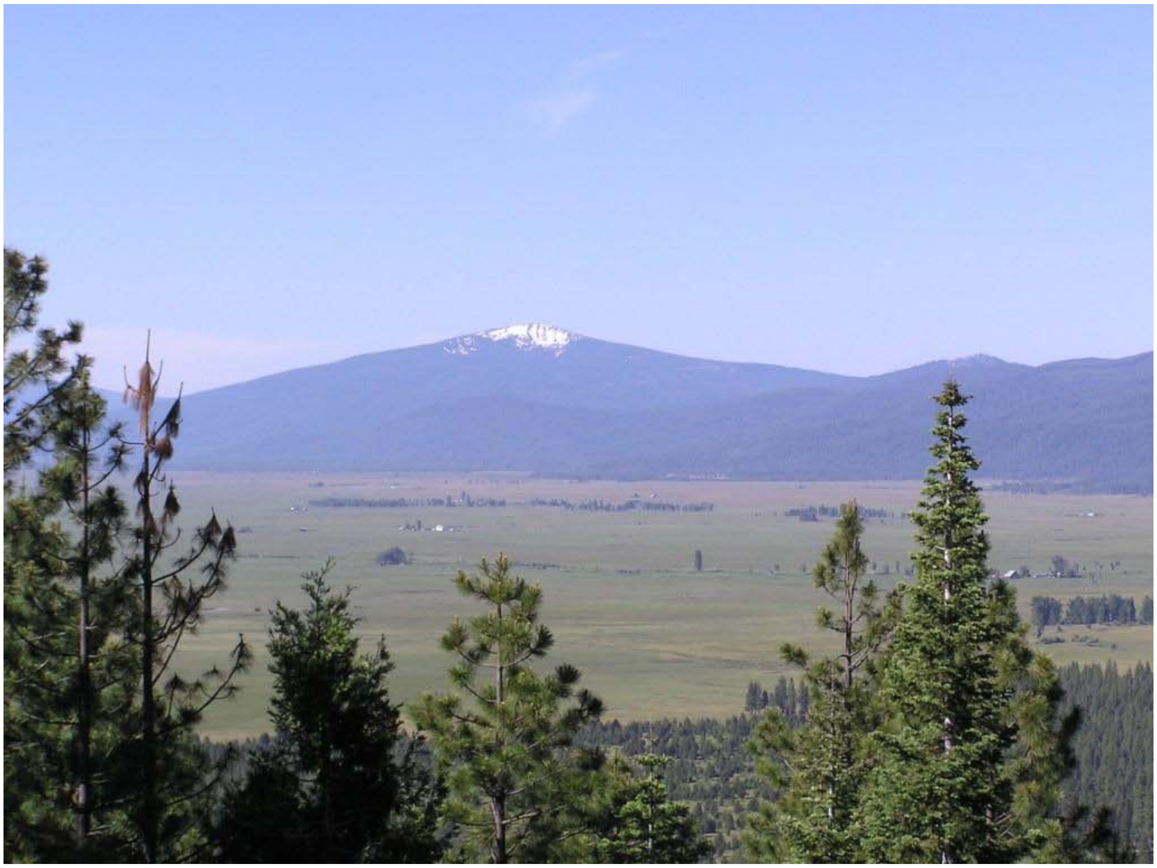
Wood River, Upper Klamath Basin, Oregon
Conservation Effects Assessment Project
Special Emphasis Watershed
Final Report

April 2010



Overview of the Wood River Valley in Oregon

Prepared by the

Oregon Natural Resources Conservation Service

Foreword

The Wood River CEAP study was initiated as a special emphasis watershed project in 2005 by the Natural Resources Conservation Service (NRCS) through the Conservation Effects Assessment Project (CEAP). CEAP began in 2003 as a multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in selected United States Department of Agriculture (USDA) conservation programs. Funding from CEAP has provided a unique opportunity to address current issues in the Wood River Watershed while also providing insights into the methodologies that can be used to measure the effectiveness of conservation in similar watersheds throughout the western United States.

The Wood River Watershed, part of the Klamath Basin in south-central Oregon, was selected because it has ranching and irrigation uses common to much of the western United States that is confronting resource issues surrounding water use, water quality, and endangered species.

Executive Summary (Project Objectives and Findings)

The Wood River CEAP focused on the effects of irrigation and grazing management in a large mountain valley typical of many ranching areas in the semi arid west. Ranchers were drawn here for the productive forage furnished by the naturally sub-irrigated meadows. Irrigation was added to extend the season for the wet meadows into late summer and early fall. Over the last couple of decades competition for abundant, clean water in the Klamath Basin, as elsewhere, jeopardized the continuance of ranching as practiced in the past. Local ranchers formed the Klamath Basin Rangeland Trust (KBRT) to study and find economic and environmental solutions. USDA, USBR and other federal/state programs were utilized to test the feasibility of restoring riparian areas, withdrawing irrigation and decreasing herd size. Starting in 2002 KBRT has been monitoring the impacts from these practices on forage, wildlife habitat, and water quantity and quality. In 2005 NRCS joined KBRT in the study of effects of these practices through the Wood River CEAP.

The primary objective of the study was to determine the levels of grazing and irrigation management that could be sustained both environmentally and economically on private lands. While this study did not specifically identify an environmental and economic sustainable level, it did provide information ranchers and natural resource managers can use to make this determination. Since the study period was only two years, caution should be given to interpreting these results. It is highly recommended that further monitoring of plant, animal, soil, and water resources be conducted to determine long-term changes that can affect livestock operations in the valley.

Study findings indicate that:

Restoring riparian areas

- Improved riparian and aquatic habitat
- Increased populations of macro invertebrates and fish
- Deepened and narrowed stream channels (increased stability - closer to reference conditions)

Reducing or eliminating irrigation from grazing lands

- Encouraged a shift from wetland obligate to facultative vegetation
- Increased the percentage of bare ground
- Decreased forage production by 15 to 25 percent (depending on grazing regime)
- Maintained the nutritional value of forage (within the requirements of grazing animals)

Improving grazing management (Prescribed Grazing)

- Increased potential forage production (30 day rest versus 10 day rest or continuous grazing) or ameliorated production decreases from removing/reducing irrigation.

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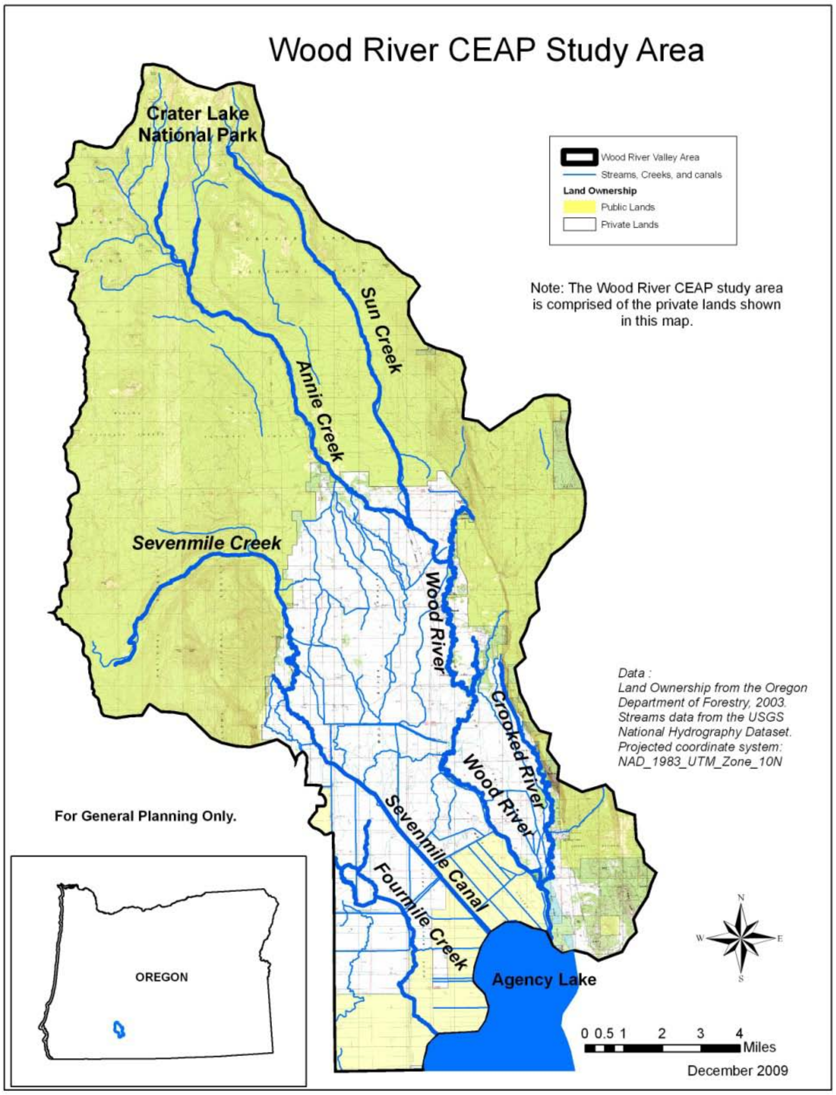
1. Wood River Valley Profile

1.1 Geographic and Historic Description

The Wood River Special Emphasis Watershed is situated in the southern region of the state of Oregon in the Cascade Mountains southeast of Crater Lake in the Wood River Valley. A component of the Klamath Basin drainage system, the Wood River Valley drains 220 square miles of land extending from Crater Lake in the north to its outlet into Agency Lake in the south. Delineated as the hydrologic boundary of six sixth field hydrologic units, the watershed comprises major streams that include the Wood River, Annie Creek, Crooked Creek, Sun Creek, Sevenmile Creek and Fourmile Creek (see Figure 1 below).



Note: The Wood River CEAP study area is comprised of the private lands shown in this map.

Data :
Land Ownership from the Oregon Department of Forestry, 2003.
Streams data from the USGS National Hydrography Dataset.
Projected coordinate system: NAD_1983_UTM_Zone_10N

December 2009

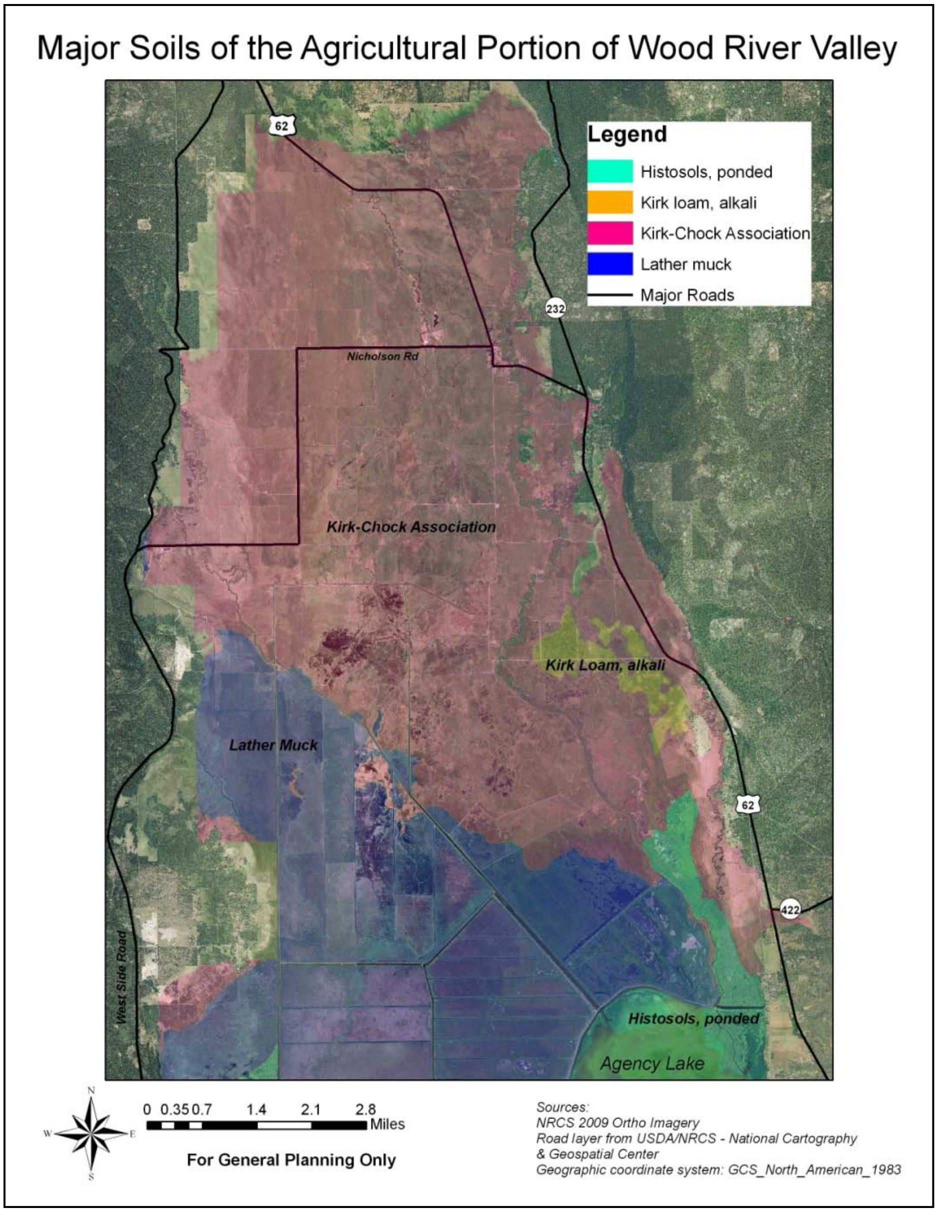
Figure 1: General Location Map of the Wood River Valley.

The study area for this project focused on the 39,000 acres of private, irrigated grazing lands in the Wood River Valley. Some estimates indicate 35,000 to 45,000 head of cattle are brought in each year. The area is noted for supporting a high rate of weight gain (2 or more pounds per day) in grazed livestock. Individual pastures are large, often in excess of 300 acres. Pasture condition is generally considered fair, with a mix of early seral stage plants.

Most livestock obtain water from streams and ditches. Portions of the Wood River and Crooked River have been fenced and livestock excluded. Sixty to 70 percent of the riparian areas within pastures, however, are not fenced and have little to no riparian vegetation.

The watershed receives an average annual precipitation of 35 inches ranging from a high of 71 inches along the Cascade Crest to a low of 13 inches along the eastern shore of Upper Klamath Lake.

The irrigated land in the Wood River Valley consists primarily of Kirk-Chock soils that were formed from alluvial deposits of ash and cinders. A top surface layer of loam lies above loamy sands and gravel. These soils, characterized by moderate permeability, seasonally high water tables, and moderately high water holding capacity, are suited to surface and sub irrigation methods. The permeable subsoils promote subsurface return flows to area ditches and streams. The Lather muck soil type is found in the lower-lying areas around Agency Lake and Upper Klamath Lake.



Sources:
NRCS 2009 Ortho Imagery
Road layer from USDA/NRCS - National Cartography & Geospatial Center
Geographic coordinate system: GCS_North_American_1983

Figure 2. Major soils of the agricultural portion of the Wood River Valley.

Livestock ranching in the Klamath Basin dates from the 1870s, and irrigation was a normal practice, as well as drainage of wetlands, which began as early as 1868 along the Lost River. The earliest irrigation projects were privately initiated, and by the 1880s several thousand acres were under private irrigation. The Reclamation Act of 1902 marked the beginning of federal involvement in local reclamation efforts. In 1905, the Klamath Basin became the twelfth in the nation –and the largest to that point – to receive funding from the Reclamation Act of 1902 (Doremus and Tarlock, 2008). Since 2002 however, a small number of ranchers have begun experimenting with dry land grazing (see Section 1.3, Conservation).

Historically, the Klamath Basin was the third most productive salmon river system on the West Coast, producing between 660,000 and 1.1 million adult salmon escapement annually (Chinook, Coho, pinks, chum, steelhead). A cascade of developments in the 20th century resulted in the present fragmentation and deterioration of the salmon habitat of the Upper Klamath Basin[1]. These included intensification of human activities with attendant increases in water demand; the arrival of the Bureau of Reclamation into the Upper Klamath Basin area in 1907, with the resulting conversion of over 79 percent of the Upper Basin's wetlands into agricultural lands. The area's natural water storage capacity was reduced. The ability of wetlands to act as a natural filter for breaking down pollutants carried by agricultural runoff was diminished, and the salmon habitat was compromised (Grader and Spain, 2001).

A highly valued "take and release" sport fishery is situated on the Wood River and several of its tributaries. Locally, there is significant interest in maintaining and restoring riparian habitat along these streams to protect and promote these fisheries while protecting agricultural operations.

1.2 Resource Concerns

A variety of interests compete for water from the Wood River Watershed. These diverse interests have precipitated frequent conflicts over the determination of how water is to be distributed for farming, ranching, tribal trust obligations, conservation, commercial fishing, and recreation. Certain grazing management practices have contributed to the deterioration of water quality, the rise in stream temperatures, and compromised habitat for sensitive or endangered aquatic, avian, or terrestrial species. The drought of 2001 provided a critical impetus for seeking solutions to water issues that would enable all interests to improve and sustain the diverse activities without compromising the quality and sustainability of the habitat and the environment.

One impact of the 2001 water shut off has been an interest in reducing water use throughout the upper Klamath basin. One area where the interest in reducing water use by agriculture has moved into action has been the Wood River Valley. Some of the ranchers in the Wood River Valley have moved to non-irrigation and dryland grazing practices. The Klamath Basin Rangeland Trust

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[1] At present, all anadromous runs of salmon and steelhead, once abundant in the upper basin of the Klamath River, are extinct above Iron Gate Dam. Because no fish passages were constructed, over 350 miles of historic salmon habitat is unreachable by fish. In all, there are six dams on the main stem of the Klamath River: Iron Gate (1962), Copco I and Copco II (1918, 1925), J.C. Boyle (1958), Keno, and Link River. ("Bring the Salmon Home. The Karuk Tribe's Effort to Remove Klamath Dams," p. 1). www.nijc.org/pdfs/Subject%20Matter%20Articles/Environment/Bring%20the%20Salmon%20Home.pdf.

(KBRT) has worked with these ranchers since 2002 to implement and monitor the impacts of shifting grazed pastures to non-irrigation and dryland grazing practices.

A field reconnaissance and aerial photo survey conducted for the NRCS's 2004 Upper Klamath Sub basin Assessment identified 70 miles of riparian areas along streams on private lands in the Wood River Valley. Twenty-one miles are in good riparian condition and another 12 miles are being restored through U.S. Fish and Wildlife and other programs. Subsequent to the 2004 Upper Klamath Sub Basin Assessment, the Klamath Basin Rangeland Trust has been working with the private landowners along Sevenmile Creek to fence additional areas. There remains approximately 35 miles of stream that might benefit from a restoration intervention involving fencing off the area; or that might be converted to riparian pasture with temporary fencing (cross fence running across the pasture) for time-controlled grazing.

While no streams or lakes in the Wood River Valley are listed on the 2004/2006 Oregon 303d list of water quality-limited water bodies, the Oregon Department of Environmental Quality has completed a Total Maximum Daily Load (TMDL) for Upper Klamath Lake[2]. The water quality of Upper Klamath/Agency Lake has been identified as impaired due to low dissolved oxygen, high pH, and excessive algal growth, all of which are parameters affecting fish survival. Phosphorus loading has been implicated as the primary mechanism triggering hypereutrophic conditions in the lake. Implementation of the TMDL, however, depends on reducing anthropogenic sources of phosphorus.

Both the Lost River sucker (*Deltistes luxatus*) and the Shortnose sucker (*Chasmistes brevirostris*) were listed as endangered under the Endangered Species Act in 1988 (USFWS, 1988). The Wood River, Sevenmile Creek and their tributaries also support populations of Bull Trout (*Salvelinus confluentus*) and Interior Redband Trout (*Oncorhynchus mykiss gairdneri*). Bull Trout have been designated under the Endangered Species Act as threatened since 2005 (ODFW, 2010).

1.3 Conservation

Agricultural producers, land managers, tribal groups, and natural resources agencies have been active in overseeing the stewardship of the Wood River Valley and seeking to improve ecological conditions across the landscape. Since 2002, the Wood River Valley ranchers have had an interest in finding new ways to enhance the valley's natural resources. Their efforts to conserve resources and increase the economic productivity of their watershed have increased dramatically. In addition to the ranchers, land owners, and operators' efforts, a variety of organizations and agencies, including the Klamath Basin Rangeland Trust and the NRCS, have provided technical and financial assistance to support conservation work in the valley.

Ongoing conservation work has involved the use of regular Environmental Quality Incentive Program (EQIP) and Klamath EQIP to implement 21,000 acres of prescribed grazing in the Wood River Watershed (mainly in the form of reduced numbers of cattle). In fiscal year 2006 about a dozen landowners in the Wood River Valley were enrolled in the Conservation Security

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[2] For the 2004/2006 report, see: http://www.deq.state.or.us/wq/assessment/assessment.htm.

Program, to begin working on enhancement conservation measures through 2009[3]. By fiscal year 2008, 23 land managers in the Upper Klamath Watershed had committed to conservation on 15,896 acres through the Conservation Security Program (CSP), supported with more than $5.7 million in funding through the life of the CSP contracts (USDA NRCS, 2008). See Section 3.3.5, Landowners, for additional information on conservation funding in the Wood River Valley.

With joint funding by the US Bureau of Reclamation and the NRCS, the KBRT helped landowners enroll 12,000 acres of private grazing land in irrigation and grazing forbearance programs that paid ranchers to not irrigate, to reduce herd size, and to assist them in transitioning from flood irrigation to dry land grazing. The KBRT has been an active partner in working with landowners in the Wood River Valley and helping to increase acreage enrollment in NRCS programs, so as to assure a full transition from flood irrigation to more permanent dry land management scenarios. Since 2002, KBRT has been carrying out ecological monitoring to assess the impacts of the management changes and partnered with the CEAP study.

In addition, the Oregon Department of Fish &Wildlife (ODFW) and Oregon Watershed Enhancement Board (OWEB) are contributing additional funding to assist ranchers in their efforts to improve their riparian areas and address fish passage issues. Of the 70 miles of streams in the study area, approximately 40 to 50 percent has been fenced either to totally exclude cattle or to create riparian pastures with time controlled grazing.

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[3] In 2002 the Conservation Security Program (CSP) — which would provide $20,000 to $45,000 per year to producers for "implementing conservation practices that enhance environmental quality, long-term sustainability, and improve profitability" was announced. Guidelines included the following outline of eligible practices: “Examples of practices that producers can initiate under the CSP program include: (A) nutrient management; (B) integrated pest management; (C) water conservation (including through irrigation) and water quality management; (D) grazing, pasture, and grazing land management; (E) soil conservation, quality, and residue management; (F) invasive species management; (G) fish and wildlife habitat conservation, restoration, and management; (H) air quality management; (I) energy conservation measures; (J) biological resource conservation and regeneration; (K) contour farming; (L) strip cropping; (M) cover cropping; (N) controlled rotational grazing; (O) resource-conserving crop rotation; (P) conversion of portions of cropland from a soil-depleting use to a soil-conserving use, including production of cover crops; (Q) partial field conservation practices; (R) native grassland and prairie protection and restoration; and (S) any other conservation practices that the Secretary determines to be appropriate and comparable to other conservation practices. http://www.oda.state.or.us/information/AQ/AQSummer2002/index.html. According to the USDA/NRCS Klamath Basin Conservation Partnership Accomplishments Document, Jan. 2007, between 2002 and 2006 the conservation partnership claimed, among its accomplishments, planning conservation systems on 256,273 acres; helping 23 land managers support ongoing conservation on 15, 896 acres; conserved irrigation water on 54,503 acres; developed habitat for fish and other aquatic species on 2,805 acres; improved wildlife habitat on over 19,113 acres; improved the quality and production of forage on 74,923 acres of pasture. http://www.klamathbasincrisis.org/conservation/summarykwuaJuly2007.htm.

2. Goals and Objectives

2.1 Introduction

The Wood River CEAP project was initiated in 2005 by the NRCS after an unsolicited proposal was received from the Klamath Basin Rangeland Trust (KBRT) describing an extensive monitoring program the Trust had been implementing since 2002 in the Wood River Valley. The KBRT monitoring program captured information on groundwater levels, stream flows, evapotranspiration, soil moisture, water quality, vegetation, and habitat on ranches that had adopted rotational grazing, riparian area management, and conversion from flood irrigation to dry land practices. This database, along with the potential to supplement past monitoring efforts, presented a unique opportunity to evaluate the effects of grazing and riparian management conservation activities.

2.2 Project Goals and Objectives

The purpose of the Wood River Special Emphasis Watershed CEAP is to determine the effects of changes in grazing management and irrigation management on forage production, animal health, stream/riparian conditions, fish habitat, and economic agricultural viability on grazing lands of the Wood River Valley. It proposed to do this by evaluating reductions in irrigation and grazing that has taken place in the study area over the last several years by comparing hydrologic, vegetative (riparian and grazing land), aquatic, and economic profiles.

The primary goal of this CEAP study was to determine the optimum level of grazing and irrigation management that could be sustained both environmentally and economically on private lands.

Individual objectives under this goal were to investigate:

- Changes in the vegetative component of grazing lands and riparian areas as irrigation water is withdrawn, including changes in vegetative structure, composition, annual biomass production, amount of bare ground, plant density, and increases in the number or populations of invasive plant species.
- Effects of reduced stocking rates when combined with changes in irrigation water management.
- Changes in the base nutritional plane of the range vegetation associated with the change from irrigated to dry land practices. Changes in the condition of livestock between irrigated and non-irrigated sites.
- Impacts of alternative levels of irrigation water and grazing management on forage production.
- Economic impact from alternative levels of irrigation water and grazing management on the local ranching community.

A secondary goal of the study was to determine the effectiveness of riparian pasture systems and cattle exclusion on the recovery of riparian and aquatic habitats.

Individual objectives under this goal were to investigate:

- Effects of different grazing management prescriptions on key stream/riparian habitat variables (vegetation, in-stream morphology, stream condition) and selected species (e.g. macro invertebrates and fish).

This study did not evaluate the effects of conservation practices on water quality and availability for downstream usage. Concurrent studies conducted by the Klamath Basin Rangeland Trust, United States Geological Survey (USGS), and the United States Bureau of Reclamation (USBR) on the effects of water banking and other water saving practices will, however, be reported separately from the current study. Pieces of these other studies and monitoring efforts have contributed to our understanding of the Wood River Valley ecological systems and are referenced where appropriate.

To meet the study goals and objectives described above various study components were developed, including pasture vegetation monitoring that included pasture and vegetation monitoring (vegetation community composition, structure, and production; forage quality; soil bulk density, etc.), crop production and irrigation modeling, riparian area monitoring, and aquatic habitat monitoring.

3. Wood River Study Hypotheses, Components, and Partners

3.1 Overview of Research Methodology Approach

Current scientific methods were used to monitor groundwater, surface flows, soil moisture and evapotranspiration rates as they pertain to vegetation and water quality responses to grazing and riparian management practices. The monitoring and research conducted by the KBRT between 2002 and 2008 provided base-line data pertaining to stream flow, water table and soil moisture levels, water quality, and other parameters. Additionally, selective pre-treatment monitoring was conducted by the United States Fish and Wildlife Service (USFWS) and the Klamath Tribes, and the limited data from their study sites was used in the base-line comparison profiles.

The study was designed to include the following components:

- Field Monitoring:
    - Pasture vegetation, including condition, trend, and productivity.
    - Livestock nutrition and health.
    - Riparian and aquatic habitat, using vegetation characteristics, channel morphology, fish biomass, and other parameters.
    - Soil moisture, water table levels, and evapotranspiration rates.
- Statistical Analysis:
    - Bovine fecal samples using the Nutritional Balance Analyzer (NUTBAL) Computerized Assessment Tool.
    - Multivariate analysis of pasture production, vegetation diversity, and abundance.
    - Wet chemistry analysis of forage quality.
    - Correlation of riparian habitat conservation implementation to recovery time.
- Computer Simulation Models:
    - Danish Hydrologic Institute (DHI) MIKE SHE hydrologic and DAISY models to simulate the effects, and study variations in soil moisture, water table levels, evapotranspiration rates, and crop growth associated with alternative levels of irrigation and grazing management.
- Economic Analysis:
    - Evaluation of the impact of grazing and irrigation management practices, pre- and post-irrigation and grazing reductions, on the economic viability of conservation strategies.

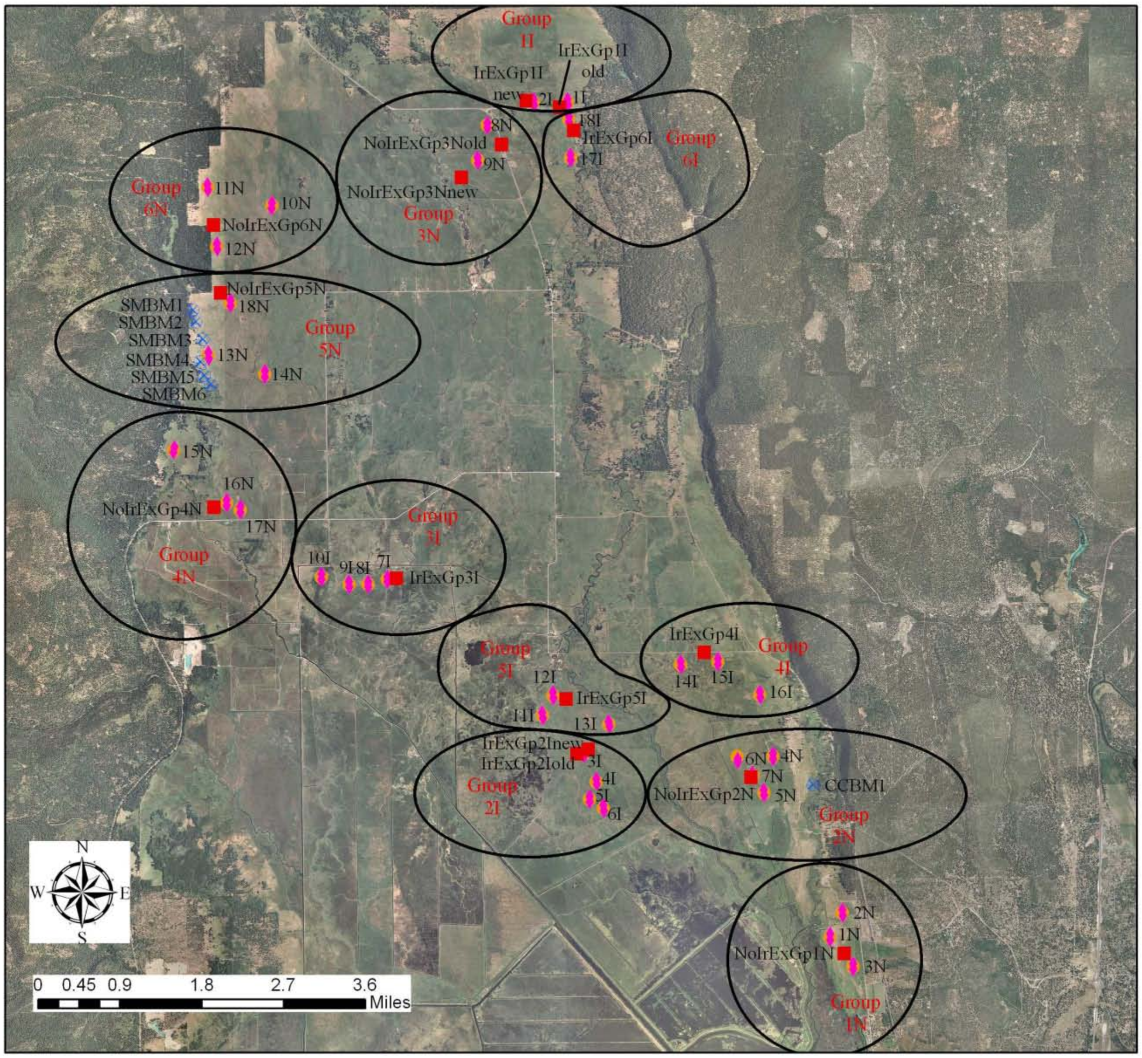
The study approach incorporated an extensive post-treatment design using data collected at paired sites representing a variety of management level combinations. These are detailed in appropriate segments of the report, below.

With the assistance of the Klamath Basin Rangeland Trust (see Chapter 3, section 3.3.2) some of the landowners in the Wood River Valley reduced grazing levels and ceased irrigation on their pastures beginning in 2002. Some of these landowners agreed to participate in this study effort.

Other landowners in the valley who had not shifted management after 2002 agreed to participate to help provide a basis for comparisons between irrigated and non-irrigated pastures.

For analytical purposes six irrigated and six non-irrigated groups of monitoring sites were established around the Wood River Valley (see Figure 3 below). Within each group several vegetation monitoring transects were established. Each group also included at least one small exclosure that protected the vegetation from grazing and provided a place to install shallow groundwater monitoring equipment. The group and sites described in detail in the various component reports included in the Appendices refer to the locations shown in Figure 3.

Approximate Locations of Monitoring Sites and Equipment in the Wood River Valley



Final Wood River Monitoring Locations

- ■ Exclosures
- ⊗ Riparian Benchmark Locations
- ● Veg Plot Center Pins
- ♦ Veg Plot North & South Pins

Notes:

Locations of the plots, exclosures, and monitoring equipment are approximate.

Monitoring plots are grouped, with six irrigated and six non-irrigated pasture monitoring study areas. Each grouping includes vegetation transects and exclosures. Each exclosure includes monitoring equipment such as shallow groundwater data loggers and soil moisture sensors. Within each grouping fecal samples and veg/forage quality data were also collected.

Key to numbering system
Group 1I = Irrigated group 1
Group 1N = Non-irrigated group 1
1N = vegetation plot 1 nonirrigated
1I = vegetation plot 1 Irrigated
NoExGp1N= Non-irrigated Exclosure, Group 1N, number 1 non-irrigated
IrExGp1I = Irrigated Exclosure, Group 1I,
(a designation of new or old indicates changed locations between data collection years).
CCBM1 = Crooked Creek riparian Benchmark location 1
SMBM1 = Seven Mile Creek riparian Benchmark location 1

For General Planning Purposes Only

Map produced on 12/08/2009 by Jim Regan-Vienop.

Figure 3. Approximate locations of the monitoring groups and sites.

3.3 Project Partners

The Wood River CEAP forged a partnership effort to study the effects of conservation practices applied or considered by landowners in the watershed. While many organizations participated in these studies, the principal partners in the undertaking are described below.

3.3.1 NRCS

- The West National Technical Support Center (WNTSC) provided technical expertise to develop and guide the technical aspects of the study. Jeff Repp, Rangeland Management Specialist at the WNTSC, assisted with the experimental design of the vegetative study and also contributed reports summarizing the data, analyses, and results submitted by the OSU teams (see Appendix 1).
- Oregon Water Resources Planning Team provided overall coordination of the project, data collection assistance, and landowner coordination.
- The Oregon NRCS Biological Sciences and Soils teams also contributed technical expertise and assistance in the data collection and analysis processes.

3.3.2 Klamath Basin Rangeland Trust

Founded in 2002, the KBRT is a 501(c)3 multi-constituent organization established in response to the “2001 Water Crisis” in the Upper Klamath Basin. A multi-constituent organization, KBRT is dedicated to conservation, education, and restoration in the Klamath Basin and to promoting sound stewardship values, principles and practices[4]. KBRT coordinates landowners with ongoing projects within existing programs that encourage sustainable land and water management practices, and works closely with landowners to implement permanent changes on their land that will result in improved surface water flows, and quality and habitat improvements in the Wood River Valley.

The KBRT contributed to the study in three general areas: Assisting with development of the grazing and monitoring protocols; recruiting, screening, and supervising landowner participants and compliance; and data sharing.

- Grazing and monitoring protocols – starting in 2002 KBRT helped with developing and implementing grazing plans for livestock reductions in the Wood River Valley. They also helped in designing and implementing supplemental vegetation/soil moisture monitoring and in formulating growth curves for vegetative responses under time-controlled grazing.

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[4] Klamath Basin Rangeland Trust Mission Statement: “The mission of the Klamath Basin Rangeland Trust is to restore and conserve the quality and quantity of water in Oregon's Wood River Valley and the upper Klamath Basin to enhance the natural ecosystem and supply needed water for downstream agriculture, ranching, native fish and wildlife populations. More specifically, the Klamath Basin Rangeland Trust seeks to strengthen its cooperative partnership with private property owners and government agencies to achieve the following objectives: *To address the over-commitment of water resources in the Klamath Basin by equitably forbearing water use in the Wood River Valley and reducing cattle grazing to levels that can be sustained without irrigation. *To increase the flow of water to Upper Klamath Lake for the downstream benefit of fish, wildlife, ranching and agriculture. *To manage cattle grazing in ways that improves water quality in rivers and lakes. *To reestablish wetlands adjacent to Agency Lake to increase water storage capacity and produce wetland-related environmental benefits. *To secure employment opportunities for the people of the Klamath Basin to implement the mission of the Klamath Basin Rangeland Trust.” http://www.kbrt.org/Index.asp.

- Recruiting, screening, and supervising landowner participants – starting in 2002 KBRT developed contractual agreements with landowners to ensure irrigation forbearance and compliance for grazing management. KBRT also coordinated with NRCS to ensure program eligibility of individual participants. Additionally, KBRT assisted NRCS with landowner interactions and activities in the Wood River Valley, including as part of this study.
- Data sharing – KBRT shared data from its collection and analysis of field monitoring undertaken since 2002 (USDA NRCS, 2007), including data from their water quality, ground and surface water, aquatic, riparian, and vegetation monitoring efforts. In addition KBRT assisted in the field monitoring and analysis of this study.

3.3.3 Oregon State University (OSU)

Much of the fieldwork and analyses were carried out by OSU through cooperative agreements with the NRCS. Pasture and riparian vegetation data collection was carried out during the 2007-2008 field seasons and final reports were completed in December 2008. Dr. Tamzen Stringham of the Dept. of Rangeland Ecology & Management at OSU (now at the University of Nevada, Reno) led the OSU team investigating the vegetation and riparian portions of the study. Dr. Stringham's team included Sarah Quistberg and Holly Craig. This team provided the NRCS with the Wood River Valley Vegetation Monitoring Summary 2007-2008 report (see Appendix 2) and the Sevenmile and Crooked Creek (Riparian) Monitoring Summary 2008 report (see Appendix 3). In addition, Dr. Chanda Engle of OSU Extension, in cooperation with Dr. Stringham, contributed data collection and analyses of pasture Forage Dry Matter Percentage and Yield (2008) and a summary of the Wet Chemistry Forage Quality data (2008, see Appendix 4).

The NRCS also had a cooperative agreement with the OSU Department of Biological and Ecological Engineering Hydrologic Science Team to provide MIKE SHE and DAISY plant production simulation modeling assistance. Dr. Richard Cuenca led the modeling team, which included Dr. Yutaka Hagimoto and Joshua Owens. This team's modeling report on Crop Production and Irrigation was completed in November 2009 and is included in Appendix 5.

3.3.4 Graham Matthews & Associates, Inc

Graham Matthews & Associates (GMA), a consulting firm specializing in hydrology, fluvial geomorphology, and stream restoration design and construction, was contracted to do the Wood River Valley aquatic habitat study[5]. GMA had conducted a similar study for the KBRT in 2002/2003 and was asked by NRCS to re-create the original study for comparative purposes. The Aquatic Habitat Study of December 2008 is included in Appendix 6.

3.3.5 Landowners

The most important cooperators in the project were the landowners. Landowners provided access to their land, shared appropriate management information, and provided occasional support to

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[5] Graham Matthews & Associates, P.O. Box 1516/Weaverville, CA 96093. http://www.gmahydrology.com/.

field operations. These cooperators provided access to 6,000 irrigated acres on three different ranch operations and 6,800 non-irrigated acres on five ranch operations. More importantly, many of these landowners are undertaking conservation work on their lands, both with and without outside financial assistance programs.

There are several financial assistance programs that have helped the landowners and local partnerships implement conservation in the area. These funding sources did not directly contribute to the CEAP study. However, landowners in the area have participated in conservation programs from various sources, including the following:

- U.S. Bureau of Reclamation, Water Bank Program
- Environmental Quality Incentive Program (EQIP), Klamath EQIP, Conservation Security Program, and Wetland Reserve Program
- Conservation Reserve Enhancement Program
- Oregon Department of Fish & Wildlife (ODFW) grants
- Oregon Watershed Enhancement Board (OWEB) grants

3.4 Introduction to the Monitoring and Analysis Summaries

The following chapters of the report describe the purpose, methods, and findings of the various study components of the Wood River CEAP. The discussions contained in many of the following chapters are summarizations from the many reports submitted by the different study teams. Chapter 11 of this report takes the information from the many investigative components of the study and attempts to synthesize and integrated the information into a coherent set of recommendations that are presented in Chapter 12.

4. Riparian Monitoring Summary

4.1 Background and Purpose

The Klamath Rapid Subbasin Assessment report as well as the Klamath Basin Rangeland Trust (KBRT) both identified restoration of riparian/aquatic habitats within the Wood River watershed as a significant resource concern. Restoring riparian habitats should help improve aquatic habitat conditions for ESA listed fish species as well as improve water quality. KBRT and others have used passive and active restoration techniques on approximately 21 miles of the 70 miles of streams in the study area. These areas have been fenced either to totally exclude cattle or to create a riparian pasture with short duration grazing. Most sites lie along Sevenmile Creek on the west side of the valley or Crooked Creek along the east side.

The riparian monitoring component of this study, in conjunction with the aquatic study, was initiated to allow for the evaluation of trends in riparian and aquatic habitats since ranchers in the area initiated restoration and conservation actions in the Wood River Valley in the late 1990s.

Many of these efforts center upon changing management of the riparian corridor along the mainstem of the Wood River and the tributaries of Crooked Creek and Sevenmile Creek (see Figure 1). In low-gradient systems like the Wood River, roots of riparian vegetation maintain the integrity of banks and bank-building processes, and thus regulate the shape (width, depth, cross-sectional and plan-form morphology) of the river channel. Channel shape, water temperature, and nutrients regulate the conditions for fish and other important aquatic resources. Integrity of the river channel also can affect floodplain groundwater levels, which in turn effect plant community composition and production and channel baseflows.

A number of different projects have been initiated on the Wood River system over the last ten years including reduction in irrigation withdrawals, riparian corridor and riparian pasture fencing along with changes in grazing practices. Given these private and institutional efforts directed towards innovative approaches to simultaneously improve riparian communities and channel conditions for the benefit of landowners and the aquatic ecosystems in the Wood River Valley, KBRT initiated riparian and aquatic habitat surveys starting around 2002/2003. However, when the CEAP proposal for the Wood River was written it was envisioned that a comparison of pre and post treatment results would provide information on riparian and aquatic habitat recovery rates.

Unfortunately, after a review, KBRT's attempts to monitor riparian habitat was limited and did not follow repeatable protocols that could be used with post treatment surveys. A second option examined was to compare current riparian conditions to representative plant communities. This option also proved unworkable. Researchers from Oregon State University identified three distinct riparian plant communities in the Wood River Valley but no truly representative sites that could be used for comparative purposes. Consequently, riparian efforts focused more on establishing detailed baseline vegetation and stream channel data following proven scientific methods so that future monitoring could be used to document changes. Appendix 3 contains a detailed report on the riparian monitoring conducted for this CEAP study. Monitoring work for both the Riparian and Aquatics portions of this CEAP study were focused on Sevenmile and Crooked Creeks.

As a complement to, and interrelated with, the riparian monitoring this CEAP study included an aquatics monitoring component. The aquatics monitoring, conducted by Graham Matthews Associates, Inc., was closely coupled with the Riparian monitoring portion of the study. The aquatics monitoring component of the study is described in Chapter 5 the Aquatic Study Summary.

4.2 Riparian Monitoring Objectives

After determining that a pre and post treatment comparison and analysis was not feasible, new objectives were developed for this portion of the study. These new objectives described the design and installation of a riparian monitoring framework that could be repeated in future monitoring efforts. The objectives included:

- Develop a riparian community type classification for the Wood River stream system located in the upper Klamath Basin of southern Oregon.
- Describe the general physiographic, edaphic, and floristic features of each community type.
- Describe the fluvial landform and stream channel type associated with the community type.
- Establish permanent channel cross-section monitoring sites on Sevenmile Creek and Crooked Creek.
- Utilize the community type information for the establishment of a network of vegetation and cross section monitoring.

No specific effects analysis was developed for the revised riparian portion of the study. Instead work involved setting up a framework to allow for more scientifically rigorous future evaluations of Sevenmile and Crooked Creeks.

4.3 Methods Overview

4.3.1 Community Type Development

Plant communities are an assemblage of plants living and interacting in the same location. Plant communities have no specific successional status (Crowe et al., 2004). A plant community type is a set of plant communities that have similar species structure and composition. A plant community type represents repeated occurrences of similar plant communities, but do not form a plant association or the plant community is not a climax community type (Crowe et al., 2004). Many of the plant communities on Sevenmile Creek would not be considered climax communities because of human disturbances, including grazing, channelization, removal of tree canopy, and irrigation withdrawal. Riparian classifications have been performed in Oregon; however these classifications are based on relatively undisturbed plant communities and the plant communities generally include the adjacent floodplain and not just the greenline plant community. There was a need to identify the plant communities currently on Sevenmile Creek, specifically on the greenline.

Sites were determined through utilization of the geomorphic information provided by the Klamath Tribes and through field reconnaissance in the summer of 2007. Consideration was also given to the Aquatic monitoring sites surveyed in 2003 and to be re-surveyed in 2008. Late seral and transitional riparian communities were identified and GPS located. Cross-sectional sketches showing the location of fluvial surfaces and both wetland/ transitional riparian and adjacent upland plant associations were created. Each fluvial surface with its corresponding plant association represented a vegetation plot. There were a total of 20 vegetation plots sampled at the various sites (see Figure 4 below).

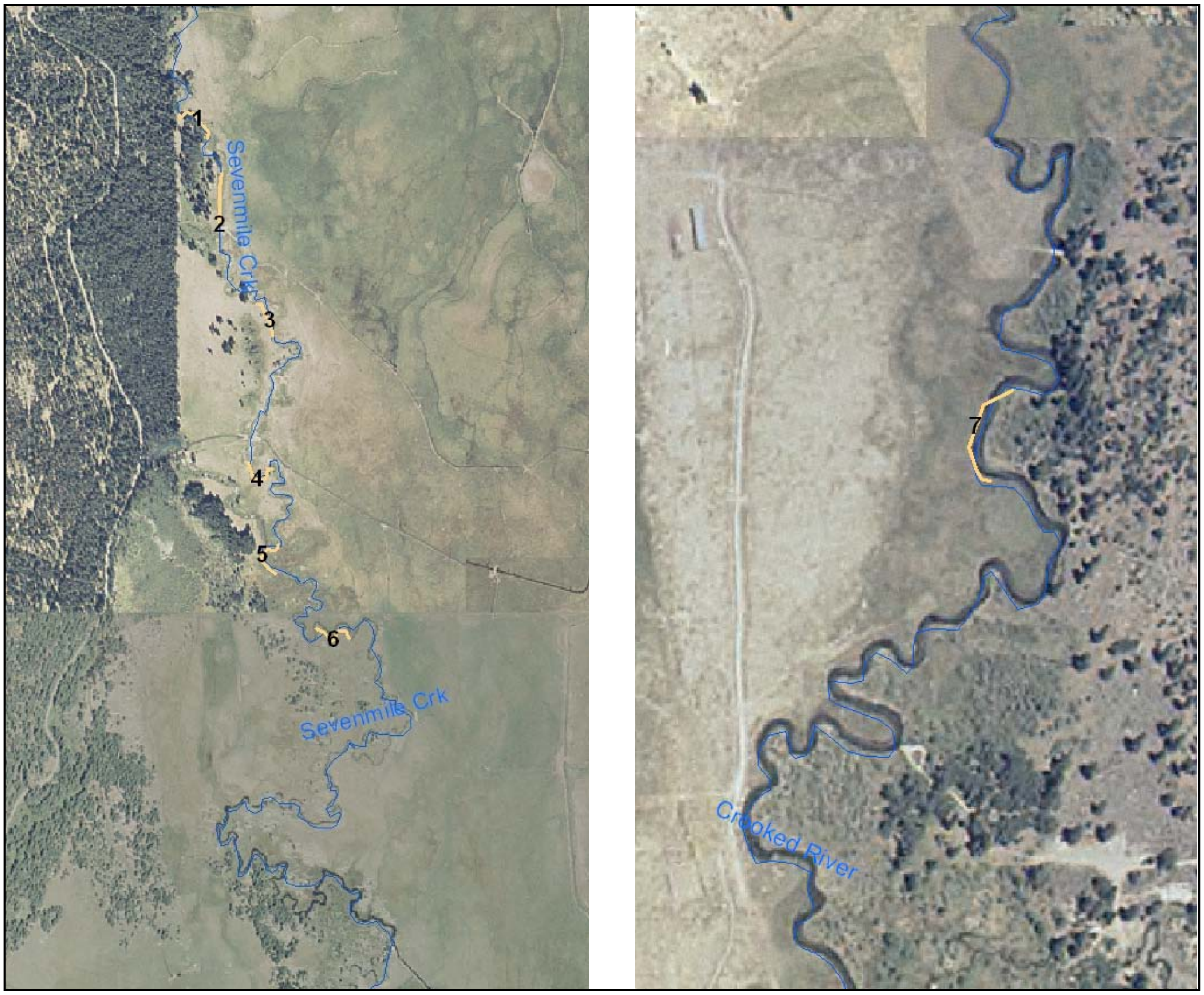


Figure 4. Riparian Study locations at Sevenmile Creek and Crooked River. Site locations are indicated in yellow.

For the vegetation sampling, the following considerations were used:

- Each community type chosen for sampling was at least twice as large as the plot in order to avoid sampling ecotones.

- A minimum sample size of 18 frames per site within homogenous plant community was chosen to insure sampling veracity. Plots were sampled using “Daubenmire” frames (30 cm by 60 cm).
- Canopy cover of dominant plants was recorded. Ocular estimates of canopy cover for each of the indicator species within a plot were made to the nearest percent up to 10 percent and to the nearest 5 percent thereafter.
- Soil was described by morphological features including: current depth of the water table; depth to which 90 percent of the vascular plant roots reach; depth to and description of redoximorphic features; depth of the surface organic horizon (if present); thickness of the epipedon (surface horizon); depth to the buried stream bed; and parent material.
- Soil horizon description included: thickness; moist color, percentage and coloring of redoximorphic concentrations and depletions; texture; current moisture status (dry, moist, wet or saturated); percentage and size class of coarse fragments, if present; and amount and diameter classes of roots.
- Rosgen stream type (Rosgen, 1996; Rosgen, 2006) was visually determined from the geomorphic information provided and recorded for each plot location.
- Valley landform descriptors (valley shape, gradient, width, side slope gradient and aspect) were recorded at each plot.

4.3.2 Riparian Monitoring Methods

The methods used for riparian monitoring in the Wood River Valley can be found in, “Monitoring the vegetation resources in riparian areas” (Winward, 2000). The only modification made for these sites were in the number of valley cross sections. Winward (2000) suggests using five transects and only three were used because of the similarity in valley/floodplain vegetation along each stream.

The monitoring sites were selected based on the vegetation community type work performed the previous season. That initial reconnaissance and intensive sampling provided the necessary information to establish permanent monitoring sites. The sites were selected based on vegetation community composition and potential for change with management.

4.3.2.1 Greenline

The Greenline was the method used to quantify riparian vegetation along the stream edge. Greenline has been defined as the first perennial vegetation that forms a patch or line (6 by 28 inches) that is at least 25 percent foliar cover of vegetation that is on or near the water’s edge (Cowley et al., 2008; Winward, 2000). Sampling the greenline can provide information about the ability of the channel to maintain bank stability and buffer the forces of water at high flow. Measurement of the greenline in a specific area over time can provide an indication of the long-term trend for the riparian area.

- The starting point of each greenline was permanently marked with rebar and a cap on the right bank of the channel, looking downstream.

- Community types or dominance/sub dominance of the vegetation along the greenline was recorded using a step transect approach (Winward, 2000) with enough steps to total a minimum of 363 feet on each side of the channel.

4.3.2.2 Valley Cross Section

This method quantifies the percent of each community type/species dominance perpendicular to the stream valley (Winward, 2000). Measurements taken in future monitoring efforts taken on the same site will provide information on the long-term changes and trend of the species within the site.

- Three transect locations were chosen based on distance downstream from the beginning of the greenline (each transect is not permanently marked).
- Each transect was paced instead of using a measuring tape.
- The first transect was located at the beginning of the greenline with the second transect 180 feet downstream from the first and the third transect another 180 feet downstream from the second transect.
- Each transect is perpendicular to the valley and at 60 and 240 degrees from magnetic north.
- Each transect was paced from the stream either to a fence line on the east side of the channel or to the conifer trees on the west side of the channel (see Figure 3 in Appendix 3).

4.3.2.3 Woody Species Regeneration

Woody species regeneration was measured using a 6-foot wide belt along the same transect used for the greenline.

- The sampler walked along the greenline with the center of a six-foot long pole over the inside edge of the greenline (that is, parallel to the edge of the stream).
- Woody species were recorded as they were encountered within the 6-foot belt transect along with the age class of the species (see Table 4 in Appendix 3).

4.3.2.4 Stream Cross Section

The stream cross sectional surveys included the following:

- Each monitoring site was benchmarked with cement and a metal pin placed in the cement. Distances and compass bearings were taken at the benchmark to the cross section and greenline so the site can be found in subsequent years.
- The endpoints of the cross section were marked using rebar.

- A measuring tape was then stretched in between the rebar going perpendicular to the channel flow. Elevations were then taken along the tape at any significant change in slope along the tape.
- At least 20 measurements were taken along the tape to accurately characterize a stream channel.
- Each cross section was located in a straight reach between two channel meander bends.

4.3.3 Data Analysis

Three different metrics were used to describe the functionality of the site, (1) successional status, (2) streambank stability, and (3) wetland rating. Detailed descriptions of successional status and streambank stability can be found in Winward (2000) and wetland rating in Burton et al. (2007). The following is a summarization of these metrics.

- Successional status was weighted by the percent of plants by successional status along the greenline.
- Streambank stability was based on the ability of a plant species to withstand the erosive forces of water. The data was summarized by weighted average for the greenline transect. Bank stability of over "7" was generally considered adequate to protect the streambank and allow them to function correctly.
- Wetland rating was a weighted average based on the wetland indicator status. The wetland indicator status was the frequency with which an individual plant species occurs in saturated soil. This was used for descriptive purposes.

4.4 Results/Findings

The predominant species found on the greenline were *Scirpus microcarpus, Poa pratensis, Carex nebrascensis, Carex aquatilis* and *Carex utriculata* (see Table 2 in Appendix 3). All the species but *Poa pratensis* are typically found only in riparian areas. They are rhizomatous and can form dense patches of vegetation along stream banks providing good bank stability. *Poa pratensis* is generally found in less saturated conditions than the other dominant riparian species. It is rhizomatous, but not as deep rooting therefore it does not provide the bank stability generally associated with these types of obligate wetland rhizomatous species. Generally, the dominant species at sites 1, 2, 5, and 6 (see Figure 4 above) are wetland plants that should continue to hold the banks together as long as water remains in the channel year round (see Tables 5 and 6 in Appendix 3). Sites 3 and 4 have plant species that are found in drier conditions that do not have the root/rhizome structure to hold the streambanks together as well as sedges and shrubs found at other sites. Reed canarygrass is present along much of Sevenmile Creek and the growth of the patches should be monitored.

Over time if sites 3 and 4 continue to develop and progress towards wetter riparian conditions, the sub-dominant species may begin to increase in cover. It will be important to monitor the sites again in 3 to 5 years to assess the trend over time. Baseline monitoring only gives a point in time snapshot of the site and observing how it develops over the course of a few years will be important in establishing a positive or negative trend (see Table 7 in Appendix 3).

The sites with young willows and bulrush were given an early ecological status because the willows are still developing. With the many young willows at the site, the numbers of willows will drop as they mature and the ecological status will probably change as they mature. Site 2 may experience the most change over time because the vegetation is still developing although the sites that have the most potential for improvement are sites 3 and 4.

Shrubs would naturally be present in patches along both Sevenmile Creek and Crooked Creek. Willows are fairly well developed in the floodplain of Crooked Creek and they are establishing in the greenline in some sites along Sevenmile Creek (see Table 9 in Appendix 3). The shrubs developing along Sevenmile Creek are mainly in the greenline because that is the area that has experienced the most change in recent years. The age class of the woody species should shift upwards as the plants mature and the number of woody plants in the youngest age classes may decrease at some sites as they mature.

The cross sections show that in the downstream section of Sevenmile during high flows, it should have access to the floodplain (see Appendix 3 [appendix 1.d; table 8]). This can also be seen in the vegetation composition on the greenline. The downstream portions of the stream have a higher composition of obligate wetland plants than do the upstream sections and the area directly influenced by the channel outside of the greenline also has the potential for a higher composition of obligate/facultative wet plants. Crooked Creek does not have the same flood generation capability as Sevenmile because it is a spring fed system that experiences limited snowmelt influence, however, the water remains near bank full year round, allowing obligate wetland plants to establish along the greenline and floodplain on the left side of the stream.

In addition to the results described here, the reader should refer to the Aquatics study results and findings in Chapter 5. The researchers involved in this CEAP study attempted to overlap reaches for the riparian and aquatics surveys where feasible so that changes in riparian habitat could be compared to changes in adjacent aquatic habitat.

5. Aquatic Study Summary

5.1 Background and Purpose

As described in the Purpose and Background section of the Riparian Monitoring Summary, in 2002, the Klamath Basin Rangeland Trust (KBRT) began a pilot project to evaluate the feasibility and effectiveness of conservation actions being undertaken in the Wood River Valley. The goal of the program was to increase the quantity and quality of water in the Klamath Basin by conserving irrigation water in the Wood River Valley, while restoring pastures and wetlands to maximize ecological value. The primary means to accomplish this goal was eliminating irrigation diversions for project lands, thus leaving this water in-stream, providing important ecological benefits and increased flows for downstream use. Other actions include various cattle management strategies, including substantial reductions in cattle numbers, riparian fencing, and active stream restoration.

Extensive monitoring of the projects promoted by KBRT was begun in 2002, including surface water, water quality, fish habitat, and stream conditions. Initial thoughts in 2002 on the potential timeframe until changes caused by KBRT management might be detectable centered on a 5-10 year period. Five years had passed since the 2002 initiation of the KBRT conservation program and it was deemed an appropriate time to evaluate potential changes to the aquatic systems.

In 2002/2003 KBRT hired a consulting firm to conduct aquatic and riparian monitoring. The 2002/2003 aquatic, pre treatment habitat monitoring was conducted following repeatable protocols. Thus, NRCS, working with KBRT, was able to hire the same consultants to conduct post treatment surveys for this study. The aquatic monitoring conducted in 2008 re-surveyed the aquatic environment and a comparison to the 2002/2003 data was undertaken. The consultants also established photo points during their 2002-03 survey which allowed a qualitative comparison of pre and post treatment riparian conditions.

The purpose of this portion of the Wood River CEAP study was to determine whether measurable impacts to the aquatic system could be shown to result from the various changes in land management initiated over the last ten years or so.

5.2 Hypotheses and Objectives

The primary objective of the aquatic monitoring portion of this Wood River CEAP study was to measure changes in fish habitat and fish numbers on Crooked Creek and fish habitat on Sevenmile Creek after five years of the KBRT sponsored land use management changes. The aquatic monitoring efforts included repeating surveys of geomorphic conditions, fish habitat, and fish abundance.

5.3 Methods Overview

Baseline conditions were established in 2002 and 2003 (Pacific Groundwater Group et al., 2003; Kann and Reedy, 2004) for fish habitat and geomorphic conditions of Crooked Creek and Sevenmile Creek (see Appendix 6, figure 1), two streams affected by management actions of KBRT. Additional monitoring work has occurred on Crooked Creek since the late 1990s, primarily associated with the planning and implementation of a specific stream restoration project.

The full report in Appendix 6 describes the monitoring objectives, methods, results, and analyses used for the aquatic monitoring portion of the Wood River CEAP study. Most of the methods were established and reported in the 2003 Fisheries Habitat Monitoring Report (Kann and Reedy 2004) and the basics are not reiterated here unless methods were altered or new methods added. The results were compared to those from 2003 to evaluate general trends for predictive purposes.

The Wood River Valley Aquatic Habitat monitoring was conducted by Graham Matthews & Associates in 2003 for KBRT. Graham Matthews & Associates was re-hired in 2008 for the Wood River CEAP study to increase confidence in having the original surveys redone at the correct locations, using the same methodologies, having similar sampling effort, etc.

The Sevenmile Creek and Crooked Creek areas were surveyed according to the following five metrics:

- Geomorphic Field Surveys: Geomorphic surveys of the channel banks and the thalweg (deepest part of the channel) were done using survey grade RTK-GPS equipment and data reduction.
- Habitat Surveys: Habitat units were delineated by measuring cover, depth, pool quality, wood and substrate parameters, and collecting photo point data. Habitat unit boundaries were defined using survey grade RTK-GPS equipment.
- Fish Surveys (Crooked River only): A snorkel survey of the creek was done to count fish.
- Macroinvertebrate Surveys (Crooked River only): Macroinvertebrate samples were collected and the samples were sent to a lab for analysis.
- Photo points: The photo point monitoring sites used in 2003 were re-located, where possible, and photos were taken in 2008 using the same orientations (upstream, downstream, and across) to provide a basis for visual comparisons with the 2003 images.

Both Sevenmile and Crooked Creeks were divided into segments for the monitoring work to differentiate hydrologic and morphological features and to facilitate the assessment and reporting process (See figures 5 and 6 below).

As described in the Riparian monitoring discussion above, the Aquatic monitoring and Riparian monitoring were geographically coordinated as much as feasible given the different needs of the study methodologies. Appendix 6 contains a more detailed description of the methodologies used in the Aquatics monitoring.

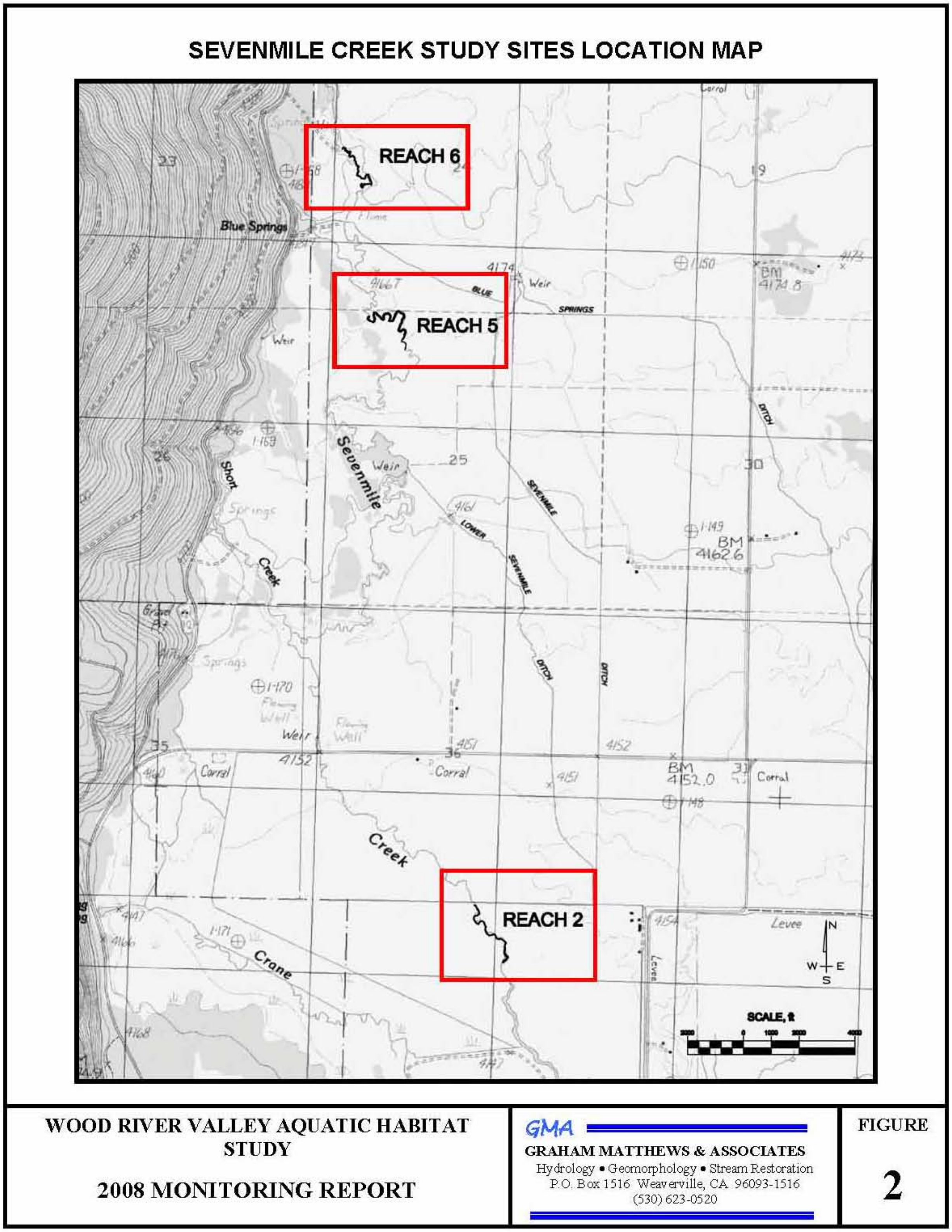


Figure 5. Sevenmile study sites.

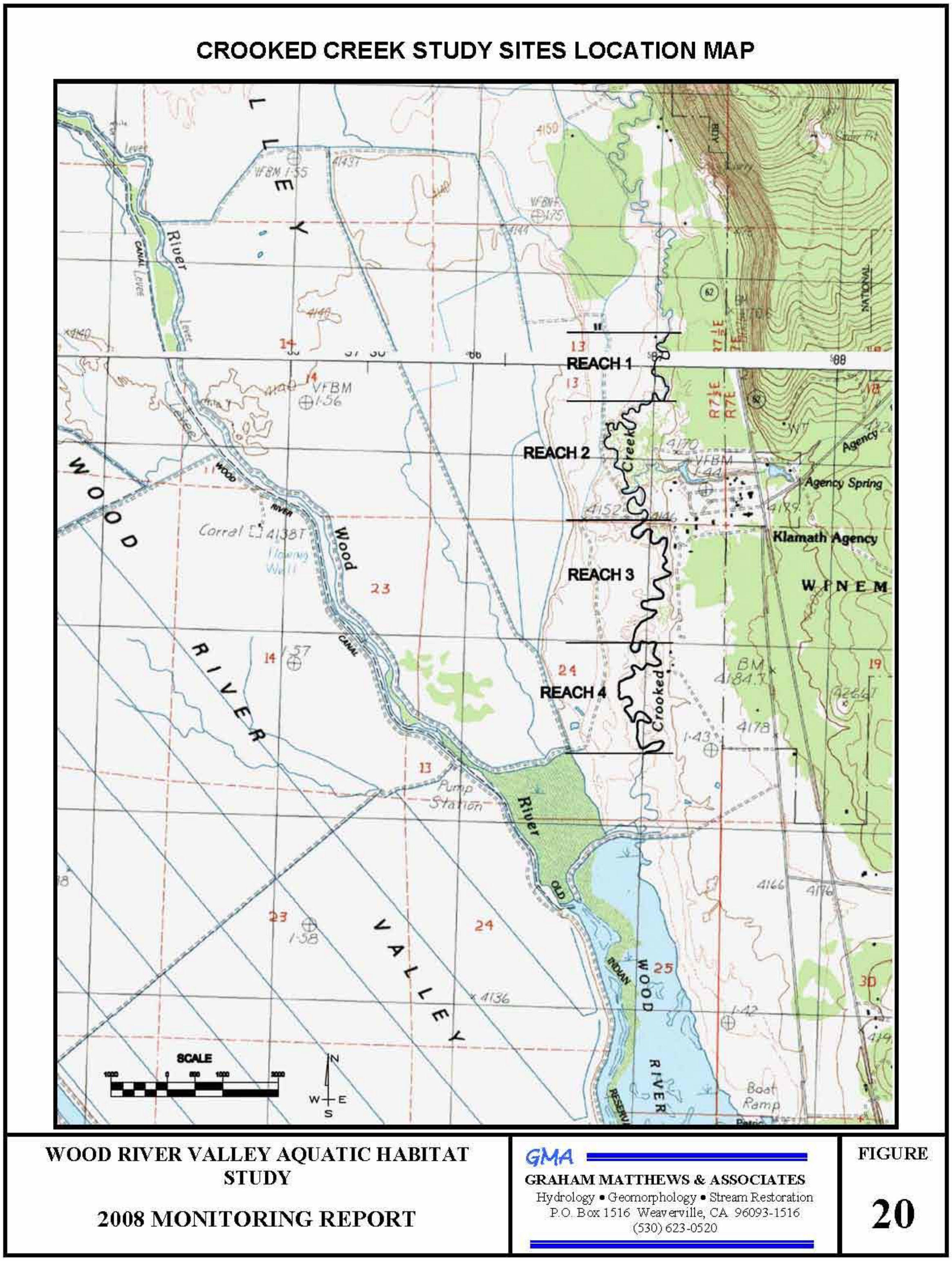


Figure 6. Crooked Creek study sites.

5.4 Results/Findings

Appendix 6 contains the full Aquatic habitat monitoring report. The following are a few of the more notable results.

On Sevenmile Creek, decreased grazing pressure has had the most impact on Aquatic Reaches 5 and 6 by allowing riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio.

Aquatic Reach 6 has experienced the most dramatic changes resulting from the KBRT sponsored land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. Graham Matthews and Associates report that Aquatic Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased stream flows to scour the bed, and (3) it likely saw the highest percentage increase in base flow, as prior to the management changes, it was essentially dewatered much of the summer.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. With less energy available to promote change, change will take a much longer period of time. Although the mean depth and large woody debris decreased in Aquatic Reach 2, there was an increase in pool quality, partly due to an increase in percentage of undercut banks. Being the most downstream reach (and lowest gradient), one would expect Aquatic Reach 2 to improve the slowest, both due to low energy available and that much of the sediment released from upstream as those reaches recover will move through the downstream reaches.

A significant increase in amount of habitat available, although not directly measured, is suggested by the increase of base stream flow during the critical summer months as shown in Figure 19 of Appendix 6. To evaluate such changes this directly, habitat would need to be measured at the same time of year (not the case for the 2003 and 2008 surveys), then, not only would the physical changes be apparent, but the available habitat (not just physically based but also dependent on the base flow amount) during critical periods could also be determined.

On Crooked Creek decreased grazing pressure has caused channel narrowing and a decrease in width to depth ratio throughout the monitoring reaches. There is a current effort to increase the cattle exclusion area along the right bank through most of Aquatic Reaches 3 and 4 which should further reduce bank erosion and increase bank undercuts.

Overall, channel widths and width to depth ratios decreased as bank erosion has decreased. Undercut banks have not increased as much as one would expect except in Aquatic Reach 1 where the difference is significant.

The most dramatic change between 2003 and 2008 has been with the distribution of adult trout in the four reaches. Although the number of fish was lower than in 2003, a much higher percentage of the fish counted were in the index section of Aquatic Reach 4. It is likely that the increase in depth and decrease in width and, even more so, the increase in large woody debris incorporated with the channel narrowing projects have improved the fish habitat and encouraged fish use.

6. Synthesis of Riparian and Aquatic Findings

6.1 Purpose

The following table and accompanying map describe basic information about the reaches surveyed for riparian and aquatic habitat. Researchers attempted to overlap reaches for the two surveys where possible so that changes in riparian habitat could be compared to changes in adjacent aquatic habitat. Figure 7 and Table 1 below show where the Riparian and Aquatic monitoring surveys overlapped on Sevenmile Creek.

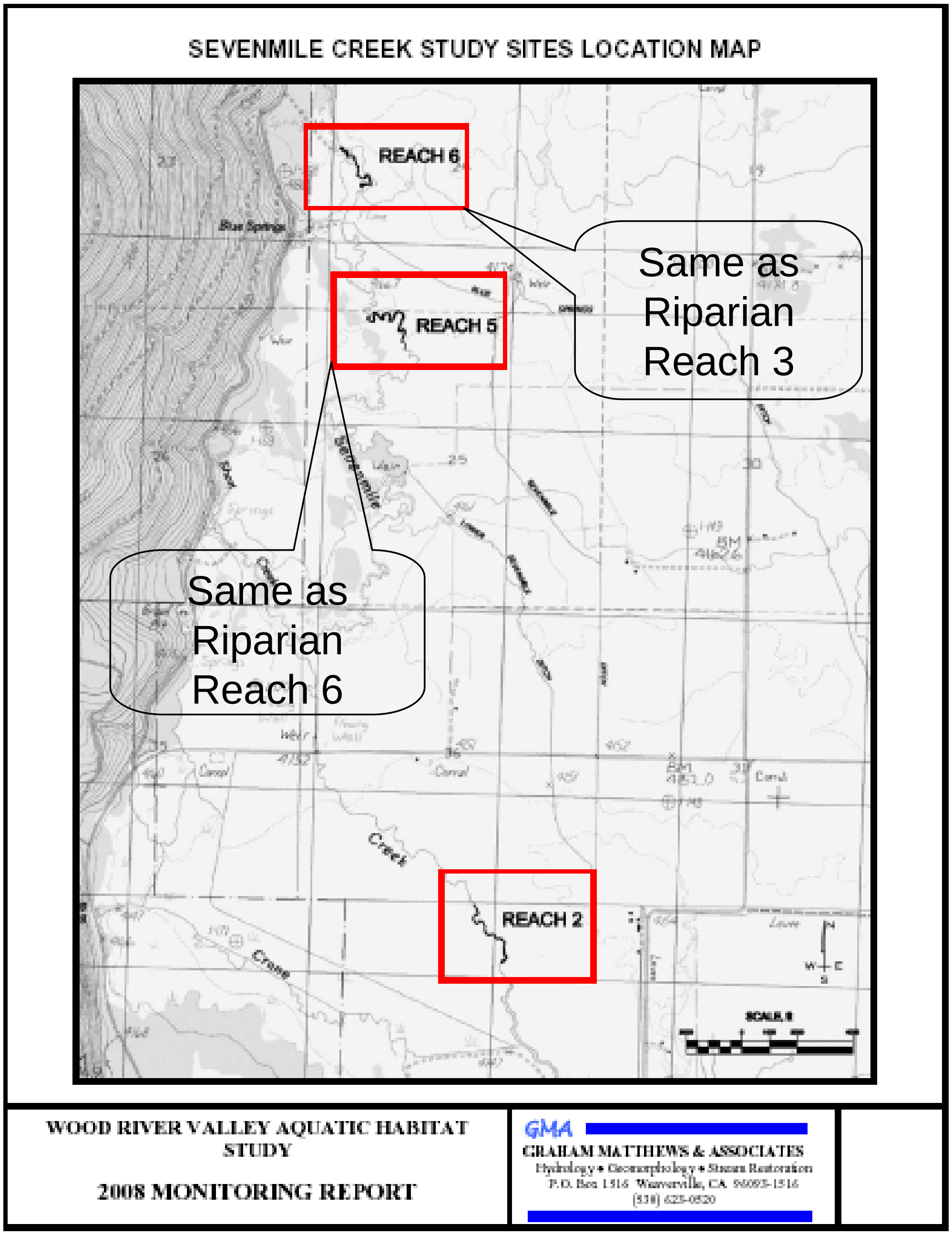


Figure 7. Sevenmile Creek study reaches.

Table 1. Riparian and Aquatic Habitat Surveyed Reaches.

Creek	Riparian Reach	Riparian Reach Length (ft)	Aquatic Reach	Aquatic Reach Length (ft)	Treatment Year	Treatment Type	Treatment Description	Post Treatment Grazing
Seven mile	1	444			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	2	432			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	3	328	6	1,247	2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	4	380			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	5	409			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	6	413	5	1,557	2006	Passive	Riparian fencing & managed grazing	none
Seven mile			2	1,490	2005	Passive	Riparian fencing & managed grazing	limited
Crooked	7	429	1	1,931	2002 – limited grazing; 2008 – fenced	Passive	Riparian fencing & managed grazing	East side – none; West side – limited
Crooked			2	5,708	2001	Passive	Riparian fencing & managed grazing	East side – none; West side – limited
Crooked			3	4,787	2001	Passive	Riparian fencing & managed grazing	East side – none; West side – horses
Crooked			4	4,695	1997	Passive & Active	Riparian fencing, channel shaping, riparian plantings & managed grazing	None

Rows with yellow highlighting indicate overlap of Riparian and Aquatic monitoring river segments.

As discussed in the Aquatic Study chapter of the report, on Sevenmile Creek the decreased grazing pressure had substantial impact on Aquatic Reaches 5 and 6. It was suggested that changes in management allowed the riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio. These parameters were measured as well as documented with photo-point monitoring. Figures 8, 9, and 10 are representative examples that illustrate the changes documented in the Aquatics portion of the study.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. The Riparian monitoring showed that the predominate vegetation in this reach (Riparian Reach 6/Aquatic Reach 5) are riparian/wetland plants that are rhizomatous, can form dense patches, provide good bank stability, and should hold the banks together if water continues to be present year round.

Figure 8. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – same location in Aquatic Reach 5, Sevenmile Creek.

Figure 9. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – also Aquatic Reach 5, Sevenmile Creek.

Aquatic Reach 6 (Riparian Reach 3) experienced the most dramatic changes resulting from the land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 (Riparian Reach 3) clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. The Aquatic Monitoring Study found that Aquatic Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased streamflows to scour the bed, and (3) it likely saw the highest percentage increase in baseflow, because prior to the management changes the reach was essentially dewatered much of the summer.

Aquatic Reach 6 is the same as Riparian Reach 3. The riparian monitoring found that this reach had plant species that are found in drier conditions that do not have the root/rhizome structure to hold the streambanks together as well as sedges and shrubs found in other parts of Sevenmile Creek. The Riparian monitoring report also noted that if the reach continues to progress towards more of a wetter riparian site over time the sub-dominant species may begin to increase in cover and provide more bank stability through a more extensive rhizomatous/root system.

Figure 10. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – Aquatic Reach 6, Sevenmile Creek.

6.2 Results/Findings

Appendix 6 contains more detailed results and findings than are summarized here. What appears clear from the Aquatic and Riparian monitoring work is that the changes in irrigation and grazing management through the KBRT sponsored program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek and Crooked Creek. Table 2 shows that on Sevenmile Creek, Aquatic Reach 6 (the uppermost section studied) showed the most improvement in fish habitat with increases in pool numbers, depth, large woody debris, and a decrease in fine sediment. Aquatic Reaches 5 and 6 both have more stable banks and narrower, deeper channels.

Table 2: Comparison of Riparian and Aquatic Reaches on Sevenmile Creek.

Riparian Reach Number			3	6
Aquatic Reach Number			6	5
Riparian Vegetation Condition 2008		Stability Rating	Moderate	Excellent
		Ecological Status	Mid	PNC
		Wetland Status	Good	Very Good
Aquatic Habitat Condition 2003 and 2008	Habitat Units	2003	37	35
		2008	50	38
	Mean Depth (ft)	2003	2.1	2.8
		2008	2.4	2.8
	Mean Width (ft)	2003	26.9	27.0
		2008	23.1	19.3
	Eroding Banks (%)	2003	16.1	0.3
		2008	6.8	0.0

The effects of the new management were somewhat less but still substantial for the Crooked Creek study reaches. Channel width and width to depth ratios decreased and bank erosion decreased. The areas of Crooked Creek Aquatic Reach 4 that have undergone restoration in the form of channel narrowing and large woody debris enhancement showed an increase in adult trout usage.

The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change. Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek. In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively flushing fine sediments. As a result, lower gradient reaches will take longer to recover.

7. Grazing Land Vegetation Monitoring Summary

7.1 Purpose

The main purpose of this study was to determine the effects of changing irrigation and grazing management in the Wood River Valley. The grazing land vegetation monitoring specifically addressed five questions:

How does “no” or “reduced” irrigation versus full irrigation affect:

- Total annual above-ground and available forage production (monthly and annual)?
- Vegetation species diversity and abundance?
- Amount of bare ground and perennial plant basal gaps?
- Forage quality (protein and energy) for use by domestic livestock?

Several additional questions link the four questions above with the researchers’ confidence in the findings to state what the long term implications may be. That is:

- Will plant community composition continue to change?
- Will percent bare ground and basal gaps continue to increase?
- Will production continue to decline?
- Will forage quality increase or decrease?

Three interconnected studies were undertaken to answer these questions. The reports prepared by the researchers include:

- 2007-2008 NIRS Forage Quality Assessment, Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon, Jeff Repp, USDA-NRCS, West National Technical Support Center, Portland, Oregon, January 2009 (included as part of Appendix 1).
- Wood River Valley Vegetation Monitoring Summary 2007-2008, Tamzen K. Stringham and Sarah E. Quistberg, Rangeland Ecology and Management, Oregon State University, December 2008 (included as Appendix 2).
- Summary of Wood River CEAP Wet Chemistry Forage Quality Data, for both Inside (ungrazed) and Outside (grazed) the exclosures, for the Year 2008, Chanda L. Engel, OSU Klamath Basin Research and Extension Center, Klamath Falls, Oregon, February 2009 (included as Appendix 4).
- 2007-2008 Exclosure Clipping Study Results, Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon, Jeff Repp, USDA-NRCS, West National Technical Support Center, Portland, Oregon, January 2009 (included as part of Appendix 1).

Each study contains more information on methods and results than are summarized in this report. Information summarized here represents those components the researchers considered most significant or useful in answering the questions posed at the outset of the study process. The researchers for the individual component studies also provided NRCS with the raw data collected in the field. In addition, information and data from studies and monitoring done by other agencies and organizations have been consulted, referenced, and incorporated as appropriate in this discussion.

7.2 Objectives

The objectives of this component of the study were to:

- Determine vegetative production, composition, structure, and forage quality on irrigated vs. non-irrigated sites.
- Compare soil compaction as measured by a relative penetronmeter and bulk density within irrigated and non-irrigated sites.
- Evaluate the base nutritional plane of the vegetative component of the biological communities or animal performance between irrigated and non-irrigated pastures.

7.3 Methods Overview

7.3.1 Field Sites

A total of 12 field groups were selected, consisting of 6 irrigated groups (1I, 2I, 3I, 4I, 5I, and 6I) and 6 non-irrigated groups (1N, 2N, 3N, 4N, 5N, and 6N) distributed throughout the Wood River Valley. All irrigated sites were fully irrigated; there were no sites with reduced irrigation levels. Three vegetation transects and one vegetation exclosure were established at each site. Water table and soil moisture sensors connected to data loggers were placed within the exclosures. Fecal and forage quality data were also taken within each grouping. A digital elevation model (DEM) of the Wood River Valley with 1-m horizontal cell resolution was obtained via LiDAR (Light Detection and Ranging data) supplied by the Klamath Basin Rangeland Trust.

7.3.2 Data Collection

7.3.2.1 Plant Production and Composition (Stringham and Quistberg)

Annual above-ground, air-dry reconstructed plant production and composition by foliar cover were measured at each of the 18 non-irrigated and 18 irrigated plots and at exclosures. Three transects and one exclosure were established for each field group. Transects were 150 feet (45.72 meters) long and oriented North-South (two per plot for 300 feet total length). Vertical point samples were collected every 2 feet (0.61 meters) along transects once a month from April to October to determine foliar cover of plant species and soil cover (150 points). Ten subplots were estimated and clipped (10 estimated and two clipped) by species along transects in 2007 to determine total annual air-dry reconstructed production (double sampling). Exclosure samples were taken concurrently. The exclosures were 64 square feet (5.94 square meters). For each sampling location the following data/observations were taken:

- Double Sampling: Annual air-dry above-ground reconstructed production (2007 only).
- Basal Gaps: Distance between rooted perennial plants.

- Line Point Intercept: Species composition by percentage of foliar cover and percent of bare ground.
- Belt Transect: Presence of invasive species by plants per area (density), especially bull thistle.
- Exclosure Clipping: Monthly air-dry production via subplot clipping and re-growth clipping. [Exclosures were placed as close as possible to fixed plots but were spatially removed from plot locations to reduce impacts to grazing animals.]

7.3.2.2 Forage Quality (Plant and Fecal Sampling)

7.3.2.2.1 Plant Sampling (Engel)

Each month during the 2008 growing season six forage samples from each field group were taken and analyzed using wet chemistry techniques for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro dry matter digestibility (IVDMD), and in vitro neutral detergent fiber digestibility (IVNDFD). These analyses were designed to estimate total and digestible fiber present in the forage so that a nutrition balance of the livestock could be made.

7.3.2.2.2 NIRS Analysis of Fecal Samples (Repp)

In 2007 and 2008, fecal samples were collected from animals in each grouping each month, May through October. When animals were not present on pastures within a group, no fecal sample was collected. Fecal samples were analyzed with near infrared reflectance spectroscopy (NIRS) for percent crude protein (CP), digestible organic matter (DOM), percent fecal Phosphorus and percent fecal Nitrogen. NIRS samples are easier and cheaper to collect and analyze than the wet chemistry samples and have been validated thoroughly for cool-season forages (Texas A&M University Grazingland Animal Nutrition (GAN) Lab). NIRS is also advantageous in that it directly samples what the animal ingested and the sampler does not have to attempt to clip forage in the same proportions that an animal would graze. Stubble height was also recorded when collecting plant and fecal samples.

7.3.2.3 Grazing Management

Visits to the field groups were made each month from April to October to estimate grazing characteristics. Observations were made for animal breed, average weight, body condition score (BCS), average age, and metabolic activity (lactating, dry, growing animal, etc.). Estimates of the amount of remaining forage and rate of plant re-growth were made visually. These observations were confirmed with the landowner when possible. The typical grazing system practiced in the Wood River Valley was continuous season-long grazing. Cattle were kept in large pastures and grazed freely throughout the growing season.

7.4 Results/Findings

7.4.1 Plant Production and Composition (Stringham and Quistberg)

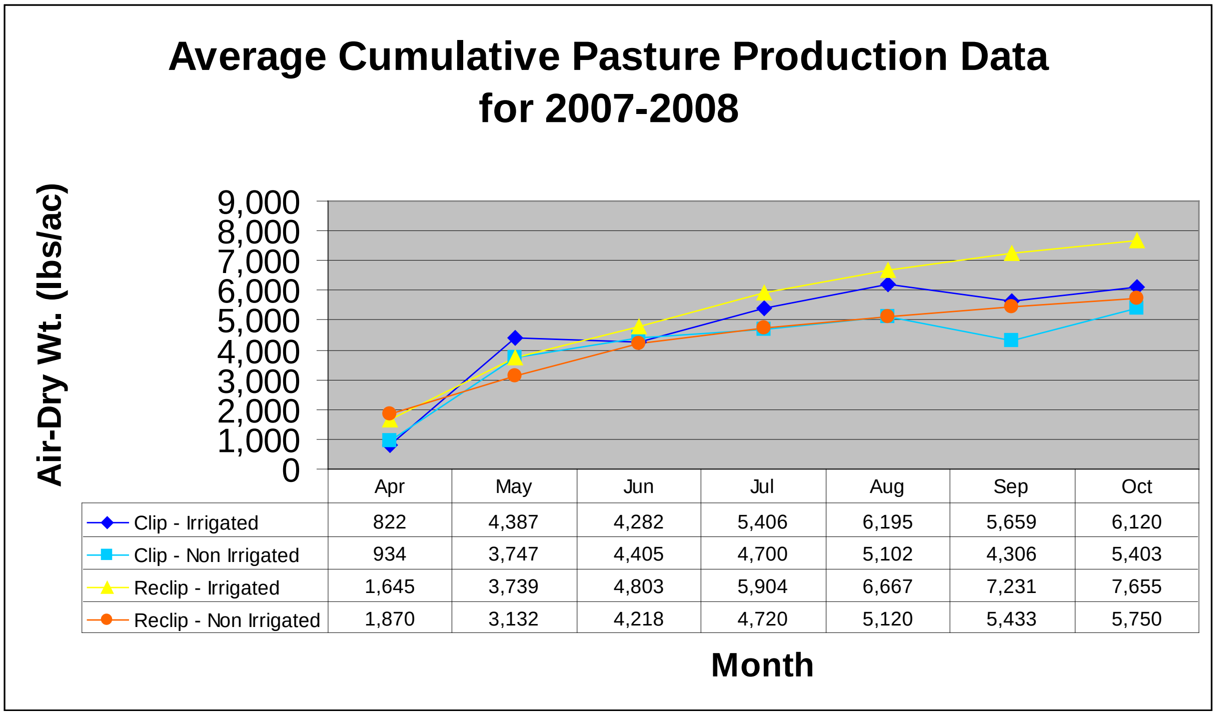
7.4.1.1 Plant Production

Double sampling for reconstructed annual air-dry above-ground production was conducted on each of the 36 plots in 2007. The method is described in Herrick et al. (2005) and has been part of the National Resource Inventory Range Study since its inception in 2003. This data provides a baseline for annual above ground air-dry production during a single year regardless of accessibility or palatability to grazing animals. Production data was not collected at the plots in 2008 so comparisons between years is not possible. The 2007 data was used to validate the production data collected by monthly cumulative and re-growth clipping in the exclosures (see Appendix 1.

Production sampled from exclosures included cumulative monthly clipping and clipping of re-growth. Each month a subplot was clipped within a new 1.92 square foot hoop thereby representing cumulative growth over each growing season (each month's growth would include the previous month's growth as well). This approximated the amount of production with no impact from grazing. Also each month each subplot clipped the previous month was re-clipped.

Samples were weighed green, air-dried (about 72 hours) and re-weighed to determine percent air-dry at time of clipping (used in reconstruction factors). The re-clip data represents re-growth since the last clipping. Consequently, re-growth clipping represents production assuming a monthly harvest or a 30-day rest period between harvests. Combining monthly accumulated clipping and re-growth clipping give a more accurate estimate of total productivity.

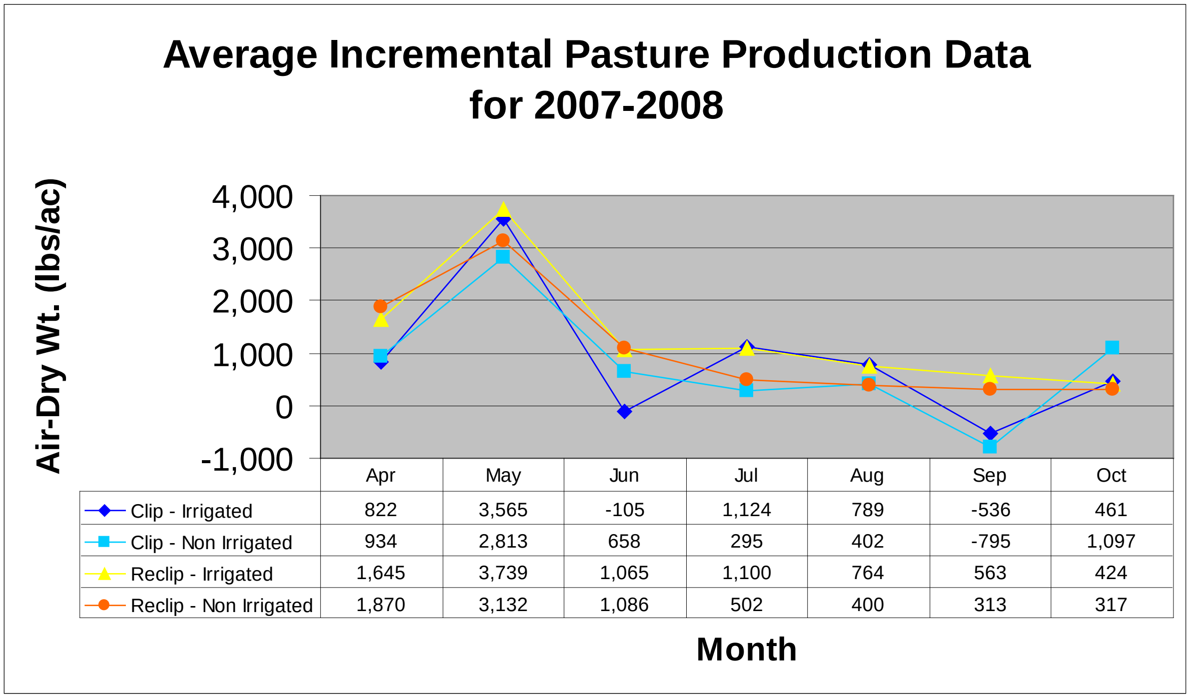
Figure 11 compares cumulative monthly plant production averaged over the two years of data collection for both clip and re-clip samples from six irrigated and six non-irrigated sites. Both clip and re-clip accumulative totals are similar (6,120 and 7,755 for irrigated sites and 5,403 and 5,750 lbs/acre for non-irrigated sites). Re-clip data totals are slightly higher than clip totals. Periodic harvesting or grazing can encourage new tiller or shoot growth sometimes referred to as compensatory growth. Production on irrigated sites is higher than non-irrigated (13 percent higher on clip sites versus 33percent higher on re-clip sites).



	Apr	May	Jun	Jul	Aug	Sep	Oct
◆ Clip - Irrigated	822	4,387	4,282	5,406	6,195	5,659	6,120
■ Clip - Non Irrigated	934	3,747	4,405	4,700	5,102	4,306	5,403
▲ Reclip - Irrigated	1,645	3,739	4,803	5,904	6,667	7,231	7,655
● Reclip - Non Irrigated	1,870	3,132	4,218	4,720	5,120	5,433	5,750

Figure 11. Average Cumulative Pasture Production.

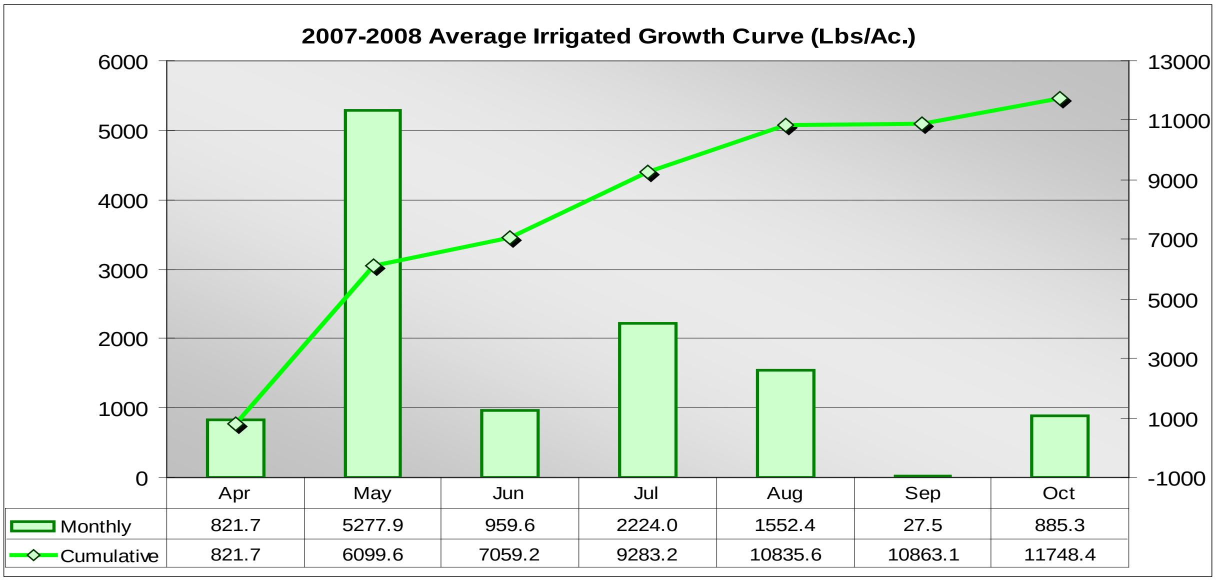
Examining the incremental monthly growth (Figure 12) shows the greatest growth occurs early in the season and tapering off into late summer and fall. This occurs both at irrigated and non-irrigated sites. Possible reasons include plant senescence following hot, dry summer weather, insect and small mammal foraging, and possibly nutrient availability.



	Apr	May	Jun	Jul	Aug	Sep	Oct
◆ Clip - Irrigated	822	3,565	-105	1,124	789	-536	461
■ Clip - Non Irrigated	934	2,813	658	295	402	-795	1,097
▲ Reclip - Irrigated	1,645	3,739	1,065	1,100	764	563	424
● Reclip - Non Irrigated	1,870	3,132	1,086	502	400	313	317

Figure 12. Average Incremental Pasture Production for 2007 – 2008.

The following figures (Figures 13 and 14) show the total monthly and annual accumulation of air-dry above-ground production from irrigated and non-irrigated sites (based on exclosure clipping: monthly and re-growth added together) and represent the average of all growth in all exclosures for both years. The bars represent the monthly growth (left Y axis) and the line represents the accumulation of growth over the growing season (right Y axis). The amount of forage available to grazing animals is a percentage of these amounts but it will still accrue according to the growth curve.

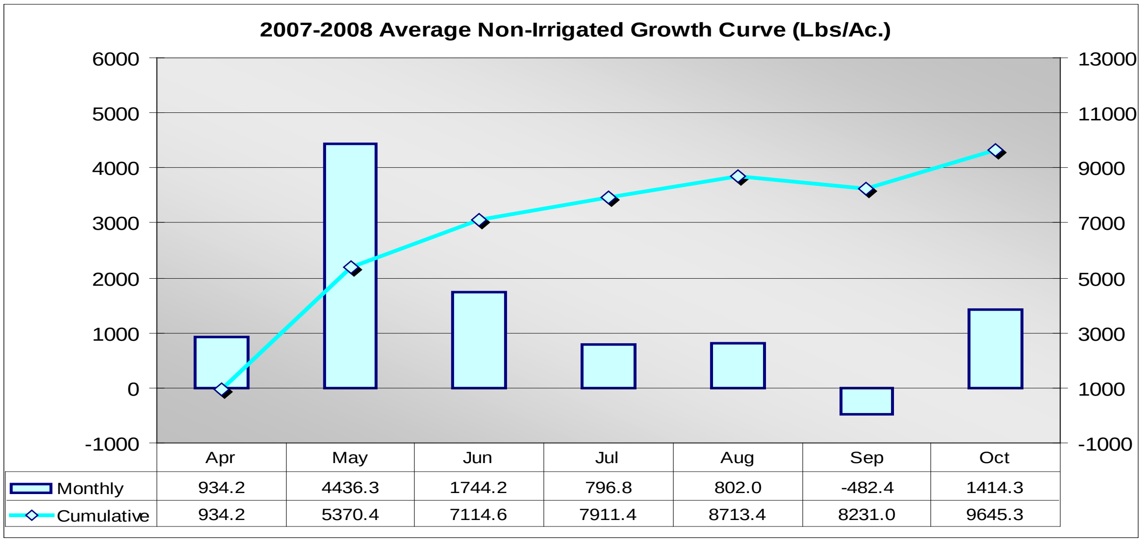


	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly	821.7	5277.9	959.6	2224.0	1552.4	27.5	885.3
Cumulative	821.7	6099.6	7059.2	9283.2	10835.6	10863.1	11748.4

Figure 13. Average Irrigated Exclosure Growth Curve for 2007-2008.

The low (or negative for non-irrigated) amounts of growth in September are most likely due to drier conditions and consumption by rodents and other creatures that had access to the exclosures. Observations indicate that there is still growth accruing in September, although at a lowered rate. Most annual growth on both types of sites occurs in May when soil water and temperatures are optimum. Irrigated sites during this period (2007-2008) were capable of producing on average, almost 12,000 pounds per acre of biomass. Non-irrigated sites produced on average, about 20 percent less or 9,650 pounds per acre of biomass.

The average irrigated exclosure growth curve for 2007-2008 was constructed from peak standing crop data along with re-growth data from monthly clippings. The curve reflects rapid growth before June, sustained growth through August, senescence in September, and fall growth (in October) before freeze-up in November. The irrigation influence can be plainly seen in the growth numbers of June through August when compared with the non-irrigated growth curve below.



	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly	934.2	4436.3	1744.2	796.8	802.0	-482.4	1414.3
Cumulative	934.2	5370.4	7114.6	7911.4	8713.4	8231.0	9645.3

Figure 14. Average non-irrigated exclosure growth curve for 2007-2008.

The average non-irrigated exclosure growth curve for 2007-2008 was constructed from peak standing crop data along with re-growth data from monthly clippings. The curve reflects rapid growth before June, sustained growth through August, increased senescence (and probably rodent and insect harvest) in September, and fall growth (in October) before freeze-up in November. Overall productivity is less than in the irrigated exclosures (about 20 percent less).

7.4.1.2 Vegetation Species Diversity and Abundance

Vegetative foliar cover was determined from each of the 36 plots in 2007 and 2008 using the line-point intercept method. The method is described in Herrick et al. (2005) and has been part of the National Resource Inventory Range Study since its inception in 2003. Foliar cover is measured at a point, and differs from canopy cover which measures the cover of individual plants. The line-point intercept method quickly and accurately measures percent foliar cover, percent bare ground, and percent basal cover when an adequate number of points are sampled.

Vegetative data was collected along three transects for each of the six irrigated and six non-irrigated groups in 2007 and 2008 and showed that:

- Non-irrigated sites had a higher ratio of native to non-native species than did irrigated sites.
- Non-irrigated sites had more grass species and less obligate and facultative wet species (Sedges) than irrigated sites.
- Grass species and native species on non-irrigated sites increased in abundance from 2007 to 2008.

More deeply rooted grass species should positively impact production and forage quality on non-irrigated sites. Nebraska sedge is a desirable facultative wet species that appears to decline in abundance on non-irrigated sites (see Figure 15). From this data alone it's difficult to predict what the long term impact of species change in diversity and abundance might have on forage production and quality.

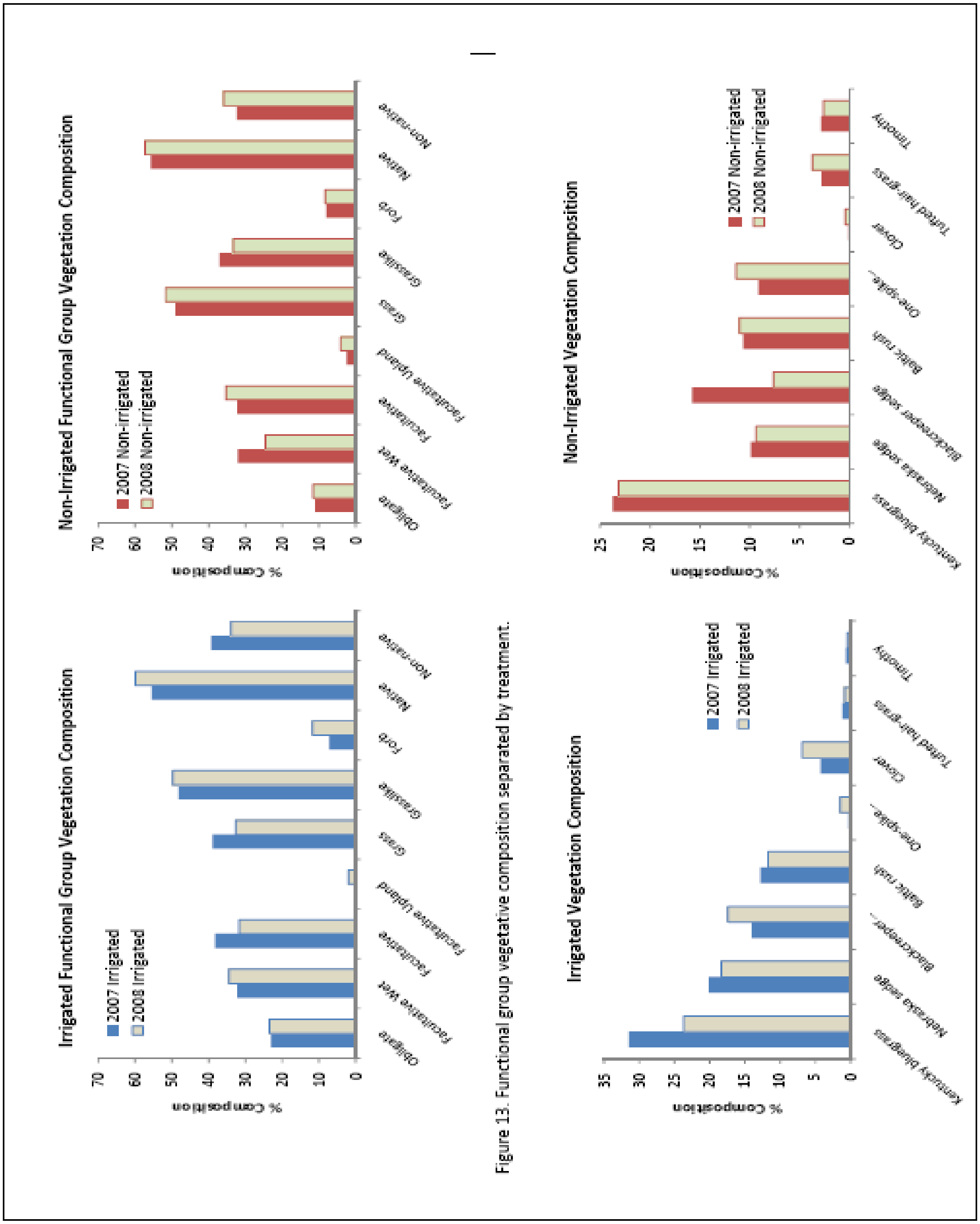


Figure 15. Vegetation Composition in Irrigated and Non-irrigated groups.

7.4.1.2 Amount of Bare Ground and Basal Gap

The amount (percent) of bare ground and basal gaps (physical space between plants) are further sources of information demonstrating resistance, resilience, and capability of a site to produce forage, protect soils, and to store moisture. Percent bare ground is an especially sensitive marker of plant community change because it shows initial changes in the plant community and it can be quickly and accurately measured. As sites respond to the reduction or removal of irrigation water, individual plants perish leaving less soil cover and protection. Basal gaps represent changes in soil protection: increase in the size of basal gaps indicates increased susceptibility to water and wind erosion. As water tables and soil moisture levels drop, fewer plants can be supported per unit area and, along with associated composition changes (plant species replacement), potential risks to soil and water resources are increased.

The average lengths of plant basal gaps for irrigated and non-irrigated groups are 139.7 cm and 196.6 cm, respectively.

A plot of the percent bare ground by years since irrigation measured along 18 transects show a slight increase over time.

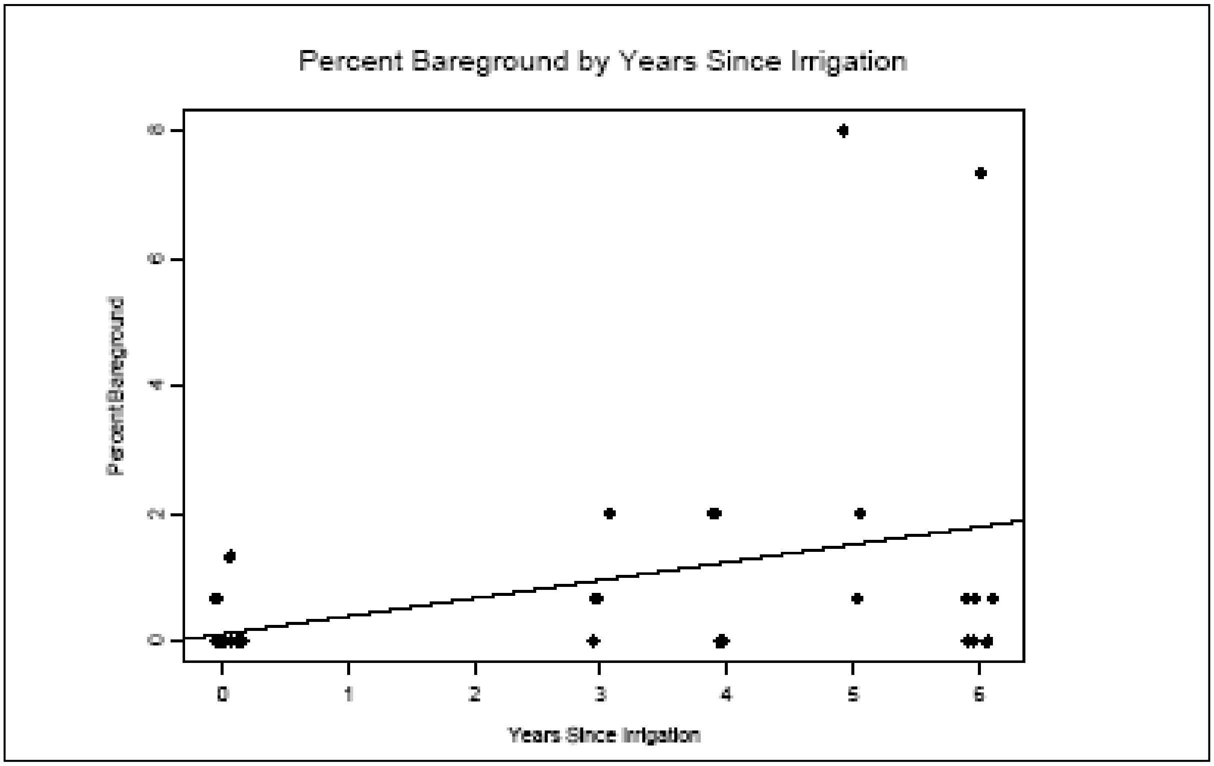


Figure 16. Percent Bare Ground by Year Since Irrigation.

7.4.1.3 Forage Quality for Use by Domestic Livestock

The feasibility of sustaining ranching in the Wood River Valley depends not only on the amount of forage produced but also its quality. It must provide adequate nutrition to enable grazing livestock to have reasonable gains in weight and maintain their health and body condition.

Some general rules on forage quality to maintain rates of gain and body condition are:

- Crude protein (CP) levels over 7 percent
- Digestible Organic Matter (DOM) - a DOM:CP ratio between 4.0 and 8.0 is considered acceptable with 4 being optimal.

Table 3 presents the finding from analysis of fecal samples (2007-2008) and wet chemistry of plants sampled (2008). Digestible organic matter (DOM) and Total Digestible Nutrients (TDN) are used here as interchangeable terms.

Table 3. Pasture Forage Quality.						
Average Irrigated Pasture Forage Quality - Fecal Samples - 2007-2008.						
	May	Jun	Jul	Aug	Sep	Oct
CP%	14.1	11.7	10.3	11.0	11.8	8.9
DOM%	65.7	64.3	63.0	62.8	64.3	61.5
DOM:CP	4.7	5.5	6.1	5.7	5.4	6.9
Average Non-irrigated Pasture Forage Quality - Fecal Samples - 2007-2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	15.2	12.7	11.0	10.5	10.2	8.4
DOM%	67.6	65.9	63.1	61.8	61.2	60.5
DOM:CP	4.5	5.2	5.7	5.9	6.0	7.2
Irrigated Pasture Forage Quality - Wet Forage Chemistry - 2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	13.5	10.9	9.6	9.8	9.8	8.7
TDN%	62.5	62.1	60.3	59.9	60.0	58.7
TDN:CP	4.6	5.7	6.3	6.1	6.1	6.7
Non-irrigated Pasture Forage Quality - Wet Forage Chemistry - 2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	15.1	10.2	8.6	8.1	7.5	6.4
TDN%	64.3	63.2	61.5	59.7	59.5	57.2
TDN:CP	4.3	6.2	7.2	7.4	7.9	8.9

Forage quality based on both methodologies meets general rules for animal nutrition stated above. The exception were October wet chemistry samples from non-irrigated pastures with Crude Protein (CP) at 6.4 percent and TDN:CP ratio at 8.9.

In all cases forage quality tapers off late in the season with decreasing CP and DOM with non-irrigated pasture values dropping most.

To address more specifically the potential effects of “reduced” irrigation and “improved” grazing management, this study included a crop growth model (see Chapter 9). By using a model calibrated by the data collected, researchers simulated different levels of irrigation and grazing management to understand effects on forage production.

8. Hydrologic Monitoring Summary

8.1 Purpose and Objectives

Changes in vegetation species, diversity and production are directly related to the amount of water available for plant use (evapotranspiration). Soil hydrology data was collected as part of this study to fully understand the changes being observed and in order to predict what future changes might be under different irrigation water management regimes (see Chapter 9 on Hydrologic Modeling).

8.2 Methods Overview

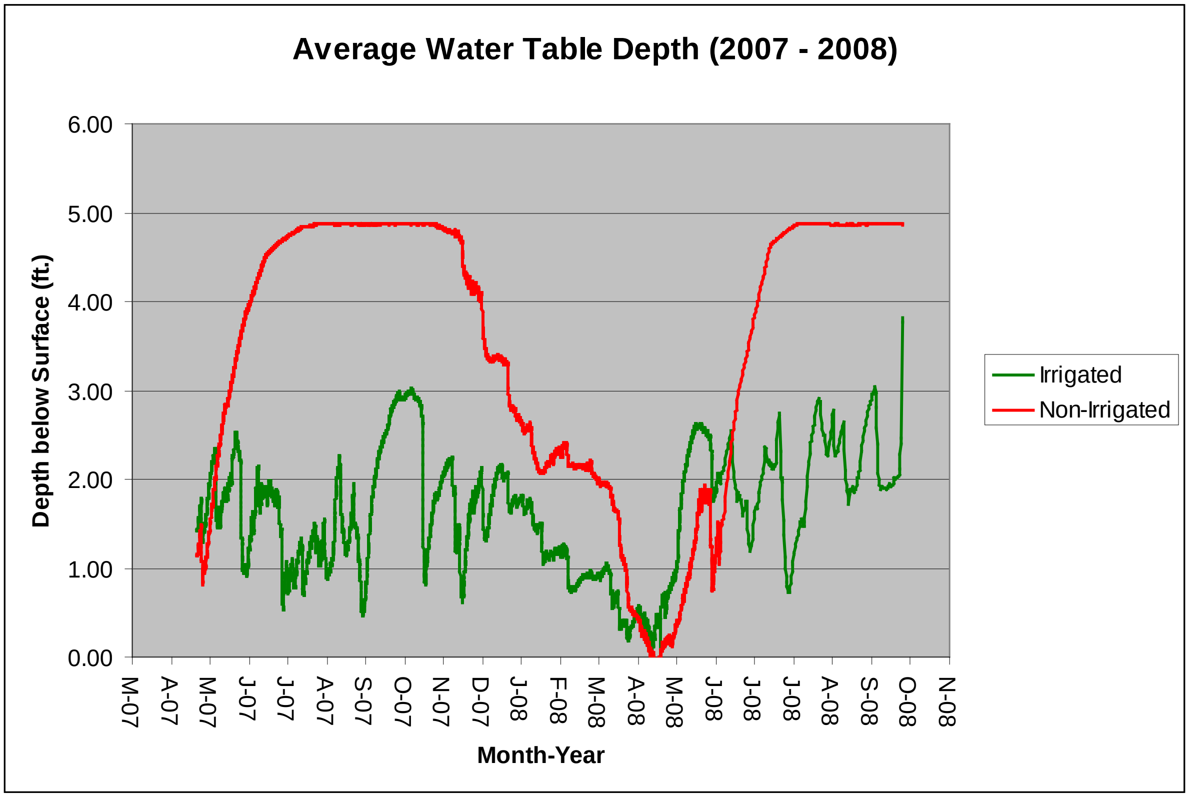
Soil hydrology data were collected within the exclosures of all of the sites. Water table elevation in the shallow aquifer was collected using pressure transducers installed between depths of 1.4 m (4.5 ft) to 2.0 m (6.5 ft). Data were collected at hourly intervals. For the non-irrigated sites the water table dropped below the pressure transducers during the summer months.

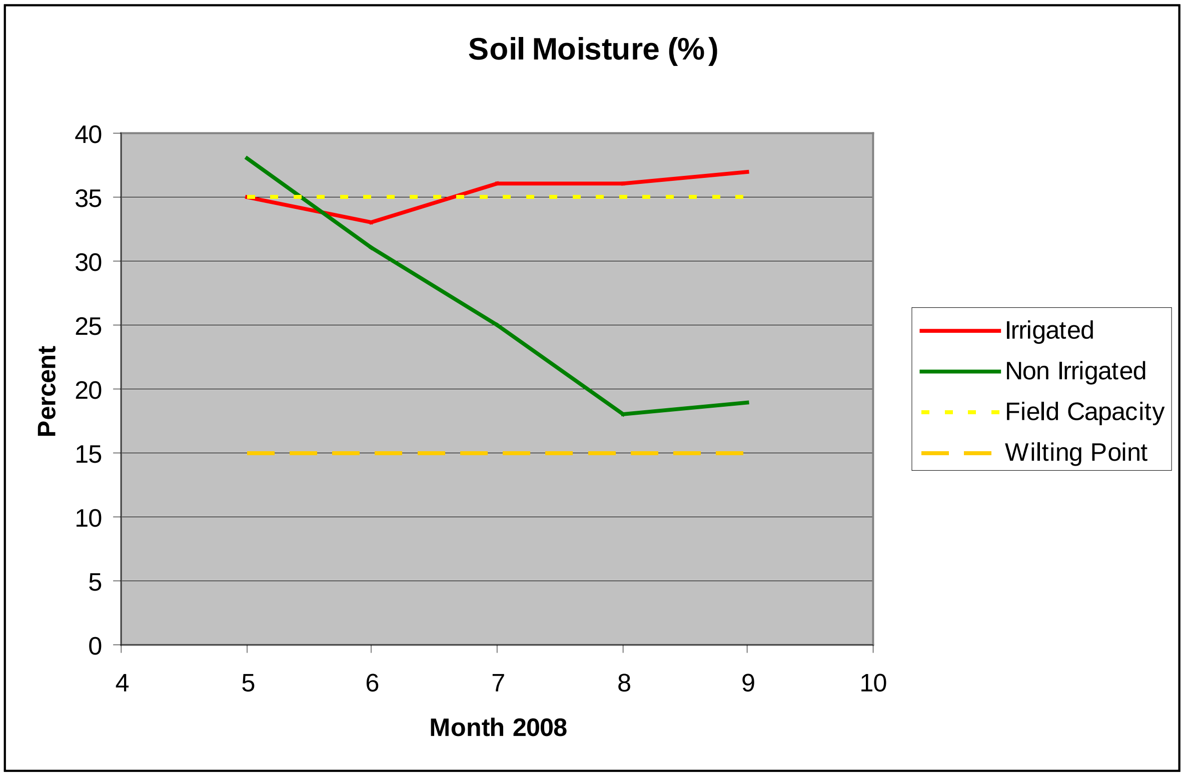
Soil water content was also collected using factory calibrated Time Domain Reflectrometry (TDR) probes. The factory calibration settings were found to be unsuitable for the volcanic andisols soils of the Wood River Valley because the soils have unique physical properties for their texture class, such as low bulk density, high porosity, and large specific surface area [Miyamoto et al., 2003]. As part of the Wood River Vegetation Monitoring study conducted by OSU, gravimetric soil moisture measurements were taken monthly during the summer of 2008 at irrigated and non-irrigated sites.

8.3 Status Assessment

The Wood River Valley is naturally sub-irrigated. Figure 17 shows that for both irrigated and non-irrigated sites water tables are at or near the surface in the spring. For non-irrigated sites water tables remain within 24 to 36 inches of the surface until June or early July. This is within the rooting depth of most deep rooted grasses. As the season progresses water tables decline to five or more feet (sensors were installed only to a depth of five feet [1.5 meters]) at non-irrigated sites while irrigation kept water tables with 12 to 36 inches of the surface.

Reliable soil moisture samples were limited in the spring – early levels were at or near field capacity in the spring and early summer for both irrigated and non-irrigated sites (see Figure 18). Irrigated sites were maintained at these levels, however soil moisture levels on non-irrigated sites declined to near the wilting point by the season’s end.





Figures 17 and 18. Plots of Average Water Table Depth and Soil Moisture.

9. Hydrologic Modeling: MIKE SHE/Daisy Models Summary

9.1 Purpose and Objectives

As previously stated, the primary objective of this CEAP study was to determine the optimum level of grazing and irrigation management that could be sustained both environmentally and economically on private lands. Observed data on forage production and hydrology only cover fully irrigated and non-irrigated scenarios with an approximate rest period of 25 to 35 days between clippings (harvests). In order to estimate production effects of other levels of irrigation and grazing management, computer simulation models were employed to simulate hydrology and crop production.

9.2 Modeling Background

Much attention in the Wood River Valley (WRV) over the last five to ten years has focused on reducing water demand by curtailing irrigation accompanied with reductions in cattle grazing intensity. Public funds have been expended to compensate ranchers for lost income through water banking and grazing forbearance programs. In 2006 the NRCS initiated this Wood River CEAP study in the Wood River Valley to determine the effects of irrigation and grazing forbearance on forage production and animal unit carrying capacity.

The models chosen to assist with the analysis were MIKE SHE a product of the Danish Hydraulics Institute (DHI) and DAISY. The European Hydrological System (SHE) was developed in the 1980s as a joint effort by the Institute of Hydrology, Societe Grenobloise d'Etudes et d'Applications Hydrauliques, and the DHI. These three groups have since developed SHE independently, and MIKE SHE is the DHI version of the model. MIKE SHE simulates the land phase of the hydrological cycle including ground water, soil moisture, overland (non-channelized) flow, precipitation and irrigation, and evapotranspiration.

MIKE SHE is a fully distributed, physically based model. It is very versatile with a modular structure that can be easily suited to project needs. The modules available in MIKE SHE include Overland Flow, Rivers and Lakes (requires MIKE 11), Unsaturated Flow, Evapotranspiration, Saturated Flow, and Advection-Dispersion for Water Quality. Each module is flexible, giving the user control over how the model is run. For example, the unsaturated flow module can be run using Richards Equation, gravity flow, and two-layer model that will be selected based on the user's requirements for accuracy and computational efficiency. Furthermore, MIKE SHE allows selection from two retention curve functions, three hydraulic conductivity functions and tabulated values for the fitting parameters. It is possible to set up very complex models but computational resources and time requirements become major factors in using MIKE SHE, especially when running 3-dimensional models over large areas or at fine spatial resolutions.

The DAISY model is a soil-vegetation-atmosphere transfer (SVAT) model used to simulate one-dimensional water balance, heat balance, solute balance and crop production in various agroecosystems. The model estimates maximum plant productivity as a function of carbohydrate production rate through photosynthesis in each development stage (e.g., germination, flowering, and maturation), then estimates actual plant productivity after accounting for stress factors (i.e. water and nitrogen deficiencies).

The DAISY model was used to simulate forage production for 8 irrigation levels and 2 grazing rest periods (total of 16 simulations). The MIKE SHE model was used to furnish time series groundwater elevations to the DAISY model for these 16 simulations.

9.3 Data and Modeling Parameters

Six irrigated and six non-irrigated pastures were selected to monitor the effects of irrigation and grazing forbearance. Grazing forbearance on non-irrigated sites has resulted in the reduction of herd sizes by 30 to 50 percent of the animal units customarily stocked on irrigated sites in the Wood River Valley. The CEAP Study monitoring work began during the 2007 growing season (April to November) and continued through the 2008 growing season. Each site (see Figure 3) had vegetation transects to measure plant composition, exclosures to measure crop growth and productivity, and continuous data loggers to measure the shallow water table elevation.

These data were used to construct and calibrate numerical models for pasture production (DAISY) and soil hydrology (MIKE SHE). These models where used to simulate intermediate levels of irrigation to develop curves describing crop production as a function of irrigation level. From these data animal unit carrying capacity can be described as a function of irrigation level. From these results an economic analysis could then be performed to determine the lost production value due to decreased irrigation, and a fair cost could be assigned to irrigation forbearance. In addition, optimal levels of grazing and irrigation may also be determined.

The full modeling report contained in Appendix 5 describes the numerical crop production and soil hydrology modeling performed by the Hydrologic Science Team at Oregon State University under the supervision of Dr. Richard Cuenca.

In addition to the hydrological modeling the OSU team undertook specifically for this CEAP study, Dr. Cuenca has been involved in measuring Evapotranspiration (ET) rates on both irrigated and non-irrigated sites in the Wood River Valley since 2003. The ET measurements Dr. Cuenca and team have reported show substantially different ET rates, which has implications for forage production and water usage/savings potential. Figure 19 below shows the data recorded in 2004. This type of data was used to help in build, calibrate, and validate the modeling process. Their work also represents the best estimates of potential water savings from reducing or eliminating irrigation. The differences in irrigated and non-irrigated ET varied from 257 mm (10.1 inches) to 320 mm (12.6 inches) for the years measured. Based on OSU's research the Klamath Basin Rangeland Trust as well as state and federal agencies have assumed approximate savings on an acre-foot of water per year in the Wood River Valley when irrigated pasture is converted to dryland management.

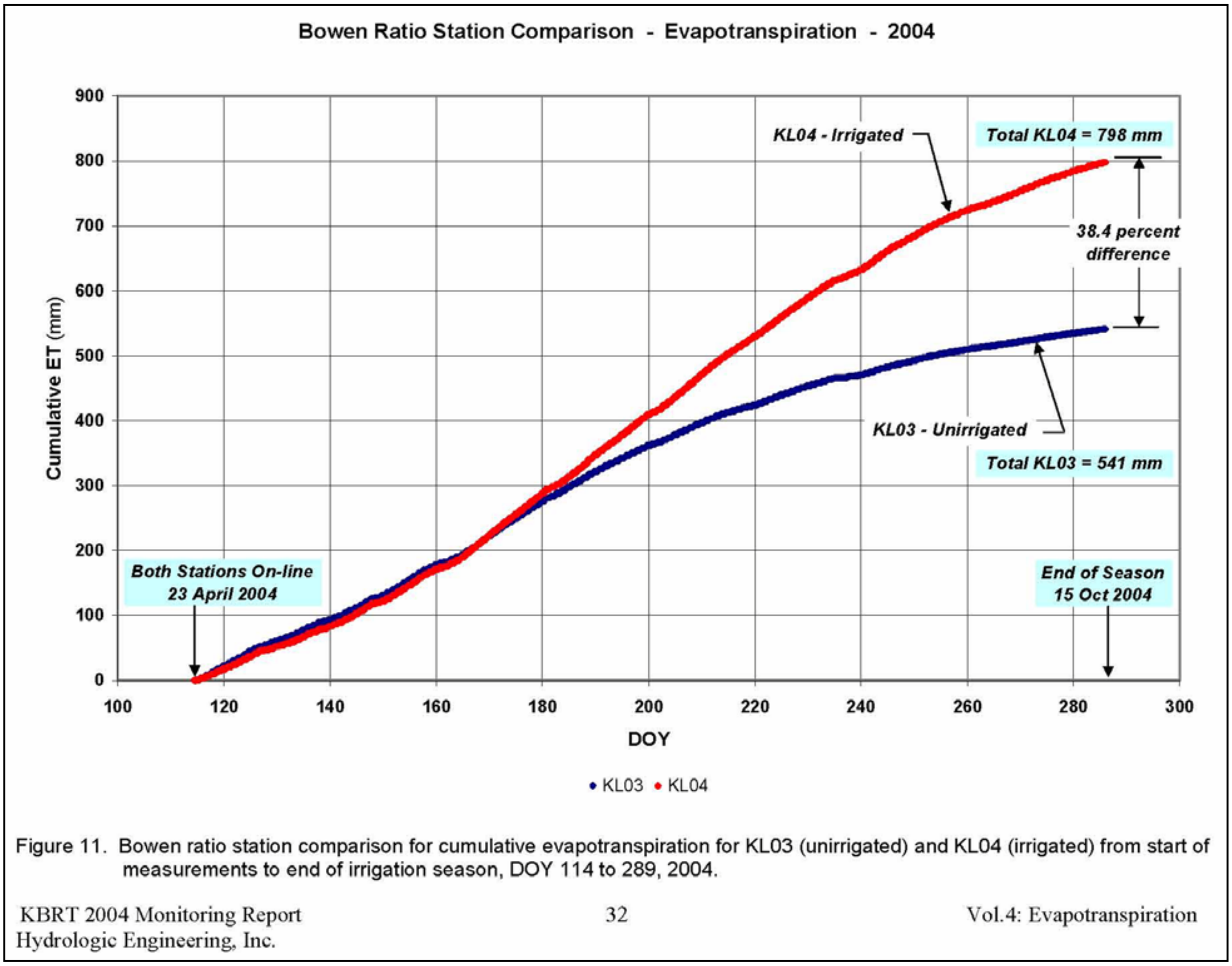


Figure 11. Bowen ratio station comparison for cumulative evapotranspiration for KL03 (unirrigated) and KL04 (irrigated) from start of measurements to end of irrigation season, DOY 114 to 289, 2004.

KBRT 2004 Monitoring Report 32 Vol.4: Evapotranspiration
Hydrologic Engineering, Inc.

Figure 19. 2004 Comparison of Evapotranspiration rates for irrigated and non-irrigated vegetation.

9.4 Methods Overview

9.4.1 Introduction

Appendix 5 contains the full modeling report detailing the methods used to model the data obtained during the field monitoring work. Much of the data used for the modeling process came from the grazing land vegetation monitoring and the hydrologic monitoring components of this CEAP study (described in Chapters 7 and 8). The following sections are a brief overview and summary of the process and methodology used for this component of the study.

9.4.2 Field Sites

As described in Chapter 7, section 7.3, a total of 12 field groups were used, consisting of 6 irrigated groups (1I, 2I, 3I, 4I, 5I, and 6I) and 6 non-irrigated groups (1N, 2N, 3N, 4N, 5N, and 6N) distributed throughout the Wood River Valley (See Figure 3). All irrigated sites were fully irrigated with no sites having reduced irrigation levels. Three vegetation transects and one vegetation exclosure were established at each site. Water table and soil moisture sensors connected to data loggers were placed within the exclosures. Fecal and forage quality data were also taken within each grouping. A digital elevation model (DEM) of the WRV with 1-m horizontal cell resolution was obtained via LiDAR supplied by the Klamath Basin Rangeland Trust.

9.4.3 Data Collection

In addition to using the plant production and composition, forage quality (plant and fecal sampling), and grazing management monitoring data previously described in Chapter 7, section 7.3, this modeling process also used data on soil hydrology, soil physical properties, meteorological conditions, and a digital elevation model.

9.4.3.1 Soil Hydrology

Soil hydrology data were collected within the exclosures of all of the sites. Water table elevation in the shallow aquifer was collected using pressure transducers installed between depths of 1.4 meters (4.5 feet) to 2.0 meters (6.5 ft). Data were collected at hourly intervals. For the non-irrigated sites the water table dropped below the pressure transducers during the summer months. Soil water content was also collected using factory calibrated Time Domain Reflectrometry (TDR) probes. The factory calibration settings were found to be unsuitable for the volcanic andisols soils of the Wood River Valley because they have unique physical properties for their texture class, such as low bulk density, high porosity, and large specific surface area.

9.4.3.2 Soil Physical Properties

Soil moisture retention curves and bulk density were obtained from NRCS National Cooperative Soil Survey (NCSS) Laboratory Characterization Data for a data sample taken near Fort Klamath (Pedon ID 67OR035013). Saturated hydraulic conductivity was obtained from an NRCS report that used an amoozemeter for in situ measurement. In addition, undisturbed soil cores were taken within field groups 3I, 4I, 6I, 2N, 4N, and 6N ranging in depth from 5 cm to 70 cm. The cores were then analyzed for soil moisture retention. Due to the length of time required to run this analysis and the suitability of the NRCS NCSS data, the soil core data were not been used in the simulations.

The soil hydraulic parameters used with MIKE SHE and DAISY were estimated based on these soil hydraulic data. Among different formulations implemented in MIKE SHE and DAISY, this study selected the van Genuchten and the Mualem equations (see Appendix 5).

9.4.3.3 Meteorological Data

Daily meteorological data used included mean daily air temperature, precipitation, global radiation, and alfalfa based reference evapotranspiration, which were obtained from the Agency Lake AgriMet Station (AGKO) located at the southern end of the Wood River Valley. MIKE

SHE and DAISY require the use of potential (grass based) evapotranspiration, which can be calculated (see Appendix 5).

9.4.3.4 Digital Elevation Model

The Klamath Basin Rangeland Trust provided a digital elevation model (DEM) of the WRV generated using LiDAR data collected from flights flown on 09/26/2004 and 09/27/2004 by Watershed Sciences, Inc. of Corvallis, OR.

9.5 Findings/Conclusions

9.5.1 Simulation Scenarios

Eight irrigation scenarios were simulated for this study. Table 4 lists these scenarios ranging from "full irrigation (Lv1-Lv4)" to "once a season (Lv5j-Lv5s)" to "no irrigation (Lv6)". Lv2 is assumed to represent the most commonly level of irrigation management currently practiced in the Wood River Valley.

Table 4. Simulation Scenarios - Irrigation timing[1].

Level	Frequency (Approx)	Application Dates
Lv1	Weekly	1, 7, 15, 22, of each month
Lv2	Twice Monthly	1, 15 of each month
Lv3	Monthly	1 of each month
Lv4	Bi-Monthly	5/1, 7/1, and 9/1
Lv5j	Once	7/1
Lv5a	Once	8/1
Lv5s	Once	9/1
Lv6	None	

[1] Irrigation timing for each level or scenario: irrigation duration is 24 hours. The irrigation season is defined as lasting from 5/1 to 9/30 in each year.

This study defines “rest period” in the model as the period between two grazing events with the grazing event taking place in one day. In continuous grazing cattle are allowed to migrate within a large pasture and will intensely graze a small area then move on, giving the area a rest period before the cattle return. Higher stocking rates will lead to increased grazing intensity and a decreased rest period. It was considered that the common grazing intensity in the Wood River Valley can be best represented by a 10-day rest period. The 8 irrigation scenarios were also run with a 30-day rest period to assess effects of the longer rest period on the pasture systems.

This analysis was done based on the results from 16 simulations (8 irrigations x 2 rest periods) during the April through October growing seasons from 2005 to 2008.

9.5.2 Model Calibration and Validation

9.5.2.1 Daisy Model Performance

Model performance for DAISY was assessed by comparing the observed vs. simulated crop production data for 2007 and 2008. Figure 20 shows a plot of simulated vs. observed values.

The results show a good fit between the model output and observed values of monthly production. The R^2 coefficient of determination for the Irrigated data is 0.96 and the R^2 for the non-irrigated data is 0.92.

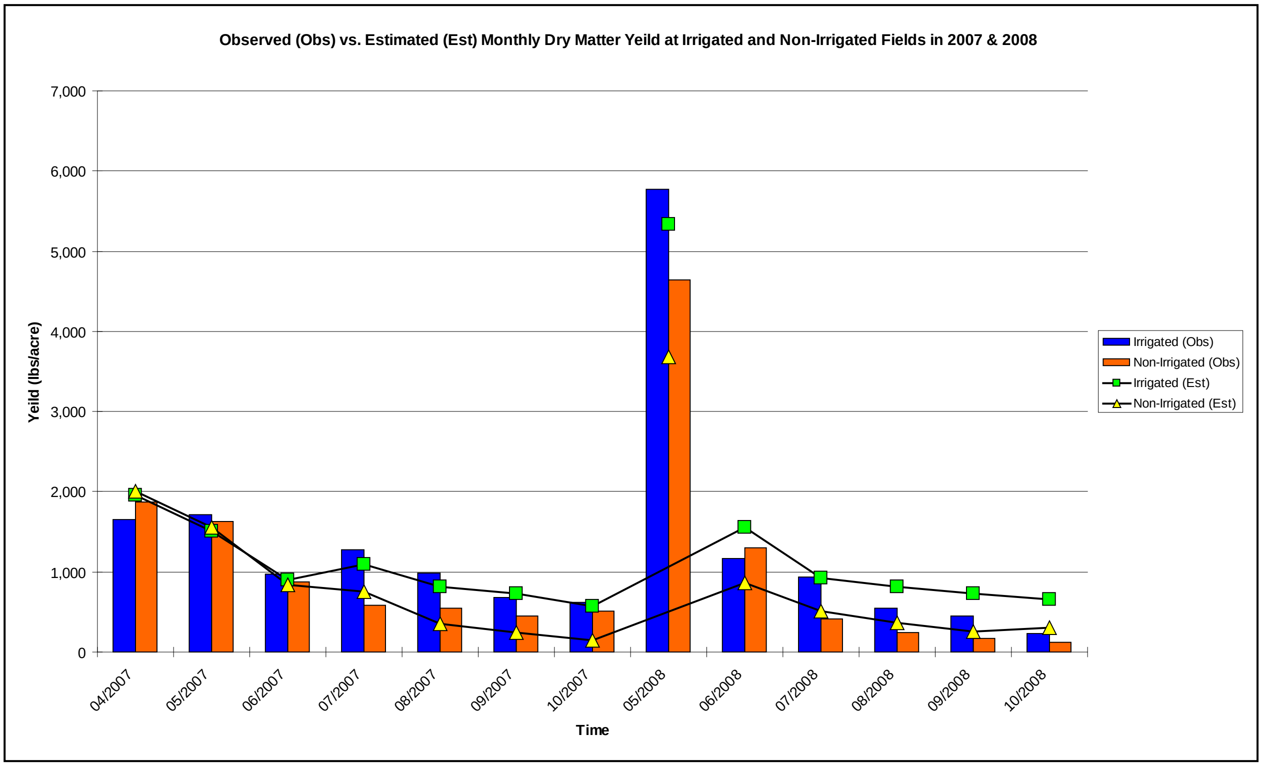


Figure 20. Simulated and Observed Crop Production for 2007 and 2008.

9.5.2.2 MIKE SHE Model Performance

Model performance for MIKE SHE was assessed by comparing observed vs. simulated water table data for site 4N which are shown as a time series in Figure 21. Table 5 displays the goodness of fit parameters for both the calibration period (2007) and validation period (2008). Both the R^2 and Nash-Sutcliffe statistics indicate a good model fit with observed data.

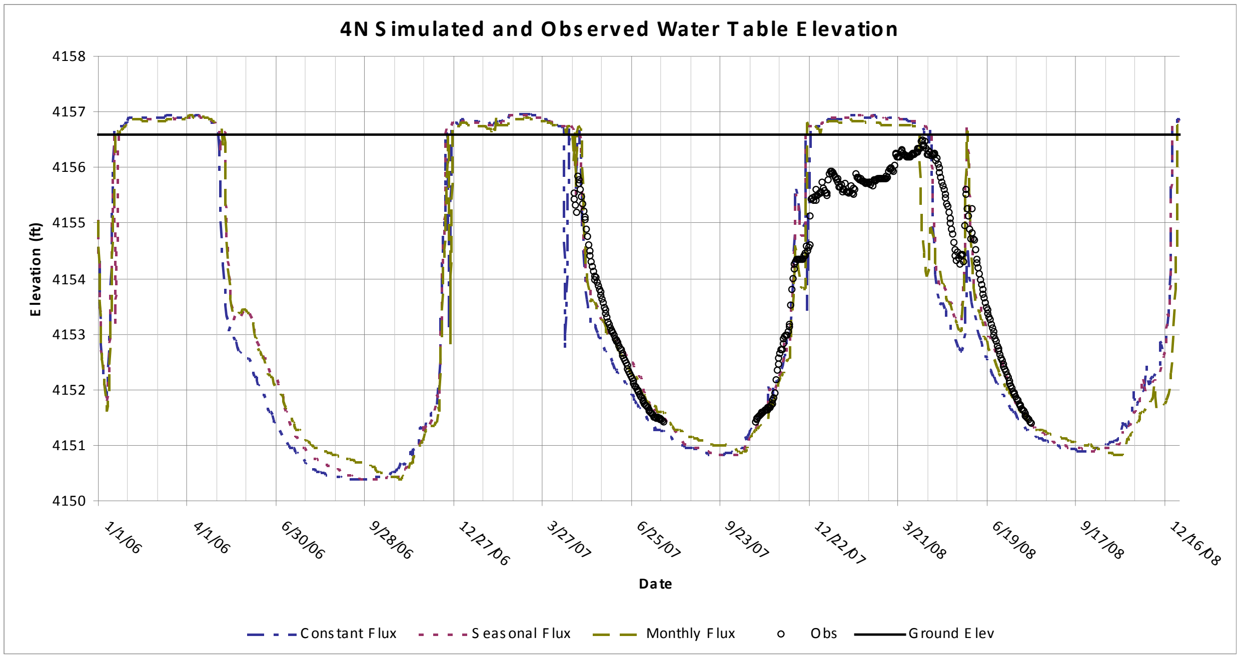


Figure 21. Simulated and Observed Water Table Elevations for Site 4N, 2006 to 2008.

Table 5. Goodness of fit parameters for the calibration period (2007) and validation period (2008).

Parameter	Constant Flux		Seasonal Flux		Monthly Flux	
	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008
Nash – Sutcliffe	.731	.415	.773	.573	.796	.515
Nash – Sutcliffe[1]	.763	.503	.893	.725	.887	.597
R^2	.846	.762	.871	.799	.871	.735
$R^{2\ (1)}$	.868	.779	.895	.802	.899	.769

[1] These parameters were calculated for 01 April to 31 October.

9.5.3 Results for 10-Day Grazing Rest Period

Table 6 summarizes the irrigation and plant production results from MIKE SHE and DAISY with a 10-day rest period that represents the typical grazing management in the Wood River Valley (results have been converted from metric units). In Table 6 Irr is the total water applied during the growing season including irrigation and precipitation and Prod10 is the total monthly plant production with a 10-day rest period.

Table 6. Total water applied and plant production with 10-day rest period during the growing season (May to October).

Level	2005		2006		2007		2008	
	Irr	Prod 10	Irr	Prod 10	Irr	Prod 10	Irr	Prod 10
	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)
Lv1	35.8	5,019	33.2	5,483	35.6	4,313	32.0	5,438
Lv2	36.1	4,867	32.0	5,340	33.9	4,197	32.8	5,251
Lv3	34.5	4,554	28.9	5,045	33.3	3,893	31.9	5,054
Lv4	37.3	4,224	32.7	4,760	35.7	3,679	33.8	4,679
Lv5j	13.7	4,081	15.7	4,635	19.2	3,465	17.2	4,528
Lv5a	18.4	4,072	15.7	4,617	19.2	3,438	17.2	4,510
Lv5s	18.4	3,974	15.7	4,510	19.2	3,322	17.2	4,438
Lv6	4.3	3,777	1.5	4,340	5.0	3,179	3.1	4,260

Figure 22 displays the monthly forage production simulated for each of the 8 irrigation scenarios with a 10-day rest period. Spring production is similar for each of the scenarios while late season production decreases with decreases in irrigation frequency. All production, even with full irrigation, decreases during the late summer and fall. The DAISY simulation results suggest that nitrogen availability in the pasture systems in the Wood River Valley (no external nitrogen sources) is not sufficient to support full productivity throughout the growing season (see Appendix 5 for more details).

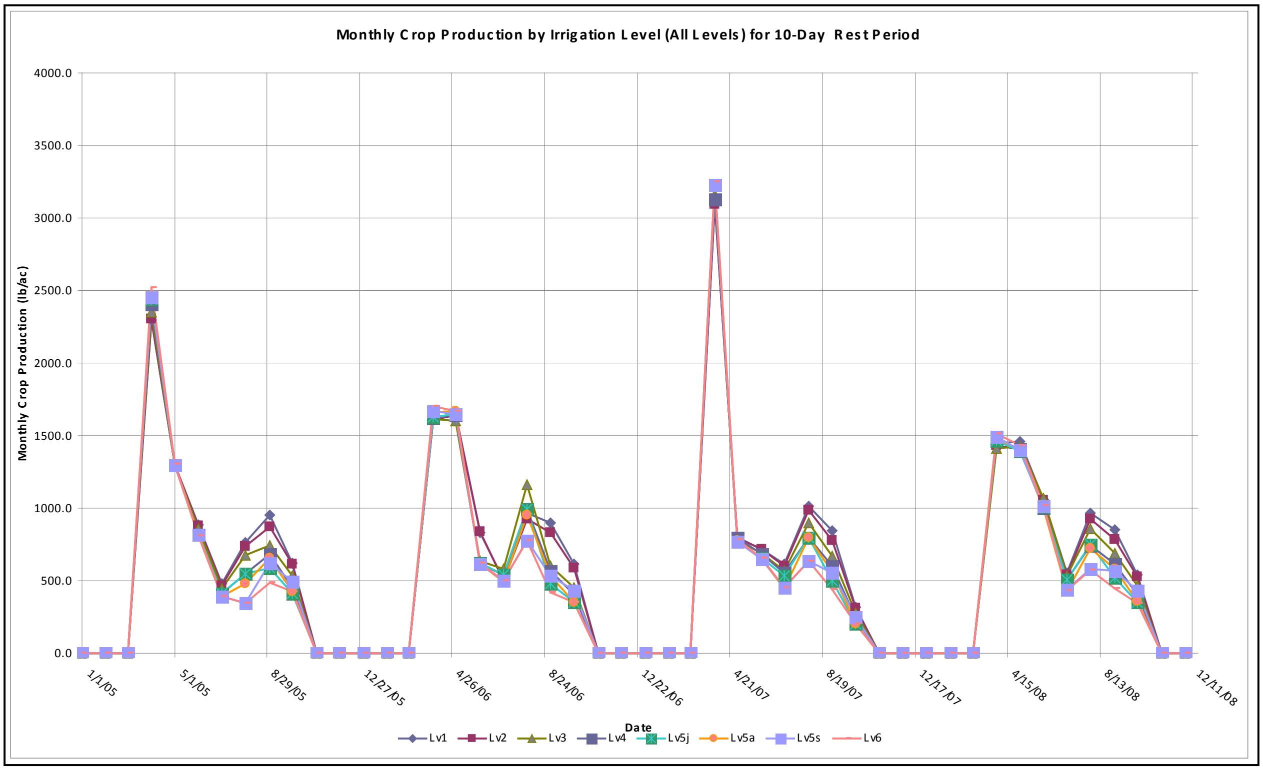


Figure 22. Four-year (2005-2008) Simulated Monthly Crop Production for a Rest Period of 10 days.

Table 7 shows the average monthly production for each irrigation scenario under a ten day rest period grazing scheme.

Table 7. Average monthly production for each irrigation group with the 10-day rest period (Prod10).

	Avg. Lv 1-4	Avg. Lv 5	Avg. Lv 6	% Change[1]	Std. Dev.[2]
	lb/ac (kg/ha)				
2005	4,660 (5,224)	4,039 (4,528)	3,772 (4,228)	-19.1	456 (511)
2006	5,152 (5,775)	4,581 (5,135)	4,335 (4,860)	-15.9	419 (470)
2007	4,017 (4,504)	3,406 (3,818)	3,176 (3,560)	-20.9	435 (488)
2008	5,101 (5,718)	4,486 (5,029)	4,251 (4,766)	-16.7	439 (492)
Average	4,733 (5,305)	4,128 (4,628)	3,883 (4,353)	-17.9	
STDEV[2]	525 (589)	536 (601)	533 (597)		

[1] percent change from Avg. Lv1-4 to Lv6.

[2] Note that the standard deviation (STDEV) between years (bottom) is larger than the Std.Dev. between irrigation groups (right).

Scenarios Lv1-4 approximate full irrigation (keep water tables elevations and soil moistures adequate for crop use). Lv5 scenarios represent supplementary irrigation. Lv6 is no irrigation other than sub-irrigation from high water tables. Percent change is the average difference between full irrigation scenarios Lv1-4 and no irrigation Lv-6. Production reduction from no irrigation ranges from 15.9 to 20.9 percent and average 17.9 percent less over the 4 years of simulations. Likewise, Lv5 scenarios produced 12.8 percent less forage than the full irrigation over the same time period.

9.5.4 Results for 30-Day Grazing Rest Period

Another set of simulations was done with a 30-day rest period using the same meteorological and field hydrological data to assess the effect of longer rest periods (shifting from continuous grazing to rotational grazing) on the pasture systems in the Wood River Valley.

Table 8 summarizes the irrigation and plant production results from MIKE SHE and DAISY with the 30-day rest period. Prod 30 is the total monthly plant production with the 30-day rest period.

Table 8. Total water applied and plant production with 30-day rest period during the growing season (May to October).

	2005		2006		2007		2008	
Level	Irr	Prod 30	Irr	Prod 30	Irr	Prod 30	Irr	Prod 30
	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)
Lv1	35.5	5,474	32.9	5,412	35.3	5,304	32.0	5,912
Lv2	35.9	5,340	31.8	5,251	33.7	5,215	32.8	5,769
Lv3	34.6	5,010	29.0	4,929	33.5	4,885	31.9	5,429
Lv4	37.6	4,724	33.0	4,697	36.0	4,653	33.8	5,188
Lv5j	13.8	4,608	15.8	4,572	19.3	4,536	17.2	5,081
Lv5a	18.5	4,608	15.8	4,617	19.3	4,483	17.2	5,019
Lv5s	18.5	4,519	15.8	4,492	19.3	4,367	17.2	4,894
Lv6	4.2	4,358	1.5	4,349	5.0	4,251	3.1	4,760

Figure 23 displays the monthly production results for each of the 8 irrigation levels with a 30 day rest period assumed between grazing. As with the 10-day rest period, early season crop production is similar for all 8, although scenarios with less frequent or no irrigations decline more dramatically later in the growing season. Table 9 shows the average monthly production for each irrigation scenario under a 30 day rest period grazing scheme.

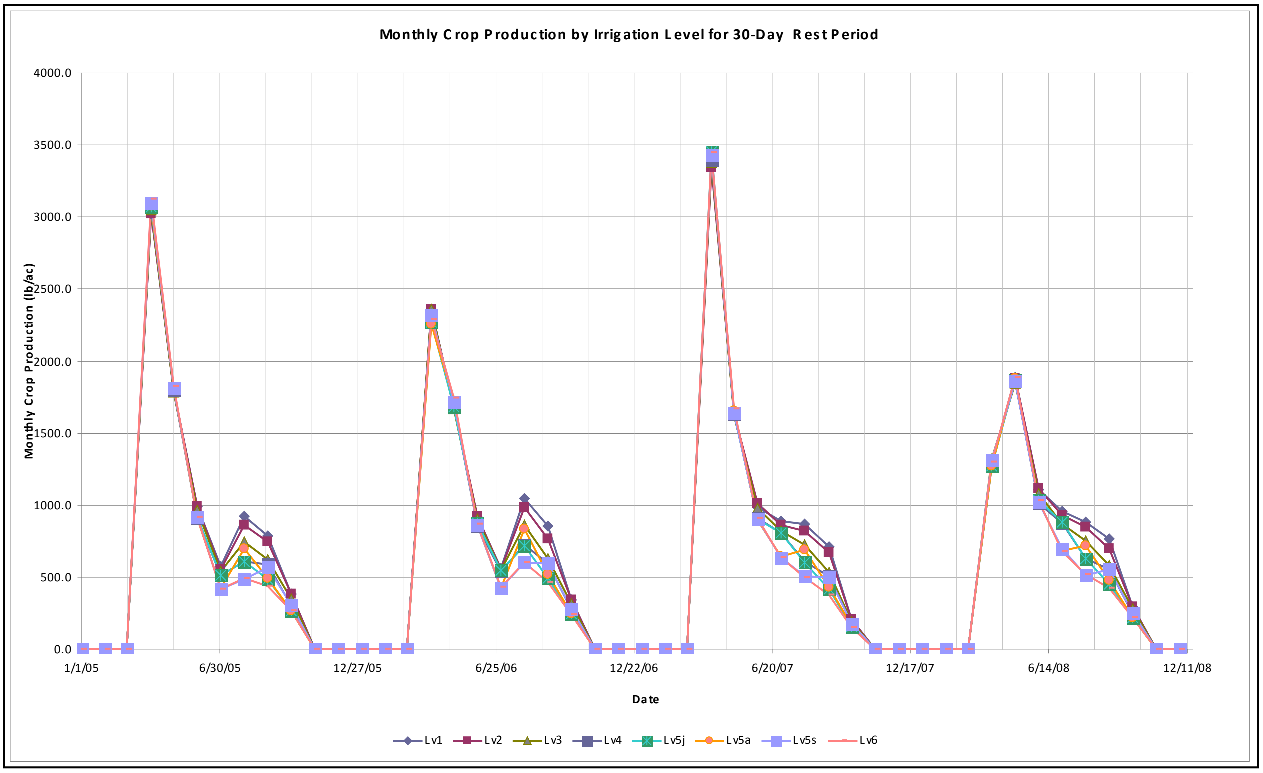


Figure 23. Four-year (2005-2008) Simulated Crop Production for a Rest Period of 30 days.

Table 9. Average monthly production for each irrigation group with the 30-day rest period (Prod10).

	Avg. Lv 1-4	Avg. Lv 5	Avg. Lv 6	% Change[1]	Std. Dev.[2]
	lb/ac (kg/ha)				
2005	5,131 (5,753)	4,573 (5,127)	4,357 (4,885)	-15.1	399 (448)
2006	5,065 (5,678)	4,555 (5,106)	4,347 (4,874)	-14.2	369 (414)
2007	5,008 (5,615)	4,459 (4,998)	4,249 (4,763)	-15.2	392 (440)
2008	5,567 (6,241)	4,993 (5,598)	4,757 (5,333)	-14.6	417 (467)
Average	5,193 (5,822)	4,645 (5,207)	4,427 (4,964)	-14.7	
STDDEV[2]	254 (285)	238 (266)	225 (252)		

[1] percent change from Avg. Lv1-4 to Lv6.

[2] Note that the standard deviation (STDEV) between years (bottom) is larger than the Std.Dev. between irrigation groups (right).

With a 30-day rest period, production reduction from no irrigation ranges from 14.2 to 15.2 percent and averages 14.7 percent less over the 4 years of simulations. Likewise, Lv5 scenarios produced 10.6 percent less forage than with full irrigation over the same time period. A reduction in forage production due to less frequent irrigation is less pronounced with a 30-day rest period between grazings than with a 10-day rest period.

9.5.5 Modeling Conclusions

This modeling study as well as the Wood River Valley Vegetation Monitoring Summary 2007-2008 report in Appendix 2 both show that there is a small, but appreciable decrease in pasture production between the irrigated and non-irrigated treatments. When considering years individually there is a consistent reduction in productivity in the non-irrigated sites (average 17.9 percent with a 10-day rest period, 14.7 percent with 30 day rest period).

DAISY simulation results suggest that nitrogen availability in the pasture systems in the Wood River Valley (no external nitrogen sources) is not sufficient to support full productivity throughout the growing season.

For better appreciation of the effect of irrigation management on pasture productivity, an additional comprehensive nutrient study is recommended.

The pasture productivity for the 30-day rest period is higher than that of the 10-day rest period as seen in Figures 22 and 23.

Another key feature of the 30-day rest period is that the year to year variation is much lower, which indicates using a 30-day rest period in grazing management enables a more consistent productivity from year to year to mitigate environmental factors that would cause productivity to drop for a given year.

One possible affect of the current patchwork of irrigated and non-irrigated fields in the WRV is that the irrigated fields may contribute to maintaining a higher water table across the WRV making sub-irrigation from the shallow aquifer to the non-irrigated sites possible. If more landowners forgo irrigation, resulting in significant amounts of land being taken out of irrigation, there may be basin-wide implications due to a lower water table.

Finally, the analysis seems to suggest that a single irrigation in July along with an increase in grazing rest period to 30 days could produce up to about 95 percent of the forage as the current, fully irrigated (every 14 days), continuous grazing scenario. This possibility suggests that in the Wood River Valley some ranches could use less water and still maintain a fairly high level of forage production. Whether any ranches chose to move towards this type of management will depend on their own specific economic considerations and situation.

10. Economic Analysis Summary

10.1 Purpose

As indicated in the Chapter 1, Wood River Valley Profile, livestock grazing is the dominant form of land use on the nearly 40,000 acres of private lands in the Wood River Valley. Grazing is an important economic activity in the valley that is and has been impacted by the water and fisheries resource concerns of the Upper Klamath Basin.

The semi-arid, western United States' grazing lands, including the irrigated/sub-irrigated Wood River Valley, require effective and efficient stewardship of water resources to maintain environmental and economic health. The need for this attentiveness became especially evident during the drought of 2001, which brought the Upper Klamath Basin to the attention of the national media. In 2002, the Klamath Basin Rangeland Trust teamed up with some of the Wood River Valley ranchers to begin searching for different ways of managing their businesses that would allow them to be more effective and efficient with their water supplies (e.g. irrigation), to provide for healthy biotic systems (e.g. riparian restoration), and to remain economically viable and sustainable (e.g. grazing).

For example, a concerted effort has been made since 2002 to restore riparian habitat both to protect endangered fish (with economic implications for Tribal groups; the recreational "catch-and-release" program and commercial fishing) and to improve water quality. Similarly, the various partners in the valley have found ways to shift to dryland grazing and water banking (non-irrigation) to conserve water and to shift grazing techniques by reducing herd sizes, fencing riparian areas, and implementing rotational and intensive grazing management practices.

In spite of these shifts many questions were being raised about the long-term feasibility or sustainability of these shifts in grazing management and irrigation practices. This study was initiated to try to answer some of the more pressing concerns related to the changes in irrigation and grazing practices being implemented since 2002.

10.2 Objectives

A primary objective of the economic analysis was to determine the optimum levels of grazing and irrigation water management that could be sustained economically and environmentally in the Wood River Valley without public financial assistance.

10.3 Methods Overview

Several ranches in the Wood River Valley have participated in financial assistance programs that have allowed them to not irrigate their pasture land in exchange for compensation for the value of the forgone forage. Through these programs the ranchers received compensation for allowing their water rights allocations be used for downstream uses (e.g. sucker and salmon needs, downstream irrigation on Bureau of Reclamation project lands) and for reducing their herd sizes as a result of the expected decreases in forage production from not irrigating their pastures. The ranches ranged in size from 400 to 3,000 acres, with the typical ranch encompassing about 1,000 acres of grazing land.

Interviews and surveys were designed and used to collect data on the impacts to the ranchers from management changes. Data was collected to begin examining the benefits and costs of management changes to:

- stocking density
- grazing lease payments
- changes in veterinarian and herding costs
- insect and weed population changes (inasmuch as these have implications for increased or decreased use of insecticides/herbicides)
- livestock weight changes
- reduced irrigation costs
- changes in supplemental feed costs
- fence and canal maintenance
- forage utilization

Eight ranchers/managers/operators in the valley were interviewed between October 15 and 17, 2008. Due to differences in how the various ranchers operate in the valley (e.g. the varied lease arrangements, different levels of detail in management records, different levels of willingness or ability to provide detailed information, etc.) a detailed economic analysis was not possible. However, from the information that was collected, along with the results from forage production modeling, a generalized comparison was made of likely shifts in benefits, costs, and unaffected items.

10.4 Results/Findings

10.4.1 Management Scenarios

Chapter 9 contains the results of the MIKE SHE/Daisy model simulations of forage production under different management scenarios. This simplified economic analysis compared three scenarios: typical irrigation and grazing (LV2 with 10 day rest), reduced irrigation with improved grazing (LV5 average with 30 day rest) and no irrigation and improved grazing (LV6 with 30 day rest). These combinations most closely approximate the levels of irrigation and grazing intensity currently practiced with scenarios that conservationists might recommend to maximize both ranching and environmental benefits.

Table 10 below summarizes results from Chapter 9 for these three scenarios.

Table 10. Management Scenarios.				
	Average Production		Average Value per acre	Average Gross Revenue for 1,000 acre Ranch
Management Scenario	lbs/acre	% of Lv2	Dollars/ acre	Dollars/ 1,000 acres
Typical Irrigation and Grazing (Lv2 with10 day rest)	4,914	100.0%	$270	$270,300
Reduced Irrigation and Improved Grazing (Lv5 Avg with 30 day rest)	4,645	94.5%	$255	$255,500
No Irrigation and Improved Grazing(Lv6 with 30 day rest)	4,427	90.1%	$243	$243,500

Most landowners in the Wood River Valley lease their lands to ranchers from out of the region who bring their cattle to the Wood River Valley to graze each season. The basis of payment to Wood River landowners varies. Payment can be based on a per acre basis, weight gain of cattle for the season or for the number of animal unit months of grazing provided. Each landowner/ rancher should evaluate the information contained in this report to determine their own ranch economics. However in order to provide some reference as to the potential impacts of these three scenarios, this analysis will value forage as if it were grass hay. According to USDA Market News as of January 2010 the average "freight on board" price for good quality alfalfa hay was $110 per ton or $.055 per pound (USDA, 2010). Using this value for the forage produced in the Wood River Valley along with the forage production simulation results would indicate for the average 1,000 acre ranch a $22,200 decrease in revenue for reduced irrigation and improved grazing (Lv5 with 30 day rest) up to a $40,180 decrease with no irrigation and improved grazing (Lv6 with 30 day rest). In order to break with typical irrigation and grazing practices (Lv2 with 10 day rest), landowner must find other ways to increase revenues and reduce costs. Table 11 (at the end of this chapter) summarizes potential revenue and cost categories which were mentioned in landowner interviews as potential sources to offset revenue losses.

10.4.2 Benefits

10.4.2.1 Increased Revenues

Interviewees indicated that the forage in the non-irrigated pastures is stronger, better quality and more vigorous, which may partially offset some of the stocking level reductions. Some ranchers indicated cattle on dryland seemed to experience a faster rate of gain although this could not be substantiated with measured observations or from estimates of rate of gain obtained from fecal sample analyses.

10.4.2.2 Reduced Costs

Typically ranches in the Wood River Valley are irrigated from 10 to 15 times per season or approximately once every other week. The reduced irrigation scenario assumes that only one irrigation would occur late in the season – August or later. Pumping costs may or may not have changed. Most ranches in the valley use (or formerly used) flood irrigation methods which incur little in the way of pumping costs for irrigation. Much of the pumping done in the Wood River Valley is during the spring and is done to pump water off the fields. Where draining the fields occurred there was no change in pumping costs. However, for those ranches that used irrigation pumps prior to switching to non-irrigation there was a reduction in energy/ power costs. For those ranchers who switched to dryland management practices, many experienced reduced ditch maintenance costs. They were able to eliminate some lateral ditches using a scraper blade or ditch plow (once every three years). However, some ranchers did not experience a change in ditch maintenance due to the need to water cattle. Time to open and close irrigation gates/dams would be substantially reduced with either reduced or no irrigation scenarios.

In some cases, the cessation of irrigation has led to a reported decrease in pests. Removing irrigation water decreased the mosquito population and associated risk of illness. This may have resulted in potential increases livestock weight gain. The ranchers also reported experiencing a reduction in plant pests either due to the lack of water or the reduction in stream/ditch bank erosion.

Some ranchers reported a decrease in veterinarian bills. Ceasing irrigation may reduce foot rot, cut respiratory illness and phenomena, decrease eye problems, and reduce Coccidiosis[6]. In addition, it appears the cattle seem to recover faster from illnesses when not left in standing water.

Fence maintenance seemed to be a mixed bag as to whether there were increases or decreases experienced with a change in management. Some ranchers reported no significant change while others increased fencing and maintenance costs. Many ranchers added additional cross fencing for cattle rotations and to protect riparian areas.

10.4.3 Costs

10.4.3.1 Reduced Revenues

As reported above there is a potential loss in revenue from switching to less frequent irrigation from $15,000 to $27,000 for a 1,000 acre ranch.

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[6] Coccidiosis is a parasitic disease of the intestinal tract of animals, caused by coccidian protozoa. The disease spreads from one animal to another by contact with infected feces or ingestion of infected tissue.

10.4.3.2 Increased Costs

Converting pastures from a continuous grazing system where cattle have season long access (simulated as 10 day rest period) to one that mandates a 30 day rest period would increase herding costs. These grazing systems typically involved four or more pastures that were grazed at least once per season, with cattle moved one to six times per month, and required two people per rotation and one day to complete.

Anecdotally, some ranchers indicated they saw the removal of irrigation water as resulting in increases in the grasshopper population with an attendant risk of reduced forage production. However, there are others who believe that there are natural cycles in pest populations and that the outbreak of grasshoppers observed the first year of non irrigation was a natural phenomenon. Subsequent to that first year the grasshopper population has not been a major problem. Whether the reduced irrigation caused or contributed to a grasshopper population explosion remains an unresolved issue. However, there were increased costs to ranchers in the valley for treatment of the grasshopper outbreak.

10.4.4 Unchanged, Uncertain, or Undocumented Impacts

Ranchers report having seen significant changes in the wildlife with the switch to dryland management. Anecdotally, the ranchers report that there has been a significant increase in bird populations, including migratory, water fowl, and raptors. Similarly, ranchers in the valley reported that they have seen the fish populations, including special status species increase greatly. These changes are undocumented and were not included as part of this CEAP study.

Weed problems vary by ranch. Most ranchers interviewed experienced some weed problems as the forage adjusted to the drier conditions of non-irrigation. Overall most ranchers reported having fewer problems with weeds than before due to reduced erosion and stream bank damage. Weed populations were examined during this study and found to be a site-specific problem in both irrigated and non-irrigated areas.

Because almost all cattle in the Wood River Valley are brought in from outside areas in the spring and removed in the late fall there is little need for supplemental feeding regardless of whether there is irrigation or not. Ranchers who switched to non-irrigation reported no change in the use of mineral block or protein supplements. It may be possible that a little more salt is used when pastures are irrigated because of the wetter soils and a higher percentage of water in forage species.

Cattle hauling costs did not change on a per animal basis between irrigated and non-irrigated ranches. However, with fewer cattle being grazed on the dryland pastures fewer animals were hauled.

Table 11 summarizes some of the benefits and costs assumed to result from a change in management practices.

10.4.5 Economic and Environmental Sustainability

Costs and returns reported by landowners varied considerably. The data and modeling results generated in this study should provide information to help individual ranchers determine what changes may be optimum for them economically.

Previous studies by KBRT and Oregon State University (Cuenca, 2004) show that converting irrigated pasture to dry land reduces evapotranspiration of water by 12.6 acre-inches per acre. Eliminating irrigation tail water intuitively should improve water quality. Restoring riparian habitat along with increasing summer base flows in valley streams by reducing irrigation diversions improves habitat for fish and other wildlife.

While this study did not specifically identify an environmental and economic sustainable level, it did provide information ranchers and natural resource managers can use to make this determination.

Table 11. Preliminary Economic Analysis.

Benefits	Costs
Increased Revenue • Increased weight gain • Reduced weight shrinkage during shipment	Decreased Revenues • Reduced grazing income – smaller heard • Increased pests – grasshopper outbreak
Reduced Costs • Reduced irrigation costs • Reduced ditch maintenance • Decrease in pests - mosquito population • Decrease in vet bills • Decrease in fence maintenance • Decrease in labor due to irrigation	Increased Costs • Increased livestock herding management •
Other • Reduced animal waste runoff into surface water • Improved water quantity and quality • Improved fish & wildlife habitat • Achievement of watershed goals	

11. Synthesis and Discussion of Study Component Results

11.1 Introduction

Chapter Three describes the various investigative components of the Wood River CEAP study. These investigative components were designed and implemented in response to the goals and objectives laid out in Chapter Two of this report. Although each of these different investigative components were implemented somewhat independently, the intention was to bring the pieces together to try and answer questions raised about shifts in irrigation and grazing management in the Wood River Valley over the last eight years or so.

Chapters Four through Ten described the different study components and the results and findings from the independent investigative components. Chapter Eleven attempts to unite the various components and describe those ties and relationships the investigators considered most significant; describe conclusions most clearly supported by our investigations; and describe information that would be most relevant to the landowners, land managers, and conservationists of the Wood River Valley area.

As noted in Chapter 3, section 3.4, the discussions contained in Chapters Four through Ten are summarizations from the many reports submitted by the different study teams. The technical appendices contain copies of the final, full reports prepared by the various investigative teams. For more complete information, findings, and conclusions on any of the investigative components refer to the technical appendices.

11.2 Summary of Significant Study Findings and Conclusions

11.2.1 Riparian Areas and Aquatic Habitats

As reported in Chapter 5 and 6, Sevenmile Creek in Aquatic Reaches 5 and 6 (see Figures 8, 9, 10) exhibited the most substantial changes to aquatic habitat and riparian condition from those measured and monitored in 2002 and 2003. Changes in management to the land along these reaches included riparian fencing, grazing management shifts, and cessation of flood irrigation in the nearby fields, including the stoppage of substantial water diversions that essentially dewatered portions of the creek in the summer and fall.

Aquatic Reach 6 exhibited the most significant measured changes to aquatic habitat. Aquatic Reach 6 likely saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches [coming off public lands with generally well-managed riparian conditions], (2) it has a much steeper gradient than the other reaches studied (4-5 times steeper) thus providing considerably more energy with the increased stream flows to scour the stream bed, and (3) it likely saw the highest percentage increase in base flow over the prior to the management, which essentially dewatered the reach for much of the summer. In addition, Aquatic Reach 6 received riparian fencing and grazing management shifts starting in 2004, whereas reaches further downstream received more recent riparian fencing and grazing management shifts. Aquatic Reach 5 and Aquatic Reach 2 received riparian fencing and grazing management shifts in 2006 and 2005 respectively.

Monitoring showed that fish habitat greatly improved as measured by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved condition of the riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 riparian vegetation was dominated by species more common to drier conditions, but with a component of species found only in riparian areas. Future monitoring of this reach should indicate whether the riparian vegetative community is changing to or away from species with good bank-holding or stabilizing root or rhizomatous root systems.

Aquatic Reach 6 demonstrated some of the possibilities for improvement to channel and riparian conditions in the Wood River Valley over a 5 year period with shifted management practices. However, conditions in other streams and creeks in the Wood River Valley tend to be more similar to Aquatic Reaches 2 and 5. That is, they are low gradient/low energy systems. Often water courses in the valley have been straightened, contained within dykes, have substantial irrigation water diversions or returns, and/or are freely accessed by cattle.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This slow improvement is likely due to the very low gradient of the reach and probably the relatively recent riparian fencing and grazing management shift (2006 compared to 2004 in Aquatic Reach 6). With less energy available to foster change, shifts may take a much longer period of time to manifest. The Aquatic Reach 5 riparian zone is dominated by vegetation species with good bank-holding or stabilizing root or rhizomatous root systems, which can be considered a positive sign. Future monitoring will indicate whether the riparian zone vegetation is shifting towards or away from such a beneficial plant community.

It seems feasible that given the more recent shifts in management in Aquatic Reach 5 (as compared to Aquatic Reach 6) that this stretch of river may already be benefitting from the changes in grazing and riparian conservation practices. In addition, it seems likely that if Aquatic Reach 6 conditions continue to improve (e.g. amount of large woody debris in the system, in-stream morphology, amount and type of sediment transport, etc.) there may be a beneficial influence to downstream reaches, including Aquatic Reach 5 (which had management changes implemented two years later than Aquatic Reach 6).

Aquatic Reach 2 is the lowest-gradient, furthest downstream reach studied on Sevenmile Creek. It showed little change from the 2002/2003 aquatic habitat measurements. Riparian vegetation community delineation was not done for this stretch of river.

Overall, restoring riparian areas in the Wood River Valley contributes to improved riparian and aquatic habitats; increased populations of macroinvertebrates and fish; and deepened and narrowed stream channels in some reaches. Cessation of irrigation in some areas may amplify these effects where stream flows are improved.

11.2.2 Pasture Vegetation and Grazing Management

As noted in 11.2.1 above, changes in grazing and riparian area management, as well as reductions in irrigation water use, can have substantial impacts to aquatic and potentially riparian habitat and resources. This study also looked to see if shifts in grazing and water use (irrigation) would have similar impacts in upland areas. To that end, various components of this study examined how changes in management of irrigation and grazing might impact the composition of the pasture vegetative community (e.g. shifts in native and invasive species, annual biomass production, amount of bare ground, forage quality, etc.), affect the base nutritional plane for livestock, influence livestock condition, etc.

Because this study collected, analyzed, and modeled the data from just two grazing seasons, results and conclusions are limited in scope and reliability. Nevertheless, there are a number of tentative conclusions and potential trends suggested by the work done in this study.

The cessation of irrigation has had an impact on the plant communities of those ranches where this change was made. Eliminating irrigation has encouraged a shift from wetland (obligate) to grass vegetation (facultative). This shift towards a grass community has increased the percentage of bare ground in the pastures. Although there was a statistically significant increase in the amount of bare ground on the non-irrigated sites as compared to the irrigated sites, it is unclear from this study how long the percentage of bare ground might continue to increase in the coming years. The percentage of bare ground increase on the non-irrigated sites may be appropriate for the grass plant community composition that is developing on the non-irrigated ranches.

The shift towards more of a grass community does not appear to have encouraged an increase in invasive species. Invasive or weed species appear to be a localized, site-specific concern on both irrigated and non-irrigated pastures in the valley. Indeed, the vegetation monitoring showed that non-irrigated sites had a greater percentage of native species than the irrigated sites.

The nutritional value of forage was maintained during the shift away from wetland plant species. That is, both wetland and grass communities provide adequate nutrition to the livestock grazing the valley throughout the growing season. Measurements of the important criteria stayed within the commonly recommended guidelines for maintenance and growth of livestock. In addition, it appears that the forage in the non-irrigated pasture may be stronger, more vigorous, and of better quality.

One of the many questions surrounding cessation of irrigation on some of the ranches in the valley revolved around if, and how much, forage production might drop without irrigation. The modeling done for this study suggests that a productivity drop of between 15 to 25 percent is not unreasonable in the Wood River Valley. Such a loss of potential forage has important implications for the economic situation of those ranchers moving towards dryland grazing practices. Such a drop in forage production would require reduced stocking rates to keep the available forage balanced with animal demand or risk long-term damage or negative impacts to the environment. This might be partially offset by what appears to be stronger, more vigorous, better quality forage of the non-irrigated pastures.

The modeling done for the study also suggests that there are various actions ranchers in the valley could take to lessen the economic impacts of ceasing irrigation, having reduced forage available, and having to reduce stocking rates. The modeling process examined a variety of scenarios with different irrigation frequency and rotational grazing management (different vegetation rest/recovery periods). The following conservation planning applications discussion presents some of the potential actions that could be taken by individual ranches to try and balance forage production, irrigation and water savings, environmental benefits, and economic considerations. Implementation of these kinds of conservation practices will depend on individual ranch economics (e.g. as discussed in the preliminary economic analysis), operational considerations, etc.

11.3 Conservation Planning Applications

The following discussion presents some of the resource concerns likely to be encountered if ranches in the Wood River Valley continue to forego irrigation or start on the path of converting from irrigated pasture to dryland conditions. These concerns should be addressed in the planning and operations of a given ranch.

Changes to the Soil Resource:

- Increases in amounts of bare ground and plant spacing (basal gaps) can be expected (consistent with the capability and potential of the site).
- Soil moisture levels may decline to the wilting point on non-irrigated sites by mid to late summer.

Changes to the Water Resource:

- Reduction in nutrient laden run-off to surface waters (reducing anthropogenic sources of phosphorus).
- Decrease in low dissolved oxygen, high pH, and excessive algal growth to Upper Klamath/Agency Lake.
- Partial restoration of historic hydrology.

Changes to the Plant Resource:

- Lowered annual forage production and potential re-growth. Without changing grazing management, reductions could be severe (greater than 1100 lbs/ac or about 0.4 AUM/ac).
- A shift in the growth curve that may leave less potential for mid to late season growth/re-growth.
- With no irrigation, the water table lowers below the rooting zone (3 ft.) by June and does not re-enter the rooting zone until January.
- Plant community composition will shift from obligate and facultative wet species to more deeply rooted native grass species.
- If heavy forage producers such as clovers are present in the irrigated plant community, they will become a minor component with the change to no irrigation.

Changes to the Animal Resource:

- Minimal changes to forage quality in the short-term (long-term changes are unknown).
- Animal health may improve from absence of water related ailments.

- Reduction in water-borne pests such as mosquitoes.
- Enhanced fish and wildlife habitat from improvement of riparian areas.

11.4 Conservation Planning Applications – Alternatives Development

The following discussion presents a number of conservation practices, generally NRCS practices with practice numbers in parentheses, which may be applicable to shifting irrigation and grazing management towards dryland production. The use of these practices will depend on the needs and objectives of the individual landowners/operators. However, these practices ought to be considered when alternative management scenarios are developed during the planning process. These considerations are based on the findings related to the study objectives as well as being related to the recommendations provided in the following chapter.

General conservation practices:

- Switching to non-irrigated rangeland grazing will require a minimum conservation system consisting of Prescribed Grazing (528) and, in some cases, Fence (382). Other practices may include Watering Facility (614), Pipeline (516), Prescribed Burning (338), and Heavy Use Area Protection (561).
- Riparian areas will need extra protection from adverse grazing (frequency, timing, and duration; intensity may be varied depending on the plant community and application of the other factors). These areas should have conservation systems developed to restore, enhance, or maintain desirable channel morphology and mosaic of vegetation.
- Livestock water is adequately provided via existing waterways and ditches. Some water gaps and hardened access points may be needed in some riparian areas.
- Reseeding is not recommended on these soils where deep plowing will bring excess pumice to the surface, reducing the potential seedbed and decreasing water holding capability and adversely affecting nutrient cycling (based on the experience of long-term ranchers in the valley).
- Among accelerating practices, Prescribed Burning (338) may prove the most useful (not usually a ground disturbing practice) to purposely alter plant communities (Tufted hairgrass ranges require intermittent disturbance to prevent deterioration to less desirable plant communities).

Prescribed Grazing Considerations:

- Harvest efficiencies may decline. Current harvest efficiencies of up to 40 percent on irrigated pastures may need to be lowered to the rangeland default level of 25 percent of standing crop allocated to livestock.
- If continuous stocking is used before and after conversion (less than or equal to 10 day rest periods between grazing events), stocking rate will need to be significantly reduced (the MIKE SHE & Daisy model simulations suggest a decrease of about 20 percent from irrigated to non-irrigated).

- If rest periods are extended to 30 days or more, stocking rate may not need to decline (the MIKE SHE & Daisy model simulations suggest a decrease of about three to five percent from irrigated to non-irrigated).
- If rotational grazing is used before and after conversion (30 day or more rest periods between grazing events) stocking rate will be significantly reduced (the MIKE SHE & Daisy model simulations suggest a decrease of about 15 percent from irrigated to non-irrigated).
- Grazing plans should include periods of grazing and rest necessary to develop the most resilient plant community, ease soil compaction problems, and to provide the best potential assemblage of plants for livestock production.
- Fenced pastures need to be monitored for potential increases in invasive and/or toxic plants. Grazing plans must be adjusted to accommodate appropriate treatments (excluding soil disturbing treatments).
- A monitoring plan should include grazing records, photo points, and measurements to capture changes in (1) plant community composition, (2) production (from field measurements and/or evaluation of grazing records – harvest amounts vs. planned trend), and (3) amount of bare ground. Additional measurements of water table level through the year may also be collected (and compared with climate records).
- A contingency plan will be necessary since drought may have more severe effects on the plant community and soil surface without irrigation. Planning for forage reductions from wild fire are also advisable (alternate feed and forage sources, destocking, etc.).

In addition to the general considerations presented above there are many other site and operation specific technical considerations that should be incorporated into grazing management plans for various ranches in the Wood River Valley. Appendix 1 presents a synthesis of the pasture and exclosure vegetation clipping, production, and hydrologic modeling work done in this study. From these data production growth curves, annual forage production, and stocking rates for irrigated (at different irrigation levels) and non-irrigated pastures is presented. This technical appendix should be considered during the process of planning grazing management in the Wood River Valley.

12. Recommendations

The following are recommendations the study authors felt confident in making in spite of study limitations and uncertainties, such as having just two years of data to analyze. As noted in Chapter 11, there are a number of tentative conclusions and potential trends suggested by the analysis done in this study. Implementation of these recommendations will need to be carefully monitored, analyzed, and adjusted and adapted to minimize unintended consequences.

As with most scientific investigation and analysis, further study and analysis is recommended to answer questions that did not get answered, were discovered or asked during this study process, and could not be addressed by this study for one reason or another (e.g. limits to funding).

Recommended additional monitoring, study, or follow up:

- Repeat the riparian area monitoring on Sevenmile Creek in three to five years based on the protocols and benchmark locations established during this study process to document trends.
- Monitor aquatic habitat in the future to document changes and verify that positive trends noted in this study continue.
- Repeat some of the vegetation monitoring to analyze changes in the amount of increase in bare ground and basal gaps resulting from cessation or reduction of irrigation. Longer term changes in plant composition (species shift) and productivity should also be measured to document when the pastures reach a new potential/ equilibrium state that displays a stable combination of composition, production, bare ground, basal gaps, and invasive species characteristics.
- Work with producers who make management shifts to verify or refute predictions made through the modeling process so that adaptive management may occur.
- Encourage landowners and managers to continue near infrared reflectance spectroscopy (NIRS) analysis of fecal samples through the Texas A&M University's Grazingland Animal Nutrition (GAN) Lab (with technical assistance from NRCS) to document further changes to the nutritional plane of the animal diet from converting pastures.
- Test, on a small acreage scale, nitrogen as a limiting factor in forage production in the valley as suggested by study modeling.
- Monitor changes in the amount of non-irrigated acreage and the shallow ground water table.
- Staff of the NRCS State Office and West National Technical Service Center should follow up by reporting results of the study to the local ranchers and partners. Those staff should also work with the ranchers and local partners in developing tools, such as an economic tool for calculating costs/benefits, that the ranchers can use in evaluating ranch-specific changes in irrigation and grazing management.

Despite limitations of this study, the report authors were able to reach the following conclusions:

Restoring riparian areas can

- Improve riparian and aquatic habitat

- Increase populations of macro invertebrates and fish
- Deepen and narrow stream channels

Reducing or eliminating irrigation from grazing lands can

- Encourage a shift from wetland (obligate) to grass (facultative) vegetation
- Increase the percentage of bare ground and basal gaps
- Reduce forage production by 15 to 25 percent
- Change the accumulation (rate and distribution) of biomass throughout the growing season
- Apparently maintain the nutritional value of forage

Improving grazing management (Rotational grazing) can

- Increase forage production (with a 30 day rest versus 10 day rest or continuous grazing)
- Ameliorate adverse changes to soil surface, micro-environment, infiltration, water holding capacity, risk from erosion, animal nutrient management, and increases of invasive plant infestations.

Reductions in forage production will result from complete cessation of irrigation. Not all producers in the valley are likely to convert to a non-irrigated operation for a variety of reasons.

Economic loss will be incurred from forage production reductions in a non-irrigated operation. There will need to be economic off-sets of that income loss to keep producers economically viable. Reductions in costs and other sources of income should be evaluated by individual operators. Some potential off-sets may include:

- Instead of complete non-irrigation, moving to a reduced irrigation operation, such as a one late season irrigation to reduce the percentage of forage production loss, may be an economically feasible option for some ranches.
- Develop a water market for water savings from foregone irrigation; consider in-stream or other water rights leases/sales, or find other similar compensatory mechanism for not using irrigation water.
- Rotational grazing with longer (30 days or more) rest/recovery times in pastures so that the vegetation stays healthy, vigorous, and achieves more optimal re-growth.
- For non-irrigated sites with grass species in the pasture, especially if the vegetation shifts to a tufted hairgrass community, consider prescribed burning as a management tool to help increase forage production.

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