depth in the survey reach.
- Woody Debris**¹: Pieces of woody debris located in the active channel at least 24 inches in diameter and 50 feet in length.

STATISTICS

Box and Whisker Plots: Water quality parameters and instream physical parameters are reviewed below using box and whisker plots for illustration. Below is an example of a box and whisker plot:



Example of box and whisker plot.

The box plots have river mile on the X-axis with the water quality parameter on the Y-axis. The box represents the data at the sampling sites, from upstream to downstream. Each box represents a summary of the data:

The upper corner of each box is the 75th percentile (75 percent of the data are below that concentration), and the lower corner is the 25th percentile (25 percent of the data are below that concentration). The upper and lower tails are the 90th and 10th percentiles, respectively. Points above and below the tails represent data higher and lower than the 90th and 10th percentiles. The dashed line in the box is the median concentration for that site (half of the data fall above and below that concentration).

Correlation Coefficient (R): Used to determine the relationship between two data sets. R-values vary between -1 and 1, where “-1” represents a perfectly inverse correlation relationship and “1” represents a perfect correlation relationship. A “0” R-value indicates that no correlation exists.

$$R = \frac{1}{n} \cdot \sum_{i=1}^n (x_i - \mu_x) \cdot (y_i - \mu_y)$$

Determinate Coefficient (R²): The R² value represents “goodness of fit” for linear regression in each of the four plots. An R² value of “1” would indicate that all of the data variability is

accounted for by the regression line. Natural systems exhibit a high degree of variability; R^2 values approaching "1" are uncommon. A value of "0" would indicate that none of the data variability is explained by the regression.

Mean (μ): Refers to the arithmetic mean.

$$\mu = \frac{1}{n} \cdot \sum x_i$$

Median: Refers to a value in the data in which half the values are above and half are below.

Standard Deviation (σ): The measure of how widely values are dispersed from the mean (μ).

$$\sigma = \sqrt{\frac{n \cdot \sum x^2 - (\sum x)^2}{n \cdot (n-1)}}$$

Appendix A
Water Quality Standards

APPENDIX A

Water Quality Standards for the Rogue (Illinois) Basin 340-041-0365

Water Quality Standards Not to be Exceeded (To be Adopted Pursuant to ORS 468.735 and Enforceable Pursuant to ORS 468.720, 468.990, and 468.992)

(1) Notwithstanding the water quality standards contained below, the highest and best practicable treatment and/or control of wastes, activities, and flows shall in every case be provided so as to maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor, and other deleterious factors at the lowest possible levels.

(2) No wastes shall be discharged and no activities shall be conducted which either alone or in combination with other wastes or activities will cause violation of the following standards in the waters of the Rogue River Basin:

(a) Dissolved oxygen (DO): The changes adopted by the Commission on January 11, 1996, become effective July 1, 1996. Until that time, the requirements of this rule that were in effect on January 10, 1996, apply:

(A) For waterbodies identified by the Department as providing salmonid spawning, during the periods from spawning until fry emergence from the gravels, the following criteria apply:

(i) The dissolved oxygen shall not be less than 11.0 mg/l. However, if the minimum intergravel dissolved oxygen, measured as a spatial median, is 8.0 mg/l or greater, then the DO criterion is 9.0 mg/l;

(ii) Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/l or 9.0 mg/l criteria, dissolved oxygen levels shall not be less than 95 percent of saturation.

(B) For waterbodies identified by the Department as providing salmonid spawning during the period from spawning until fry emergence from the gravels, the spatial median intergravel dissolved oxygen concentration shall not fall below 6.0 mg/l;

(C) A spatial median of 8.0 mg/l intergravel dissolved oxygen level shall be used to identify areas where the recognized beneficial use of salmonid spawning, egg incubation and fry emergence from the egg and from the gravels may be impaired and therefore require action by the Department. Upon determination that the spatial median intergravel dissolved oxygen concentration is below 8.0 mg/l, the Department may, in accordance with priorities established by the Department for evaluating water quality impaired waterbodies, determine whether to list the waterbody as water quality limited under the Section 303(d) of the Clean Water Act, initiate pollution control strategies as warranted, and where needed cooperate with appropriate designated management agencies to evaluate and implement necessary best management practices for nonpoint source pollution control;

(D) For waterbodies identified by the Department as providing cold-water aquatic life, the dissolved oxygen shall not be less than 8.0 mg/l as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen shall not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen shall not fall below 8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a seven-day minimum mean, and shall not fall below 6.0 mg/l as an absolute minimum (Table 21);

(E) For waterbodies identified by the Department as providing cool-water aquatic life, the dissolved oxygen shall not be less than 6.5 mg/l as an absolute minimum. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen shall not fall below 6.5 mg/l

as a 30-day mean minimum, 5.0 mg/l as a seven-day minimum mean, and shall not fall below 4.0 mg/l as an absolute minimum (Table 21);

(F) For waterbodies identified by the Department as providing warm-water aquatic life, the dissolved oxygen shall not be less than 5.5 mg/l as an absolute minimum. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen shall not fall below 5.5 mg/l as a 30-day mean minimum, and shall not fall below 4.0 mg/l as an absolute minimum (Table 21);

(G) For estuarine water, the dissolved oxygen concentrations shall not be less than 6.5 mg/l (for coastal waterbodies);

(H) For marine waters, no measurable reduction in dissolved oxygen concentration shall be allowed.

(b) Temperature: The changes adopted by the Commission on January 11, 1996, become effective July 1, 1996. Until that time, the requirements of this rule that were in effect on January 10, 1996, apply. The method for measuring the numeric temperature criteria specified in this rule is defined in OAR 340-041-0006(54):

(A) To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-041-0026(3)(a)(D), no measurable surface water temperature increase resulting from anthropogenic activities is allowed:

(i) In a basin for which salmonid fish rearing is a designated beneficial use, and in which surface water temperatures exceed 64.0°F (17.8°C);

(ii) In waters and periods of the year determined by the Department to support native salmonid spawning, egg incubation, and fry emergence from the egg and from the gravels in a basin which exceeds 55.0°F (12.8°C);

(iii) In waters determined by the Department to support or to be necessary to maintain the viability of native Oregon bull trout, when surface water temperatures exceed 50.0°F (10.0°C);

(iv) In waters determined by the Department to be ecologically significant cold-water refugia;

(v) In stream segments containing federally listed Threatened and Endangered species if the increase would impair the biological integrity of the Threatened and Endangered population;

(vi) In Oregon waters when the dissolved oxygen (DO) levels are within 0.5 mg/l or 10 percent saturation of the water column or intergravel DO criterion for a given stream reach or subbasin;

(vii) In natural lakes.

(B) An exceedance of the numeric criteria identified in subparagraphs (A)(i) through (iii) of this subsection will not be deemed a temperature standard violation if it occurs when the air temperature during the warmest seven-day period of the year exceeds the 90th percentile of the seven-day average daily maximum air temperature calculated in a yearly series over the historic record. However, during such periods, the anthropogenic sources must still continue to comply with their surface water temperature management plans developed under OAR 340-041-0026(3)(a)(D);

(C) Any source may petition the Commission for an exception to subparagraphs (A)(i) through (vii) of this subsection for discharge above the identified criteria if:

(i) The source provides the necessary scientific information to describe how the designated beneficial uses would not be adversely impacted; or

(ii) A source is implementing all reasonable management practices or measures; its activity will not significantly affect the beneficial uses; and the environmental cost of treating the parameter to the level necessary to assure full protection would outweigh the risk to the resource.

(D) Marine and estuarine waters: No significant increase above natural background temperatures shall be allowed, and water temperatures shall not be altered to a degree which creates or can reasonably be expected to create an adverse effect on fish or other aquatic life.

(c) Turbidity (Nephelometric Turbidity Units, NTU): No more than a ten percent cumulative increase in natural stream turbidities shall be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity. However, limited duration activities necessary to address an emergency or to accommodate essential dredging, construction or other legitimate activities and which cause the standard to be exceeded may be authorized provided all practicable turbidity control techniques have been applied and one of the following has been granted:

(A) Emergency activities: Approval coordinated by DEQ with the Department of Fish and Wildlife under conditions they may prescribe to accommodate response to emergencies or to protect public health and welfare;

(B) Dredging, Construction or other Legitimate Activities: Permit or certification authorized under terms of Section 401 or 404 (Permits and Licenses, Federal Water Pollution Control Act) or OAR 141-085-0100 et seq. (Removal and Fill Permits, Division of State Lands), with limitations and conditions governing the activity set forth in the permit or certificate.

(d) pH (hydrogen ion concentration): pH values shall not fall outside the following ranges:

(A) Marine waters: 7.0 – 8.5;

(B) Estuarine and fresh waters (except Cascade lakes): 6.5 – 8.5. The following exception applies: Waters impounded by dams existing on January 1, 1996, which have pHs that exceed the criteria shall not be considered in violation of the standard if the Department determines that the exceedance would not occur without the impoundment and that all practicable measures have been taken to bring the pH in the impounded waters into compliance with the criteria;

(C) Cascade lakes above 3,000 feet altitude: pH values shall not fall outside the range of 6.0 to 8.5.

(e) Bacteria standards:

(A) Numeric Criteria: Organisms of the coliform group commonly associated with fecal sources (MPN or equivalent membrane filtration using a representative number of samples) shall not exceed the criteria described in subparagraphs (i) and (ii) of this paragraph:

(i) Freshwaters and Estuarine Waters Other than Shellfish Growing Waters:

(I) A 30-day log mean of 126 E. coli organisms per 100 ml, based on a minimum of five (5) samples;

(II) No single sample shall exceed 406 E. coli organisms per 100 ml.

(ii) Marine Waters and Estuarine Shellfish Growing Waters: A fecal coliform median concentration of 14 organisms per 100 milliliters, with not more than ten percent of the samples exceeding 43 organisms per 100 ml.

(B) Raw Sewage Prohibition: No sewage shall be discharged into or in any other manner be allowed to enter the waters of the State unless such sewage has been treated in a manner approved by the Department or otherwise allowed by these rules;

(C) Animal Waste: Runoff contaminated with domesticated animal wastes shall be minimized and treated to the maximum extent practicable before it is allowed to enter waters of the State;

(D) Effluent Limitations and Water Quality Limited Waterbodies: Effluent limitations to implement the criteria in this rule are found in OAR 340-041-0120(12) through (16). Implementation of the criteria in this rule in water quality limited waterbodies is described in OAR 340-041-0026(3)(a)(I) and OAR 340-041-0120(17).

(f) Bacterial pollution or other conditions deleterious to waters used for domestic purposes, livestock watering, irrigation, bathing, or shellfish propagation, or otherwise injurious to public health shall not be allowed;

(g) The liberation of dissolved gases, such as carbon dioxide, hydrogen sulfide, or other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable uses made of such waters shall not be allowed;

(h) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed;

(i) The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish shall not be allowed;

(j) The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry shall not be allowed;

(k) Objectionable discoloration, scum, oily sleek, or floating solids, or coating of aquatic life with oil films shall not be allowed;

(l) Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch shall not be allowed;

(m) Radioisotope concentrations shall not exceed maximum permissible concentrations (MPC's) in drinking water, edible fishes or shellfishes, wildlife, irrigated crops, livestock and dairy products, or pose an external radiation hazard;

(n) The concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 110 percent of saturation, except when stream flow exceeds the ten-year, seven-day average flood. However, for Hatchery receiving waters and waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 105 percent of saturation;

(o) Total Dissolved Solids: Guide concentrations listed below shall not be exceeded unless otherwise specifically authorized by DEQ upon such conditions as it may deem necessary to carry out the general intent of this plan and to protect the beneficial uses set forth in OAR 340-041-0362: 500.0 mg/l;

(p) Toxic Substances:

(A) Toxic substances shall not be introduced above natural background levels in the waters of the state in amounts, concentrations, or combinations which may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels

that adversely affect public health, safety, or welfare; aquatic life; wildlife; or other designated beneficial uses;

(B) Levels of toxic substances shall not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted;

(C) The criteria in paragraph (B) of this subsection shall apply unless data from scientifically valid studies demonstrate that the most sensitive designated beneficial uses will not be adversely affected by exceeding a criterion or that a more restrictive criterion is warranted to protect beneficial uses, as accepted by the Department on a site specific basis. Where no published EPA criteria exist for a toxic substance, public health advisories and other published scientific literature may be considered and used, if appropriate, to set guidance values;

(D) Bio-assessment studies such as laboratory bioassays or instream measurements of indigenous biological communities, shall be conducted, as the Department deems necessary, to monitor the toxicity of complex effluents, other suspected discharges or chemical substances without numeric criteria, to aquatic life. These studies, properly conducted in accordance with standard testing procedures, may be considered as scientifically valid data for the purposes of paragraph (C) of this subsection. If toxicity occurs, the Department shall evaluate and implement measures necessary to reduce toxicity on a case-by-case basis.

(3) Where the naturally occurring quality parameters of waters of the Rogue Basin are outside the numerical limits of the above assigned water quality standards, the naturally occurring water quality shall be the standard. However, in such cases special restrictions, described in OAR 340-041-0026(3)(a)(C)(iii), apply to discharges that affect dissolved oxygen.

(4) Mixing zones:

(a) The Department may allow a designated portion of a receiving water to serve as a zone of dilution for wastewaters and receiving waters to mix thoroughly and this zone will be defined as a mixing zone;

(b) The Department may suspend all or part of the water quality standards, or set less restrictive standards, in the defined mixing zone, provided that the following conditions are met:

(A) The water within the mixing zone shall be free of:

(i) Materials in concentrations that will cause acute toxicity to aquatic life as measured by a Department approved bioassay method. Acute toxicity is lethality to aquatic life as measured by a significant difference in lethal concentration between the control and 100 percent effluent in an acute bioassay test. Lethality in 100 percent effluent may be allowed due to ammonia and chlorine only when it is demonstrated on a case-by-case basis that immediate dilution of the effluent within the mixing zone reduces toxicity below lethal concentrations. The Department may on a case-by-case basis establish a zone of immediate dilution if appropriate for other parameters;

(ii) Materials that will settle to form objectionable deposits;

(iii) Floating debris, oil, scum, or other materials that cause nuisance conditions;

(iv) Substances in concentrations that produce deleterious amounts of fungal or bacterial growths.

(B) The water outside the boundary of the mixing zone shall:

(i) Be free of materials in concentrations that will cause chronic (sublethal) toxicity. Chronic toxicity is measured as the concentration that causes long-term sublethal effects, such as significantly impaired growth or reproduction in aquatic organisms, during a testing period based on test species life cycle. Procedures and end points will be specified by the Department in wastewater discharge permits;

(ii) Meet all other water quality standards under normal annual low flow conditions.

(c) The limits of the mixing zone shall be described in the wastewater discharge permit. In determining the location, surface area, and volume of a mixing zone area, the Department may use appropriate mixing zone guidelines to assess the biological, physical, and chemical character of receiving waters, and effluent, and the most appropriate placement of the outfall, to protect instream water quality, public health, and other beneficial uses. Based on receiving water and effluent characteristics, the Department shall define a mixing zone in the immediate area of a wastewater discharge to:

(A) Be as small as feasible;

(B) Avoid overlap with any other mixing zones to the extent possible and be less than the total stream width as necessary to allow passage of fish and other aquatic organisms;

(C) Minimize adverse effects on the indigenous biological community especially when species are present that warrant special protection for their economic importance, tribal significance, ecological uniqueness, or for other similar reasons as determined by the Department and does not block the free passage of aquatic life;

(D) Not threaten public health;

(E) Minimize adverse effects on other designated beneficial uses outside the mixing zone.

(d) The Department may request the applicant of a permitted discharge for which a mixing zone is required, to submit all information necessary to define a mixing zone, such as:

(A) Type of operation to be conducted;

(B) Characteristics of effluent flow rates and composition;

(C) Characteristics of low flows of receiving waters;

(D) Description of potential environmental effects;

(E) Proposed design for outfall structures.

(e) The Department may, as necessary, require mixing zone monitoring studies and/or bioassays to be conducted to evaluate water quality or biological status within and outside the mixing zone boundary;

(f) The Department may change mixing zone limits or require the relocation of an outfall if it determines that the water quality within the mixing zone adversely affects any existing beneficial uses in the receiving waters.

(g) Alternate requirements for mixing zones: For some existing or proposed discharges to some receiving streams, it may not be practicable to treat wastewater to meet instream water quality standards at the point of discharge or within a short distance from the point of discharge. Some of these discharges could be allowed without impairing the overall ecological integrity of the receiving streams, or may provide an overall benefit to the receiving stream. This section specifies the conditions and circumstances under which a mixing zone may be allowed by the Department that extends beyond the immediate area around a discharge point, or that extends across a stream width. An alternate mixing zone may be approved if the applicant demonstrates to the Department's satisfaction that the discharge (A) creates an overall environmental benefit, or (B) is to a constructed water course, or (C) is insignificant. The three circumstances under which alternate mixing zones may be established are described further below.

(A) Overall environmental benefit.

(i) Qualifying for alternate mixing zone based on overall environmental benefit: In order to qualify for an alternate mixing zone based on a finding of overall environmental benefit, the discharger must demonstrate to the Department's satisfaction the following:

(a) That all practical strategies have been or will be implemented to minimize the pollutant loads in the effluent; and

(b) For proposed increased discharges, the current actual discharge and mixing zone does not meet the requirements of a standard mixing zone; and

(c) Either that, on balance, an environmental benefit would be lost if the discharge did not occur, or that the discharger is prepared to undertake other actions that will mitigate the effect of the discharge to an extent resulting in a net environmental benefit to the receiving stream.

(d) For the purposes of this rule, the term "practical" shall include environmental impact, availability of alternatives, cost of alternatives, and other relevant factors.

(ii) Studies required and evaluation of studies: In order to demonstrate that, on balance, an environmental benefit will result from the discharge, the following information shall be provided by the applicant:

(I) The effluent flow and pollutant loads that are detected or expected in the effluent, by month, both average and expected worst case discharges. The parameters to be evaluated include at a minimum temperature, biochemical oxygen demand, total suspended solids, total dissolved solids, pH, settleable solids, e. coli bacteria, oil and grease, any pollutants listed in Table 20 of this rule division, and any pollutant for which the receiving stream has been designated by the Department as water quality limited; and

(II) Receiving stream flow, by month; and

(III) The expected impact of the discharge, by month, on the receiving stream for the entire proposed mixing zone area for all of the pollutants listed above. Included in this analysis shall be a comparison of the receiving stream water quality with the discharge and without the discharge; and

(IV) A description of fish, other vertebrate populations, and macroinvertebrates that reside in or are likely to pass through the proposed mixing zone, including expected location (if known), species identification, stage of development, and time of year when their presence is expected. For existing discharges, the applicant shall provide the same information for similar nearby streams that are unaffected by wastewater discharges. In addition, any threatened or endangered species in the immediate vicinity of the receiving stream shall be identified; and

(V) The expected impact of the discharge on aquatic organisms and/or fish passage, including any expected negative impacts from the effluent attracting fish where that is not desirable; and

(VI) A description of the expected environmental benefits to be derived from the discharge or other mitigation measures proposed by the applicant, including but not limited to improvements in water quality, improvements in fish passage, and improvements in aquatic habitat. If the applicant proposes to undertake mitigation measures designed to provide environmental benefits (e.g., purchasing water or water conservation rights to increase stream flows or establishing stream cover to decrease temperature), the applicant shall describe the mitigation measures in detail, including a description of the steps it will take to ensure that the benefits of the mitigation measures are attained and are not lost or diminished over time.

(VII) Some or all of the above study requirements may be waived by the Department, if the Department determines that the information is not needed. In the event that the Department does waive some or all of

the above study requirements, the basis for waiving the requirements will be included in the permit evaluation report upon the next permit renewal or modification relating to the mixing zone.

(VIII) Upon request of the Department, the applicant shall conduct additional studies to further evaluate the impact of the discharge, which may include whole effluent toxicity testing, stream surveys for water quality, stream surveys for fish and other aquatic organisms, or other studies as specified by the Department.

(IX) In evaluating whether an existing or proposed increase in an existing discharge would result in a net environmental benefit, the applicant shall use the native biological community in a nearby, similar stream that is unaffected by wastewater discharges. The Department shall consider all information generated as required in this rule and other relevant information. The evaluation shall consider benefits to the native aquatic biological community only.

(iii) Permit conditions: Upon determination by the Department that the discharge and mitigation measures (if any) will likely result in an overall environmental benefit, the Department shall include appropriate permit conditions to insure that the environmental benefits are attained and continue. Such permit conditions may include but not be limited to:

(I) Maximum allowed effluent flows and pollutant loads;

(II) Requirements to maintain land ownership, easements, contracts, or other legally binding measures necessary to assure that mitigation measures, if any, remain in place and effective;

(III) Special operating conditions;

(IV) Monitoring and reporting requirements; and

(V) Studies to evaluate the effectiveness of mitigation measures.

(B) Constructed water course: A mixing zone may be extended through a constructed water course and into a natural water course. For the purposes of this rule, a constructed water course is one that was constructed for irrigation, site drainage, or wastewater conveyance, and has the following characteristics:

(i) Irrigation flows, stormwater runoff, or wastewater flows have replaced natural streamflow regimes; and

(ii) The channel form is greatly simplified in lengthwise and cross sectional profiles; and

(iii) Physical and biological characteristics that differ significantly from nearby natural streams; and

(iv) A much lower diversity of aquatic species than found in nearby natural streams; and

(v) If the constructed water course is an irrigation canal, then it must have effective fish screens in place to qualify as a constructed water course.

(C) Insignificant discharges: Insignificant discharges are those that either by volume, pollutant characteristics, and/or temporary nature are expected to have little if any impact on beneficial uses in the receiving stream, and for which the extensive evaluations required for discharges to smaller streams are not warranted. For the purposes of this rule, only filter backwash discharges and underground storage tank cleanups are considered insignificant discharges.

(D) Other requirements for alternate mixing zones: The following are additional requirements for dischargers requesting an alternate mixing zone:

- (i) Most discharges that qualify for an alternate mixing zone will extend through the receiving stream until a larger stream is reached, where thorough mixing of the effluent can occur and where the edge of the allowed mixing zone will be located. The portion of the mixing zone in the larger stream must meet all of the requirements of the standard mixing zone, including not blocking aquatic life passage; and
 - (ii) An alternate mixing zone shall not be granted if a municipal drinking water intake is located within the proposed mixing zone, and the discharge has a significant adverse impact on the drinking water source; and
 - (iii) The discharge will not pose an unreasonable hazard to the environment or pose a significant health risk, considering the likely pathways of exposure; and
 - (iv) The discharge shall not be acutely toxic to organisms passing through the mixing zone; and
 - (v) An alternate mixing zone shall not be granted if the substances discharged may accumulate in the sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare; aquatic life; wildlife; or other designated beneficial uses; and
 - (vi) In the event that the receiving stream is water quality limited, the requirements for discharges to water quality limited streams supersede this rule.
- (5) Testing methods: The analytical testing methods for determining compliance with the water quality standards contained in this rule shall be in accordance with the most recent edition of Standard Methods for the Examination of Water and Waste Water published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation, unless the Department has published an applicable superseding method, in which case testing shall be in accordance with the superseding method; provided, however, that testing in accordance with an alternative method shall comply with this rule if the Department has published the method or has approved the method in writing.

Appendix B
Water Quality Trending

ADDITIONAL WATER QUALITY TRENDING ANALYSIS

Seasonal water quality trending analysis for parameters measured in the Illinois River at the Kerby monitoring station (RM 48.4 – see **Image 2**) by the Oregon Department of Environmental Quality (ODEQ), which were not presented in Chapter 3.1, are presented below. In addition, “historic” water quality trending analysis of data collected at this station was performed in order to determine if water quality conditions are 1) Improving, 2) Static, or 3) Degrading. Results from this analysis are presented later on in this Appendix.

ADDITIONAL SEASONAL WATER QUALITY TRENDING ANALYSIS

Alkalinity and Total Solids

Alkalinity is defined as a measure of the capacity of a water solution to neutralize a strong acid. In natural waters this capacity is attributed to bases associated with carbonate buffering system. Algal production and consumption of CO₂ during respiration and photosynthesis, respectively, effect the carbonate proton balance, and thus the pH of the solution. Alkalinity acts as a buffer against pH changes due to carbonate proton balance changes. Western Oregon streams generally have low pH buffering capacity (i.e. alkalinity). This is attributed in part to the high precipitation rates that dilute carbonates, dissolved solids, and other material weathered from the watershed. Accordingly, alkalinity levels tend to increase during the low flow, summer, period. Seasonal total alkalinity and total solids trends are presented in **Figure B-1**.

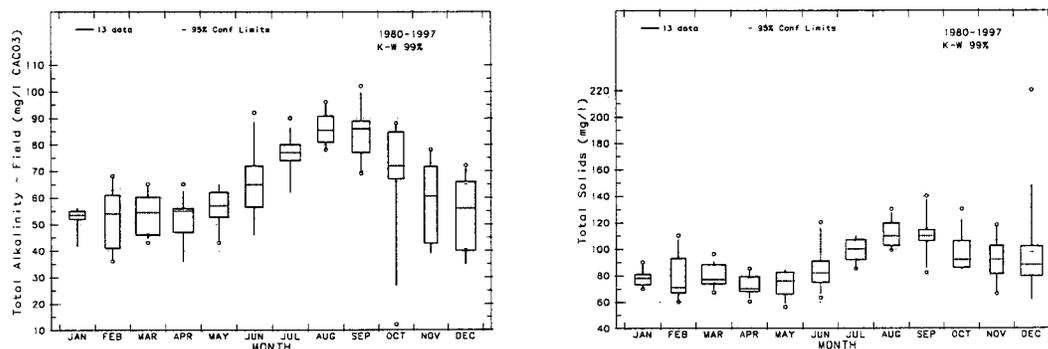


Figure B-1. Seasonal total alkalinity and total solids trends in the Illinois River downstream of Kerby.

Suspended Solids and Turbidity

Suspended solids can adversely affect fish and other aquatic organisms both directly in the water column and indirectly by depositing on redds and adversely impacting egg development. Turbidity is a measure of the level at which light passage through water is restricted by suspended material in the water column. High turbidity indicates high suspended material conditions in the water column, as well as low water transparencies. Observed turbidity and total suspended solids levels in the Illinois River downstream of Kerby (RM 48.4) are very low during the summer period, however levels are occasionally elevated during the high flow conditions during late fall and early winter periods. Turbidity and total suspended solids data is presented in **Figure B-2**.

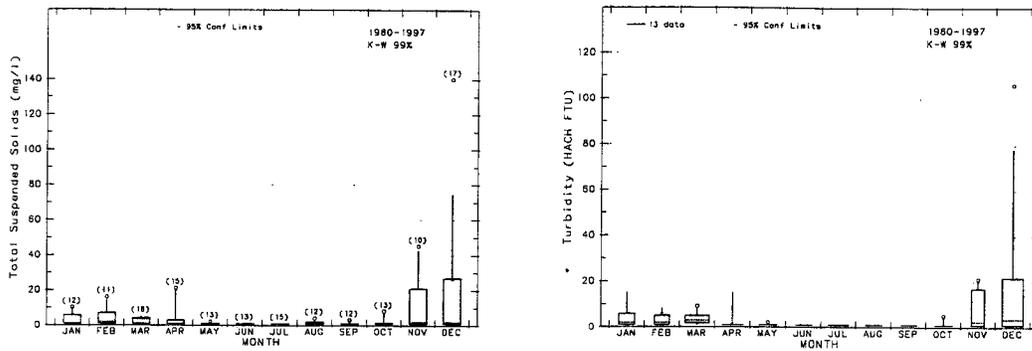


Figure B-2. Seasonal total suspended solids and turbidity trends in the Illinois River.

Bacteria

The OAR specifies that the 30-day log mean concentration of *E. Coli* shall not exceed 126 organisms per 100 ml and that no single sample shall exceed 406 *E. Coli* organisms per 100 ml. The available data set for *E. Coli* is very sparse, with data only available at this site since 1996, with a total of seven samples. The available data does not show any standard violations, however, the data not insufficient to draw any conclusions, other than to conclude that more data is needed (Figure B-3).

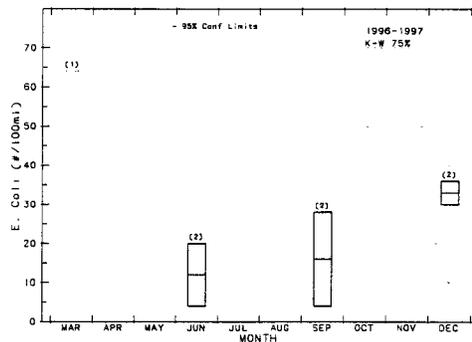


Figure B-3. Bacteria concentrations in the Illinois River

Chlorophyll *a*

Algae may be in the form of suspended algae (phytoplankton) or benthic algae (periphyton). Algal populations may be quantified by chlorophyll *a* concentrations. Since benthic algae is attached to rocks and other substrate, only phytoplankton populations show up in water column chlorophyll *a* measurements. Chlorophyll data is presented in **Figure B-4**.

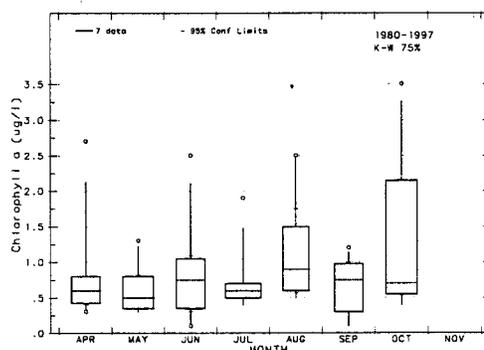


Figure B-4. Seasonal chlorophyll *a* trend in the Illinois River downstream of Kerby.

The OAR specifies an action level for chlorophyll *a* of 15 ug/L for rivers (OAR 340-41-150). If such a level is exceeded, the Rule requires DEQ to conduct studies to determine the probable causes of the exceedance and beneficial use impact; and develop a proposed control strategy for attaining compliance where technically and economically practicable. Where natural conditions are responsible for the exceedance or where beneficial uses are not impaired, the 15 ug/L level may be modified to an appropriate value for the water body. Observed chlorophyll *a* concentrations in the Illinois River downstream of Kerby (RM 48.4) are well below the 15 ug/L action level, as stipulated in the OAR.

HISTORIC WATER QUALITY TRENDING ANALYSIS

An assessment of water quality trends can answer some of the most fundamental questions about the quality of the water in the Illinois River.

- Are things getting better, getting worse, or by and large remaining static?
- Are efforts on the whole leading to improvements in water quality?
- Are there increasing levels of human activities that are resulting in deteriorating conditions?

There are two types of trends found in time series of water quality data, monotonic and step trends. A monotonic trend is a gradual change, taking place over many years and with no reversal of direction, whereas a step trend is a sudden increase or decrease in the data that occurs as a result of some change in the basin, such as the termination of a point-source discharge.

For this assessment, efforts were restricted to analyzing monotonic water quality trends of ambient data collected by the Department of Environmental Quality (DEQ) at the ambient water

quality monitoring site located downstream of Kerby on the Illinois River (River Mile 48.8). Step Trend analysis should only be attempted when a prior knowledge of activities within a basin suggests that a step trend should be present. No step trend analysis was attempted.

Monotonic statistical analyses were performed on data collected at this station since 1980 for the summer period (May through October), and the winter period (November through April). The summer period was considered a relative low flow, warm weather, condition, and such parameters such as pH, dissolved oxygen, chlorophyll a (e.g. algae), and temperature are of particular concern during this period. High river flows, along with low sun light intensities, ensure that biological productivity during the winter period will not be a major factor affecting water quality. However, flow dependent parameters could be of concern during this high flow period.

Methods

Software used for this assessment was the WQHydro Package developed by E. Aroner. A detailed description of statistical methods used for trend analysis are presented in the WQHydro User's Manual (Aroner, 1993). Similar statistical analytical methods were used to develop water quality trends presented in the 1990 Oregon 305b Report (Water Quality Status Assessment Report).

Seasonal Kendal Test

The general monotonic trending technique applied for this assessment was the Season Kendal Test. A seasonal version of Sen's non-parametric (distribution-free) method was used to estimate the magnitude of the trend slope. A trend of some magnitude will almost always be measured. The test estimated the likelihood that the trend measured from the sample does **not** exist in the water quality population sampled, or the probability that the sample trend could be the result of random sampling variability. This estimate is known as the "P" value and is recorded on the trend plots. The P value is compared to a predetermined statistic, which represents the chance we are willing to accept an incorrect conclusion, is referred to as the "significance level." A significance level of 90 percent indicates, for this test, that a 10 percent maximum probability of error is acceptable in concluding that a significant trend exists.

Chi-Square Test for Homogeneity of Trend Between Seasons

It is possible with the Seasonal Kendall Test for a significant trend in one season to offset a trend in the opposite direction in another season, yielding a global statistic that suggests an absence of trend. To check for this possibility, a statistic is computed to measure the homogeneity of trend across the period of analysis. Where this chi-square statistic suggested a non-homogenous trend, the Seasonal Kendall Test was performed and recorded independently for sub-units of the respective season.

Flow-Adjusted Concentration (FAC) and Hour of Collection (HCAC) Adjustments

It is useful information to know if a trend exists in the raw, basic data. However, it is possible for an apparent trend in water quality to be caused by a trend in streamflow, or by other exogenous (outside) factors. For example, trends in diurnally influenced parameters (e.g. dissolved oxygen, dissolved oxygen percent saturation, pH, and temperature) should be viewed with caution because results are affected by the time of sample collection. Special trending techniques were used when a significant relationship between water quality and streamflow/time of sample collection was found in order to reduce the effects of these outside influences on observed trends.

If a distinctive relationship exists between streamflow and concentration for a water quality constituent, then a trend in flow for the particular sequence of flows sampled can create a trend or obscure an anthropogenic (e.g. human induced) trend. Flow-adjusted concentration (FAC) refers to a methodology for reducing this influence. If it is determined that no significant regression correlation exists between the parameter and flow, then FAC was not included in trend determination for the particular parameter.

Trends in the time of day at which samples are collected may alter water quality trends for those variables influenced by the diurnal activity of algae. These variables typically are dissolved oxygen and pH. The hour of sample collection of data (HCAC) is an exogenous factor and was treated similarly to streamflow. If it is determined that no significant regression correlation exists between the parameter and time of sample collection, then HCAC was not included in trend determination for the particular parameter.

* * *

Changes and variability in field and laboratory analytical techniques were scrutinized to determine possible bias that could affect the trend result. It was reported in the 1990 303b Report for the State of Oregon that Total phosphorus (TP) analytical procedures changed in May 1982, and therefore only TP data collected since June 1982 were included in the trend analysis. In addition, it was reported in this report that pH analytical techniques changed in 1983. Therefore, only field pH data collected since 1984 were in the trend analysis. Finally, the minimum reporting limit for dissolved ortho-phosphorus changed in 1988. Therefore, only dissolved ortho-phosphorus data collected since 1988 was included in the trend analysis for this parameter.

Finally, it should also be noted that if more than 25 percent of the data included in a data set to be tested were at the minimum reporting level, the statistical test was rendered invalid.

RESULTS AND DISCUSSIONS

Water quality collected data at the DEQ Illinois River ambient (e.g. long-term) monitoring station at Kerby were analyzed to determine whether over 25 percent of collected samples for a particular parameter were at/below the minimum DEQ laboratory reporting limit. It was found that most nutrient constituents did not satisfy this requirement, and therefore statistical analysis was not performed on this data. (This included total nitrogen (TKN), ammonia nitrogen (NH₃-N & NH₄-N), and dissolved ortho-phosphorus.) In addition, over 25 percent of collected samples for turbidity and fecal coliform were at/below their respective laboratory reporting limit.

A decreasing water discharge streamflow trend (90% Significance Level) was calculated from data collected at the USGS Stream gauging station on the Illinois River near Kerby (#14377100) (River Mile 50.5) during the winter period. However, no significant trend for flow was measured at this station during the summer period. Accordingly, a Flow-Adjusted concentration (FAC) correction was included Seasonal Kendal analysis for the winter period. Results of this analysis are presented in **Figure B-5**.

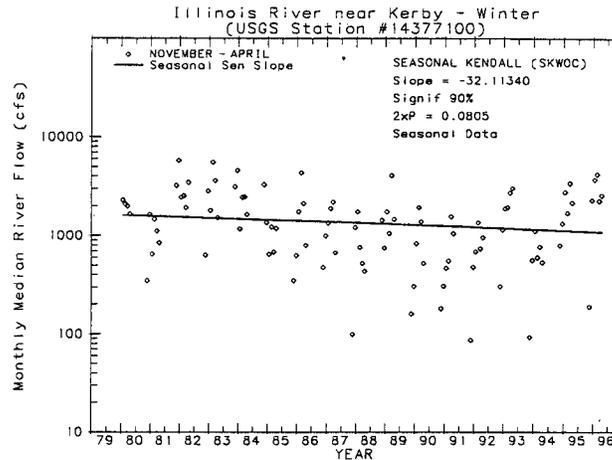


Figure B-5. Trend of River Discharge at the USGS Stream Gauging Station at Kerby.

It was also determined that a trend existed for time-of-sample-collection (99% Significance Level) at the DEQ monitoring station at Kerby during the summer period. Specifically, the observed trend was negative, indicating that sample time collection was decreasing during the 1980 through 1996 period. Accordingly, an hour-of-collection adjusted concentrations (HCAC) correction was included Seasonal Kendal analysis for the summer period. Results of this analysis are presented in **Figure B-6**.

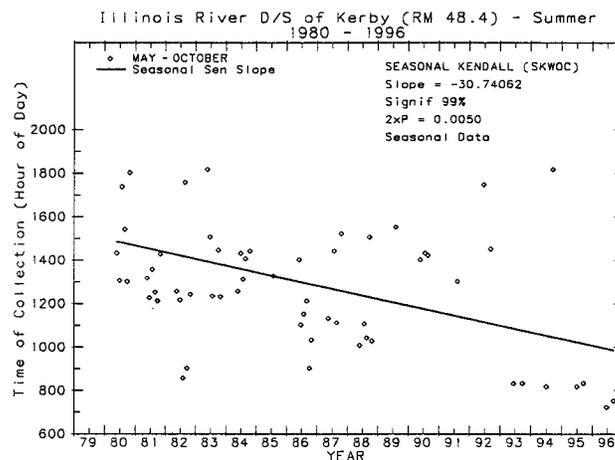


Figure B-6. Trend of Time-of-Sample-Collection at the DEQ water quality monitoring site on the Illinois River downstream of the City of Kerby (RM 48.4).

pH (Hydrogen Ion Activity)

No trend was measured for pH for both the summer and winter periods at an eighty-percent (80%) significance level. This indicates that pH conditions at this location have not changed at a statistically significant level between 1984 through 1996. However, a significant trend was calculated if pH data collected before 1984 was included in the analysis. As mentioned earlier, analytical techniques for pH analysis changed in 1984, which is the cause of the apparent trend using the entire data set (1980 through 1996).

Dissolved Oxygen and Dissolved Oxygen Percent Saturation

Analysis for dissolved oxygen and dissolved oxygen percent saturation failed the chi-square statistical test for both the winter and summer periods. This indicates that trends within each period are too variable to allow for statistical confidence in Seasonal Kendall Trend test. Therefore, statistical trend analyses for these parameters were not possible.

River Temperature

River Temperature measured in grab samples collected at the DEQ ambient water quality monitoring site at Kerby (RM 48.4) did **not** indicate a significant trend between 1980 through 1996. This does **not** indicate that river temperature conditions at this location are improving, but only that there is not a significant statistical trend (80% Significance Level) in river temperature. In addition, accounting for HCAC for the summer did not provide a statistically significant regression (e.g. $R^2 = 0.07$ for a Linear Ordinary Least Squares Regression).

Nitrate and Nitrite Nitrogen

Nitrate and Nitrite Nitrogen measured in grab samples collected at the DEQ ambient water quality monitoring site at Kerby (RM 48.4) were **not** shown to indicate a trend between 1980 through 1996. This does **not** indicate that concentrations of this constituent at this location are improving, but only that there is not a significant statistical trend (80% Significance Level) in nitrate and nitrite nitrogen.

Chlorophyll a

Chlorophyll a measured in grab samples collected at the DEQ ambient water quality monitoring site at Kerby (RM 48.4) were **not** shown to indicate a trend between 1980 through 1996. This does **not** indicate that concentrations of this constituent at this location are improving, but only that there is not a significant statistical trend (80% Significance Level).

Total Solids

Total Solids measured in grab samples collected at the DEQ ambient water quality monitoring site at Kerby (RM 48.4) during the **winter** indicated an increasing trend (90% Significance Level) between June 1980 through 1996. (Note: The winter period for total solids trend analysis was parsed into the November through March period as a result of chi-square analysis.). Accounting for FAC was found to be significant during the winter period (e.g. $R^2 = 0.36$ for a Linear Ordinary Least Squares Regression). The trend of Total Solids during the **winter** period is presented in **Figure B-7**.

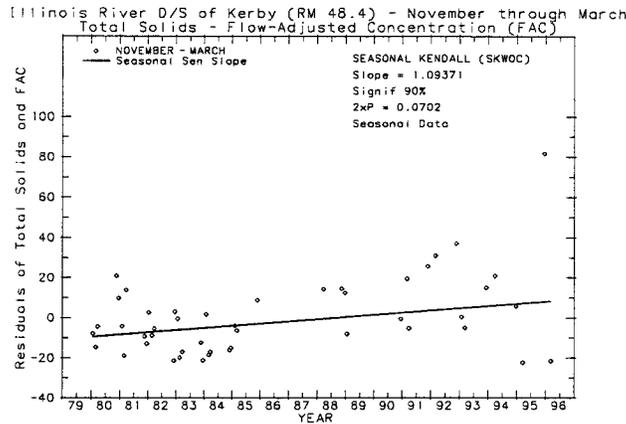


Figure B-7. Trend of the calculated regression residuals between winter total solids and measured flow at the DEQ water quality monitoring site on the Illinois River downstream of the City of Kerby (RM 48.4).

Total Solids measured during the **summer** indicated an increasing trend (80% Significance Level (almost at 90% - $2xP=0.1001$)) between June 1980 through 1996. Accounting for HCAC for the **summer** did not provide a statistically significant regression (e.g. $R^2 = 0.02$ for a Linear Ordinary Least Squares Regression) and therefore was not included in trend analysis (**Figure B-8**).

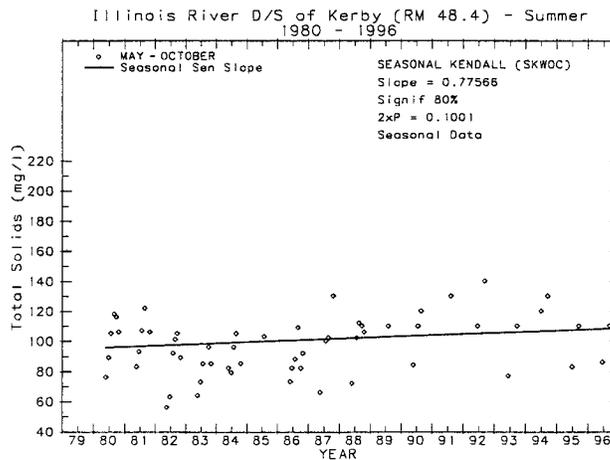


Figure B-8. Trend of summer total solids measured at the DEQ water quality monitoring site on the Illinois River downstream of the City of Kerby (RM 48.4).

Total Phosphorus

Total phosphorus measured in grab samples collected at the DEQ ambient water quality monitoring site at Kerby (RM 48.4) were shown to indicate a decreasing trend between June 1982 through 1996 for both the winter and summer periods.

A decreasing winter total phosphorus concentration trend (80% Significance Level) was observed for the winter period. The water quality significance of this result is limited as a result of other factors affecting biological activity in the river during the winter period (i.e. low light intensity, and low water temperature, etc.). Accounting for FAC was found to be significant during the **winter** period (e.g. $R^2 = 0.78$ for a Linear Ordinary Least Squares Regression). The trend of Total Phosphorus during the **winter** period is presented in **Figure B-9**.

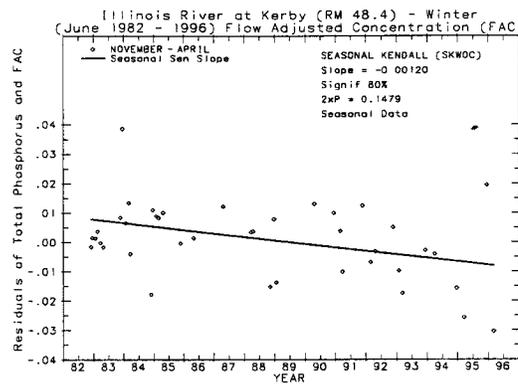


Figure B-9. Trend of the calculated regression residuals between winter total phosphorus and measured flow at the DEQ water quality monitoring site on the Illinois River downstream of the City of Kerby.

A decreasing summer total phosphorus concentration trend (99% Significance Level) was observed for the summer period. Accounting for HCAC for the **summer** did not provide a statistically significant regression (e.g. $R^2 = 0.03$ for a Linear Ordinary Least Squares Regression) and therefore was not included in trend analysis. The trend of Total Phosphorus during the **summer** period is presented in **Figure B-10**.

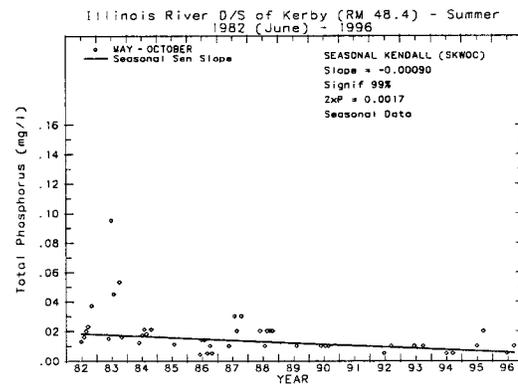


Figure B-10. Trend of summer total phosphorus measured at the DEQ water quality monitoring site on the Illinois River downstream of the City of Kerby (RM 48.4).

**Appendix C is an Excel spreadsheet of Illinois Sub Basin
Temperature Data**

Available through DEQ Medford Office
(541) 776-6010 Ext. 240 John Blanchard
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Appendix D
Temperature Technical Analysis

APPENDIX D - TEMPERATURE TECHNICAL ASSESSMENT

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, the condition of the riparian area, channel morphology and hydrology can be affected by land use activities. Specifically, the elevated summertime stream temperatures attributed to anthropogenic causes in the Illinois River Basin result from the listed conditions below. Analysis that supports these conditions is presented in the remaining portions of this document.

Channel widening (increased width to depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation.

Riparian vegetation disturbance that compromises stream surface shading and decreased riparian vegetation height and density (Shade is commonly measured as percent shade and open sky percentage.).

A large portion of the total stream miles in the Illinois River basin has been surveyed and this stream morphology data meets Oregon Department of Fish and Wildlife (ODFW) data quality standards. ODFW stream survey data is formatted for geographic information systems (GIS) and has been made available to the public. Using Illinois River basin channel morphology data, the relationships between temperature data and instream physical parameters were evaluated. Further, FLIR thermal imagery provides insight into various heating and cooling processes.

Stream Heating Processes

Stream temperature is an expression of heat energy per unit volume, which in turn is an indication of the rate of heat exchange between a stream and its environment. Detailed descriptions of stream heating processes are presented in **Chapter 4, Section 1**, and are illustrated in **Figure 14**.

Temperature Related to Stream Surface Shade

Removal of riparian vegetation, and the shade it provides, contributes to elevated stream temperatures (Rishel et al., 1982; Brown, 1983; Beschta et al., 1987). The principal source of heat energy delivered to the water column is solar energy striking the stream surface directly (Brown 1970). While exposed to summertime midday solar radiation, large quantities of heat energy will be imparted to the stream. Exposure to direct solar radiation will often cause a dramatic increase in stream temperatures. When shaded throughout the entire duration of the daily solar cycle, far less heat energy will be transferred to the stream. The ability of riparian vegetation to shade the stream throughout the day depends on vegetation height, density and position relative to the stream.

The condition of the riparian vegetation varies considerably in the Illinois River basin. The majority of the upper watershed tributary riparian vegetation is composed of narrow bands of hardwood and conifer species, where larger trees have been selectively removed. Land surrounding Illinois Valley streams have been historically managed such that current riparian vegetation stand stocks have changed (IVWC, 1995). In addition, clearing for homesteads and

farming ground was widespread on the valley floor, which changed the vegetation structure to a system dominated by non-woody vegetation or no vegetation at all.

Mechanics of Shade

The percentage of open sky is a fraction of the horizon above the stream that is void of canopy and/or topographic barriers (stream bank slope, hills and ridges). In essence, the percentage of open sky is a measure of the absence of shade. **Figure D-1** clarifies the measures (percentage open sky and percentage shade) using 75% shade and 25% open sky as an example. The Oregon Plan minimum shade benchmark for the Illinois River basin is 75%. It is important to emphasize that this 75% shade benchmark is a minimum value (e.g. The % shade benchmark is > 75%).

The percent open sky (or percent shade equivalent) is perhaps one of the easiest and straightforward stream parameters to address in terms of management and recovery processes. In the Illinois River basin, undisturbed riparian areas generally progress towards late seral staged woody (mixed hardwood and coniferous) vegetation communities. Few, if any, riparian areas in the Illinois basin are unable to support either late seral riparian vegetation or tall growing herbaceous vegetation. Further, the climate and topography are well suited for growth of large woody vegetative species in the riparian areas.

Observed Relationships

Oregon Department of Fish and Wildlife stream survey data collected since 1991 has been used to relate open sky measurements to riparian vegetation communities (i.e. type and age). **Figure D-2** displays these relationships. The Oregon Plan's minimum benchmark level for percent shade for the Illinois Basin is 75%. This directly corresponds to a 25% maximum percent Open Sky benchmark. This value is included on **Figure D-2**.

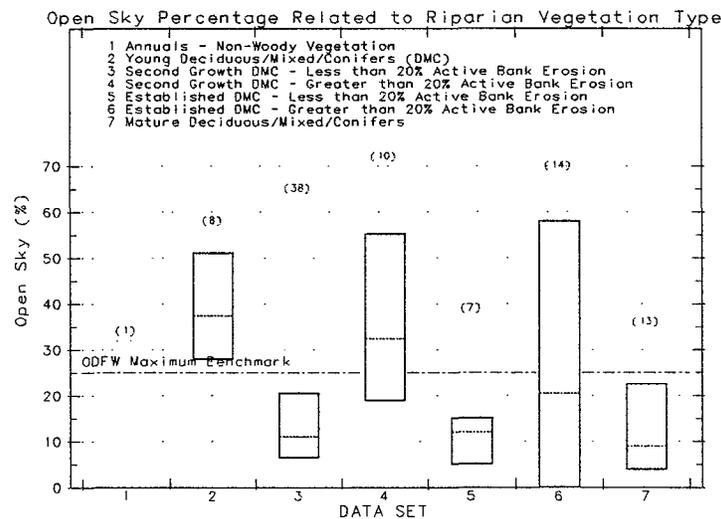
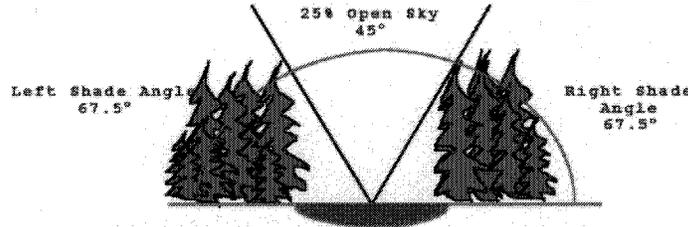


Figure D-2. Open sky measurements that correlate with riparian vegetation type and age classification in the Illinois River basin, both mainstem and tributary data are displayed (Data from ODFW, 1997).

What a Minimum of 75% Shade Implies:

Of the 180° (half-circle) above the stream 135° should be occupied by topographic barriers or riparian vegetation, preferably a 67.5° shade angle along each stream bank, while the remaining 45° may be open to the sky (canopy opening).

$$\text{Shade angle required to achieve 75\% shade: } \frac{(180^\circ * 75\%)}{2} = 67.5^\circ$$



What 67.5° Vegetation Shade Angle Implies:

The vegetation shade angle is a function of vegetation height and the position of the vegetation relative to the stream. Assuming that the vegetation is vertical along the stream banks, the estimated required vegetation height needed to produce a 67.5° vegetation shade angle is:

$$\text{Height}_{\text{vegetation}} = \tan(67.5^\circ) * \frac{1}{2} \text{Width}_{\text{stream}}$$

where,

- Height_{vegetation}: Vegetation height
- Width_{stream}: Width of the active channel

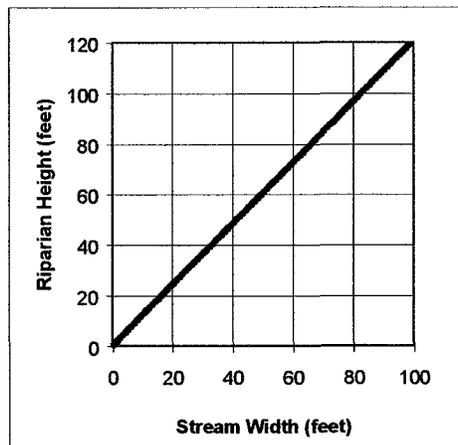


Figure D-1. Relationship between the percent open sky and percent shade.

The data suggest that annual (i.e. grasses) riparian vegetation types offer low stream surface shading levels, with a median open sky value of 32%. This Open Sky value correlates to a 68% stream surface shade. Because the sample size for annual riparian vegetation was only 1 (n=1), this result should be viewed with extreme caution.

Observed Open Sky for young woody vegetation (i.e. Deciduous/Mixed/Conifers) in the Illinois Basin was 32%. This corresponds with a 68 % shade value, which is well below the 75% Oregon Plan's Minimum Target Value. Young woody vegetation was specifically defined by ODFW (1997) as "Young Established trees or Saplings" and the age range was 1 to 3 years of age.

Observed Open Sky was highly variable in second growth stands (15-30 years of age) and established stands (30-50 years of age) in the Illinois Basin. Active Eroding Stream Bank (AESB) measurements were used to account for this observed variability. Accordingly, Open Sky data for these two vegetation types were parsed into units greater than and less than 20% AESB. Although the Oregon Plan does not specifically address AESB through establishing benchmark values, an 80% Bank Stability criteria was designated by PACFISH and was used to assess AESB conditions in the Illinois Basin. An 80% Bank Stability corresponds to a 20% AESB.

It was determined that percent Open Sky was well below the Oregon Plan's maximum benchmark of 25% for second growth and established stands in areas which AESB was below 20%. However, it was found that Open Sky values were much greater in areas that the AESB is greater than the 20% benchmark. This indicates that stream bank erosion is a major factor effecting the amount of light energy reaching the stream surface, regardless of the age of the woody-vegetation stands. The observed median 91% shade value for "mature" vegetation stands (Greater than 50 years of age) was well above the minimum shade benchmark set for the Illinois Basin. This indicates that sufficient stream shading is possible in the Illinois Basin using vegetation species currently present.

Forward Looking Infrared Radiometer (FLIR) Thermal Imagery

Forward looking infrared radiometer (FLIR) thermal imagery coupled with color videography and geographic positioning systems (GPS) produces spatially continuous temperature imagery. FLIR and color video images are collected with instruments mounted to a helicopter that can "fly" as much as 100+ kilometers of river/stream per day. The output data consists of GPS-tagged FLIR digital images that cover approximately 100 x 150 meters with less than 1 meter of spatial resolution and $\pm 0.5^{\circ}\text{C}$ accuracy. The spatial continuity of the FLIR data has made it possible to visually observe many of the thermodynamic processes associated with stream heating as they occur. Groundwater interactions with the stream column also register distinctly in the FLIR data imagery. Perhaps the greatest contribution of FLIR technology is the ability to display thermal habitat fragmentation of warmed reaches separated by isolated cool-water refugia. Further FLIR imagery is produced at a relatively low cost (\$100 to \$400 per river mile). Dr. Bruce McIntosh is currently developing this new and innovative technology¹ and sponsors of the project include the USDA Forest Service Pacific Northwest Research Station, Oregon State University and the Environmental Protection Agency (EPA) Office of Water.

¹ Dr. Bruce McIntosh is an associate professor in the Department of Forest Science at Oregon State University.

It was not possible to obtain collected FLIR Thermal Images for the Illinois Basin from Dr. McIntosh at the time of this draft release. Accordingly, FLIR Images presented in this draft document were collected from other parts of Oregon. However, water heating processes illustrated on these images highlight water temperature processes which are occurring within the Illinois Basin. It is the intention of the author that FLIR images collected for the Illinois Basin will be included in future versions of the document.

It may be helpful to remind the reader that this image measures only surface temperatures of the ground, stream or riparian vegetation. In essence, FLIR thermal imagery measures the temperature of the outermost portions of the bodies/objects in the image (i.e. ground, riparian vegetation, stream). **Finally, it is important to note once again that FLIR images presented in this document were measured in a different basin and should be viewed as a method to present principles surrounding water temperature dynamics.**

In the case of **Image D-1**, the outer surfaces of the trees are depicted along with ground and stream temperature. **Image D-1** illustrates the cooling influence that shade has upon ground and stream temperatures. Contained in the thermal image are trees that are casting shadows. Distinct cooling effects of shade can be observed. The cultivated ground temperature is greater than the calibrated sensitivity of the FLIR instrumentation (greater than 26°C or 79°F). An individual tree can be seen on the left bank of the stream in the middle of the frame and two trees are visible on the right bank in the upper and lower regions of the frame. All three trees are labeled as such in **Image D-1**. The outer surfaces of the trees are warm ($\approx 26^\circ\text{C}$ or $\approx 79^\circ\text{F}$). The ground and stream temperatures are markedly cooler in the shadows cast by these three trees. Stream temperatures outside of shadows "A" and "B" are 19°C (66°F), but are cooler (18°C or 64°F) within the shadows. In the case of ground temperature, there is greater than 9°C (16°F) difference between the cultivated ground surfaces inside and outside of Shadow "C". Cooler temperatures of both ground and stream surfaces are distinctly associated with shadows cast by riparian vegetation. It is apparent that the thermal environment differs significantly between the shaded and non-shaded conditions.

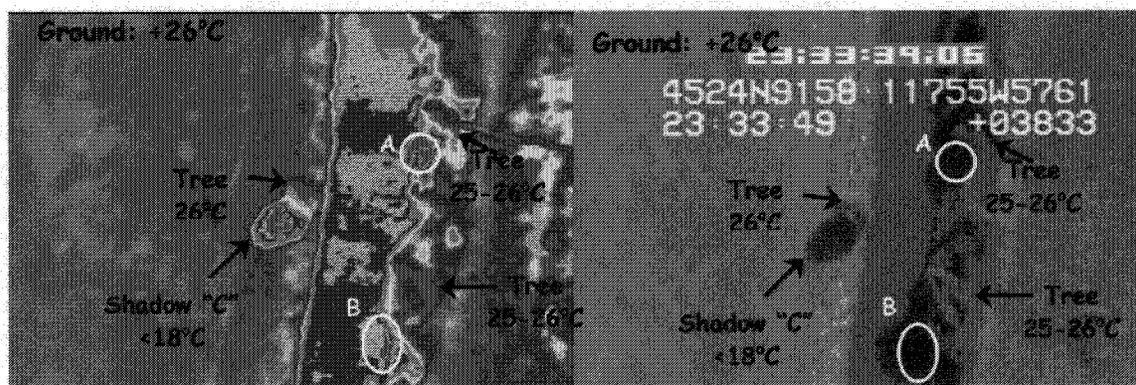


Image D-1. Example of the effects that shade has on ground and stream temperatures.

Image D-2 displays a densely vegetated riparian area that is casting a partial shadow over the surface of the stream. Stream temperatures increase in the downstream direction as the stream surface shading decreases (i.e. once stream water leaves the shade and enters partial to low levels of stream shade). The location of the road on the left bank reduces stream surface shade because

riparian vegetation is prohibited from establishing close to stream. The simple geometry presented in **Figure D-2** suggests that shading levels decrease as the distance between riparian vegetation and the stream bank increases. Regardless, the FLIR thermal image shows that when the solar radiation energy pathway is not reduced or eliminated by shade, increasing surface temperature result (i.e. ground and water temperatures)

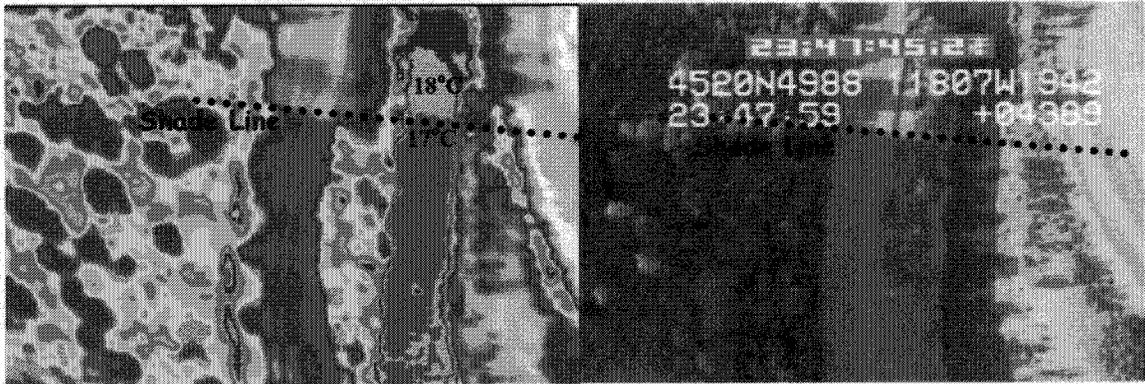


Image D-2. Example of shade that maintains cooler stream temperatures.

The cooling effect of shade can also be seen in **Image D-3**. Notice the stream surface shade provided by large conifers (most likely Douglas Fir) on the left stream bank. A circle marks the shaded portion of the stream, which is 1°C cooler that portions of the stream surface exposed to solar radiation. Apparently large woody conifer riparian vegetation can establish in these lower mainstem riparian areas when landuse allows. Lastly, the road located on the right bank serves to decrease shading levels by increasing the distance between the stream and riaparain vegetation.

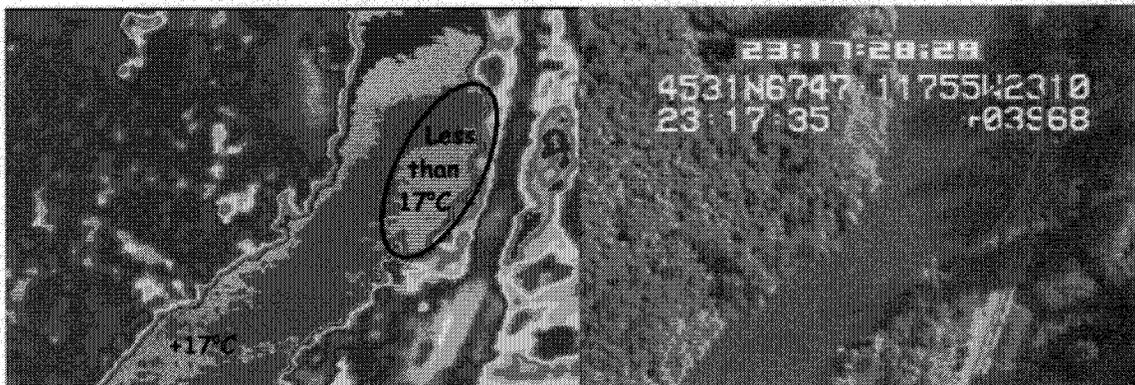


Image D-3. Example of shade that maintains cooler stream temperatures.

Temperature Related to Channel Morphology

Changes in channel morphology can impact stream temperatures, especially channel widening. As a stream widens, the surface area exposed to radiant sources and ambient air temperature increases, resulting in increased energy exchange between the stream and its environment (Boyd, 1996). An additional benefit inherent to narrower/deeper channel morphology is a higher frequency of pools that contribute to aquatic habitat. Further, narrower/deeper channels reduce the surface area for aquatic algae growth, which is directly related other water quality enhancement, namely: pH and dissolved oxygen.

CHANNEL WIDTH AND STREAM TEMPERATURE

The width to depth ratio (W:D) is a fundamental measure of channel morphology. High W:D imply wide shallow channels, while low W:D suggest that the channel is narrow and deep. The Oregon Plan's target for wetted width to depth ratio for the Illinois Valley is 15.0. The author recognizes that natural heterogeneity exists in terms of channel form and function. Proposed targets should not serve to simplify channels by striving to meet uniform channel characteristics. Further, channel morphology targets are to be met by natural recovery pathways and not mechanical manipulations of the channel. Channel morphology targets are threshold levels that should be considered upper limits, above which conditions are considered poor/degraded.

Fifty (50) continuous temperature-monitoring sites were located within ODFW stream survey reaches in the Illinois River Basin. This relatively small sample size may prohibit conclusive correlation. In short, instream physical parameter relationships between stream temperature may or may not exist, despite the implied relationships, or lack there of. As is often the case, the number of sampling sites are limited and often fail to occur in areas where other data has been collected. In addition, strong correlation between one stream parameter and stream temperature is rare because no one parameter is solely causing stream temperature change. For example, a correlation between channel width and stream temperature fails to capture the effects of shading and flow.

The number of data points (n) is extremely important. As the number of sample points increases, the confidence in calculated R^2 values also increases. The R^2 value may be controversial when considering whether a specific R^2 value implies correlation between the data and regression (see **DEFINITION OF TERMINOLOGY: STATISTICS**). Stream temperature and width:depth correlation is comprised of 50 temperature data sets. If this number were to increase, as will be case after the 1998 monitoring season, confidence in the implied relations may change. In addition, possible relationships may emerge that are not currently apparent.

Regression between stream temperature (median 7-day temperature statistic) and the wetted width:depth ratio that extends at least ½ mile upstream of the temperature monitoring site implies that there is a relationship between temperature and W:D (**Figure D-3**). Some scatter is expected because the wetted width to depth ratio is not the only factor affecting stream temperature. However, **Figure D-3** does suggest that W:D is a controlling factor directly related to stream temperature magnitude.

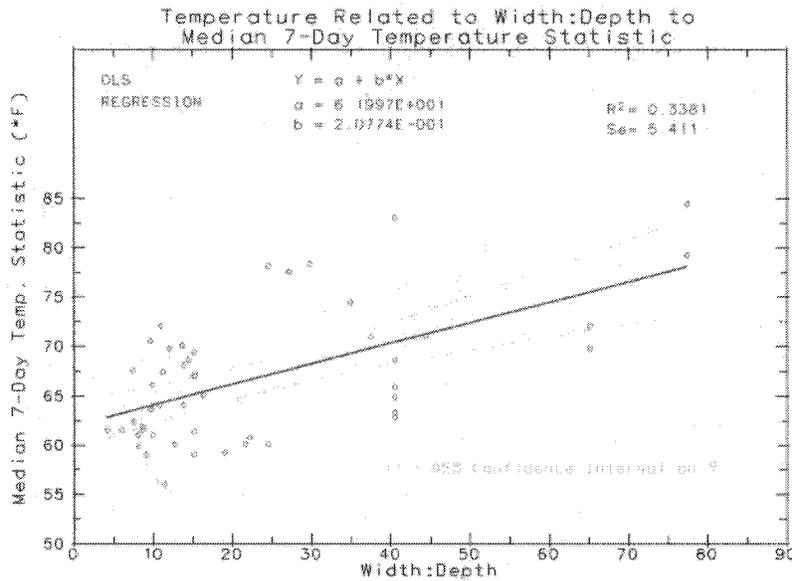


Figure D-3. Wetted width to depth ratios corresponding to measured stream temperatures (*median maximum 7-day moving average daily maximum*).

[A linear regression line has been fitted to the data and continuous 95% (Y-axis - temperature) confidence intervals are also presented. Using this regression line, it can be seen that width:depth values of 15 or less correspond to a 7-day statistic of approximately 64°F. Wetted width:depth values of 15 or less correspond to the Oregon Plan *minimum* target for the Illinois Basin. (Data collected from the USFS database (1995).]

Image D-4 shows a stream reach with varying channel widths and depths. The narrowest constriction (indicated as “W”) is the upstream delineation of a pool. “3W” indicates where the stream width is three times greater downstream of point “W”. Stream temperature apparently increases as the channel widens and becomes shallower. It should be noted that the temperature response indicated in **Image D-4** may be due to a ground water seep. However, no saturated soils or ground water plume can be observed in the thermal image. It is the judgment of the author that stream temperature responses are related to the change in channel morphology.



Image D-4. Example of channel width and corresponding stream temperatures.

It is worth noting that riparian areas portrayed in **Image D-4** are impacted by humans. Agricultural and rural residential encroachment, mining activities, roads and forestry have reduced, and in some cases eliminated, the riparian areas in the Illinois basin. Widespread temperature problems coupled with highly disturbed riparian areas justify more in depth analysis of channel forming processes.

Factors that Affect Stream Width

Channel widening often is related to degraded riparian conditions that allow increased stream bank erosion and sedimentation of the streambed. Both active stream bank erosion (measured as the ocular estimate of stream bank that is actively eroding) and sedimentation (measured as the ocular estimate of the stream bed occupied by fine sediment - particles less than 6.4 mm), correlate strongly with riparian vegetation type and age classification.

Riparian vegetation contributes to rooting strength and flood plain/stream bank roughness that dissipates erosive energies associated with flowing water. The condition of riparian vegetation will ultimately determine the width and depth that a stream channel will gravitate towards. Established/Mature woody riparian vegetation adds the highest rooting strengths and flood plain/stream bank roughness. Annual (grassy) riparian vegetation communities offer less rooting strength and flood plain/stream bank roughness. It is expected that width to depth ratios would be lower (narrower and deeper channels) when established/mature woody vegetation is present. Annual (grassy) riparian communities may allow channels to widen and become shallower.

Figure D-4 displays various W:D related to riparian vegetation types/age. Observed W:D for woody vegetation river reaches were generally below the 15 minimum target set by the Oregon Plan, however variability was high. As mentioned earlier, large variability of Active Stream Bank Erosion (ASBE) was observed in river reaches with Second Growth and Established woody vegetation age classes. Observed W:D for river reaches with ASBE less than 20% was much less than values measured at ASBE greater than 20%.

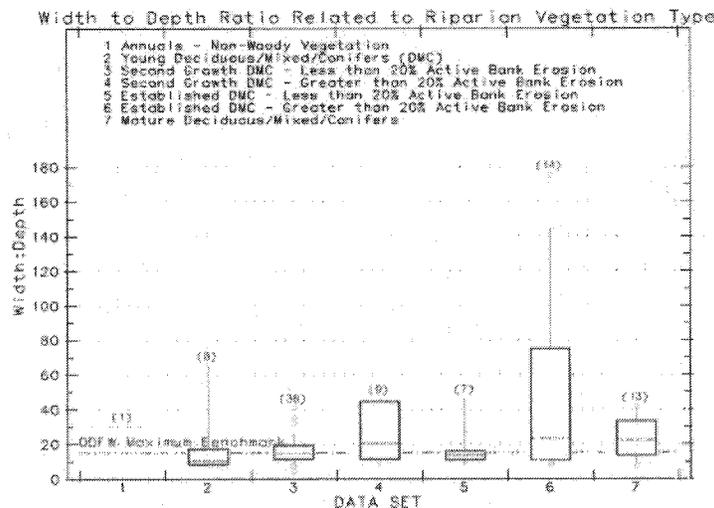


Figure D-4. Width:depth ratios related to various riparian vegetation types. (Data from ODFW, 1997).

Unfortunately, the relationship between channel form and riparian condition is complicated by a difference between the time in which riparian vegetation communities are established and the time it takes for channels to react to the riparian condition. In essence, there is a difference between riparian vegetation growth/maturation periods and stream geomorphic temporal periods of change. In effect, there is a lag-time between riparian vegetation alterations and channel modifications. This lag-time is referred to as a *legacy condition*. Land use and natural events have shaped the current composition of riparian vegetation: major forest fires, insect and disease damage to forested riparian stands, timber harvesting, road building/maintenance, agricultural encroachment into riparian areas, urbanization, grazing and trampling of riparian areas by cattle and mining. Some of these land use patterns continue today to varying degrees, while other occurred years (decades) in the past. However, the channel effects from each of these distinct human and natural riparian disturbance events are still apparent in many of the stream reaches surveyed.

Further, channel morphology, namely wetted width:depth values, are not solely dependent on riparian conditions. Sedimentation can deposit material in the channel and aggrade the streambed, reducing channel depth and increasing channel width. Flow events play a major role in shaping the stream channel. Channel modification usually occurs during high flow events. Naturally, land uses that affect the magnitude and timing of high flow events may negatively impact channel width and depth.

However, riparian vegetation conditions will affect the resilience of the stream banks/flood plain during periods of sediment introduction and high flow. Linking width to depth ratios to riparian vegetation is fundamental. Disturbance processes may have drastically differing results depending on the ability of riparian vegetation to shape and protect channels. Desirable low width to depth ratios (less than 15.0) are thus related to riparian vegetation community composition and condition by:

1. ***Building stream banks:*** Trap suspended sediments, encourage deposition of sediment in the flood plain and reduce incoming sources of sediment.
2. ***Maintaining stable stream banks:*** High rooting strength and high stream bank and flood plain roughness prevent stream bank erosion.
3. ***Reducing flow velocity (erosive kinetic energy):*** Supplying large woody debris to the active channel, high pool:rifle ratios and adding channel complexity that reduces shear stress exposure to stream bank soil particles.

STREAM BANK EROSION

Stream bank erosion results from detachment, entrainment and removal of bank material as individual grains or aggregates via fluvial processes. *Stream bank failure* indicates a gravity-related collapse of the stream bank by mass movement. Both *stream bank erosion* and *stream bank failure* result in *stream bank retreat*, which is a net loss of stream bank material and a corresponding widening of the stream channel.

Stream bank stability reflects the condition of riparian vegetation contributing to rooting strength in stream bank soils and flood plain roughness. Riparian vegetation rooting structure serves to strengthen the stream bank and resist the erosive energy exerted on the stream bank during high flow conditions. Flood plain roughness reflects the ability of the flood plain to dissipate erosive flow energy during high flow events that over-top stream banks and inundate the flood plain.

Riparian vegetation disturbance often has a compounding effect of increased stream bank erosion, increased kinetic energy exposure, decreased bank rooting strength, loss of soil cohesion and loss of flood plain roughness.

A high correlation between width to depth ratios and active stream bank erosion indicates that stream banks are unstable and the stream channel is likely widening. A weak correlation between the width to depth ratio and active eroding stream banks may indicate that stream channels are currently degrading or that a legacy condition exists. Figure D-5 relates width to depth ratio to active stream bank erosion. Three type of relations emerge from the data relationships:

1. **Desired:** Stream reaches falling in the lower width to depth ratio ranges that correspond to lower rates of stream bank erosion suggest a level of stability and/or stream bank building processes in which stream banks may be aggrading (collecting additional soil, rock and organic particles).
2. **Legacy Condition:** Stream reaches with higher width to depth ratios corresponding to low rates of active stream bank erosion imply that historic widening of the stream channel has occurred. However, low erosion rates suggest that the stream bank is either in a stable condition (no longer experiencing bank retreat) or in a bank building condition (collecting additional soil, rock and organic particles).
3. **Degrading:** Stream reaches that have high rates of stream bank erosion and are currently experiencing stream bank retreat and channel widening.

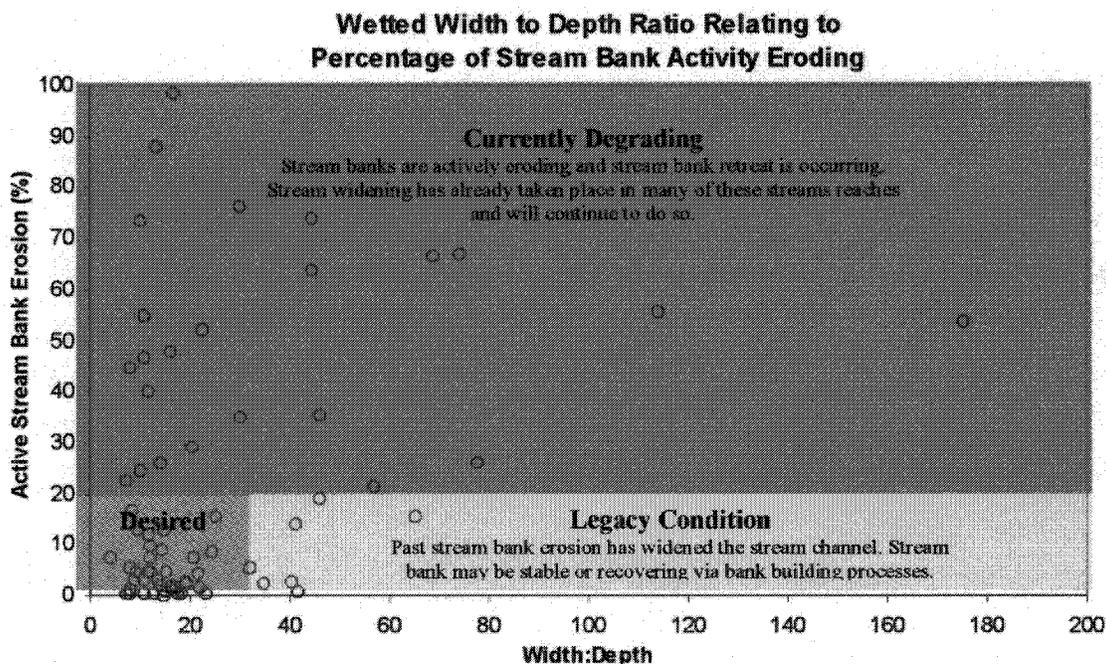


Figure D-5. Comparison of active stream bank erosion and wetted width to depth ratios for survey reaches in the Illinois River basin (Data from ODFW, 1997).

Image D-5 presents spatial patterns between active stream bank erosion and measured wetted to depth ratios for rivers in the Illinois Basin. Examples of all three conditions (Legacy, Currently Degrading, and Desired) are illustrated in Image D-5.

INSERT IMAGE D-5

STREAM BANK PROTECTION AND RIPARIAN VEGETATION

Stream bank erosion recovery processes requires the concurrent occurrence of two elements that induce stream bank building:

- *Protect Stream Banks From Kinetic Energy (Bank Particle Cohesion)*
- *Reduce Kinetic Energy (Stream Bank/Flood Plain Roughness)*

High levels of stream bank cohesion tend to protect the stream bank from erosive kinetic energy associated with flowing water. Stream bank erosion reflects looseness of bank soil, rock and organic particles. The opposite condition is cohesion of stream bank soil, rock and organic particles. Vegetation strengthens particle cohesion by increasing rooting strength that helps bind soil and add structure to the stream bank. Different riparian vegetation communities (annual, perennial, deciduous, mixed and conifer dominated) offer a variety of rooting strengths to stream banks. It is a general observation that all healthy/intact indigenous riparian vegetation communities will add preferable stream bank cohesion over bare soil/ground conditions.

Figure D-6 demonstrates a correlation between stream bank erosion and different riparian vegetation communities at various developmental stages. It appears that woody riparian vegetation provides more protection against active bank erosion than annual communities (non-woody vegetation), however a sample size of 1 (n=1) for annuals only provides limited confidence with the observed bank erosion value. The variability of bank erosion values observed for “Second Growth” (15 to 30 years old riparian stands) and “Established” (30 to 50 years old riparian stands) was great. Numerous reasons could be responsible for this high variability, however it is important to point out that management activities have changed since these periods. Very little stream bank erosion was measured at mature riparian stands.

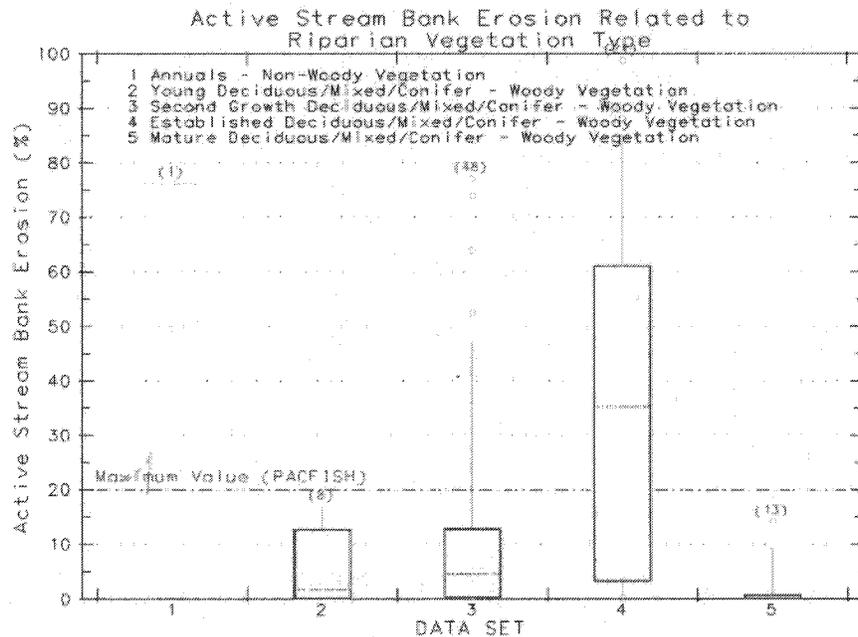


Figure D-6. Active stream bank erosion related to various riparian vegetation types using ODFW stream survey data for riparian classifications and stream bank erosion (ODFW, 1997).

Sedimentation

Streambed *finer* are defined as sand, silt and organic material that have a grain size of 6.4 mm or less. Sediments may affect the spawning success of salmonids (**Figure D-7**). Sedimentation of spawning gravel has been shown to significantly impair the success of juvenile emergence from gravel *redds*. Sedimentation may affect survival through entombment of juvenile or through reduction of intergravel dissolved oxygen delivery.

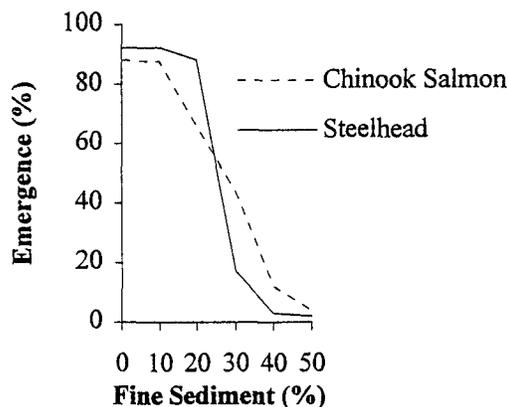


Figure D-7. Percentage emergence of fry from newly fertilized eggs in gravel-sand mixtures. Fine sediment was granitic sand with particles less than 6.4 mm (Bjornn 1969).

Studies have shown that fry emergence is seriously compromised as fine sediments are introduced into spawning gravel (Tappel and Bjornn, 1993). When fine grain sized substrate cover spawning gravel (*redds*) anadromous *sac-fry* (larval fish) may emerge prematurely. *Sac-fry* are often forced out of gravel before they have absorbed their yolk sacs as a fine sediments fill the interstitial pore spaces of the *redd*, resulting in a lack of oxygen (Tappel and Bjornn, 1993). Low survival rates accompany *sac-fry* that have been forced to prematurely emerge from the *redd*.

Everest et al. (1987) observed that stable channels containing stored sediments and large woody debris are more productive at every trophic level than either degraded channels devoid of sediment or channels that are aggraded and unstable. Stowell et al (1983) in Chapman and McLeod (1987) found that increased fine sediment in spawning gravel has been shown to decrease survival of juvenile salmon emerging from the *redd*. Similar relationships have been presented by Hall and Lantz (1969), Moring (1975), Phillips et al. (1975), Waters (1995), Irving and Bjornn (1984), and Tappel (1981). Deposition and embeddedness can influence embryo survival, emergence from the gravel and juvenile or adult use of the habitat. Chapman and McLeod (1987) and Harvey (1993) found no functional predictors that would quantify the effects of sedimentation on the survival or rearing of salmonids, but recommended that any incremental increase in embeddedness should be avoided.

Increases in bed sediments, affected by landscape and bank mass failures, are often accompanied by channel widening and braiding resulting in increased bank erosion and decreased pool riffle amplitude. Reduced channel complexity may be associated with reduced habitat complexity for aquatic species (salmonids and food sources such as macroinvertebrate communities).

Beschta et al. (1981) concluded that bedload processes are extremely important in shaping the character of quality of stream habitats. Sedimentation of the stream substrate, particularly the gravel used for spawning, produces significant detrimental effects on salmonid resources (Iwamoto 1978). Fine sediments can act directly on the fish by (Newcombe and McDonald 1991):

- *Killing salmonids or reducing growth or reducing disease resistance,*
- *Interfering with the development of eggs and larvae,*
- *Modifying natural movements and migration of salmonids,*
- *Reducing the abundance of food organisms, or*
- *Impairing sport fishing.*

Everest et al (1987) observed that watershed characteristics, as well as the erosion and bedload processes, will affect the level of risk to salmonids by accelerated sedimentation.

High fine sediment distributions in the Illinois River basin correlate strongly with active stream bank erosion (Figure D-8). In addition, it was found that annual riparian vegetation types (e.g. non-woody vegetation) had a very high percent fine value of 36%. Although only one annual riparian vegetation site was sampled in the Illinois watershed (ODFW database 1997), very similar values have been observed for other basins in Oregon (DEQ 1998-a). Mature deciduous/mixed/conifer riparian vegetation correlate to the lowest percent fine values.

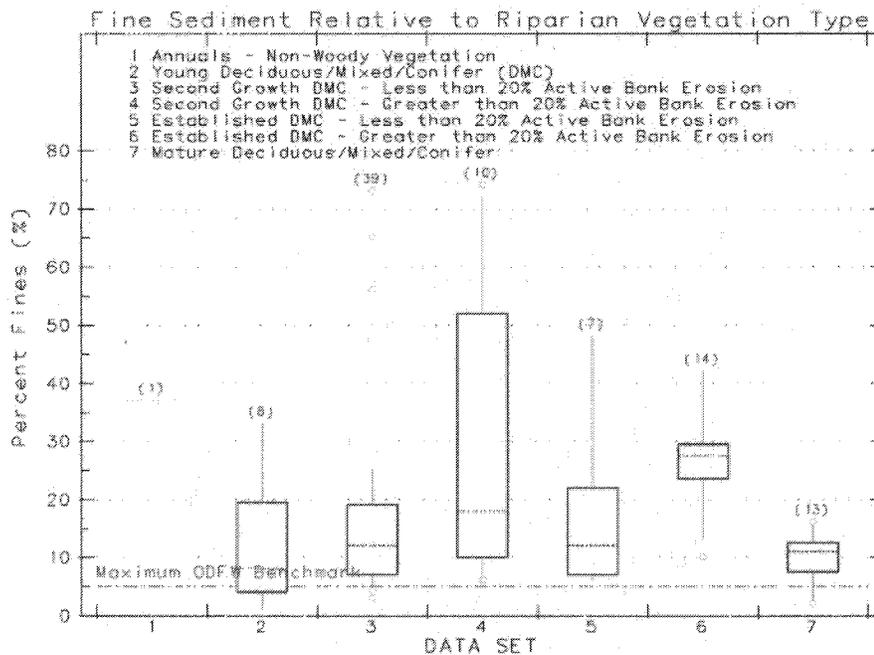


Figure D-8. Streambed percent fines related to various riparian vegetation types using only ODFW stream survey riparian vegetation classifications and percent fines data for the Illinois River basin (data from ODFW 1997). The Oregon Plan set a maximum benchmark of 5% fine sediment target for southwest Oregon streams, and fair percent fines conditions range from 5 to 15%.

Referring back to **Figure D-7**, 10% of fine sediment distributed over *redds* is an upper limit before serious *sac-fry* impairment occurs. The widespread high distribution of fine sediments constitutes worrisome impacts to egg incubation and *sac-fry* emergence/survival. Serious detriment to *sac-fry* is occurring in all streams with dominant annual and perennial riparian vegetation communities, especially in river reaches with elevated active stream bank erosion. In addition, non-woody riparian vegetation (annual) communities correlate to fines sediment distributions that would prevent most *sac-fry* emergence. Simply stated, these survey reaches are degraded to a level that reduces salmonid reproductive fitness to near zero levels.

Salmonids do not utilize the entire stream length to spawn. Instead, salmonids spawn (build *redds*) in gravel substrate riffle portions of the reach. If the relatively high fine sediment measurements were collected in non-spawning areas, perhaps there is less impairment to salmonids than the data suggests. This possibility is discounted by correlating fine sediment material in the total survey reach length to the fine sediment measured in the gravel/riffle portions of the survey reach. **Figure D-9** shows a strong correlation between fine sediment in the total reach length and fine sediment solely measured in gravel portions of the survey reach (spawning areas). It can also be seen that most fine sediment observations in the Illinois River basin were well above the threshold level for reduced fry emergence (see **Figure D-8**).

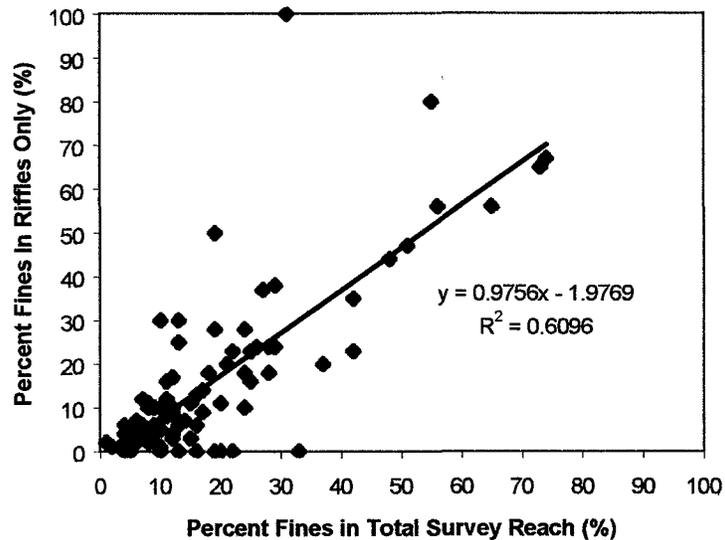


Figure D-9. Streambed percent gravel related to various riparian vegetation types for the Illinois River basin (Data from ODFW, 1997).

* * *

Streams with “large” levels of fine substrate must ultimately experience a decrease in fine sediment loading into the water column before recovery can occur. Sediment sources, both upslope and instream, are elevated in some portions of the Illinois Basin. Before lasting improvements in channel substrate can take place, these sources must be reduced, in some cases, dramatically.

Once sediment is introduced into the stream channel it either becomes deposited in the bed substrate, deposits along banks, or remains suspended in the water column (i.e. transported

downstream). Fine sediment deposited in the stream bed material may be re-suspended during **high flow** events and subsequently transported downstream or deposited in the flood plain/stream bank areas bordering the stream channel. These processes occur during hydrologic events that are relatively infrequent. Major sediment moving events have return periods measured in decades. **Figures in Appendix E** illustrate that very intense high flow events occur within this basin.

Further, if the stream channel, riparian zone and/or upslope landscape is in a degraded state, the same high flow events that transport sediments out of the stream channel can introduce large quantities of fine sediment. The condition of the stream channel and upslope landscape will create drastically different consequences in terms of sedimentation during high flow events:

- **Resilient/Healthy System:** Prevent large introductions of fine sediment from upslope or riparian areas, maintain stream bank stability, encourage deposition in the flood plain and bank building processes, introduce disturbed riparian vegetation (large woody debris into the active channel) and allow the resuspension and transportation of existing stream bed fine substrate in the downstream direction.
- **Degrading/Impaired System:** Allow large introductions of fine sediment from upslope or riparian areas, experience moderate to high rates of active stream bank erosion, allow erosion in the flood plain and bank retreating processes, is unable to introduce disturbed riparian vegetation (large woody debris into the active channel) and resuspended/transported stream bed fine substrate is replaced by incoming fine sediment sources.

Temperature Related to Hydrology

Ground water inflow has a cooling effect on summertime stream temperatures. Subsurface water is insulated from surface heating processes and most often groundwater temperatures fluctuate little and are cool (45°F to 55°F). Many land use activities that disturb riparian vegetation or the flood plain affect the connectivity of the Illinois River and its tributaries to groundwater sources. Groundwater inflow not only cools summertime stream temperatures, but also augments summertime flows. Reductions or elimination in groundwater inflow will have a compounding warming effect on the Illinois mainstem and tributaries. **Image D-6** shows three distinct seeps that deliver groundwater to a river. Plumes of cooler groundwater that mix with the stream are marked with arrows.

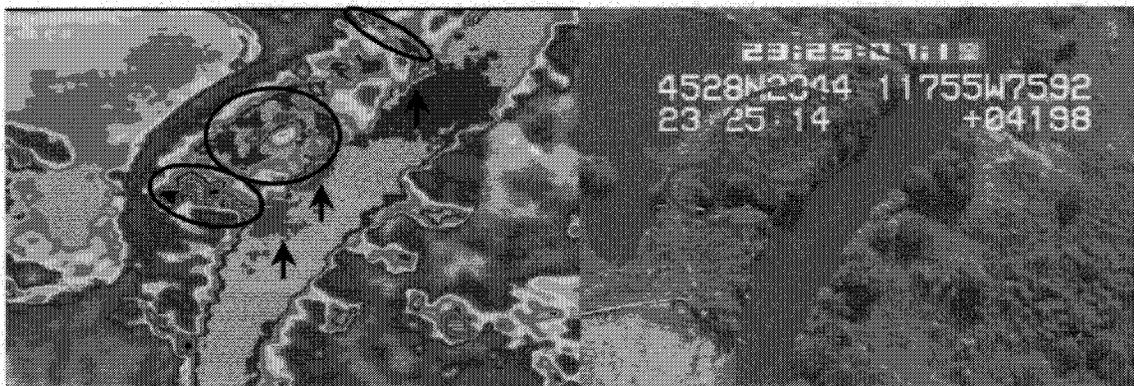


Image D-6. Example of groundwater seeps into the stream channel and corresponding stream temperatures

Image D-7 shows saturated riparian soils. The saturated area may not have a cooling influence on the river if the saturated soils do not mix with the stream or if the volume of water mixing with the stream is small. The proximity of the saturated area with respect to the stream may determine whether saturated riparian soils will impact stream temperature. **Image D-7** contains two areas with saturated soils, marked "A" and "B". Saturated area "A" is isolated from the stream and no groundwater/stream mixing is apparent. Saturated area "B" is large and extends to the stream. A corresponding plume of cooler water is being infused into the stream. **Image D-7** demonstrates that the extent of saturated riparian soils (volume) and the distance from the stream (proximity) determine the thermal impact of groundwater sources.

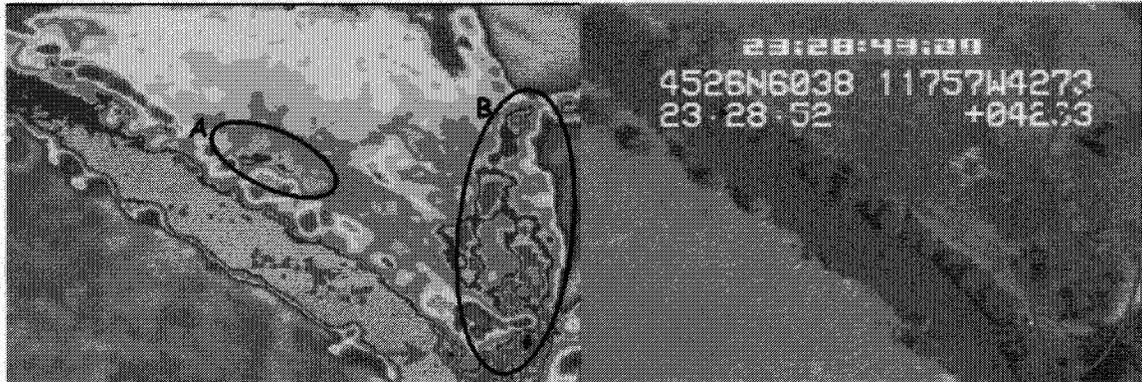


Image D-7. Example of groundwater seeps into the stream channel and corresponding stream temperatures

The ability of riparian soils to capture, store and slowly release groundwater is largely a function of the level of riparian disturbance. Human land use can reduce the storage capacity of riparian soils. **Image D-8** depicts a cultivated riparian area that no longer stores subsurface water. Riparian disturbance can also separate the flood plain from the stream. Although the undisturbed riparian area on the right bank is small, the measured soil and vegetation temperatures are dramatically cooler (9°C to 7°C or 16°F to 13°F). The circled region in **Image D-8** represents a irrigation pipe that has wetted soils.

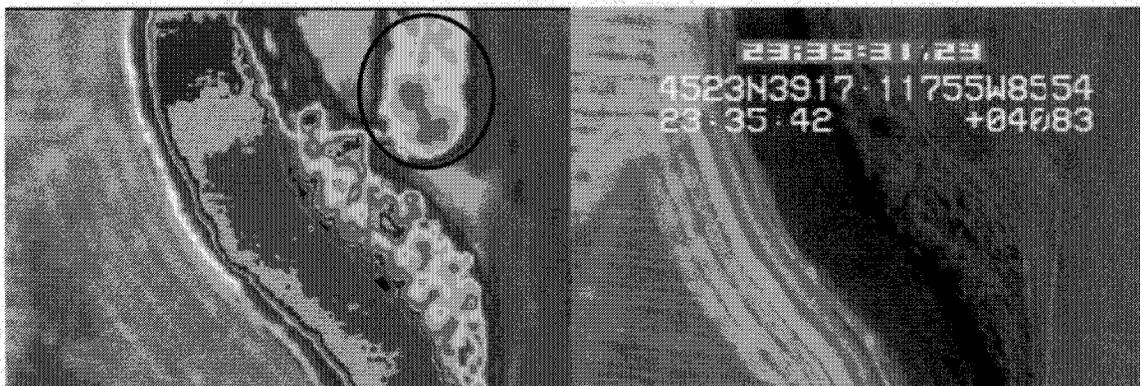


Image D-8. Example of the effects of riparian disturbance (cultivated riparian area) on groundwater storage and seeps into the stream channel and corresponding stream temperatures.

Flood plain disruption can occur when a barrier prevents normal flood plain functions, such as connecting saturated riparian soils with the river and tributaries. **Image D-9** shows a road that has

imposed a barrier between saturated riparian soils and the river. Ground water mixing with the river is completely disrupted on the left bank where the road bed has reduced soil permeability, most likely by compacting riparian soils (a dotted line marks the position of the road). The right bank (flood plain) also contains saturated soils. However, groundwater extends to the streams water column and mixing with the stream is apparent (marked with arrows). **Image D-9** demonstrates that flood plain disruption can reduce or eliminate the stream cooling impacts that saturated riparian can soils impart.



Image D-9. Example of the effects of riparian disturbance (roads) on groundwater storage and seeps into the stream channel and corresponding stream temperatures.

Image D-10 underscores the relationship between soil water content and the associated riparian vegetation condition. Contained in the image are examples of the thermal effects that relatively undisturbed riparian vegetation (A) and highly disturbed riparian area (B). Saturated or wetted soils are apparent riparian area "A" and provide cool water to the river as is evident by a long cool water plume in the stream (marked with arrows). Riparian area "B" is cultivated to the streams edge and has no measurable soil saturation or water content. In this case, flood plain disruption is complete. All of the processes inherent to functioning riparian areas are absent in riparian area "B". Specifically, processes that are impaired in riparian area "B" are: capturing, storing and slowly releasing water to the river water column, stream surface shading, stream bank rooting strengths and maintaining high levels of flood plain roughness. Disturbance in the riparian area often has real, measurable and sometimes significant stream temperature effects.



Image D-10. Example of the effects of riparian disturbance/encroachment on groundwater storage and seeps into the stream channel and corresponding stream temperatures.

Surrounding Thermal Environment

The thermal environment, displayed in **Image D-10**, is drastically different for the partially vegetated riparian area "A" (surface temperatures of 17°C to 20°C) and the cultivated riparian area "B" (greater than 26°C). The thermal environment (surface temperatures) in which a stream is surrounded will affect stream temperatures. Ground temperatures can become a source of heat energy to the stream. When the ground is warmer than the stream, heat will transfer from the stream bank to the water column. In fact, the ability of soils and ground surface to conduct heat to the stream is much higher than that of air. Solids (ground surfaces) have higher conductivity than gases (air). Conductivities of soils are on the order of 500 to 3,500 times greater than that of air (Halliday and Resnick, 1988). Simply stated, ground surfaces can conduct heat to the stream hundreds of times faster than that of the air column surrounding the stream.

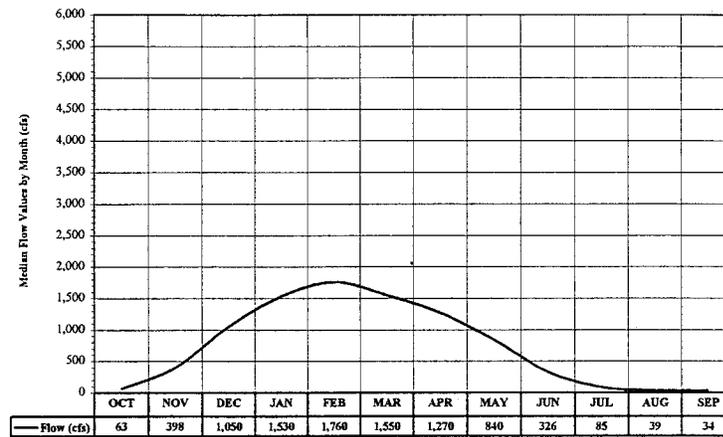
Following this line of logic, warmer soil/ground temperatures will transfer heat to the stream via bed conduction. Thus, degraded riparian areas that allow excessive stream bank warming will introduce heat into the stream faster than cooler stream bank temperatures. Once again, riparian condition is implicated as a controlling factor in stream temperature dynamics because ground/soil temperatures are a function of the shading. Riparian condition (i.e. vegetation type and age) is a controlling factor for the thermal regime of stream bank materials as well as the water column.

Air affects stream temperatures at a slower *rate*. Nevertheless, this should not be interpreted to mean that air temperatures do not affect stream temperature. Simply stated, the rate of energy transfer controls that amount of energy that is delivered over a specific time interval. Air temperature can deliver heat to a stream via the convection/conduction pathway, which is the slowest of the water energy transfer processes (Bowen, 1926; Beschta and Weathered, 1984; Boyd, 1996). However, prolonged exposure to warm air temperatures (i.e. air temperatures warmer than the stream) can induce gradual stream heating. Because the rate of energy transfer is slow, air temperature related stream column heating cannot explain the rapid daily heating and cooling cycles that streams experience. The convection/conduction energy pathway does not occur fast enough to contribute the large quantities of heat energy that is required to produce the large daily fluctuations in stream temperature that are commonly measured in the Illinois River and tributaries. It follows that cooler riparian areas are those that are well vegetated. All of the FLIR imagery displayed in this document supports this conclusion.

Appendix E
Stream Discharge Statistics

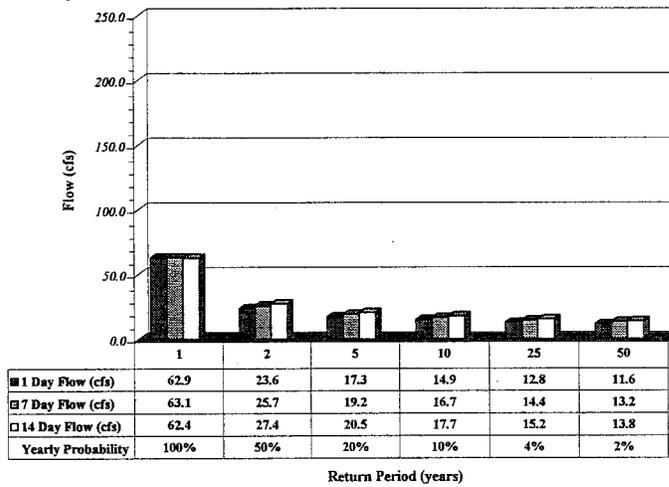
USGS Gage #14377000
 Period of Record: 1928 to 1960
 Drainage Area: 364 sq. miles

Illinois River at Kerby - Median Flow by Month



USGS Gage #14377000
 Period of Record: 1928 to 1960
 Drainage Area: 364 sq. miles

Illinois River at Kerby Low Flow Statistics



USGS Gage #14377000
 Period of Record: 1928 to 1960
 Drainage Area: 364 sq. miles

Illinois River at Kerby High Flow Statistics

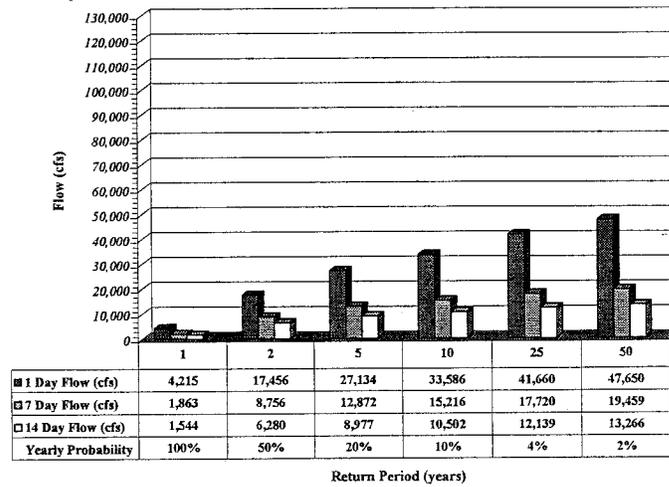
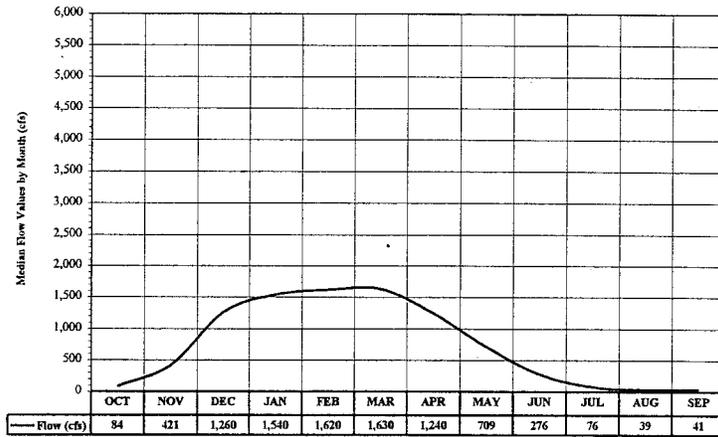


Figure D-1. River Discharge Statistics for the Illinois River at Kerby.

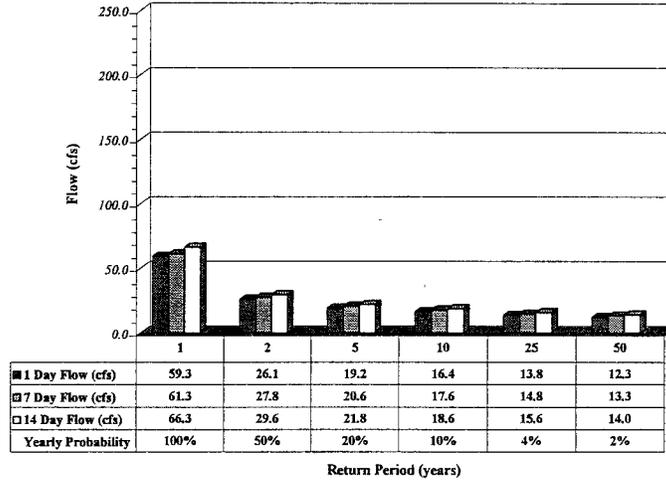
USGS Gage #14377100
 Period of Record: 1961 to 1995
 Drainage Area: 380 sq. miles

Illinois River Near Kerby - Median Flow by Month



USGS Gage #14377100
 Period of Record: 1961 to 1995
 Drainage Area: 380 sq. miles

Illinois River Near Kerby Low Flow Statistics



USGS Gage #14377100
 Period of Record: 1961 to 1995
 Drainage Area: 380 sq. miles

Illinois River Near Kerby High Flow Statistics

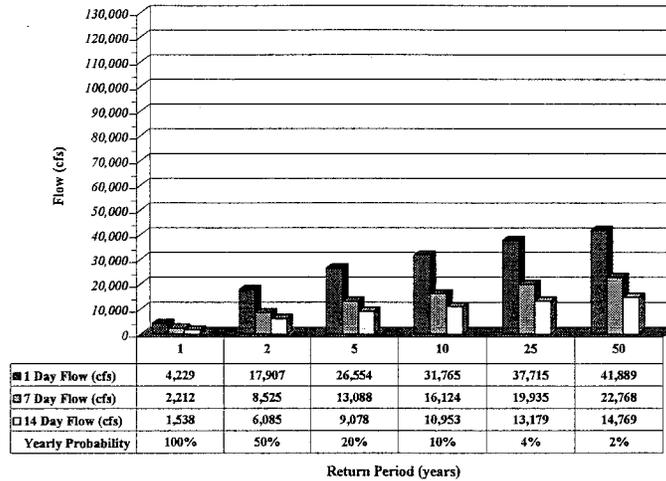
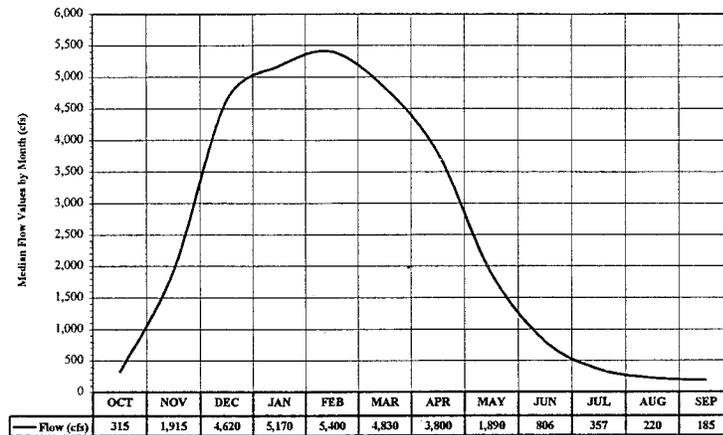


Figure D-2. River Discharge Statistics for the Illinois River Near Kerby.

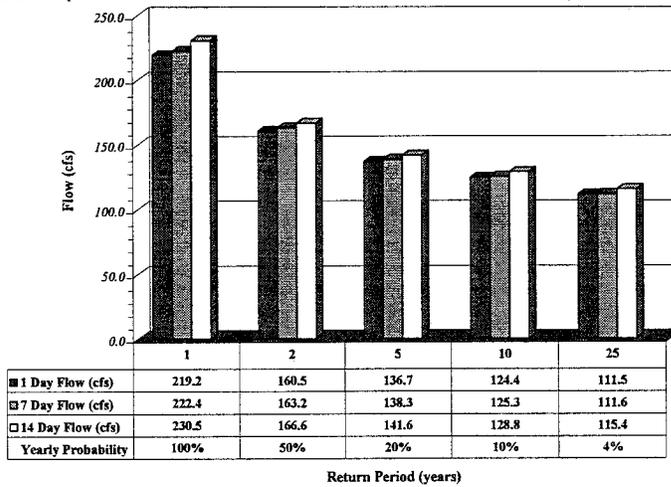
USGS Gage #14378200
 Period of Record: 1960 to 1980
 Drainage Area: 988 sq. miles

Illinois River Near Agness - Median Flow by Month



USGS Gage #14378200
 Period of Record: 1960 to 1980
 Drainage Area: 988 sq. miles

Illinois River Near Agness Low Flow Statistics



USGS Gage #14378200
 Period of Record: 1960 to 1980
 Drainage Area: 988 sq. miles

Illinois River Near Agness High Flow Statistics

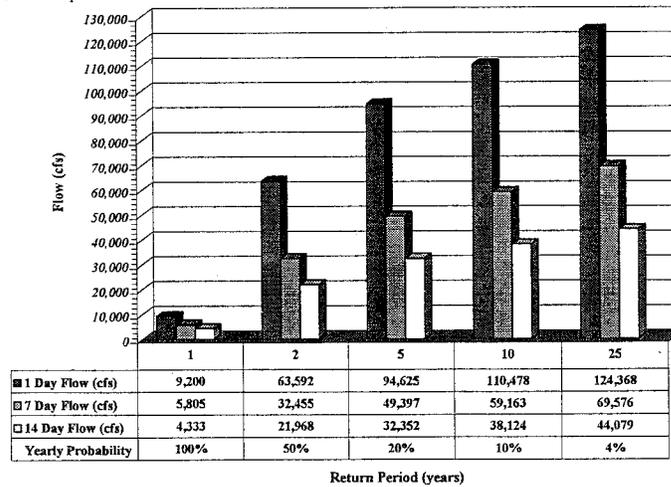
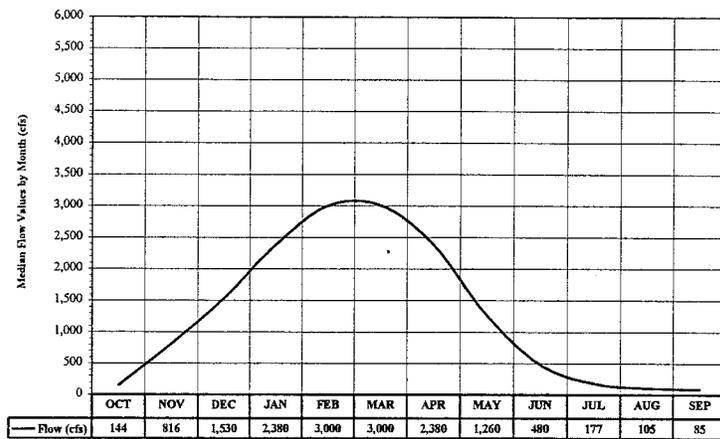


Figure D-3. River Discharge Statistics for the Illinois River Near Agness.

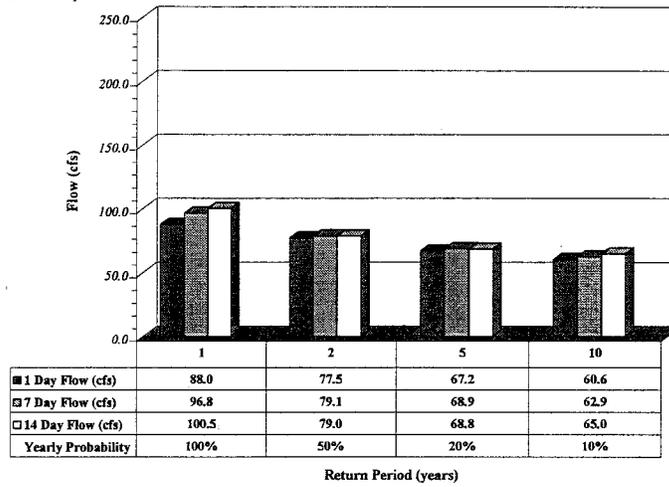
USGS Gage #14378000
 Period of Record: 1956 to 1966
 Drainage Area: 655 sq. miles

Illinois River Near Selma - Median Flow by Month



USGS Gage #14378000
 Period of Record: 1956 to 1966
 Drainage Area: 655 sq. miles

Illinois River Near Selma Low Flow Statistics



USGS Gage #14378000
 Period of Record: 1956 to 1966
 Drainage Area: 655 sq. miles

Illinois River Near Selma High Flow Statistics

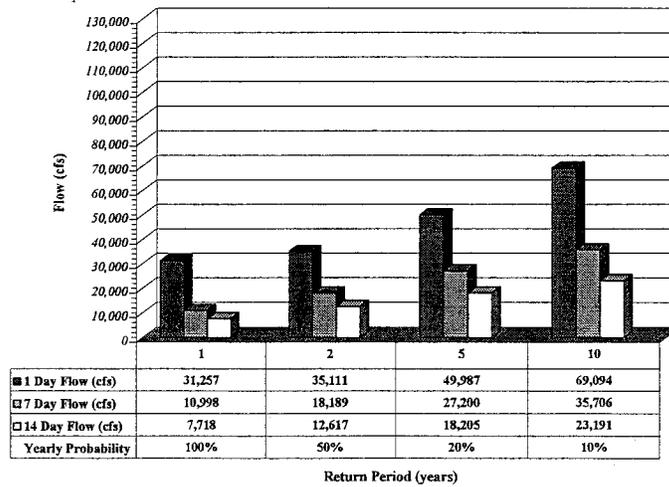
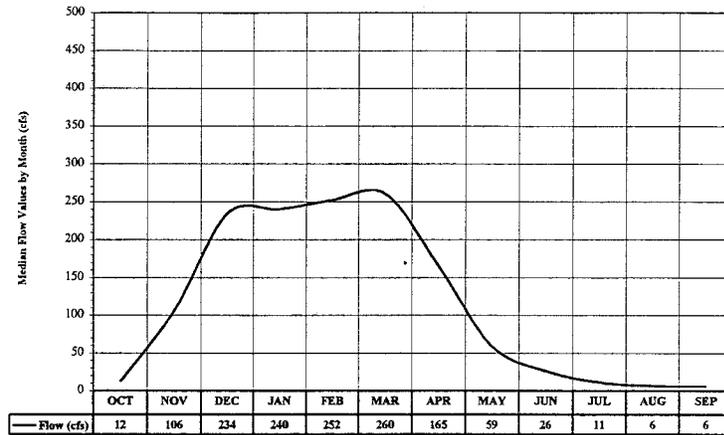


Figure D-4. River Discharge Statistics for the Illinois River Near Selma.

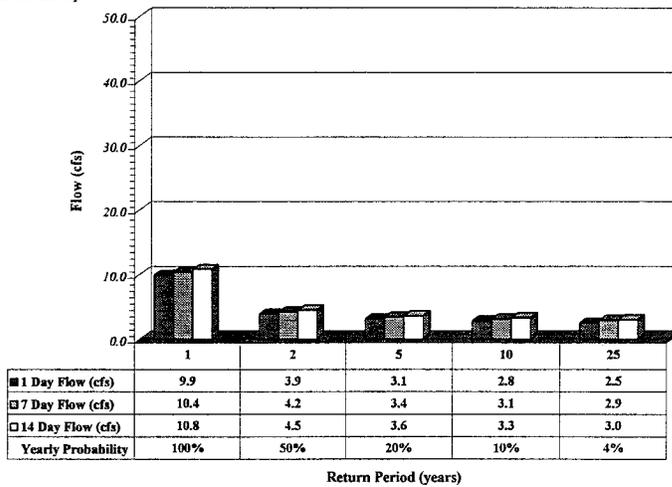
USGS Gage #14375500
 Period of Record: 1954 to 1984
 Drainage Area: 42.4 sq. miles

West Fork Illinois River Below Rock Creek Near Obrien
 Median Flow by Month



USGS Gage #14375500
 Period of Record: 1954 to 1984
 Drainage Area: 42.4 sq. miles

West Fork Illinois River Below Rock Creek Near Obrien Low Flow Statistics



USGS Gage #14375500
 Period of Record: 1954 to 1984
 Drainage Area: 42.4 sq. miles

West Fork Illinois River Below Rock Creek near Obrien High Flow Statistics

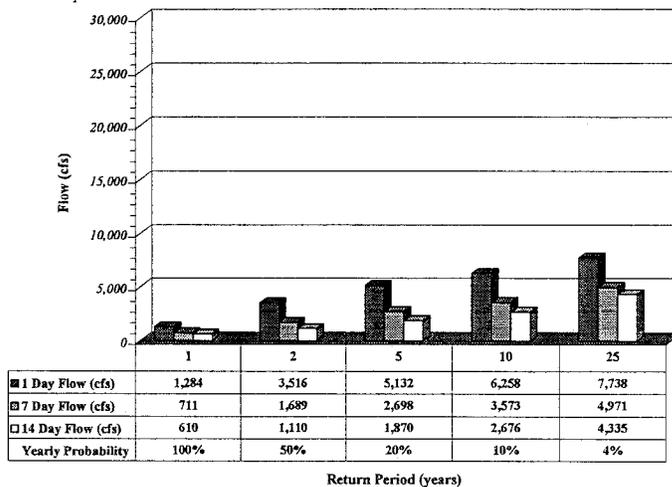
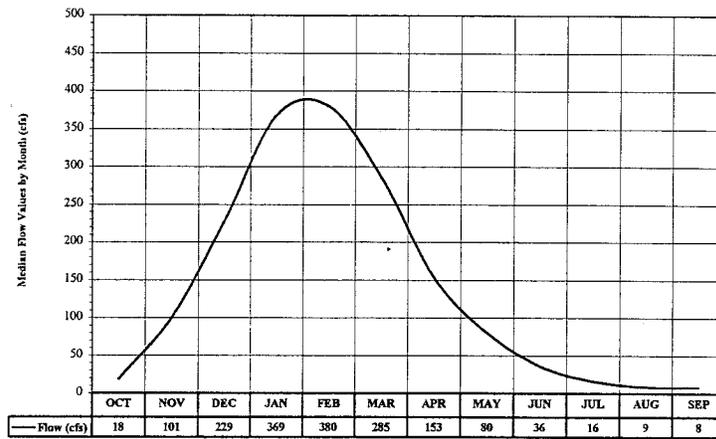


Figure D-5. River Discharge Statistic for a Tributary Stream of the Illinois River (W. Fork Illinois below Rock Ck.).

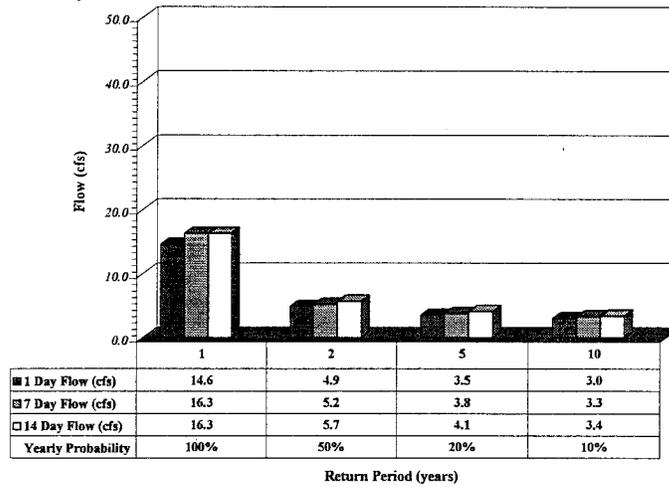
USGS Gage #14376500
 Period of Record: 1946 to 1953
 Drainage Area: 48.6 sq. miles

West Fork Illinois River Near Obrien
 Median Flow by Month



USGS Gage #14376500
 Period of Record: 1946 to 1953
 Drainage Area: 48.6 sq. miles

West Fork Illinois River Near Obrien Low Flow Statistics



USGS Gage #14376500
 Period of Record: 1946 to 1953
 Drainage Area: 48.6 sq. miles

West Fork Illinois River near Obrien High Flow Statistics

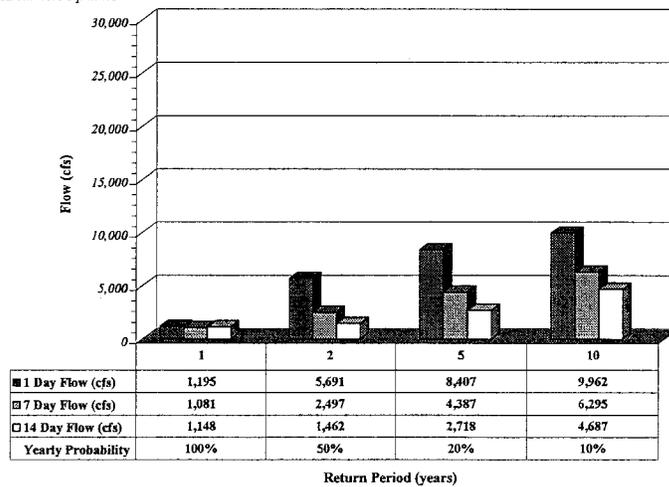
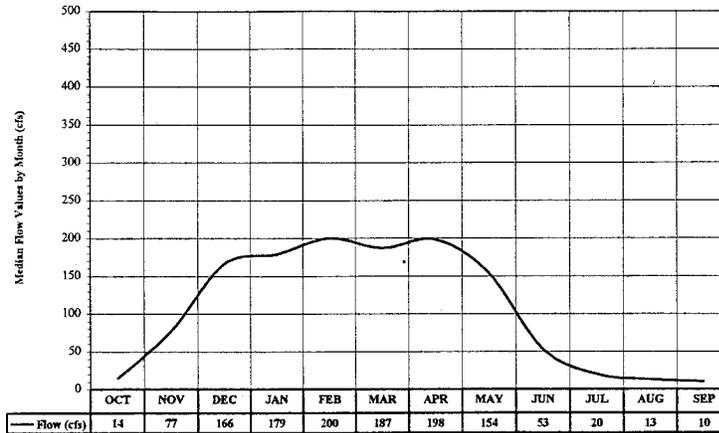
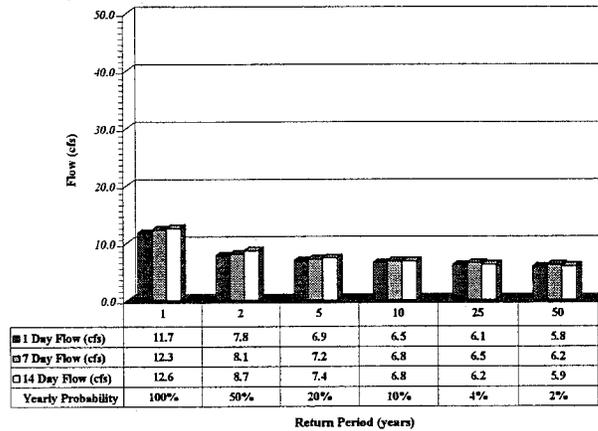


Figure D-6. River Discharge Statistic for a Tributary Stream of the Illinois River (West Fork Illinois Near Obrien.).

USGS Gage #14372500
 Period of Record: 1941 to 1990
 Drainage Area: 42.3 sq. miles



USGS Gage #14372500
 Period of Record: 1941 to 1990
 Drainage Area: 42.3 sq. miles



USGS Gage #14372500
 Period of Record: 1941 to 1990
 Drainage Area: 42.3 sq. miles

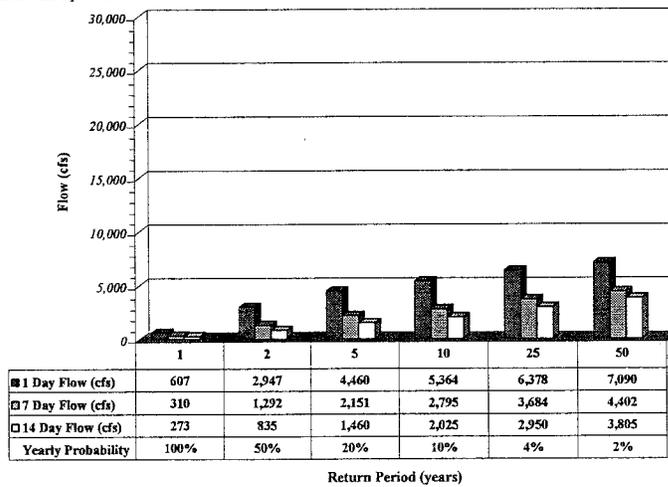
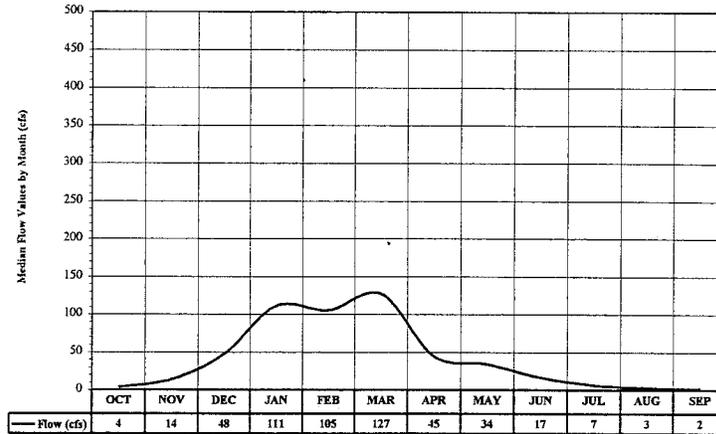


Figure D-7. River Discharge Statistic for a Tributary Stream of the Illinois River (East Fork Illinois Near Takilma).

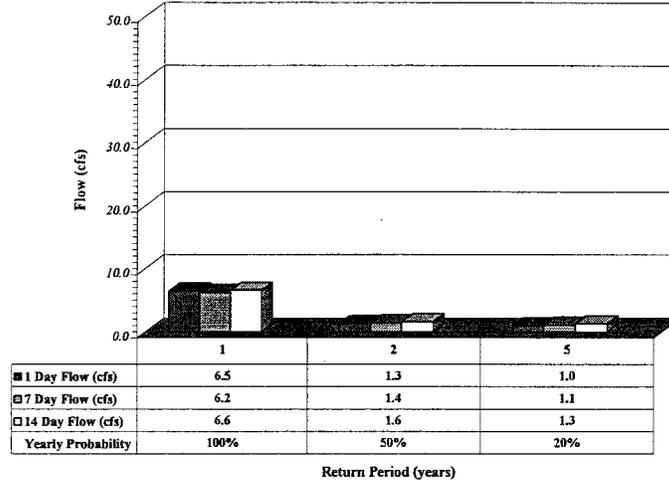
USGS Gage #14375400
 Period of Record: 1985 to 1990
 Drainage Area: 26.6 sq. miles

Elk Creek Near Obrien - Median Flow by Month



USGS Gage #14375400
 Period of Record: 1985 to 1990
 Drainage Area: 26.6 sq. miles

Elk Creek Near Obrien Low Flow Statistics



USGS Gage #14375400
 Period of Record: 1985 to 1990
 Drainage Area: 26.6 sq. miles

Elk Creek near Obrien High Flow Statistics

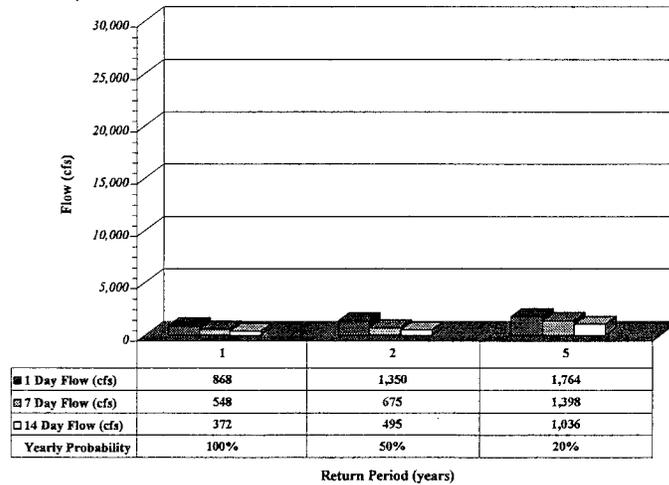
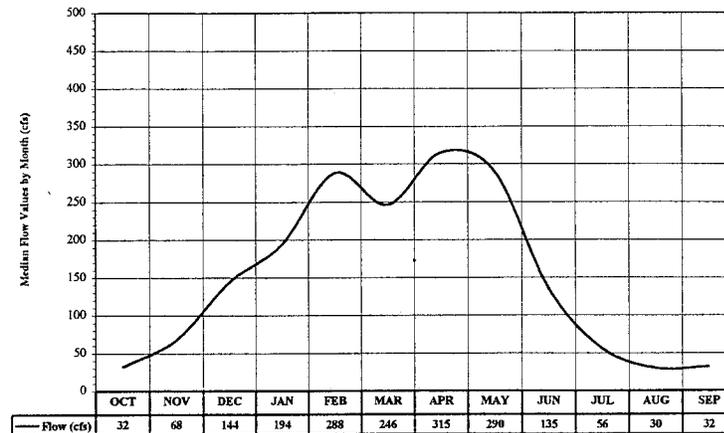


Figure D-8. River Discharge Statistic for a Tributary Stream of the Illinois River (Elk Ck Near Obrien).

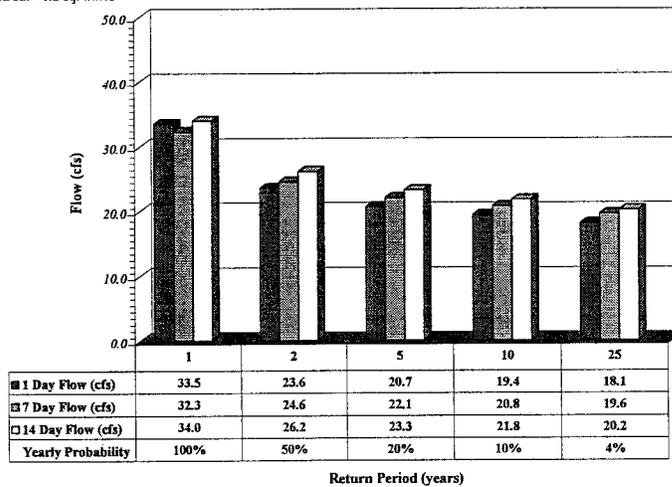
USGS Gage #14375000
 Period of Record: 1941 to 1964
 Drainage Area: 76.2 sq. miles

Sucker Creek Near Holland - Median Flow by Month



USGS Gage #14375000
 Period of Record: 1941 to 1964
 Drainage Area: 76.2 sq. miles

Sucker Creek Near Holland Low Flow Statistics



USGS Gage #14375000
 Period of Record: 1941 to 1964
 Drainage Area: 76.2 sq. miles

Sucker Creek near Holland High Flow Statistics

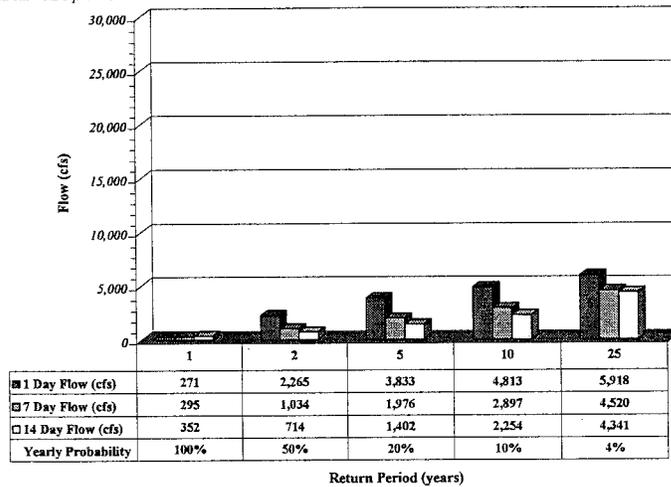
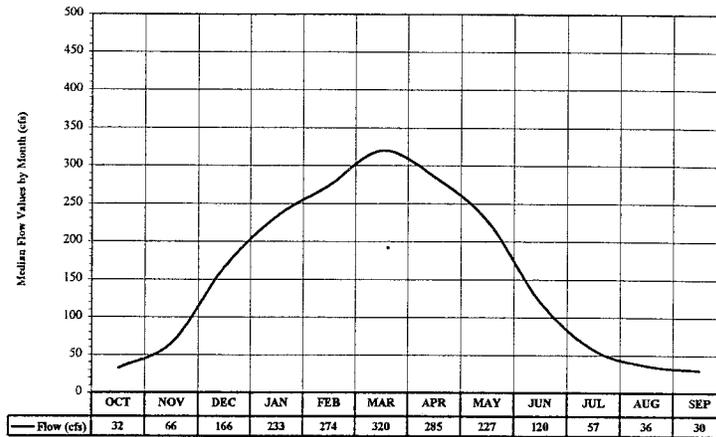


Figure D-9. River Discharge Statistic for a Tributary Stream of the Illinois River (Sucker Creek Near Holland).

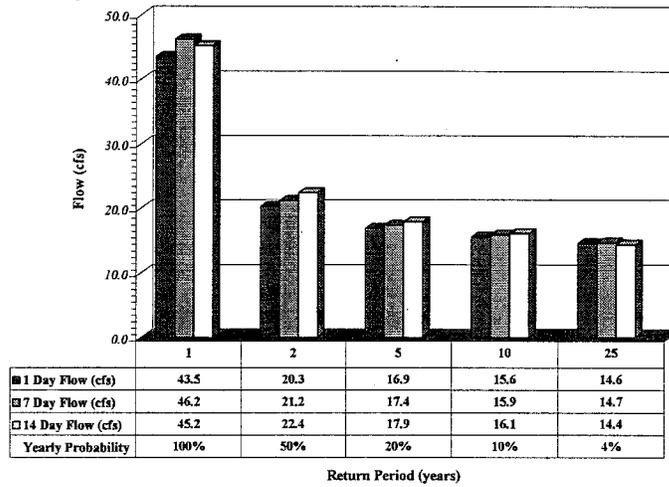
USGS Gage #14375100
 Period of Record: 1965 to 1990
 Drainage Area: 83.9 sq. miles

Sucker Creek Below Little Grayback - Median Flow by Month



USGS Gage #14375100
 Period of Record: 1965 to 1990
 Drainage Area: 83.9 sq. miles

Sucker Creek below Little Grayback Low Flow Statistics



USGS Gage #14375100
 Period of Record: 1965 to 1990
 Drainage Area: 83.9 sq. miles

Sucker Creek below Little Grayback High Flow Statistics

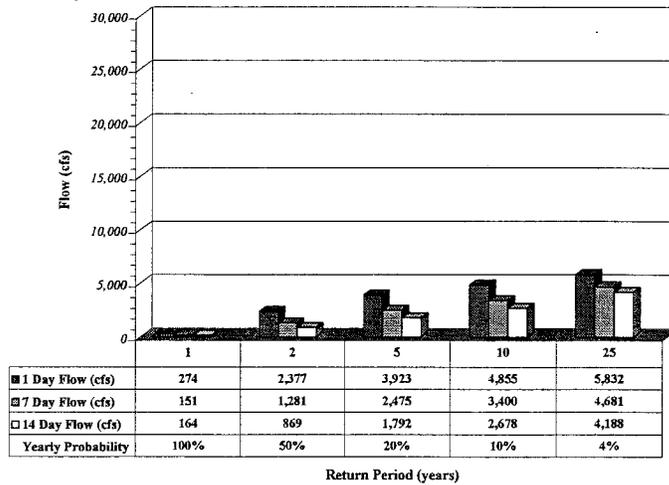
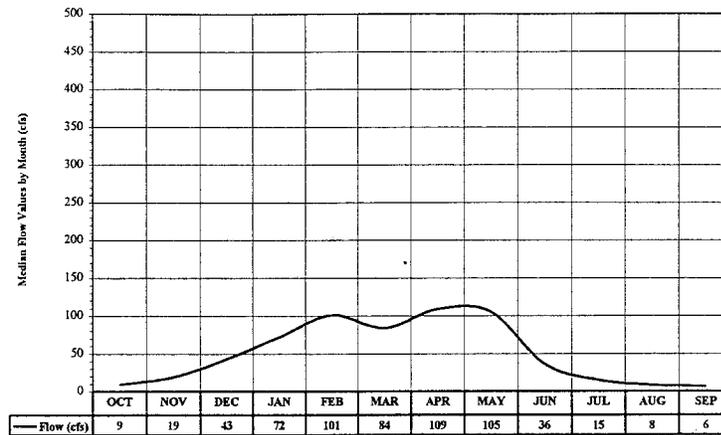


Figure D-10. River Discharge Statistic for a Tributary Stream of the Illinois River (Sucker Creek Bl Lt Grayback).

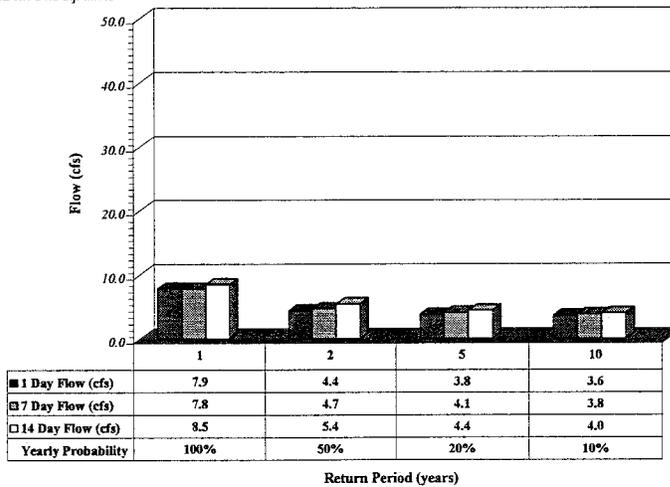
USGS Gage #14373500
 Period of Record: 1946 to 1952
 Drainage Area: 24.3 sq. miles

Althouse Creek Below Holland - Median Flow by Month



USGS Gage #14373500
 Period of Record: 1946 to 1952
 Drainage Area: 24.3 sq. miles

Althouse Creek below Holland Low Flow Statistics



USGS Gage #14373500
 Period of Record: 1946 to 1952
 Drainage Area: 24.3 sq. miles

Althouse Creek below Holland High Flow Statistics

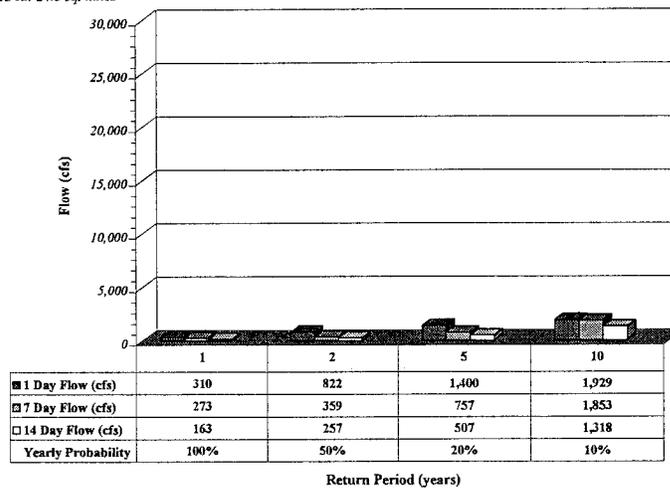
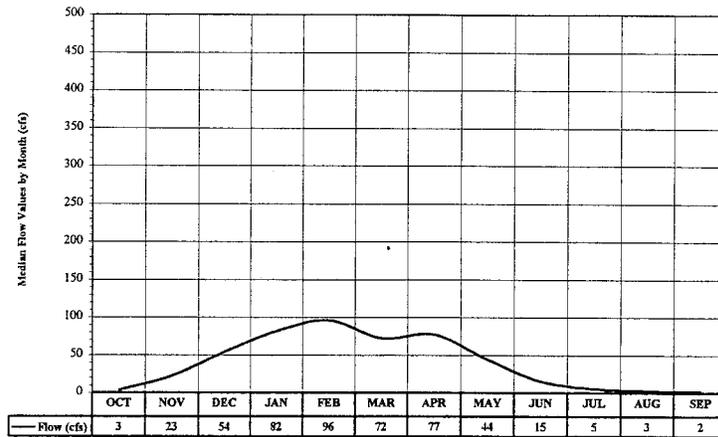


Figure D-11. River Discharge Statistic for a Tributary Stream of the Illinois River (Althouse Creek Near Holland).

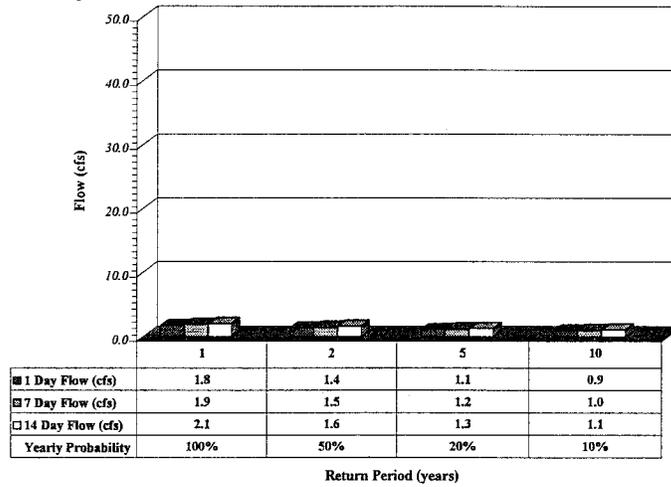
USGS Gage #14377500
 Period of Record: 1942 to 1955
 Drainage Area: 22.0 sq. miles

Deer Creek Near Dryden - Median Flow by Month



USGS Gage #14377500
 Period of Record: 1942 to 1955
 Drainage Area: 22.0 sq. miles

Deer Creek Near Dryden Low Flow Statistics



USGS Gage #14377500
 Period of Record: 1942 to 1955
 Drainage Area: 22.0 sq. miles

Deer Creek Near Dryden High Flow Statistics

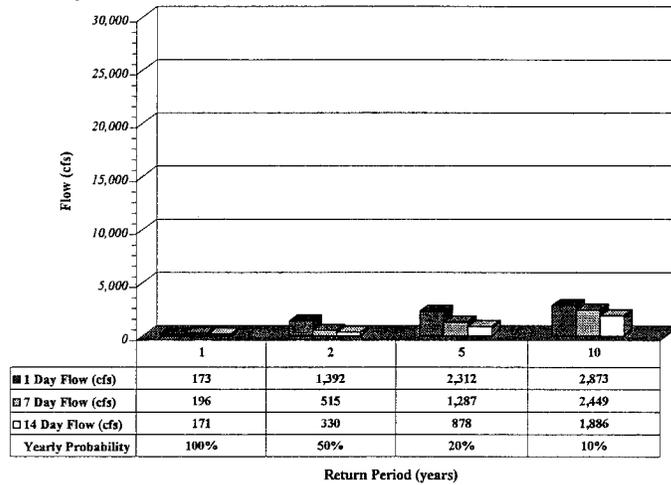


Figure D-12. River Discharge Statistic for a Tributary Stream of the Illinois River (Deer Ck Near Dryden).