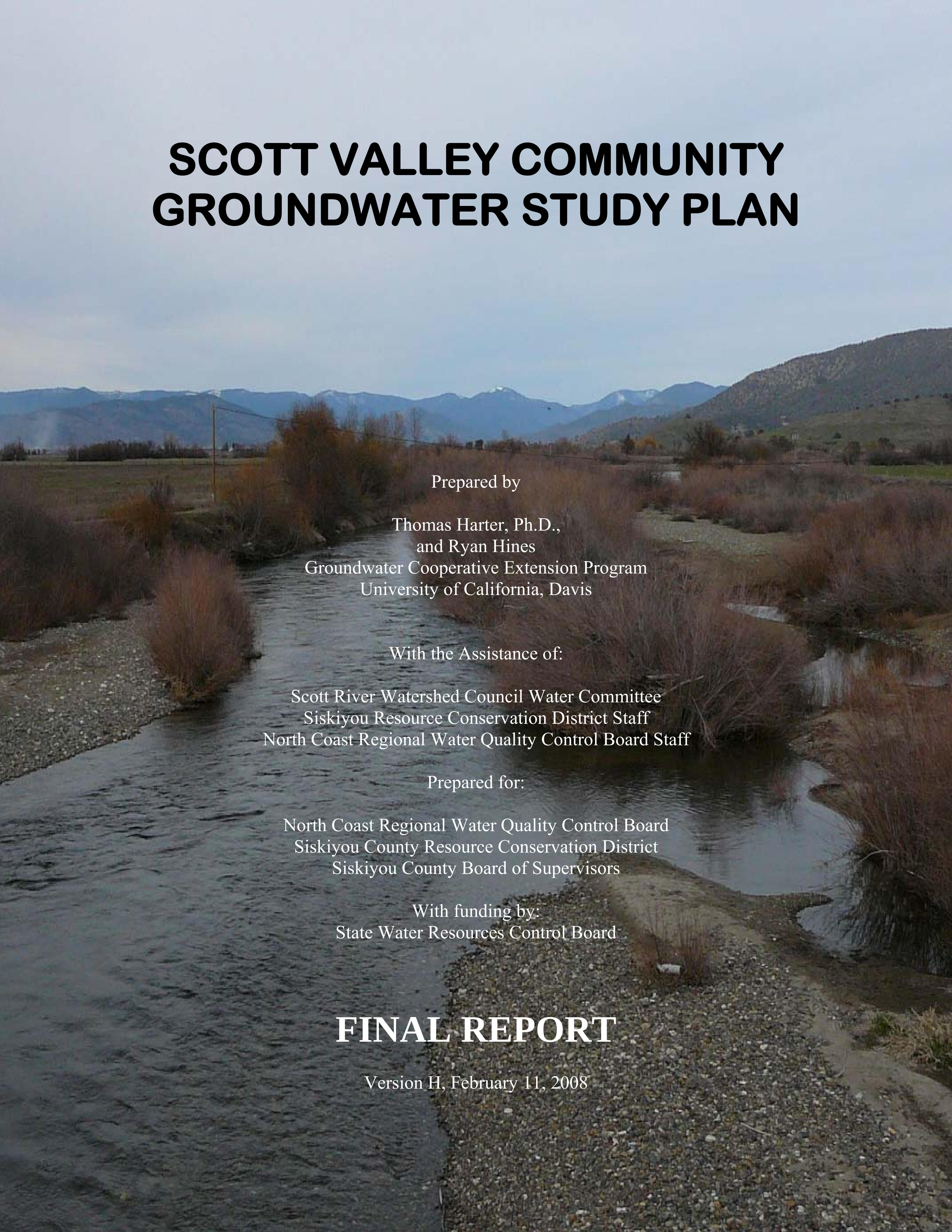

SCOTT VALLEY COMMUNITY GROUNDWATER STUDY PLAN

Prepared by

Thomas Harter, Ph.D.,
and Ryan Hines
Groundwater Cooperative Extension Program
University of California, Davis

With the Assistance of:

Scott River Watershed Council Water Committee
Siskiyou Resource Conservation District Staff
North Coast Regional Water Quality Control Board Staff

Prepared for:

North Coast Regional Water Quality Control Board
Siskiyou County Resource Conservation District
Siskiyou County Board of Supervisors

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Scott River Watershed Council Water Committee members
Jim De Pree, Siskiyou County, Natural Resource Policy Specialist
Marc Horney, Ph.D., Natural Resource Conservation Service
Steve Orloff, UC Cooperative Extension – Yreka Office
Sari Sommarstrom, Ph.D., watershed management consultant, Etna

Siskiyou Resource Conservation District Staff
Danielle Quigley (former staff)
Erich Yokel

North Coast Regional Water Quality Control Board staff
Bryan McFadin, P.E., Scott River TMDL Coordinator

This is the Scott Valley Community Groundwater Study Plan. An electronic copy of this Plan can be obtained from the following website: http://groundwater.ucdavis.edu/ScottValley.htm

For further inquiries, please contact Ryan Hines, RJHines@ucdavis.edu or Thomas Harter, ThHarter@ucdavis.edu .

Thomas Harter, Ph.D.
125 Veihmeyer Hall
University of California
Davis, CA 95616-8628
Phone: 530-752-2709

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1 INTRODUCTION

1.1 Background

This Scott Valley Groundwater Study Plan (GW Study Plan) has been requested of Siskiyou County and its Scott Valley stakeholders, as set forth in the Action Plan for the Scott River Temperature Total Maximum Daily Load (TMDL) (adopted Dec. 2005 by the California North Coast Regional Water Board [RWB]). The Action Plan sets forth the elements to be contained in this GW Study Plan; it also sets forth the needs of the RWB for certain information to be developed from the groundwater studies set forth in the GW Study Plan. It has been agreed by Siskiyou County and Regional Water Board staff that the hydrology of the entire valley needs to be understood in order to know the possible array of solutions to any water issues or problems in the Scott Valley. Siskiyou County with its management jurisdiction over groundwater (the RWB has water quality jurisdiction over groundwater under the Porter-Cologne Act) will take a community-based approach to groundwater management planning and to implementing this GW Study Plan.

Data, information, and analysis are needed through studies to understand the groundwater hydrology of the Scott River system and its relationship to surface hydrology, especially in areas where groundwater could affect Scott River water temperatures, potential riparian vegetation, and habitat connectivity for anadromous fish. Without knowledge of the overall groundwater hydrology of Scott Valley, solutions to specific issues outlined in the TMDL Action Plan and the Scott River Watershed Council (SRWC) Strategic Action Plan will not be possible. It will be more cost effective to discover and prevent problems before they occur. Baseline data will be needed to determine the best approach in the design and implementation of water projects and water management alternatives and strategies to protect anadromous fish while also protecting the other beneficial uses, including the needs of agricultural operations. Much of this information will need to be developed over a period of time necessary to have a sufficient record from which to discover and test feasible and effective management strategies.

This GW Study Plan was developed by the University of California at Davis (UC Davis) with the voluntary assistance of communities, landowners, the SRWC, and the Siskiyou Resource Conservation District (SRCD). The GW Study Plan is intended to be a living blueprint of the hydrologic, ecologic, water resource management, and agricultural management research needs and of the investigative approaches that can be taken to develop management practices that meet the mandate for protection of water, agricultural, and ecological resources in the Scott Valley. The GW Study Plan summarizes the current status of knowledge about the hydro-agro-eco-geography of the Scott Valley and outlines potential approaches to addressing critical current research needs. Individual study projects and tasks are described and scheduled in a way that is most efficient and timely to make the best use of funds to collect the information and data needed.

1.2 Format of the Groundwater Study Plan

To facilitate the application process to fund the proposed studies, the GW Study Plan presented here has been written to serve as template and resource for writing future proposals that would fund the various study elements suggested here. The format of the GW Study Plan follows that of most state and federal agency proposal guidelines:

- Statement of objectives with a statement of (testable) hypotheses.
- Summary of current status of knowledge.
- Description of the methods and approaches used.
- Road map and preliminary cost estimates.
- List of bibliographic resources cited.

Future proposals generated from this GW Study Plan and the resources cited in the plan will identify specific objectives, hypotheses, and associated methods and approaches, as required by the various funding agencies and their funding objectives. Siskiyou County assumes the primary responsibility for raising the necessary funding, in close cooperation with and with support from RWB, National Resources Conservation Service (NRCS), University of California Cooperative Extension, UC Davis, and other cooperating partners.

1.3 Role of Water Quality Planning

Although the need to better understand the interaction of groundwater and surface water had previously been identified by the SWRC, the impetus for the development of this groundwater study plan came from the Scott River Temperature TMDL Action Plan.

The Scott River TMDLs for Sediment and Temperature were established in accordance with Section 303(d) of the Clean Water Act. The State of California has determined that the water quality standards for the Scott River are exceeded due to excessive sediment and elevated water temperature.

Elevated water temperatures in the Scott River and its tributaries have resulted in the impairment of beneficial uses of water and have exceeded water quality objectives. The primary beneficial uses impaired in the Scott River watershed are in relation to the cold water salmonid fishery, including the migration, spawning, reproduction, and early development of cold water fish such as coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), and steelhead trout (*O. mykiss*), as well as contact and non-contact recreational uses. The coho salmon population in this watershed is listed as threatened under the federal Endangered Species Act and the California Endangered Species Act.

The water quality objective for temperature that applies to the Scott River is stated in the *Water Quality Control Plan for the North Coast Region*:

> "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial

> uses. At no time or place shall the temperature of any COLD water be increased by more than 5° F above natural receiving water temperature."

The purpose of the Scott River Temperature TMDL is to estimate the assimilative capacity of the system by identifying the total loads of thermal inputs that can be delivered to the Scott River and its tributaries without causing an exceedence of water quality standards. The TMDL also allocates the total loads among the sources of thermal loading in the watershed.

The temperature source analysis identifies the various water heating and cooling processes and sources of elevated water temperatures in the Scott River watershed. The source analysis found that **the primary human-caused factor affecting stream temperatures is increased solar radiation resulting from reductions of shade provided by vegetation. Groundwater inflows are also a primary driver of stream temperatures in the Scott Valley.** Diversions of surface water lead to relatively small temperature impacts in the mainstem Scott River, but have the potential to affect temperatures in smaller tributaries, where the volume of water diverted is large relative to the total flow. Microclimate alterations also have the potential to impact stream temperatures.

To define stream shade requirements in the context of the water quality objective for temperature, the Regional Board and its contractor, the Information Center for the Environment at UC Davis, estimated the amount of shade that would be produced by riparian vegetation under natural conditions. The estimates were developed based on historic photos, current vegetation, the location of streams, and a digital representation of topography. The resulting calculations of stream shade were used to define the load allocation for stream shade.

Although the TMDL evaluates the effects that groundwater has on stream temperatures, the degree to which water use affects the elevation of groundwater is unknown. While the TMDL temperature source analysis found that changes in groundwater accretion and surface water flow can have a deleterious effect on stream temperatures and the beneficial uses associated with the cold water fishery, the analysis did not determine whether the use of groundwater or surface water has caused a decrease in groundwater accretion rates. The analysis also did not determine whether surface water use is affecting groundwater accretion rates.

Therefore, the RWB determined that additional research must be conducted to study the connection between groundwater and surface water in the Scott River watershed, the impacts of groundwater use on surface flow and on the beneficial uses associated with the cold water fishery, and the impacts of groundwater levels on the health of riparian vegetation. The RWB then requested that the County of Siskiyou, in cooperation with the Quartz Valley Indian Community, SRCD, and other appropriate stakeholders, conduct the above mentioned study. This study plan was developed to satisfy, in part, the following request made by the RWB:

> The Regional Water Board requests the County, in cooperation with other appropriate stakeholders, to study the connection between groundwater and surface water, the impacts of groundwater use on surface flow and beneficial uses, and the impacts of groundwater levels on the health of riparian vegetation in the Scott River watershed. The study should: (1) consider groundwater located both within and outside of the interconnected groundwater area delineated in the Scott River Adjudication, (2) the amount of water transpired by trees and other vegetation, and (3), if deleterious impacts to beneficial uses are found, identify potential solutions including mitigation measures and changes to management plans.

The GW Study Plan shall also include the following elements pursuant to the RWB TMDL Action Plan (numbers in parentheses refer to the appropriate sections of the GW Study Plan):

1. Goals and objectives (section 2);
2. Data collection methods (sections 3-5, 7);
3. General locations of data collection sites (sections 3-5, 7);
4. Data analysis methods (sections 3-5, 7);
5. Quality control and quality assurance protocols (not applicable at this time);
6. Responsible parties (section 6);
7. Timelines and due dates for data collection, data analysis, and reporting (section 6);
8. Financial resources to be used (section 6);
9. Provisions for adaptive change to the GW Study Plan and ultimate study report based on additional study data and results, as applicable (sections 5 and 6).

2 GOALS & OBJECTIVES

2.1 Community-Identified Goals

The community's effort to better understand the groundwater resources of Scott Valley has developed over many years (see Appendix A). The Scott River Watershed Council's Strategic Action Plan (2004) adopted the following as its Water Goal:

> "*Work for adequate water flows in the Scott River system to protect the migration, spawning, and rearing needs of the salmon and steelhead stocks, while also protecting other beneficial uses.*"
> Objective #1*: Improve our understanding of the hydrology of the Scott River system and the relation to water use.*
> *Task A: Evaluate the ground and surface water recharge effects of irrigation ditches. More information is needed on the return rate, quantity, and location of the ditch seepage*
> *to streams.*
> *Task B: Investigate feasibility and effectiveness of various water recharge methods.*
> *Task C: Conduct a groundwater study including connectivity of groundwater to streams.*

In agreement with the goals and objectives of the Strategic Action Plan, a proposed goal for this Groundwater Study Plan is:

> *To provide a scientific approach that can be used by Siskiyou County, the Scott Valley community, the State of California, and other interested parties to objectively assess the Scott Valley's groundwater resources and their affect on surface water resources.*

In order to meet the above goal, the following six objectives have been identified for this GW Study Plan:

1. Characterize the hydrogeology of the Scott Valley including events and flows;
2. Evaluate effects of groundwater on health of riparian vegetation;
3. Evaluate cumulative effects of groundwater and surface water use on the Scott River System (mainstem and tributaries) flows and temperature, particularly between late Spring and early Fall;
4. Identify opportunities and potential solutions for increasing water storage and/or addressing Scott River temperature issues;
5. Develop a tool capable of investigating the groundwater hypotheses developed by the Scott River Watershed Council's Water Committee, and others; and
6. Identify and collect baseline data useful to develop, evaluate, and assess the design and implementation of water projects and water management alternatives with respect to protecting the needs of anadromous fish, agriculture, and other beneficial uses.

A general "Road Map" for how these objectives, and the overall goal will be met, is outlined in Section 6.

2.2 Stakeholder Expectations

The various stakeholders in the Scott Valley each have contributed to the drafting of this GW Study Plan and have each brought a set of expectations regarding the scope, outcomes, and usability of the resulting groundwater study. The expectations of the local Scott Valley community, the SCRD, and the RWB staff are all discussed below. If additional expectations are identified during the course of review and comment of this GW Study Plan, they will be appropriately added to this section.

The RWB staff expects that at the conclusion of the groundwater study, the following will have been accomplished:

- The effects of water use on groundwater inputs to the Scott River are quantified with reasonable certainty.
- The affects of water use on the health of riparian vegetation is determined.
- A tool is developed that allows for the evaluation of alternative water management scenarios, particularly conjunctive use strategies.
- A tool is developed that allows for the evaluation of the effects of water use on Public Trust values.

Siskiyou County stated the following expectations for the groundwater study:

- The study plan should provide a priority, sequence, and time schedule, subject to revision based on information obtained in conducting the studies set forth in the plan, of studies that will provide tools and information necessary to obtaining an understanding of groundwater hydrology and its relationship to surface water hydrology in the Scott River watershed in Scott Valley.
- The studies included in the study plan shall be scheduled such that information from the studies can be used to formulate and test water management actions to resolve water and fish issues as soon as appropriate. Those resulting actions, based on the information and tools developed, shall be developed and able to be taken locally with County oversight.
- The study plan and studies shall be professionally and expertly developed and able to withstand peer review.

The Scott Valley Community stated the following expectations for the groundwater study:

- Due to the limited information about the Scott River's hydrologic system, more accurate knowledge of how and when water moves through the Scott Valley will assist water users in making decisions about water management necessary for the survival of both salmon and the rural economy.
- Scott Valley's Community-based Groundwater Measuring Program (the “Program”) to collect baseline data on water table fluctuations, which was begun with wide support in 2006, is a critical first step towards addressing groundwater issues in the valley.
- The Program assumed that it "may take a decade or more to adequately characterize the range of water table level fluctuations by month and geographic location". There remain a number of specific questions about groundwater characteristics or management alternatives which directed research may be able address more quickly. Some specific examples include:
    - The potential impacts of groundwater supplied irrigation (sprinkler, etc.) vs. surface diversion-supplied flood irrigation on river flows and temperatures.
    - A definitive determination as to whether significant down-cutting is taking place in the Scott River, above the canyon, and, if it is, construction of a model to evaluate how this may influence groundwater movement and river flows over time, if not corrected.
    - Whether water table elevations where riparian plantings are planned are suitable for the establishment and long-term survival of riparian trees and shrubs.
    - A determination of the likely causes of observed Scott River temperature drops below the Scott Valley Irrigation District (SVID) diversion, Kidder Creek and Meamber Bridge.
- Future groundwater studies would include confidentiality of water table data collected on private land and collaborative meetings engaging local water users, both of which were shown to be key to developing community support for the Program.
- Any groundwater models used for interpreting data on groundwater or surface water

behavior must be transparent and made understandable to non-technical members of the community. The general operation of the model (inputs and processing steps), all assumptions that it employs, and estimates of its accuracy when operating on available data should all be made explicit. Model assumptions should be thoroughly documented, with special attention given to the conditions on which their validity is based.

- Researchers proposing and carrying out groundwater studies in Scott Valley will need to work closely with the Scott River Watershed Council's Water Committee and the SRCD. The Committee will continue to inform the County Board of Supervisors annually on groundwater study results and recommendations.
- The GW Study Plan should clearly describe the needed steps to answer the questions and issues raised by the RWB's TMDL Action Plan and Department of Fish and Game's (DFG) Coho Recovery Strategy and Incidental Take Permits (ITP).

2.3 Hypotheses / Study Elements

The stakeholders and community members in the Scott Valley represent a wide spectrum of interests, professional training, and personal experience with respect to the valley's watershed and groundwater system. Numerous reports, field studies, and monitoring data have been published for the Scott River watershed, describing what a number of local, state and federal efforts since the 1950's have revealed about its hydrogeology, and ecology. Stakeholders have raised many questions about the watershed and the management of its resources over the years, especially as state and federal regulatory activity has increased over Clean Water Act enforcement and the listing of the coho salmon, which spawns in this system. Agencies and organizations that have been involved in public outreach and education include the North Coast Regional Water Quality Control Board, the Scott Valley Watershed Council, the SRCD, Siskiyou County, the NRCS, University of California Cooperative Extension, and UC Davis.

In the last several years community members have worked with the Scott River Watershed Council to develop questions to guide investigations into topics that may yield information useful for better managing groundwater resources in the Scott Valley. These questions resolve into roughly five different topic areas:

1. Effects of climate change on the form and amount of precipitation delivered in the Scott River Watershed.
2. Attempts to construct a water balance and/or river flow forecasting tool capable of ensuring appropriate decisions for maintaining river flows during critical periods.
3. Effects of groundwater extraction on water table elevations, and consequently, Scott River flows.
4. How and where groundwater accretions to the Scott River affect flows and temperatures, and opportunities for manipulating those effects.
5. The influences of vegetation on river flows and temperature; including whether changes in types and densities of upland tree/shrub species may have contributed to present flow/temperature "impairments".

The following is a summary of these questions, all but the last group expressed in form of testable research hypotheses. It should be noted that the first topic area identified above, the effects of climate change on the Scott River Watershed, is out of the scope of this GW Study Plan. Furthermore, climate change effects have been researched to a minor degree. The results of this preliminary research, where relevant, may be incorporated into findings of the resulting groundwater study. These hypotheses guide the overall design of the Scott Valley GW Study Plan and its various study elements. Note that a hypothesis can be stated to be either affirmed or disproved and does not imply an answer.

2.3.1 Scott Valley Water Balance

a) Currently, sufficient data are available to estimate all significant components of the Scott Valley average monthly water balance at the watershed scale, but significant gaps exist on the stresses to the groundwater system (recharge, pumping, crop water use, and private water use).

2.3.2 Groundwater Levels

a) There is a statistically significant correlation between the water content of snowpack, total annual precipitation, and average Scott Valley groundwater table elevation in subsequent months/years. The correlation depends on the specific annual date at which snowpack is measured and the specific (later) date or time period during which representative groundwater levels are measured.
b) The magnitude and dynamics of seasonal and intraannual groundwater level fluctuations have significantly changed since 1950 (♫).
c) Groundwater pumping in Scott Valley has significantly increased since the 1950s and is the main cause for changes in groundwater level dynamics in Scott Valley (♫).
d) Groundwater pumping at any depth affects the water table elevation.

2.3.3 Groundwater-Surface Water Connection

a) Groundwater in Scott Valley is a major contributor to base-flow conditions in the Scott River System during summer and early fall (♫).
b) Groundwater discharge into the Scott River System has a significant cooling effect on surface flows (♫).
c) Groundwater seeps into the Scott River System only when groundwater levels near the Thalweg (bottom) of the Scott Valley are higher than stream water levels.
d) Local geologic heterogeneity (e.g., presence of a clay layer) may prevent stream seepage to groundwater, even though groundwater levels are lower than stream stage.
e) Current groundwater level monitoring is sufficient to predict, whether groundwater is discharging into the Scott River.
f) Rating curves can be developed to predict the amount of average groundwater discharge from the Scott Valley aquifer into the Scott River based on the current groundwater level monitoring network.
g) Water loss or incidental recharge from ditches, irrigation canals, and over-irrigation of fields during winter, spring, and/or early summer significantly influences the amount of later groundwater discharge into the Scott River System, during summer and fall ("delayed base-flow contribution").

h) The amount of delayed base-flow contribution from ditches, irrigation canals, and overirrigated fields is controlled by the location, timing and amount of these recharge events.

i) Groundwater pumping during the summer and, hence, groundwater levels during the mid to late summer months also significantly control groundwater contributions to the Scott River.

j) Stream flows in the valley exhibit a direct correlation to changes in groundwater table elevation.

k) Time-varying (transient) groundwater table elevations, and thereby stream flows, are partially caused by leaky ditches, deep percolation, artificial recharge, and by pumping, ET, and discharge to streams.

l) Twenty to thirty feet of drawdown near a pumping well does not prevent groundwater from discharging to the Scott River.

m) Higher irrigation efficiency (application of less water) through recently introduced pivot sprinkler systems has a significant but unknown impact on groundwater levels and, hence, on summer and fall Scott River base-flow and temperature. While there is decreased demand for groundwater pumping in the summer, there is also a simultaneous decrease in groundwater recharge.

n) Higher irrigation efficiency (application of less water) impact base-flow and stream temperature only over a limited time period (rather than the entire summer and early fall base-flow period).

o) Maximizing groundwater use and groundwater discharge to the Scott River is an optimization problem with several control variables/processes.

p) Under optimal management, the type of water year (total winter precipitation and winter/spring stream runoff) will partially determine the water management options to be practiced in any given year.

q) The removal of the SVID dam below Fort Jones in the 1980's has caused a downcutting of the stream channel and directly correlates with a drop in groundwater levels throughout Scott Valley.

r) Additional beaver dams within the Scott River System increase the amount of average total groundwater storage in the Scott Valley aquifer.

s) Potential consequences of downcutting/re-damming in the Scott River include:
    - Changes in surface water flows;
    - Changes in groundwater discharge to the Scott River;
    - Total usable groundwater storage in the Scott Valley;
    - Lower groundwater levels in the Scott Valley (see above); and
    - Decreased effective total groundwater evapo-transpiration via alfalfa, other crops, and riparian vegetation in the floodplain.

2.3.4 Vegetation-Hydrology

a) Recent changes in vegetation type and density in the eastside hills, westside mountains and on the valley floor have significant impact on groundwater levels and surface water discharge.

b) The onset of cold weather causes evapotranspiration throughout the Scott River watershed to drop dramatically, thus increasing river flows by both, increased base-flow contributions in the headwaters and increased base-flow contributions in the Scott River System within Scott Valley (♫).

c) There has been a significant historical decline in the amount of riparian vegetation (♫).

d) The decline in riparian vegetation has two consequences:

1. Increased (groundwater) base-flow to the stream; and
2. Increased stream temperatures in the Scott River System due to the lack of shade over the stream.

The net effect of these competing effects (shade over the stream vs. reduction of cold groundwater discharge due to increased riparian groundwater use) is unknown.

e) The rate of decline in the water table near the stream during late spring may significantly reduce the opportunity for riparian seedlings to get established.

f) A maximum depth to groundwater can be established that riparian trees require for their health.

g) Riparian vegetation has no impact on hydraulic conductivity, but by affecting groundwater discharge to streams may impact stream temperature, which in turn may affect hydraulic conductivity.

2.3.5 Stream Temperature and Its Controls

a) The location and timing of incidental recharge in ditches, irrigation canals, and Scott Valley fields not only impacts base-flow (groundwater discharge), but also the temperature of that discharge to the stream.

b) The location, timing, and intensity of groundwater pumping does not significantly impact groundwater temperature.

c) Summer discharge of organic- or sediment-rich agricultural return waters (e.g., from irrigation, dairies) into the stream is a significant contribution to elevated stream temperatures.

d) Groundwater discharge to the stream is not continuous across a reach or sub-catchment, but occurs rather spotwise (local) (♫).

e) Aquifer heterogeneity near the Scott River and overall connectivity of coarse sediments across the Scott Valley aquifer are the key controls of the localized groundwater discharge pattern to the Scott River.

f) Knowledge of stream morphology (channel, channel-bars, alcoves) is critical to understand hyporheic flows and their contribution to stream temperature.

g) The localized distribution of hyporheic flows and deeper groundwater inflow (groundwater accretion) control stream temperature distribution.

2.3.6 Additional Research Questions

a) What were the primary factors contributing to temperature variations in the Scott River prior to anthropogenic impacts? While a higher riparian vegetation density would intercept groundwater flow, higher water levels on the valley floor and no groundwater pumping may have been sufficient to offset riparian water use.

b) Can a model predict historical stream temperatures in the Scott River during the summer and early fall months? Is there geologic evidence that can be used to reconstruct prehistoric stream temperatures?

c) Historically, were Scott River flows always sufficient to sustain salmon fishery or only in some years?

d) Can modifications to the streambed (stream restoration) force sufficient hyporheic exchange to lower the temperature without increasing water levels in the surrounding floodplain?

e) What role may the dredge tailings play in lowering the stream temperature?

f) Do diurnal temperature and geochemical parameter signals travel downstream with stream flow (so-called “Lagrangian component”)?

g) What were pre-development groundwater flow patterns?

h) The 2004 RWB infrared thermal survey raised several questions:

    a. Downstream of Meamber Bridge, stream temperatures drop by 4 centigrade. Is the drop in temperature because groundwater from Scott Valley is forced to the stream or because groundwater from Quartz Valley is forced to the stream?

    b. Why is there a downstream temperature drop at Scott River & Kidder Creek despite the warmer temperatures of Kidder Creek?

    c. Another temperature drop is observed downstream of the SVID diversion for about 1 to 2 miles, despite much lower flow volume in the river. Do canal recharge and irrigation return force groundwater flow to stream, thereby cooling stream temps?

i) What is the usable aquifer storage under various minimum flow requirements in the Scott River?

j) What fraction of groundwater recharge is due to irrigation canal seepage?

k) How would increased groundwater pumping (rather than surface water diversions) influence low flow discharges?

Note: (♫) indicates hypotheses for which already significant data exist in support of the hypothesis.

3 BACKGROUND: CURRENT SCOTT VALLEY CONDITIONS

The intent of this section is to summarize the relevant information already known about the various aspects of the Scott Valley that are the subject of this GW Study Plan. This section contains local knowledge of the environmental, physical, and economic aspects of the Scott Valley. In addition, some information presented in this section has been identified and obtained from historical reports prepared on the Scott Valley. Each of the reports is referenced below, with a full citation appearing in either Section 7 (Siskiyou County Resources) or Section 8 (Bibliography). The purpose of this background section is to provide a summary of the scientific and technical knowledge that serves as the starting point for developing the GW Study Plan.

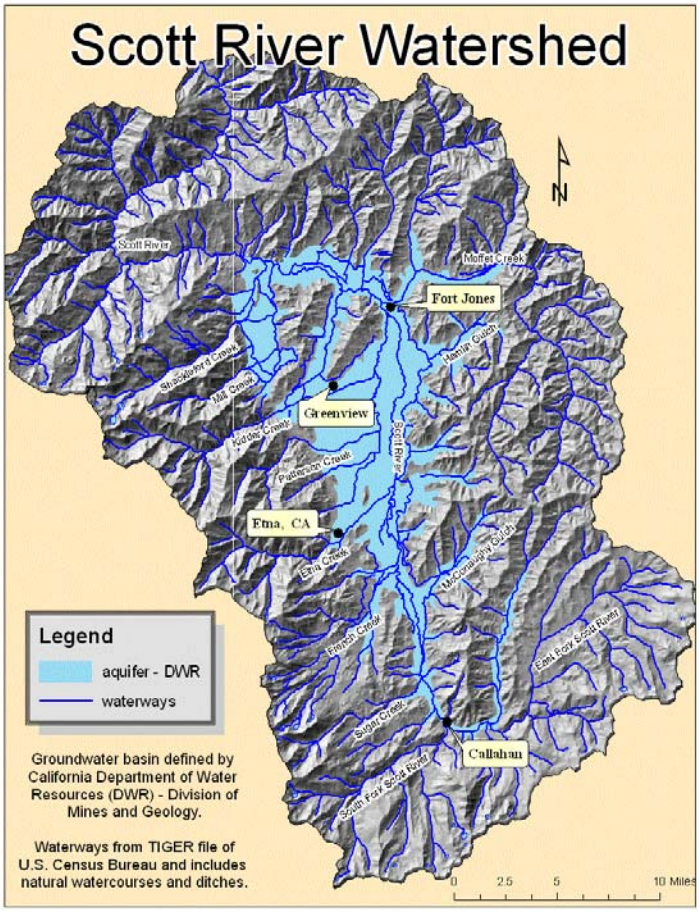


Figure 3-1: Scott River Valley Watershed

3.1 Physical Setting

3.1.1 Geography of the Scott Valley

The Scott Valley is located in the Klamath Mountains of Northern California, approximately 30 miles south of the Oregon border in Siskiyou County. Scott Valley is located west of Shasta Valley. It is approximately 25 miles long and 10 miles wide at the largest point, although much of Scott Valley is less than 3 miles wide. Approximately 8,000 people live in Scott Valley and its two towns of Fort Jones and Etna. Land use, and the local economy, is dominated by agriculture, primarily beef cattle-raising and forage production (alfalfa hay and pasture), with a few dairies. The Scott River flows through the middle of the valley, from south to north, and is a major tributary of the Klamath River.

3.1.2 Climate, Temperature, and Precipitation

The Scott River drainage is bordered to the west and south by 7,000 to 8,000 foot (2,134 to 2,438 meter) elevation mountain ranges: the Marble, Salmon, Trinity Alps and Scott Mountains. These ranges exert a strong orographic effect on incoming storms, which allows the higher elevation mountains, along the west and south side of the Scott drainage, to receive 60 to 80 inches (152 to 203 cm) of precipitation annually. In contrast, the rain-shadow effect that the west-side mountains create reduces the amount of annual precipitation to 12 to 15 inches (30.5 to 38.1 cm) on the eastside of the watershed.

The elevation of Scott Valley ranges from 3130 feet at Callahan in the southern end, to 2747 feet at Ft. Jones near the valley center, to 2620 feet at the north end. The mouth of the Scott River below Scott Bar is at 1600 feet. The area experiences distinct seasons of a Mediterranean type. Predominant weather systems are from the northwest with diminishing levels of precipitation as systems spread southeast.

Air temperatures in Fort Jones range from a mean of 69.7^{o}F (20.9^{o}C) in the summer to a mean of 32.9^{o}F (0.5^{o}C) in the winter. The Scott River is an inland drainage with hot dry summers. Summer temperatures commonly exceed 100^{o}F during a four-week period including later July and early August.

Average annual precipitation for the entire Scott River watershed, including high and low elevation areas, is 36 inches (91 cm). Fort Jones, located at the northern end of Scott Valley, has averaged 21.8 inches (55.7 cm) since records began in 1936. In Fort Jones, rainfall has ranged from 10.1 inches (1949) to 35.07 inches (1970), showing the wide variation that can occur. Most of the precipitation in the Scott River watershed falls on the west side, with snow prevailing during the winter above the 5,500 foot-level. Snowfall is an important component of total precipitation.

3.1.3 Geologic Setting

The geologic formations in the Scott Valley can be divided into two units, the surficial alluvial deposits, and the underlying bedrock that also comprises the upland areas surrounding the valleys. The consolidated bedrock deposits range from pre-Silurian to Jurassic and possibly Early Cretaceous age, and consist of the following strata in order of upward succession: Abrams and Salmon schists, the Chanchelulla formation of Hinds, greenstones which correlate to either the Copley greenstone or the Applegate group, and ultrabasic and granitic intrusive rocks (Mack, 1958; State of California, State Water Resources Control Board, 1975).

The unconsolidated deposits of the Scott Valley are of recent alluvial origin. Throughout much of its early history the Scott River was an actively degrading stream, cutting down in response to regional uplift. The uplift was apparently intermittent because at several localities along the valley margins there are remnants of highly dissected fans and terraces which probably were formed in Pleistocene time during pauses in the uplift. With the passage of time the dividing ridges between the western tributaries that had once abutted well out into the main valley area were reduced and slowly worn back by erosion toward the present western mountain front. The regimen of the Scott River and its tributaries gradually changed, and they eventually began to aggrade their courses. The aggradation process was not uniform throughout the valley area, for in the wide part of Scott Valley between Etna and Greenview the depth of bedrock, and consequently the thickness of the alluvial fill, appears to be much greater than it is farther downstream (Mack, 1958).

Most of the deposits are younger alluvium including stream-channel, flood-plain, and alluvial-fan deposits. A line extending northward, from the east side of the low hills that rise from the alluvium about one mile northeast of Etna, to the northeastern corner of Chapparal Hill marks the approximate western limit of the alluvium deposited by Scott River in the area between Etna and Fort Jones. This line corresponds also with what was the western boundary of Scott Valley during much of its early physiographic history when the Scott River was an active, downcutting stream. During the recent epoch, the eastern margin of the valley floor appears to have remained in its present position, whereas the western valley margin has been shifted about 3 miles westward by erosion (Mack, 1958).

The trend of Scott Valley westward from Fort Jones is probably controlled by the nearly east-west orientation of marked fault and fracture systems. Between Etna and Fort Jones, however, it appears that the initial course of the Scott River was determined chiefly by the relative softness of the underlying bedrock. Thus, along the east side of the valley between Hamlin Gulch and the vicinity of Etna, serpentine is intrusive into the Abrams mica schist and generally has a sill-like relationship with the enclosing beds, the overall effect resembling lit-par-lit injection on a regional basis. If the outcrops of the serpentine are projected toward the valley, it is seen that serpentine can probably be inferred to underlie the alluvium in much of the reach of the valley. Inasmuch as the serpentine is generally highly sheared it is therefore readily susceptible to erosion. Moreover, the Abrams along this reach of the valley is highly micaceous and contains many limestone beds. Hence it is much less resistant and more susceptible to erosion than the more massive quartzitic members exposed along the margins of the northern part of the valley (Mack, 1958).

The isolated patches of Pleistocene alluvium located along the valley margins are most continuous at the south end of the Scott Valley near Callahan where they underlie narrow terraces along both sides of the valley. The maximum exposed thickness of the Pleistocene alluvium deposits is less than 50 feet. The deposits are poorly sorted and consist of sand and silty clay with well-rounded granodiorite, serpentine, chert, and quartzite boulders that average 1 foot in diameter. In the northern portion of the Scott Valley, the Pleistocene alluvium is found in isolated patches along the edges of the Oro Fino Creek Valley and Quartz Valley, and at the mouth of Etna Creek. Those deposits along Quartz Valley and at the mouth of Etna Creek represent old alluvial fans formed by Shackleford and Etna Creeks. The alluvial fans consist of poorly sorted boulders of western-mountain origin set in a matrix of brown sandy clay to a depth of approximately 100 feet (Mack, 1958).

The remainder of the alluvium located in the Scott Valley is from a more recent time composed of alluvial fan deposits, and stream-channel and floodplain deposits of the present course of the Scott River and its tributaries. The recent alluvium ranges in thickness from 0 feet to greater than 400 feet in the center of the Scott Valley at its widest point. The thickness of the alluvium decreases to both the north and the south. The alluvial deposits vary greatly in composition based on spatial distribution. Along the west side of the valley, from Etna northward to Quartz Valley, the principal streams have built large bouldery and cobbly alluvial fans which are generally most permeable in their mountainward reaches (fan apex). The channel deposits of these streams differ with regard to the percentage of granitic bouldery material which they contain, ranging from mainly finer clay and sand to larger gravel and granitic boulder debris. The composition of the alluvium deposited by the tributary streams to the Scott River differs to such an extent that while most of the tributaries run dry during the early part of the summer, due to irrigation and infiltration into the coarse gravel of the fanhead areas, other tributaries such as Crystal Creek maintain flow throughout the year owing to the relatively impervious nature of the underlying granitic rocks which prevent infiltration of streamflow to the groundwater aquifer (Mack, 1958).

At the downstream edge of the alluvial fans, the alluvium becomes progressively less coarse ranging to fine sand, silt, and clay. Groundwater well logs from these areas have shown that alluvium consists of lenses of water-bearing gravel confined between fairly impermeable beds of clay. The alluvium in this zone is much less permeable than the floodplain and stream channel deposits of the Scott River (Mack, 1958).

3.1.4 Soil Characteristics

The soils of Scott River Watershed have developed on flood plains, alluvial fans, and mountain slopes. **Flood Plain Soils** are very deep, nearly level and gently sloping, poorly drained and somewhat poorly drained loams. The soils have a high water table or are subject to flooding, or both, because of the high rainfall and snowmelt in winter and spring. They formed in medium textured to moderately fine textured alluvium derived from mixed rock sources. Settlemeyer Soil occurs on flood plains south of Fort Jones and has slopes of 0 to 5 percent and is poorly drained. Typically, the profile has stratified loam, fine sandy loam, silt loam and sandy clay loam. Diyou Soil occurs mainly on flood plains south of Fort Jones and has slopes of 0 to 2 percent and is somewhat poorly drained. Typically, the profile has stratified loam, sandy loam, silt loam and clay loam. Of minor extent in the flood plain are the poorly drained Copsey, Odas, Pit, and Settlemeyer Variant soils along small streams on the higher positions on the landscape. Esro soils are in low areas. Riverwash soil is variable in texture and occurs along the river and streams (USDA 1983).

Alluvial Fan Soils are very deep, nearly level to strongly sloping, well drained, gravelly sandy loams and loams and are found along the streams that drain into Scott Valley. They formed in moderately course textured to medium textured alluvium derived from mixed rock sources. Stoner Soil occurs mainly on alluvial fans and has slopes of 0 to 15 percent and is well drained. Typically, the profile has gravelly sandy loam surface layer with a gravelly sandy loam and very gravelly loam subsoil. Of minor extent in alluvial fans is the somewhat excessively drained Atter soil that has many rock fragments on the surface and throughout the profile. Duzel, Kinkel, and Kindig soils are well drained and occur on the upper slopes of the fans. Bonnet soil occurs mainly in the upper Moffett Creek area and has loam or gravelly loam surface layer and a gravelly sandy loam and very gravelly loam subsoil with lime accumulation.

Klamath Mountain Range Soils are very shallow to very deep and are well drained to excessively drained and have medium textured to moderately course textures. Soils derived from granitic parent material are noncohesive and usually highly erodible. About 56,900 acres of granitic soils are found in the Scott River watershed, mainly on the south and west sides of Scott Valley (Sommarstrom, Kellogg, and Kellogg 1990).

3.1.5 Watershed Characteristics

The northern, western and southern mountains surrounding the Scott Valley area are covered with mixed conifer forested stands with mixed hardwoods and complex plant and animal life. The eastern mountains are covered more with annual and perennial grasses, shrubs and foothill transition type grading to conifer stands dominated by ponderosa pine. Streams, lakes and the Scott River provide water for wildlife, including steelhead and salmon, irrigation and recreation.

For further characterization, the sub-watersheds of the Scott River watershed are divided into 6 geographical regions. These regions have been identified as; East Headwaters (East Fork above Callahan), West Headwaters (South Fork above Callahan), Valley (Callahan to lower end of Scott Valley) Westside Mountains (Marble Mountains), Eastside Foothills and Moffett Creek, and Canyon. The main focus of the GW Study Plan is the Scott Valley itself.

East Headwaters (East Fork above Callahan): The East and South Fork of the Scott River meet at the town of Callahan to form the headwaters of the Scott River mainstem. The East Fork drains the Scott Mountains flowing in a southwesterly direction where it meets the South Fork (Scott River Mile 58). Elevations of this drainage range from 3,120 feet (951 m) at Callahan to 8,540 feet (2,603 m) at China Mountain. The East Fork drains a total of 72,650 acres (113.5 square miles or 294 square km) or 14% of the Scott River watershed. The headwater tributaries in this region are generally small, steep high gradient streams. These high gradient streams flow into alluvial channels of low gradient, moderately confined valley bottoms. These low gradient valley channels are bordered by discontinuous alluvial floodplains. Land use consists of a mix of federal and commercial forestland, rangeland and irrigated agricultural land.

West Headwaters (South Fork above Callahan): The South Fork of the Scott River drains the Salmon Mountains in the Southwest portion of the Scott Valley and flows in a northeast direction towards its confluence with the East Fork. Elevations in this reach range from a low of 3,120 feet (951 m) at Callahan to 7,400 feet (2,255.5 m) at the Scott-Salmon divide. The South Fork drains 25,133 acres (39.3 square miles or 101.8 square km), which represents 4.8% of the Scott River watershed. Mean annual precipitation ranges from 40-60 inches (101.6 to 152.4 cm). This watershed is comprised primarily of commercial forestland and wilderness areas with scattered rural residences along the South Fork. The morphological characteristics of this watershed include small, low-order, steep headwater tributaries, which are significantly influenced by snow accumulations and runoff that transport quickly through steep stream reaches to the lower gradient Scott River.

Valley (Callahan to lower end of Scott Valley): This region area includes about 37 miles (48.3 km) of the Scott River, which runs south to north turning west near Ft. Jones and turning in a northerly direction again in the canyon area near Canyon Creek. Elevation ranges from a high of 3,120 feet (951 m) at Callahan down to 2,630 feet (801.6 m) at the heading of the canyon area. The valley encompasses nearly 60,000 acres (93.8 square miles or 242.9 square km), which represents 11.5% of the watershed. Precipitation ranges from 10 to 35 inches (50.8 to 76.2 cm) annually. Land use is primarily agricultural (32,000 irrigated acres). Much of the river and the lower reaches of tributaries within the valley's channels are stabilized by riprap to prevent erosion. The US Army Corps of Engineers built levees for flood control in the middle of the valley in the late 1930's.

The morphological characteristics of this region include the lower end (alluvial deposits) of numerous tributaries. Some of the larger tributary streams are Etna Creek, French Creek, Kidder Creek, and Shackleford Creek. The stream channels are generally unconfined and contain streambed gradients of less than 2%. This region also includes the alluvial valley mainstem channel of the Scott River. General landform processes have created a wide, flat floodplain and a sinuous channel pattern where bars, islands, side and/or off-channel habitats are common. The gradient of the Scott River through Scott Valley averages less than a 0.1% slope, typical of a broad, alluvial valley. The most gentle gradient reaches near Fort Jones are sand-dominated, while the higher gradient reach near Callahan is cobble-dominated. The rest of the river channel's streambed is primarily gravel (Sommarstrom et al., 1990).

Westside Mountains (Marble Mountains): The Marble Mountains lying to the west of Scott Valley are the source of several perennial streams. Major tributary streams emanating from the Marble and Salmon Mountains include from south to north: Sugar Creek, French Creek, Etna Creek, Kidder/Patterson creeks, and Shackleford/Mill creeks. Elevations range from 2,700 feet (823 m) in Quartz Valley to 8,200 feet (2,499.4 m) at Boulder Mountain. The Westside region drains 116,342 acres (181.8 square miles or 470.9 square km), which represents 22.3% of the watershed. Mean annual precipitation ranges from a low of 30 inches (76.2 cm) at the lower elevations to a high of 80 inches (203.2 cm) at the upper elevations. Most of the precipitation above 5,000 feet (1,219.2 m) falls as snow, which sustains tributary flows through the early summer months. Numerous diversions originate in the mid to lower reaches of these tributaries. Land use in this region is primarily wilderness and commercial forestland with an increasing rate of rural residences in the lower elevations.

The geomorphic characteristics of this region include steep headwater tributaries that are generally small, low-order, high gradient streams. Streamflows are greatly influenced by snow accumulations and snowmelt runoff, which transport quickly through steep stream reaches, slowing down when flows reach the lower gradient valley reach. These high gradient streams flow into narrow alluvial mountain channels that are low gradient, moderately confined valley bottom streams. The tributary stream channels are bordered by discontinuous alluvial floodplains in their lower reaches. In most west side streams, flows naturally go sub-surface through the pronounced alluvial fans during the summer months (Mack, 1958).

Eastside Foothills and Moffett Creek: The eastside of the Scott Valley is dominated by generally dry foothills extending north from the Scott Mountains. The elevation of this region ranges from 2,700 feet to 6,050 feet (823 to 1,844 m). The largest watershed is the Moffett Creek that drains 145,846 acres (227.9 square miles or 590.3 square km) representing 28% of the Scott River Watershed Other streams along the eastside are ephemeral, flowing only during the winter and spring months after prolonged periods of precipitation. In the dry summer months much of the water sinks into the coarse, permeable gravel of the upland areas, and the streams do not normally maintain flow to the valley floor after the beginning of July. (Mack, 1958)

Canyon: The lower Scott River winds for approximately 20 miles (32.2 km) in a steep canyon through the center of the region. The dissecting of these mountains with streams has established a wide variety of slopes, aspects, elevations, and soil types that support a very diverse vegetative cover. Vegetative cover in the landscape area is primarily of the Klamath mixed conifer type. Douglas fir and at least two other conifer species define the Klamath mixed conifer type. Douglas-fir/live oak is typical at the lowest elevations while true fir and sub-alpine types are found at the higher elevations. Perennial tributaries in this river reach include Canyon, Kelsey, Middle, Tompkins, and Mill Creeks. Six different geomorphic landscapes occur in this area, predominated by steep, mountainous terrain prone to debris slides and flows (KNF, 2000 - TBO).

3.2 Hydrology and Water Balance of the Scott Valley

The water supply produced by the Scott River watershed is used for economical as well as ecological resources. The continuing dilemma over identifying the required amount of water needed for a healthy ecological system while maintaining the viability of the local agricultural based economy remains the primary question for landowners in the watershed. The information contained in this section reports the estimated water supply as well as the factors which affect the condition of the supply.

3.2.1 Surface Water Resources: Streams, Lakes, Diversions

The major water resource feature in the Scott River Watershed is the Scott River, a tributary to the Klamath River. The Scott River, within the Valley, is fed by a number of tributaries, many of which have been observed to run dry or exhibit sub-surface flow conditions in the summer months. It is estimated that there are over 700 miles of streams within the basin. The Scott River is 58 miles long and is one of the four major tributaries to the Klamath River contributing about 5% of the entire Klamath's runoff (yearly average of 615,000 acre feet). The forks of the Scott River begin high in the Trinity Mountains. At their confluence, the Scott River meanders thru a wide open agricultural valley (Scott Valley). The river then descends into a canyon carved along the eastern edge of the Marble Mountains before reaching the Klamath River.

The Scott River Watershed has no significant surface water storage facilities. There are some small local impoundments, but none are of significant size. More than 30 high-altitude lakes occur within the Scott River sub-basin. Several of these natural mountain lakes have been used to increase summer flows for irrigation through the construction of small rock and earth dams at the natural outflow points (CDWR 1991).

The U.S. Geological Survey (USGS) reports the Scott River stream flow for its gage near Fort Jones, with records beginning in 1941. Annual discharge has ranged from a peak of 1,081,013 acre-feet in water year 1974 to a low of 54,106 acre-feet in 1977 and reveals an annual average of 452,700 acre-feet. Highest runoff occurs from January to May, with August and September representing the lowest average monthly discharges (see CDEC website). Despite the lowest recorded annual discharge in 1977, there has been a decline in base flows in the Scott River in the since the late 1970s. Prior to 1977, the mean daily discharge of the Scott River had never dropped below 20 cfs, but has consistently since that year. This trend in declining base flows can be seen in Figures 3-2 and 3-3 below.

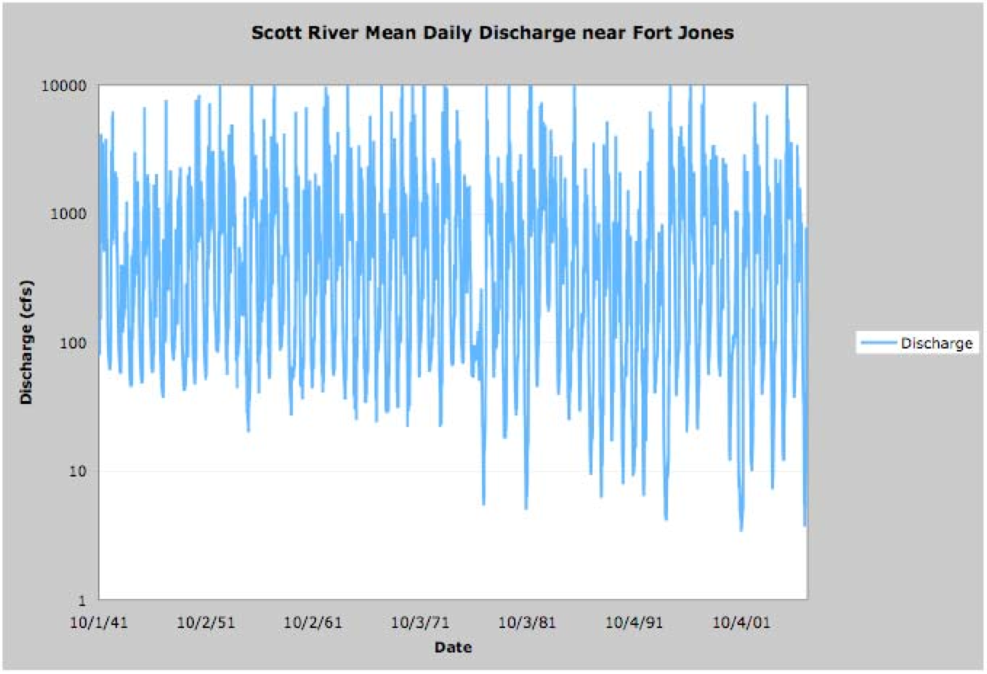


Figure 3-2: Logarithmic Plot of Mean Daily Discharge of the Scott River as recorded at the USGS gauge in Fort Jones. Note the decreasing trend in base flow beginning the late 1970s.

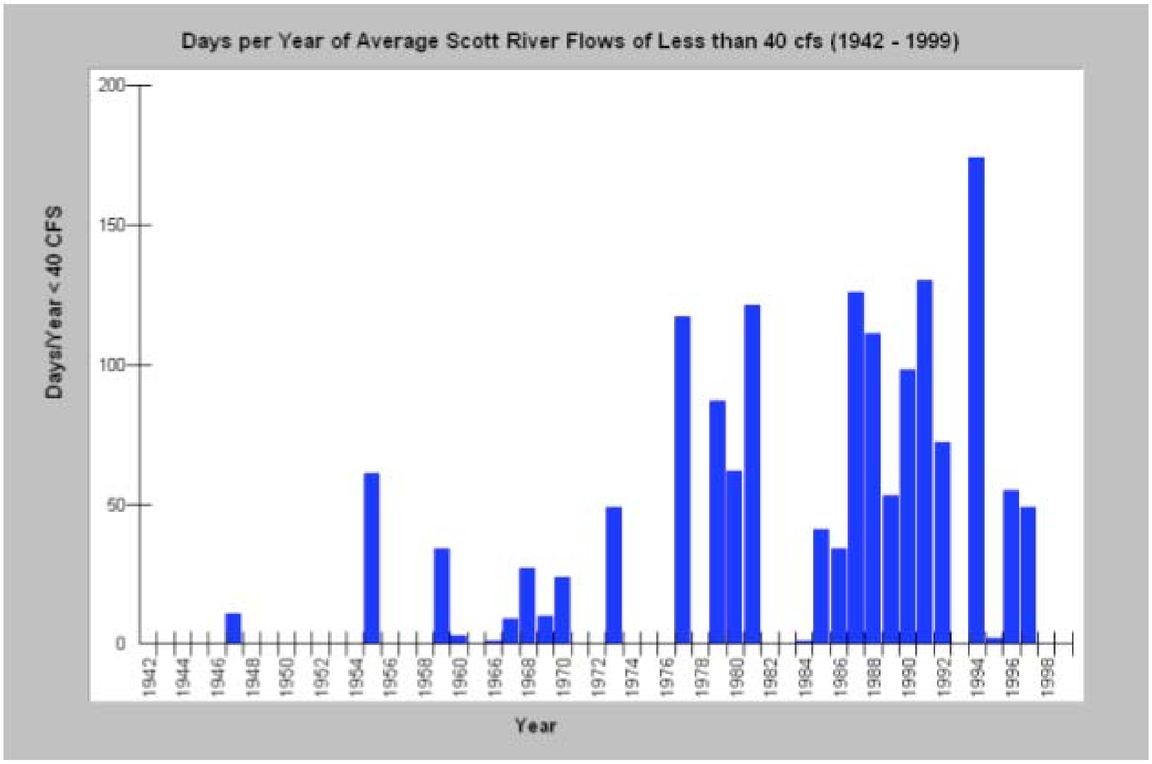


Figure 3-3: Days per Year of Average Scott River Flows of Less than 40 cfs. Graph producted from *Quartz Valley Indian Community Scott River TMDL Comments* (QVIC, 2006A).

Reduced Scott River base flows result from a myriad of interconnected concerns including surface diversions, decreased base flows due to changes in upland conditions which include riparian vegetation, native vegetation, and cropping patterns, decreased available surface water due to aggradation of the stream channel, and increased groundwater pumping. Additionally, it has been identified that climate changes also impact stream flows, particularly by a trend in the decrease of snow water content of the snowpack in the mountains surrounding Scott Valley. Lower base flows have an affect on habitat for salmonids and place increased stress on these species particularly when they occur at critical times in the salmonid life cycle.

Similar decreases in base flows have been observed on several of the major tributaries to the Scott River, however, these tributaries do not have the same flow data set that the main stem Scott River. Shorter-term gages are currently collecting low-flow data on the East Fork, South Fork, French Creek, and Shackleford Creek. The watershed has nine snow stations and a precipitation station in Fort Jones (see Deas and Tanaka, 2005, for summaries of available data). Figure 3-2 below helps visualize the interaction of snow melt, rainfall, tributary inflows, groundwater storage, and water diversions in the Scott Valley.

3.2.2 Stream Channel Characteristics of the Scott River Mainstem

The morphological characteristics of the mainstem channel of the Scott River, from Callahan to the lower end of Scott Valley, include alluvial deposits from the lower end of numerous tributaries. Some of the larger tributaries are French Creek, Etna Creek, and Kidder Creek. The stream channels are generally unconfined and contain streambed gradients of less than 2%. General landform processes have created a wide, flat floodplain and a sinuous channel pattern where bars, islands, side and/or off-channel habitats are common.

A significant reach of the Scott River, through Scott Valley, is very flat (0.08 %) and is a sand-dominated channel, while the northern and southern ends of the Scott Valley possess spawning-sized gravels due to increased gradient (0.7%) and other factors (Sommarstrom, Kellogg, and Kellogg, 1990). At the southern end of the mainstem Scott River from Callahan (RM 58) to Fay Lane (RM 50) the river channel is a higher gradient stream reach, cobble-dominated, and significantly affected by the 5 to 6 miles of dredger tailings remaining from pre-1950 Yuba Dredge gold mining in the stream channel and its floodplain. Between just below the confluence of the mainstem with French Creek and Young's Dam (RM 46), the gradient is lowered artificially by the presence of the 12 foot high dam. Downstream from Young's Dam to Hwy. 3 (RM 33), visible entrenchment of the stream has occurred, partly as a result of the dam and partly because of some significant channeling work by the U.S. Army Corps of Engineers in the late 1930s and subsequent bank armoring by landowners. The lowest gradient reach of the river lies between river mile 30 and 35 where the substrate is very sandy and lacks the coarser gravels that are supportive of spawning habitat for salmonids. Chinook salmon primarily spawn in the mainstem Scott River while coho salmon and steelhead primarily spawn in the tributaries (see "Biological Setting" below).

Stream cross sections were established by Alvin Lewis of the (then) Soil Conservation Service and are recorded in his exhaustive report about the stream and riparian condition of the Scott (Lewis, 1992). Some local stream surveys (longitudinal and cross-sectional) have recently been implemented by the Siskiyou County RCD. Besides standard topographic maps, no complete survey of stream geomorphology and topography currently exists.

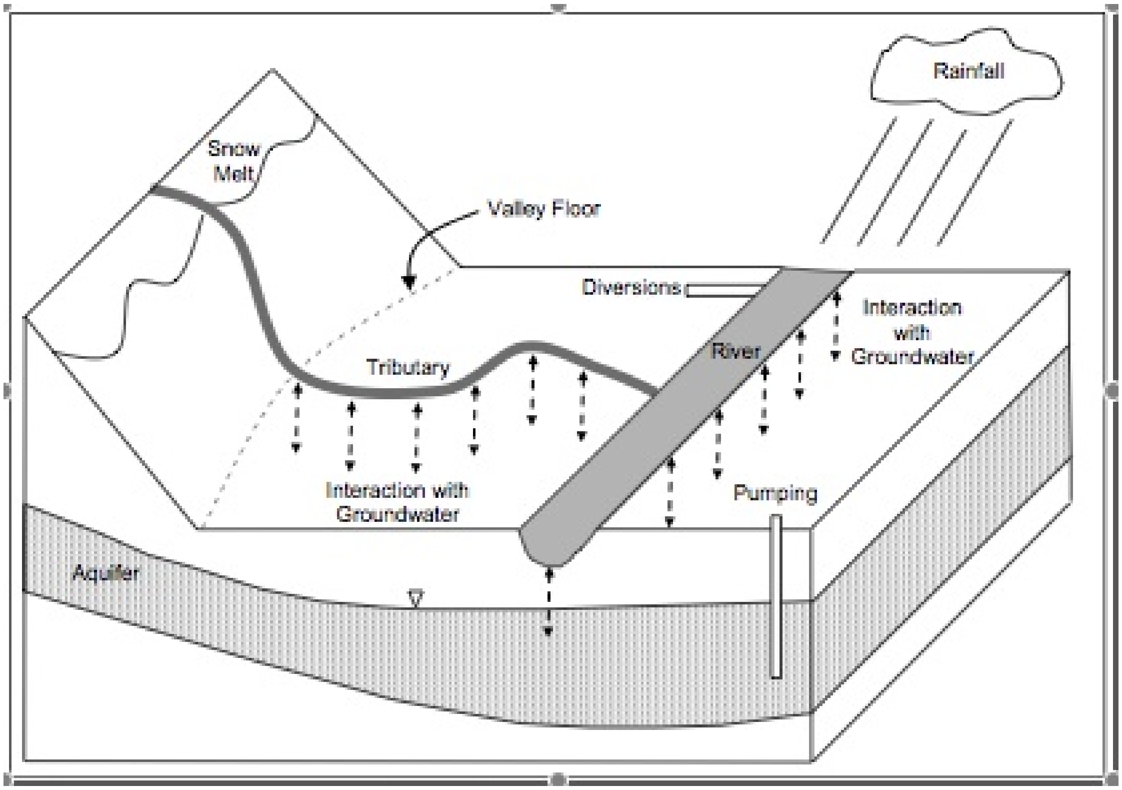


Figure 3-4: Major Water Interactions of the Scott Valley System

3.2.3 Groundwater Aquifers

The largest water storage in the watershed occurs in the alluvial fill of Scott Valley, a groundwater basin, which is recharged annually by the Scott River, tributary streams, and by infiltration of precipitation and snow melt (DWR, 2003). Of the geologic units comprising the Scott Valley, the stream channel, floodplain, and alluvial-fan deposits of the younger alluvium constitute the only important water-bearing deposits in the Scott Valley. According to data obtained from well logs and previous hydrologic studies, the most permeable alluvium underlies the east side of the Scott Valley between Etna and Fort Jones. However, aquifer tests conducted to determine various hydrologic properties of the alluvial deposits (i.e. yield, permeability) identified a high degree of variability based on the description of the geologic unit in which the well was screened. Heterogeneity in the geologic deposits, which range from sand and gravel due to historical Scott River and tributary streambed locations, to denser clay and silt floodplain deposits, relate to differing hydrologic properties (Mack, 1958).

The sedimentation processes that determine a typical fan structure are favorable to the production of confined aquifer systems. Normal streamflow occurs between the banks of a stream issuing from the mountain front and commonly carries well-sorted sand and gravel that are deposited between the banks. Subsequent flooding may cause water to overtop the banks and spread coarse material over the fanhead area, but in the lower areas of the fan, deposition of coarser material is generally restricted to a stream channel, and the subsiding flood water may deposit finer sediments over the area between channels.

New channels are cut by flood waters which overtop the banks, particularly near the apex of the fan. Flow downslope from the fan is radial, and the course taken by a new channel may diverge from the direction of an older channel. Near the foot of the fan a stream separates into diverging forks because of decreased gradient that causes a stream channel to fill with silt and eventually to seek a new course (Mack, 1958).

These processes create a series of diverging and poorly connected aquifers represented by coarse channel deposits, each separated by a layer of finer sediments which constitute an aquitard. The principal source of most of the confined and unconfined groundwater in the alluvial fan is from infiltration in the belt of coarse permeable sediments around the apex of the alluvial fan, which extends down present and buried channels. Near the base of the alluvial fan is a discharge zone where the confined water that moves through the aquifers is discharged by leakage to the land surface. This landscape of alternating geologic units has given rise to several artesian aquifers having been formed in the Scott Valley (Mack, 1958).

An area with a perched water table was identified on the west side of the valley, encompassing approximately 100 acres. The perched water table area is located to the east of a crescent-shaped bedrock hill which is concave toward the valley. Coarse alluvial fan material from Kidder and West Patterson Creeks has been built up around the northern and southern margins of the hill, and the topographically lower, inner concave part is underlain by silty clay deposited along the peripheral zones of ht emerging fans. Inflow to the perched water table area is likely affected by infiltration from precipitation and seepage from nearby springs (Mack, 1958).

3.2.4 Groundwater Storage

The groundwater storage capacity of the aquifers underlying the Scott Valley were calculated in 1958 using aquifer characteristics determined from records of wells at that time and from pumping tests conducted on those wells. Aquifer characteristics such as the thickness of saturated deposits, specific yield, and areal extent of the deposists were used to calculate an estimate of the total groundwater storage capacity of the Scott Valley.

The Scott Valley was divided into six groundwater storage units, of which the largest is the area underlain by the flood plain deposits of the Scott River. This flood plain aquifer area was calculated to represent greater than half of the total groundwater stored in the Scott Valley. The remaining aquifer units identified were distinct areas along the west side of the valley area (units 2, 3, and 4). Unit 2 consisted of discharge zone at the edge of the western mountain fans in an area mapped to be underlain by the finer fraction of the alluvium carried by the western tributary streams. Unit 3 consists of the northwestern portion of the Scott River watershed, including Oro Fino valley and the western mountain fan area from Etna northward to Greenview. Unit 4 includes the Quartz Valley and covers an area of about 4,800 acres. The geology of Unit 4 aquifer is dominated by the sediments deposited by Shackleford Creek and the other streams in the area, generally consisting of a high proporation of rounded boulders. Storage Unit 5, includes the valley lands adjacent to Moffett and McAdam Creeks, an area of about 2,600 acres. Unit 6 comprises the Hamlin Gulch area, an area of approximately 1,560 acres. The following table represents the totals of the estimated groundwater storage capacity of the aquifer underlying the Scott Valley:

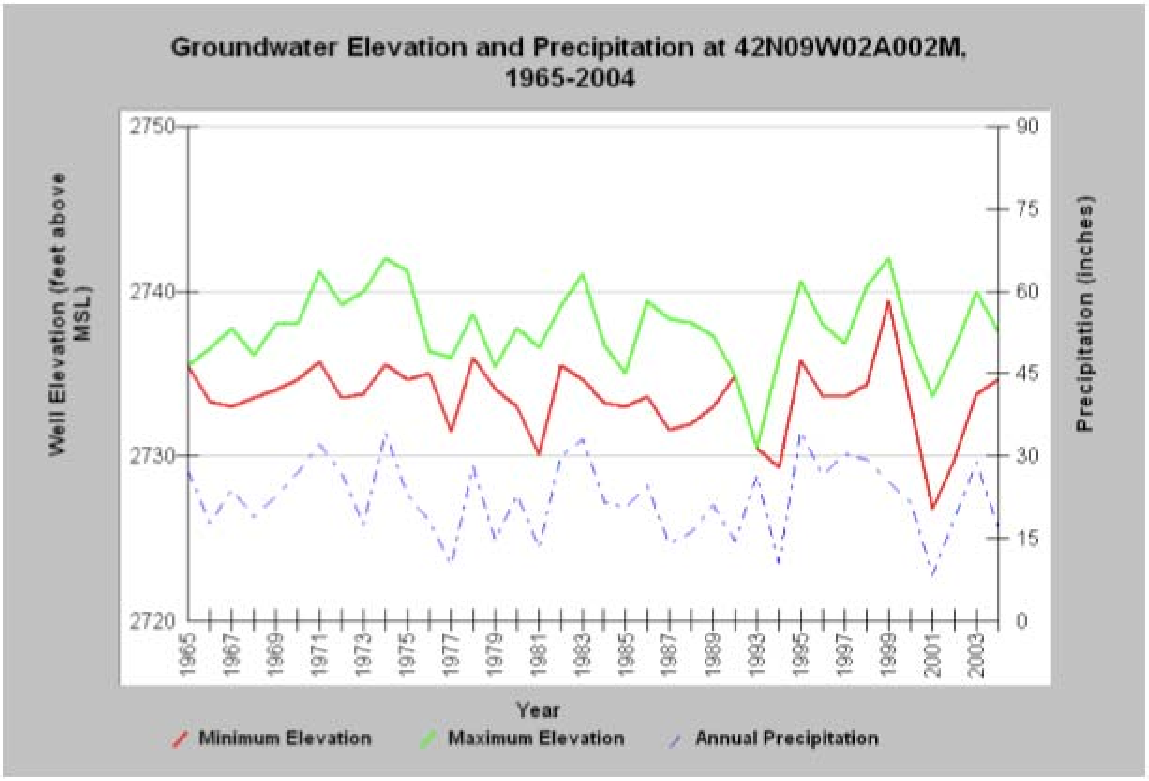
1.	Scott River Flood Plain	220,000 acre-feet
2.	Western Mountain Alluvial Fan Discharge Zone	31,000 acre-feet
3.	Western Mountain Alluvial Fans and Oro Fino Valley	50,000 acre-feet
4.	Quartz Valley	61,000 acre-feet
5.	Moffett-McAdam Creek	35,000 acre-feet
6.	Hamlin Gulch	10,000 acre-feet
	Total:	400,000 acre-feet

Table 3-1: Estimated Groundwater Storage Capacity, Scott Valley

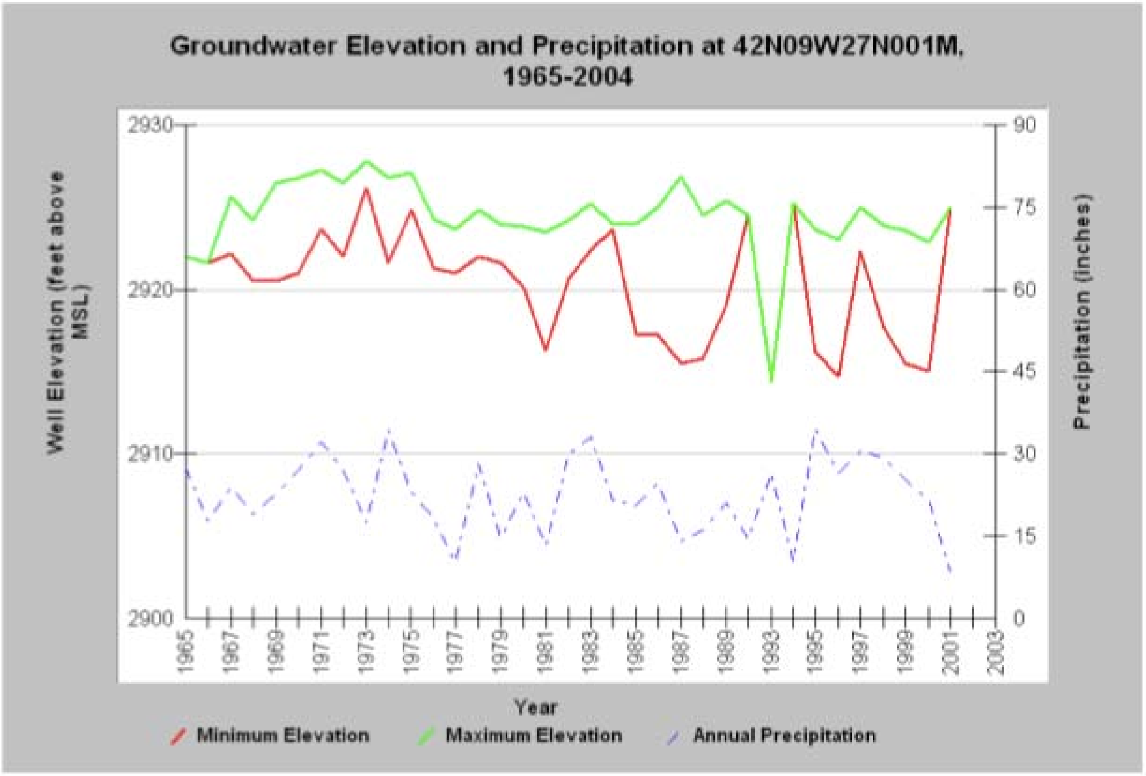
This is an estimate for gross storage capacity and does not represent usable groundwater. The usable groundwater capacity in the Scott Valley is less than 400,000 acre-feet, considering that few of the current wells tap groundwater to the full depth of the aquifer (as assumed in the above estimates). Usable groundwater storage may in fact be much smaller than indicated above, particularly if base-flow contributions from the aquifer to the Scott River during the annual dry season are indeed shown to be critical to meet TMDL requirements. At a regional scale, it may thus not be possible to lower water levels in the aquifer to elevations below the Scott River (Mack, 1958).

3.2.5 Historic Groundwater Levels and Fluctuations

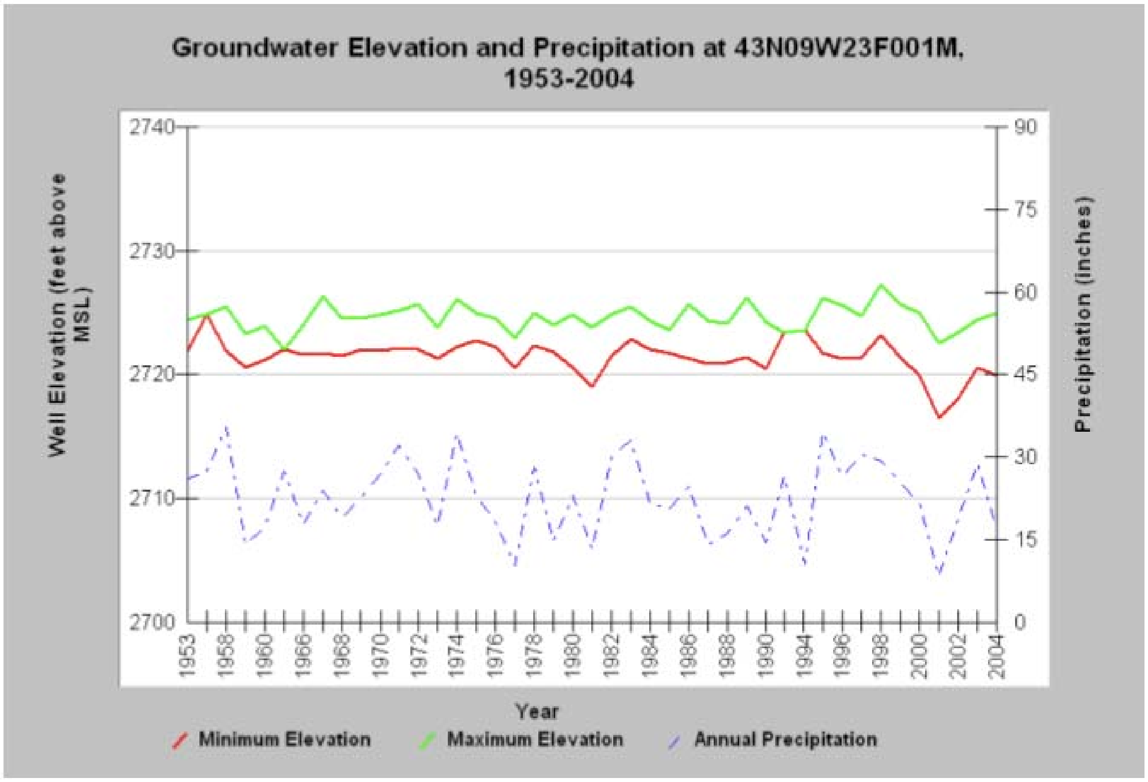
Scott Valley's groundwater was identified by the State as being interconnected in certain areas with the surface water of the Scott River (CSWRCB, 1975). The Scott River Valley Adjudication of 1980 recognizes a zone of interconnected ground and surface waters in its water rights determination along the Scott River below Fay Lane (see discussion below). Figure 3-5 shows that groundwater levels drop each summer and then recover the following fall/winter for the wells that have long-term records, which is typical for this region. For the wells shown, groundwater levels have remained fairly constant over the last 40 years and have recharged for the most part each year for monitoring wells (#1 and #3) near the Scott River, and one well (#5) 1 mile from the river. Well monitoring data are not available prior to the 1950s. While there is an interconnection between groundwater and the Scott River, it is unknown how quickly the interconnection occurs or its extent, and thus the exact nature of the impacts of groundwater pumping on streamflow. One goal and objective of this GW Study Plan is to quantify the rates of groundwater movement associated with this interconnection in different areas of the Valley and in different water year types (e.g., critically dry versus wet).

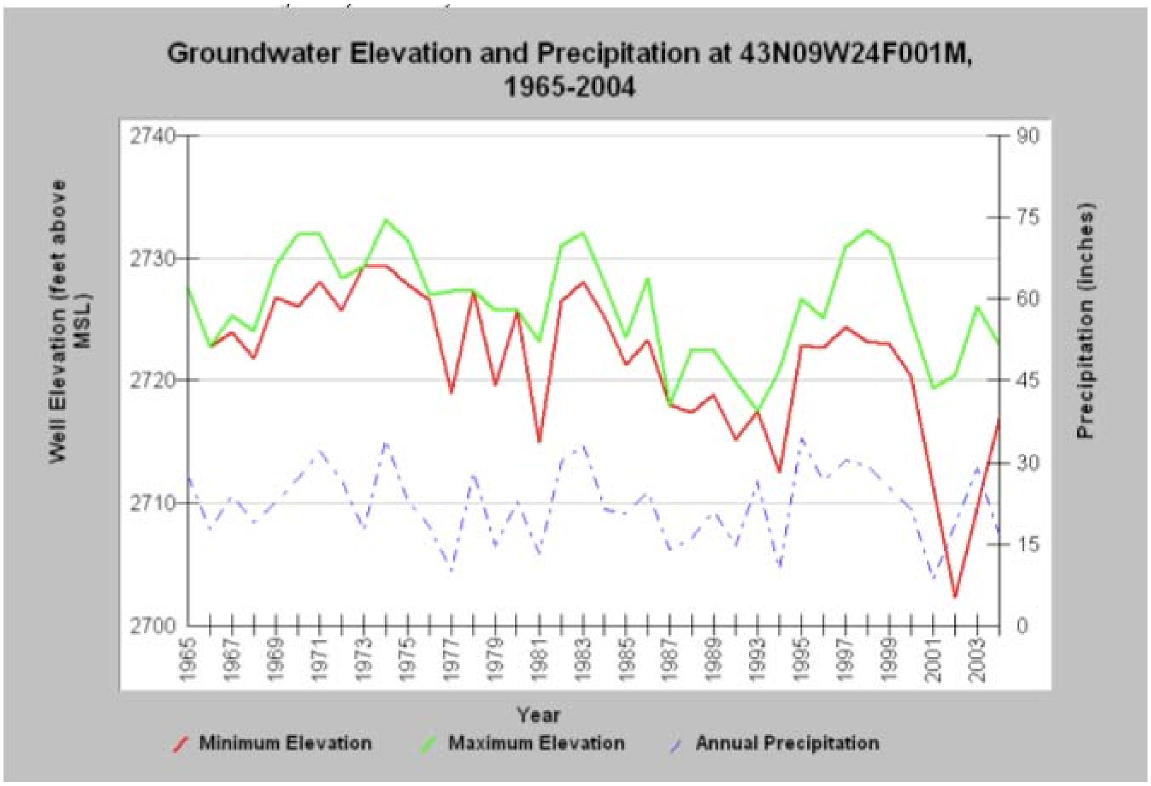


Groundwater Elevation and Precipitation at 42N09W02A002M, 1965-2004



Groundwater Elevation and Precipitation at 42N09W27N001M, 1965-2004


Groundwater Elevation and Precipitation at 43N09W23F001M, 1953-2004
Well Elevation (feet above MSL)
2740
2730
2720
2710
2700
Precipitation (inches)
90
75
60
45
30
15
0
Year
1953
1958
1960
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1994
1996
1998
2000
2002
2004
Minimum Elevation
Maximum Elevation
Annual Precipitation


Groundwater Elevation and Precipitation at 43N09W24F001M, 1965-2004
Well Elevation (feet above MSL)
2740
2730
2720
2710
2700
Precipitation (inches)
90
75
60
45
30
15
0
Year
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1993
1995
1997
1999
2001
2003
Minimum Elevation
Maximum Elevation
Annual Precipitation

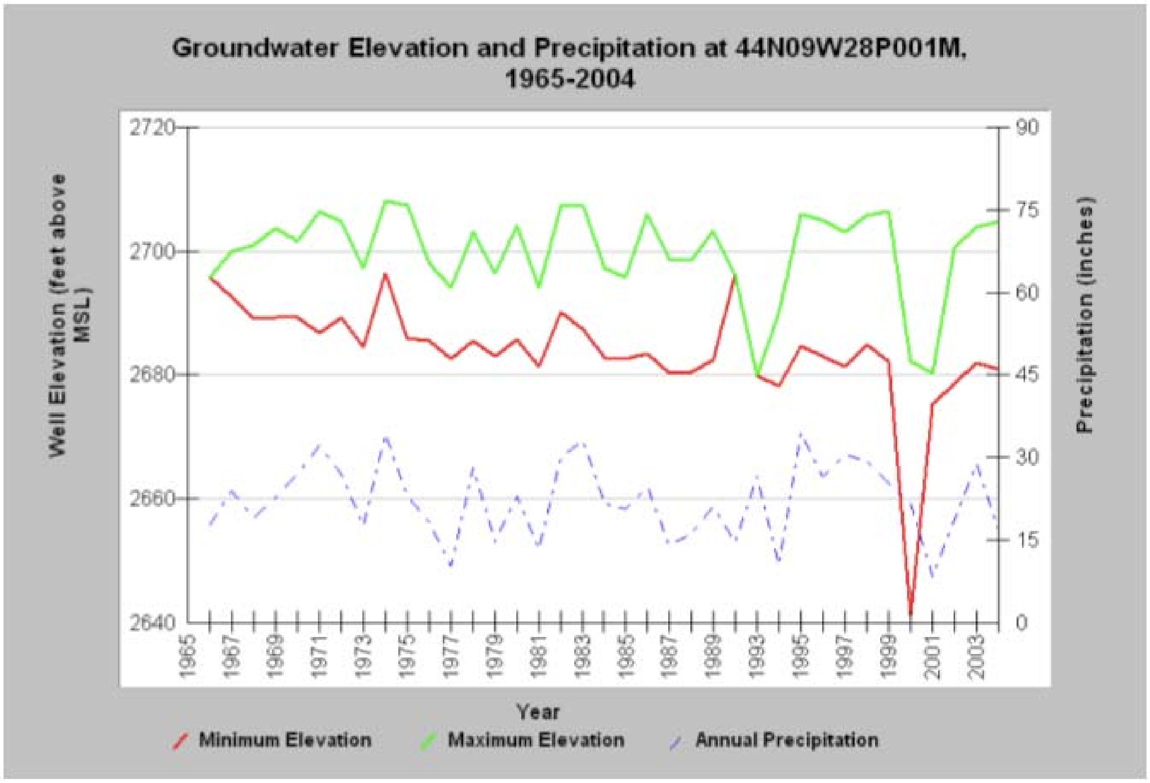


Figure 3-5: Scott River Valley Well Levels and Precipitation DWR Data, 1965-2004

Graphs obtained from Quartz Valley Indian Community (2006a). Data obtained from California DWR and precipitation data obtained for the Fort Jones station from the California Data Exchange Center (CDEC). Note: In 2000 the spring level is lower than the fall level. This is due to the fact that the spring measurement was taken in March, and either snowmelt or precipitation (or both) must have brought the well level up after March (Quigley, personal communication

The above graphs display long-term groundwater level measurements along with precipitation data for five wells that have been monitored since at least 1965. A strong correlation between groundwater level measurements and precipitation can be seen in data from all of the wells. As displayed in the above graphs showing long-term groundwater level measurements from five wells located within Scott Valley, annual maximum groundwater measurements have remained fairly consistent over time, neglecting changes observed related to precipitation. However, the minimum groundwater level measurements observed have shown a decline in almost all cases, when taking into account fluctuations due to differences in precipitation. This trend in declining minimum levels of groundwater measured in these wells corresponds to a period when an increase in the number of groundwater wells installed within Scott Valley has been observed. Surface water flows and riparian vegetation have likely been impacted by this decrease in groundwater levels during critical times. A goal of this GW Study Plan is to better determine the effects that groundwater levels have on surface water flows and how they may be associated with the health and abundance of riparian vegetation.

With the assistance of Siskiyou County, Scott River Watershed Council (SRWC) and the USDA Natural Resources Conservation Service (NRCS) – Klamath Basin Watershed Team, water users in the Scott Valley have established a Community-based Groundwater Measuring Program to collect baseline data on water table fluctuations and address groundwater issues in the valley (SRWC 2007).

The groundwater program currently measures approximately 35 wells that have been volunteered for this purpose by local residents to supplement the 5-7 wells that are monitored semi-annually by CDWR. Static water levels are being measured on a monthly basis throughout the year (4 are measured semi-annually). Wells have been selected on the basis of their geographical distribution and depth. Both shallow (domestic) and deep (irrigation) wells were included in as many areas as possible, and wells were selected so as to represent the entire central area of the Scott Valley, from Callahan north to Fort Jones. The only other long-term monitoring of groundwater has been conducted by the Department of Water Resources (DWR), which has records that date to the 1950's. However, DWR has historically operated only four or five wells in the valley, taking water level measurements usually only twice per year (spring and fall). This limited number of DWR monitored wells with limited geographical distribution and frequency of measurement is inadequate for generating the data necessary for understanding aquifer recharge and discharge characteristics. A Memorandum of Understanding has been agreed upon and committed to by all participants for the duration of five year intervals (SRWC 2006).

3.2.6 Water Quality

Temperature and sedimentation are two water quality issues falling under a category of "non-point source pollution" (NPS). Polluted runoff, or NPS pollution, is the leading cause of water quality problems in the state. NPS arises from multiple land uses such as runoff from agriculture and timber harvesting areas, mine drainage, subdivisions, and range and dairy cattle areas. Rainfall, snowmelt, or irrigation water that moves over and through the ground also contributes to NPS pollution. As the runoff moves, it picks up and carries away natural, animal, and anthropogenic pollutants, depositing them into lakes, rivers, wetlands, groundwater, and other inland waters. These discharges threaten the quality of the state's waters.

Federal law requires states to identify all water bodies that do not meet water quality standards. For those "impaired" water bodies failing to meet standards, the states must establish total maximum daily loads, or TMDLs. TMDLs define how much of a specific pollutant a water body can tolerate and still meet relevant water quality standards. All of the combined pollution sources in a watershed may not discharge more than the total limit (CSWRCB, 2001, pages 6-7). The Scott River watershed's TMDL process began in 2003 and was completed approximately two years later (NCRWQCB 2005).

3.2.6.1 Temperature

The oldest record of water temperature in the Scott River was taken by CDFG on June 14, 1934, 1 mile south of Fort Jones, where the temperature was 72°F (approx.

22°C), and the survey noted “excellent pools and shelter” with “willows dense along the shore” (CDFG 1934). The USGS along with the California Department of Water Resources (CDWR) collected water temperatures annually, since the early 1950’s, using a variety of field techniques and reported these temperatures by collection station in annual reports (USGS, 1997). The USGS and CDWR also summarized the 1951- 1970 annual reports into a reference guide for many of the monitoring stations (Blodgett, 1970 - TBO). Historical water temperatures in Northern California watersheds similar to the Scott River watershed indicate that instantaneous water temperatures in the region have exceeded 21°C (70.2°F) since the early 1950’s (Blodgett, 1970).

Historical water temperatures have been documented in the Scott River Watershed at eight separate stations (Blodgett, 1970). Due to the various methods, time periods and total number of measurements, limited information and conclusions can be drawn from historical data in the Scott River watershed. In the Scott River watershed the USGS and CDWR used the “periodic observation” method for collecting water temperatures. This method entailed using a hand held thermometer and directly reading the thermometer temperature. The stations were located far enough downstream of tributary inflow to ensure that waters were well mixed and usually the stations were associated with water flow gaging stations. Blodgett (1970) reported “...the probable inaccuracies resulting from the sum of instrumental and thermometer placement errors should be less than + or – 1.5° F (+ or – 0.8°C) degrees for periodic data collected with hand-held thermometers.” The instantaneous maximum water temperatures of the eight stations located in Scott River indicate that these portions of the Scott River watershed have exceeded 20°C (68°F). Historical water temperatures were collected prior to the 1964 flood. The 1964 flood had a strong impact on the channel structure. The present day channel is more open and has less vegetation than prior to 1964.

The RWB completed an in-depth temperature analysis of the Scott River while completing the TMDL. This analysis identified five factors influenced by human activities in the Scott River watershed that have an impact on stream temperatures, including:

- Stream shade;
- Stream flow via changes in groundwater accretion;
- Stream flow via surface diversion;
- Channel geometry; and
- Microclimate.

Data collected in support of the analysis included:

- Eighty-nine flow measurements at thirty-two sites,
- Forty-three water temperature records,
- Thirty-four meteorological records,
- Bankfull geometry measurements at twenty sites,
- One hundred fifteen effective shade measurements.

The analysis and data collected also included a shade model developed for the Scott River watershed, and a Thermal Infrared Radiometry (TIR) completed in 2003 and 2004. The results of the TIR survey showed that the temperature profile of the Scott River exhibited local special variability, particularly where seeps or hyporheic exchange was occurring in the river.

The TMDL ultimately concluded that human activities have resulted in significant increases in temperature in many areas of the watershed. The primary factor affecting stream temperatures identified by the RWB was increased solar radiation resulting from reductions of shade provided by riparian vegetation. Groundwater accretion was also found to be a primary factor affecting stream temperatures in Scott Valley. Diversions of surface water lead to relatively small temperature impacts in the Scott River, but add to the cumulative impacts of human activities and have the potential to significantly affect temperatures in smaller tributaries, where the volume diverted is large relative to the total flow. Overall, the TMDL found that the temperature of the Scott River is very sensitive to the amount of groundwater entering the river.

3.2.6.2 Sediment

Water quality in the Scott River system is strongly affected by its geology and soil conditions, natural events like fires, and past and present management practices. This condition is described in the previous Geology and Soils chapter.

Early records of sediment problems in the stream have been compiled for the Scott River (Sommarstrom, Kellogg, and Kellogg 1990). Mining pollution from placer and hydraulic mining in the late 1800s, followed by gold dredging north of Callahan in the 1930s – 1940s, created chronic turbidity and siltation problems. Mining silt impacts were noted in two surveys of the Scott conducted in 1934 due to the dredging activity (CDFG 1934, Taft and Shapovalov 1935). Aquatic bottom food organisms (benthic macroinvertebrates) were measured at riffles above and below sites affected by mining in the upper Scott, and the average number of organisms was always less below mining sites than above.

Excessive sand in the river was not noted by CDFG until about 1948, when field notes began to comment on the “too sandy” nature of the river near Fort Jones, creating very poor spawning area for about 7 miles. A CDFG biologist believed in 1962 that the former bucket dredge operation below Callahan had contributed to the deterioration of suitable spawning habitat in the river, and the effect was still continuing with the winnowing of sand and fines below the dredger site: “Many spawning areas have been displaced by sand”. The 1955 flood contributed much sediment also. A 1968 survey in French Creek noted the lower reach to be very sandy and “probably not used to a significant degree by steelhead for spawning.” This observation followed the 1964 flood and its impacts.

A significant local fisheries problem is excessive sand-sized (<6.3 mm) sediment derived from highly erodible decomposed granitic (DG) soils located on the western slopes above Scott Valley (Lanse, 1972; CH2M Hill, 1985). Excessive fine sediment causes problems for fish because it smothers their eggs and aquatic invertebrates in spawning gravels, eliminates bottom cover, and reduces the size and number of pools for rearing. Scott Valley exemplifies a low gradient river system, dropping 264 feet in 29 miles, and is a natural area for sediment to deposit (Lewis, 1992). The sediment composition of the Scott River's streambed in Scott Valley (and in a few tributaries) was systematically evaluated in 1989 to help identify the reaches that provided various qualities of spawning habitat (Sommarstrom et al., 1990). Periodic floods tend to move sediment through the system, deposit sediment on the floodplain and the streambed, and also cause stream bank erosion.

A 1990 study identified accelerated DG erosion sources in the Scott to be roads (63% of total), upslope streambanks (23%), and logging skid trails (13%); certain subwatersheds also produced more DG sediment than others (Sommarstrom et al, 1990). At that time, it was estimated that 60% of the granitic sediment yield to the Scott River was due to the human activities while 40% was natural background.

3.2.6.3 Other Water Quality Issues

State and federal agencies have not identified problems for beneficial uses due to dissolved oxygen (DO), nutrients or pesticides in the Scott River and its tributaries. Similarly, although limited information is known regarding the quality of groundwater in the Scott Valley, it is assumed to meet the quality objectives required for use. A study of groundwater composition was completed in 1953, mainly focusing on dissolved inorganic constituents. The groundwater investigation determined that the groundwater in Scott Valley is calcium-magnesium bicarbonate water (hard water). In addition, other inorganic constituents detected included potassium, sulfate, chloride, nitrate, fluoride, and boron. However, several samples of groundwater exhibited higher than average concentrations of chloride and nitrate, which is typical of a highly agricultural area or can be associated with discharge of human waste such as through a septic system and leach field (Mack, 1958).

3.2.7 Water Balance

A preliminary framework for the completion of a water balance study was completed in 2004 (Deas 2004). Since then, a spreadsheet calculation has been maintained as an estimate of the groundwater balance in the Scott Valley. The water balance is based on the assumption that Scott Valley is essentially a closed system, where the only input is in the form of precipitation (either through direct precipitation or runoff associated with spring melt of snow and ice from the upland areas). For the purposes of the current water balance, an assumption is made that groundwater neither flows into or out of the valley from the aquifer, but rather would flow from the valley as part of the Scott River system.

The main outflows from the Scott Valley System are discharges from Scott River, and its tributaries, evaporation from the Scott River and surface detentions following precipitation events, transpiration by plants, and urban use. Evaporation of surface water and transpiration are generally grouped together during calculations and are referred to collectively as evapotranspiration.

In order to complete a water balance, proper data must be accumulated for each of the inflows and outflows into the Scott Valley System. Precipitation data can be logged at weather stations and is usually collected into a rain gage which is reported in inches of precipitation. For an area the size of Scott Valley, with differing weather resulting from the orographic patterns caused by the surrounding mountains, several rain gages should be utilized in order to get an accurate depiction of differing quantities of precipitation into the Scott Valley System which can then be summed for the purposes of the calculation.

The evapotranspiration term for the Scott Valley is dominated by the transpiration of vegetation within the valley and upland areas. Accurate accounts of acreage by type of vegetation are maintained, whether it be agricultural lands or riparian vegetation along the lengths of the Scott River and tributaries. Accurate estimations of acreage by crop are kept in order to calculate the evapotranspiration. For example, agricultural areas have been split into acreage by the following plant types: grain, alfalfa, alfalfa-x, pasture, and meadow pasture. The amount of surface water used for irrigation on each of these crops is also estimated based on known surface water, groundwater/surface water, and meters on groundwater withdrawals outside of the adjudicated area. However, not all groundwater withdrawals located outside of the adjudicated area are metered and therefore, estimates are used based on the known withdrawals.

Urban use is calculated through flow meters on intakes to the community water supplies. Estimates can also be used for private domestic groundwater pumps that are not metered. Surface water gages are located in several locations along the main stem of the Scott River, as well as in several tributaries. These gages are used to determine the quantity of water that flows from the basin. The inflow and outflow values are then summed in order to determine the quantity of water recharged or ultimately utilized from the groundwater basin.

Although much data is available regarding the various inputs and outflows from the system, the preliminary framework completed in 2004 indicated that several data gaps were still present, and that additional or updated data could be gathered to more accurately complete the water balance (Deas, 2004). For example, data associated with groundwater development/use (such as well information, pumping quantities and periods, water levels, conjunctive use, recharge, etc.) are not uniformly documented and in some cases unavailable. Although agricultural and irrigation uses are generally well defined additional data to help refine the balance such as transit losses and tail water volumes are not available or could be better quantified. Additionally, explicit upland area data are limited. In all cases, estimations and approximations can be made to complete preliminary water balance; however, greater accuracy can be achieved by addressing the data gaps. Also, with greater accuracy, the water balance becomes a more useful tool for planning and management of groundwater resources going forward.

3.2.6.1 Scott River Runoff Forecast Model

As part of the Water Balance effort, an investigation was performed of the potential formulation of a runoff forecast model for the Scott River (Deas and Tanaka 2005). The purpose is to find a method to help predict the volume and timing of runoff that will be available later in the year so water managers can try to allocate their water supply in an efficient and productive manner. Since the Scott does not have appreciable surface water storage, any forecast modeling would more likely be based on snow pack or precipitation conditions. Examining several statistical relationships through models, the report found that the multivariable snow water content relationship illustrated the best performance for runoff prediction. Limiting the certainty of these models was the insufficient record for tributary inflow and groundwater conditions.

3.2.6.2 Water Supply Indices for the Scott River Sub-Basin

Another component of the Water Balance is the determination of water year types to help classify historic and forecasted flows. Year types, or indices, are a means of describing the volume of water originating in a river or basin in response to differing hydrologic conditions. A report was prepared on this topic specific to the Scott River Valley (Deas and Tanaka 2006). Various categories of water year types for single year and multi-year conditions (e.g., dry, normal-dry, dry-dry-wet) were examined using the long-term precipitation record for the Scott Valley (collected in Fort Jones since 1936). One other aspect of this study was the groundwater component: since there appears to be some correlation between surface water runoff and groundwater levels in portions of the basin, there may be some aspect of groundwater storage that could be useful in defining water year types in Scott Valley. Monthly depths to water table measurements were recommended to “assist in better capturing the annual drawdown and refill cycle.”

3.3 Biological Setting

The Scott River historically supported a robust aquatic ecosystem, including anadromous salmonids. Three salmonid species are currently present in the Scott River: Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and rainbow (steelhead) trout (*O. mykiss*). Chinook salmon are the basis of important commercial, sports, and tribal fisheries in Northern California and the Klamath River. Coho salmon in this area are listed as “threatened” under the California and Federal Endangered Species Act. These anadromous fish require suitable habitats on a watershed scale as they move from freshwater to estuarine and marine ecosystems and back in order to successfully complete their life cycle.

Impaired water quality and quantity in fresh water streams is believed to be one of the largest “bottlenecks” to the production of salmonid “smolts” entering the ocean and can impede adult salmonids from accessing suitable spawning areas. In addition to water quality and quantity parameters, it is hypothesized that in-stream habitat degradation and historic watershed alteration (upslope and in-channel) produce a cumulative effects on freshwater survival from the egg stage to the smolt stage.

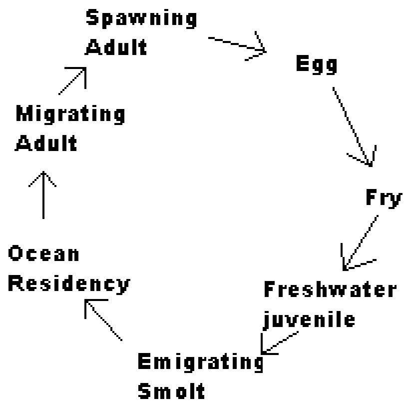


Figure 3-6: Salmon life cycle

The three different salmonids utilizing the Scott River follow the salmon life cycle depicted in Figure 3-6 with the different species having characteristic timing and lengths for the various stages. The exception is some rainbow trout that can complete the life cycle without a period of ocean residency. This discussion will focus on the Chinook and coho salmon due to their economic, cultural, and regulatory significance combined with their more "rigid" life cycle patterns and habitat preferences.

Adult Chinook salmon enter the Scott River in early October through November and largely spawn in suitable habitats of the main stem Scott River. Adult Chinook will spawn in both the canyon and valley of the Scott River if the flow regime allows for fish passage through a series of barriers that include disconnected stream reaches in critically dry years. A major priority is to enable the adult Chinook to access as much suitable habitat as possible with emphasis placed on providing fish passage to the low gradient spawning areas of the Scott Valley above Etna Creek.

After successful spawning, the Chinook eggs incubate in the inter-gravel environment of the "redd" until fry emergence - starting in early March in the Scott River (Chesney and Yokel, 2003). During the fry and juvenile stages Chinook rear in the Scott River for several months and then outmigrate via the Klamath River for a period of ocean residence that can last from two to five years (three years is average). Outmigrant trapping efforts in the Scott River have shown that the majority (to all) juvenile Chinook emigrate from the Scott River before the flow regime reaches low (base) flow. For this reason, it is believed that groundwater's effect on instream flow (which would be greatest during the period of base flow) is not playing an essential role to the survival of juvenile Chinook.

The significant differences between the Chinook and coho life cycles are in the duration and timing of the life stages. Potentially the most significant difference is that juvenile coho typically rear for an entire year in freshwater habitat. This requires juvenile coho to rear through the low flow period of summer when habitat quantity and quality (especially temperature) can be limiting. During this period of summer rearing, groundwater effects on the Scott River can be locally significant (in some water years) in providing suitable rearing habitats for this cold water fishery.

Adult coho return to the Scott River as three year old fish in November and December and spawn mainly in the lower alluvial reaches of the large tributaries of the "west side" of the Scott Valley. Fry emergence occurs in early April through May – timing is affected by the different winter stream temperature regimes of the different tributaries. Fry and juvenile coho favor low velocity habitats with good cover and a suitable temperature regime.

The majority of documented juvenile rearing of coho in the Scott Watershed occurs in the natal tributaries in which water temperatures are suitable for most (all) of the low flow summer period. Monitoring efforts recording the "ambient" stream temperatures of the East Fork Scott River and mainstem Scott River have shown that during average to low water years there are periods in which the stream temperatures are stressful to lethal for juvenile coho. Direct observation surveys have shown that these reaches contain limited juvenile coho salmon utilizing isolated areas with suitable water temperatures. Efforts to understand the distribution, nature, and biological utilization of the cold water inputs throughout the Scott Watershed are an ongoing effort.

These areas offering the rearing fishery "thermal refugia" are the most salient features showing a potential link between groundwater accretion and increased carrying capacity due to the amelioration of an impaired temperature regime. In dry water years (e.g., 2001 and 2007), portions of the main stem Scott River become disconnected and the alluvial portions of many tributaries become disconnected in most water years. These disconnected reaches negate juvenile rearing potential and can impede adult salmon migration if they persist into late fall and winter. An understanding of how the ground water and channel morphology are "interacting" might help us understand the processes that define losing and gaining reaches of the Scott River and tributaries.

Finally, stream temperature data has shown that the Shackleford – Mill watershed has warmer water temperatures in winter and cooler water temperatures in summer in the alluvial reaches of Quartz Valley, when compared to other significant tributaries of the Scott (e.g. the French – Miners). It is hypothesized that this watershed has a greater groundwater influence on the year round flow regime than other west side tributaries. This greater groundwater influence would moderate the stream temperatures year round. The more moderate temperature regime possibly benefits salmonids at all life stages allowing for earlier emergence and greater growth throughout the year creating emigrating fish with superior condition.

Scott River - timing of salmon life stages

Chinook salmon

	month											
lifestage	October	November	December	January	February	March	April	May	June	July	August	September
spawning	☒	☒										
incubation	☒	☒	☒	☒	☒	☒	╱					
juvenile rearing						☒	☒	☒	☒	╱		

coho salmon

	month											
lifestage	October	November	December	January	February	March	April	May	June	July	August	September
spawning		☒	☒	╱								
incubation		☒	☒	☒	☒	☒	☒	☒				
juvenile rearing	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒

steelhead trout

	month											
lifestage	October	November	December	January	February	March	April	May	June	July	August	September
adult rearing (1)	☒	☒	☒					╱	☒	☒	☒	☒
spawning			╱	☒	☒	☒	╱					
incubation				☒	☒	☒	☒	☒	☒			
juvenile rearing	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒

(1) - period of freshwater rearing for "summer" ecotype of adult Steelhead trout in Scott River. Timing of spawning for this ecotype is largely unknown.

Table 3-2: Scott River Salmonid Life Cycle Timing

Steelhead (rainbow) trout have a more robust and varied suite of life cycle options available for successful survival and spawning in comparison to the previously discussed salmon species. Steelhead and rainbow trout are two names for the same species of fish - a steelhead trout is an individual of the species that displays the anadromous form of the life cycle, that is, it has migrated to the ocean. The majority of steelhead (winter ecotype) migrate as sexually mature fish during the winter months and spawn from January through March or April in the Scott River. Additionally, the summer ecotype of steelhead migrates into fresh water as sexually immature adults in early summer. These adult “summer” steelhead must find suitable freshwater habitat in which to spend the summer until they spawn in the late fall and winter months. Insufficient water quantity and inadequate water quality (e.g. temperature) could impede the migration and/or survival of this important ecotype of steelhead trout.

Juvenile rainbow trout rear in fresh water during all seasons of the year. Juvenile rainbow trout (especially ‘young-of-the-year’ trout) are not as sensitive to water temperatures and habitat requirements as juvenile coho salmon, yet they require suitable cold water habitats in the tributaries and mainstem of the Scott River for successful rearing. Larger juvenile rainbow trout (yearling, two year olds, etc.) require deeper waters and prefer the presence of fish cover elements. Habitat degradation coupled with increased water temperature regimes could limit the availability of habitat in the mainstem Scott River and East Fork Scott River during summer rearing. Additionally, limiting the suitable habitat for salmonids to a “small” volume in reaches of the Scott watershed could limit the condition and/or survival of all species by limiting the availability of "partitioned" habitats and creating inter-specific competition and predation.

3.3.1 Adult spawning of Chinook and coho salmon in Scott River

Adult Chinook salmon have been found to predominantly spawn in two reaches of the Valley portion of the mainstem Scott River – above and downstream of the mouth of Shackleford Creek and an approximately 8 mile reach from Fay Lane to below the mouth of Etna Creek. Historic Chinook spawning ground surveys documented a significant utilization of lower Shackleford Creek by adults, but the aggraded mouth of Shackleford currently negates connectivity and access to adult fish during most water years. The reach of the Scott River from below Etna Creek to Meamber Bridge is characterized by low to very low occurrences of Chinook spawning. This is largely due to the lack of suitable sized and sorted spawning gravels and a high occurrence of sand and smaller gravels.

Adult Chinook surveys have not been performed upstream of the tailing pile below Callahan. It is hypothesized that some spawning could occur in the East Fork Scott River if the disconnected reach in the tailing pile becomes connected and allows adult passage.

Adult coho spawning occurs predominantly in the tributaries of the Scott River. Limited spawning of coho salmon in the main stem Scott River (around the mouth of Shackleford Creek and in the tailings) has been observed in the early period of the coho spawning season when access to the tributaries is prohibited or limited. It is not known if this main stem spawning is volitional or an adaptation to the inability to access preferred habitat.

3.4 Water Use Setting

The Scott River Sub-basin of the Klamath River Basin encompasses 813 square miles or 520,600 acres. Of this amount, ownership is 63% private land and 37% federally managed lands. Public lands are managed by the Bureau of Land Management (BLM) and United States Forest Service (USFS). Valley floor lands are used primarily for agricultural purposes, with limited residential use (KNF, 1994 Community Action Plan, 6). Tribal trust lands amount to 447 acres, including the Quartz Valley Indian Reservation. Scott Valley's watershed represents the upper portion of the sub-basin, or about 620 square miles (400,000 acres). The size of the valley floor is about 40,000 acres.

About 47% of the area is woodland (mixed conifer and oak), 42% is rangeland or shrubs and grasses, 9% is irrigated agriculture, and about 2% urban or residential (USDA SCS 1972). Uses of the watershed reflect its rural and wildland nature: farming, ranching, forest management, residential, commercial, recreation, mining, fish and wildlife habitat, open space, and wilderness. Current population is estimated at 8,000, with the cities of Etna and Fort Jones representing about 1,500 of that total (SRWC 2005). Smaller communities of Scott Valley are Greenview and Callahan.

Public lands surrounding the valley have traditionally provided multiple use resources, forage, timber, and mining as well as recreational opportunities for visitors and residents. Timber harvest levels have declined drastically over the last 10-20 years, a result of changes in forest management policies on public and private lands.

Based on historical accounts, much of the vegetation of the Scott River watershed has changed. In general, the tree age of forests has shifted to younger and therefore smaller trees with higher density. Large areas of the watershed are now occupied by brush species and there has been a shift from perennial to annual grasses. The effect of these vegetation shifts on evapotranspiration rates and total water consumption and release patterns for the watershed is not known but could be significant.

Logging: When logging on private land in California, the State Board of Forestry rules mandate stream-zone management to protect all beneficial uses of water. This includes water temperature control and streambed and flow modification by utilizing large woody debris (LWD), filtration of organic and inorganic material, upslope stability, bank and channel stabilization, and vegetation structure diversity for fish and wildlife (USFS, BLM, 1994). In the upland and canyon riparian zones, some riparian cover has been disturbed as a result of logging and flooding.

Logging has been included as one of many causes in the decline of anadromous fish populations throughout the west. There are conflicting data, however, and the exact relationship between logging and fish populations is unclear. In some cases logging and associated activities, especially the associated road system, can cause increased sediment inputs into streams if they are improperly maintained. This can affect access to clean spawning gravel, water quality (e.g. turbidity), stream morphology, and water temperature. Improper culvert installation on forest roads commonly created barriers to upstream fish movement. Past logging practices may have also caused increased water temperatures by removing overhead canopy cover thereby increasing the amount of solar radiation that reaches the stream. It was also a common practice in the past for loggers to remove large amount of large woody debris from streams as it was mistakenly thought by biologists and fish and game agencies at the time that this debris was a barrier to fish movement.

Agriculture: Farming began in Scott Valley during the Gold Rush era of the 1850s to provide food for the region’s miners and their livestock as well as for other settlers. Various crops have been grown over the years but the mountain valley climate creates a short growing season, limiting the types of crops possible for commercial production. Primary crops today are alfalfa, pasture and grain with very limited acreage in fruit, vegetable and herb crops. Ranches raise mostly beef cattle, a dominant economic factor in the County’s agricultural economy. A few dairy operations are also active.

The amount of irrigated agricultural land has averaged about 32,000 acres since figures were first collected in 1953, with crop prices and water availability often affecting the cropping patterns and acreage (Mack, 1958; CDWR 2003). Alfalfa represented 40% of the irrigated acreage in 2000 and is grown on the better drained soils in the center of the valley, while pasture (at 52%) tends to be found on the less well drained soils to the south and west. Alfalfa hay and grass hay are the products that are sold locally or exported out of the valley. Grain (at 6%) is usually grown as a short-term crop rotating with the perennial alfalfa every 4 to 5 years.

Water use for agriculture varies by crop type, irrigation system, and water year type, among other factors (UCCE 2001). Irrigation of alfalfa, for example, usually begins in April and ends in September. Wheel line irrigation of alfalfa tends to apply 3 acre-feet (36 acre inches) per season while center pivot irrigation applies 2.3 acre-feet (28 acre inches) (UCCE 2001). In 2000, applied water for agricultural crops in Scott Valley was estimated to be 92,200 acre-feet (CDWR 2003). The water sources for this amount were assumed to be 56% from surface water and 44% from groundwater.

Stock Water: During the fall and winter months, in Scott Valley, the majority of the diverted water use is for the purpose of livestock watering. Mature cattle need from 10-20 gallons of water per day, with highest demand occurring during hot days and lowest demand during the fall and winter months. The sources of livestock water include both surface water that is diverted into ditches for gravity delivery, and groundwater. Due to the fact that water for stock during the fall and winter is often delivered through open irrigation ditches, substantially more water than that actually consumed by the livestock is diverted into ditches during fall and winter.

Irrigation: For DWR water use assessments, the amount of applied water was estimated by assuming an irrigation efficiency of 75% for applied groundwater, mostly sprinklers and 65% for applied surface water, primarily flood (CDWR, 1993a). In this estimate it is critical to recognize three important factors. First, when crops are irrigated for the full growing season (typically mid April to mid September) the amount of water used by the plant and lost through evapotranspiration is the same whether the water is applied as surface (flood) or sprinkler. Second, more water is applied as surface irrigation than when pumped from groundwater and applied with sprinklers. Third, surface irrigation, dependent on diversion, are more likely to be limited to partial season irrigation due to stream sources becoming dry part way through the season. Thus, crops in the 1950s and 1960s that were dependent on surface irrigation were probably often only irrigated for a portion of the growing season. The exception to this is grain, which was likely fully irrigated due to its early maturity. Considering the changes in crops, acreage and the factors above, the amount of water likely used by crops has increased from 1958 to 2000 by between 15 percent (10,000 more acre feet) and 30 percent (20,000 acre feet) depending on the date when surface irrigation stops, i.e. July 15, Aug 1 or Aug 15. Most of the additional water applied occurs later in the growing season from groundwater, and the rapidity of interconnectivity between groundwater and streamflows is uncertain. It is also important to recognize the magnitude of the increased use, on the order of 5 to 20 thousand acre feet compared to a total groundwater storage capacity of 400,000 acre feet. On the other hand, the relationship between irrigation and stream flow for fish remains relatively unknown and is a major issue to be addressed in this GW Study Plan.

The earliest estimate of irrigated acreage was in 1953, which claimed 15,000 acres irrigated by surface water, 15,000 acres by natural sub-irrigation, and 370 acres by wells, for a total of 30,370 irrigated acres (Mack, 1958). Based on periodic land use surveys, the amount of irrigated farmland in the valley has not changed significantly since 1958 (CDWR, 1993). However, the amount of acreage by crop has changed, with small grains decreasing from over 7,000 acres in 1955 to less than 2,000 acres in 1990, while alfalfa has increased from 10,000 acres to 14,000 acres in the same period (Table 3-3). Acres of pasture have fluctuated during this time period but are about the same now as during the 1950s.

Crop	**1958**	**1968**	**1978**	**1991**	**2000**
Grain	3,570	5,027	3,681	1,757	2,000
Alfalfa	9,850	9,032	10,405	14,313	13,000
Pasture	16,000	19,294	15,971	16,070	16,500
Other	2,803	446	1,607	303	300
Total	32,223	33,799	31,664	32,443	31,800

Table 3-3. Scott Valley Irrigated Acreage, 1958-2000 (CDWR data)

A study was conducted by the UC Cooperative Extension (Orloff., 1998; Orloff et al., 2005; Orloff, 2007) to evaluate current irrigation practices by monitoring the soil moisture status of several irrigated pastures and alfalfa fields. The study demonstrated that there was potential for improved water management and water conservation on some ranches. There were times when fields were irrigated when the soil moisture levels did not indicate irrigation was needed. The sensors also showed that under-irrigation occurred on other ranches, largely because the irrigation system was inadequate to meet peak crop needs in the mid-summer.

An irrigation cut-off experiment was also conducted in the Scott Valley. The date of the last irrigation affected the soil moisture content, but only the earliest cutoff dates had an appreciable effect on alfalfa yield in the years evaluated. Regardless of the irrigation cutoff date, alfalfa in all plots fully recovered by the following season and first and second cutting yields were essentially the same. Soil type may affect these results and a greater impact would likely occur on fields with a lower water-holding capacity. Irrigation after the final alfalfa cutting of the season appeared unnecessary for the soil type evaluated. Late-season irrigation (terminating irrigation in mid September versus late September or early October) had little effect on pasture yield. However, early irrigation termination (early August) resulted in the death of some pasture grasses and reduced yield. Cool-season pasture grasses were less able to withstand drought than was alfalfa.

An increasing number of growers are using soil moisture sensors as a result of these programs, educational events, and a brochure developed on using soil moisture to improve irrigation management. In addition, growers are improving their irrigation system efficiency by installing new uniform nozzles, repairing leaks, and switching to more efficient systems. Over the past decade, there has been a gradual but continual shift to center pivot irrigation from wheel-line irrigation—there were no center pivots 10 years ago while there are now approximately 15 center pivots. This trend is expected to continue somewhat but field size, shape, and the location of buildings limits the fields that are suitable to this irrigation system. This shift toward center pivots represents a significant improvement in irrigation efficiency, as wheel-lines typically have a distribution uniformity of 75% while center pivots often have a distribution uniformity of greater than 90%.

Urban Water Use: Residential water use in the Valley by the estimated non-urban population of 6,000 is greater than that of the two cities, but figures are not readily available. Assuming an average local water demand of 200 gallons per person per day (based on per capita figures ranging from 170 to 266 for the two cities), an estimated water demand for this category would be about 1,350 acre-feet a year. Most rural residences use wells but a few are served by springs and surface diversions.

The City of Etna (population 800) diverts surface water from Etna Creek for its water supply. In recent years, an average of 87,745 gallons per day (about 98 acre-feet per year) was produced although actual use was only 53% of that total due to high losses through the distribution system (Larson, Oscar & Associates 2004 "Water Master Plan Report for the City of Etna Water System", Prepared for the City of Etna.) Fort Jones (population 700) uses groundwater from wells in the interconnected zone of the Scott River above Moffett Creek.

Industrial use is almost exclusively found within the city limits of Fort Jones. No sawmills or other large industrial water uses are currently active in Scott Valley, though historically about 13 sawmills were scattered around the valley (SRWC 2005).

Upland Water Use: Native vegetation in the Valley's watershed varies from dense conifer forests on the wetter west side to oak woodlands and grasslands on the drier east side. Mountain meadows and rangelands on private and public lands provide summer forage for local cattle ranchers. Changes in upland vegetation patterns and water use have been documented during the past 150 years, due to grazing, fire suppression, logging, and climate change.

3.5 Water Management in the Scott Valley

Given the alluvial characteristics of the valley floor, Scott Valley's groundwater is interconnected in certain areas with the local perennial, intermittent and ephemeral stream systems (CSWRCB, 1975). The Scott River Adjudication of 1980 recognizes a zone of interconnected ground and surface waters in its water rights determination in the Scott River watershed below Fay Lane. However, the interconnected zone was designated with limited available information. Because the Scott Valley aquifer is situated in an alluvial valley it is conceivable that any withdrawal affects surface flow. More information is needed to determine the interconnection between groundwater and surface flows.

Until the late 1960's, agricultural water was mainly derived from surface water diversions, from the Scott River and its tributaries; flood irrigation was the primary application method (McCreary-Koretsky, 1967). Most wells were shallow and only used for domestic and stock supplies (Mack, 1958). Gradually much of the surface water use switched to groundwater wells and the irrigation method changed to sprinkler irrigation. State data, on well drilling in the Scott Valley, indicate an increase in the number of new wells each year, during the 1970's. Well drilling peaked after the 1976-77 drought and the number of new wells dropped to lower levels in the 1980's. A small increase again occurred in 1992, during another drought period (CDWR, 1993b).

CDWR estimates that applied water use for agriculture in Scott Valley for Year 2000 is 92,200 acre-feet. Net water use, which takes into account evapotranspiration of applied water, is approximately 65,600 acre feet – the difference is losses due to percolation, ditch and run-off. (Cervantes, T.; Water Balance Workshop Handout, 2002).

3.5.1 Scott River Water Rights and Adjudication

All surface water rights in the Scott River watershed, above the USGS gage station, are determined under three adjudications: Shackleford Creek (1950), French Creek (1958), and the Scott River (1980). Each one was developed by the State's Division of Water Rights under the SWRCB. By decree of the Superior Court of Siskiyou County, these adjudications have defined: 1) the amount of water each user is entitled to divert from surface streams or to pump from the interconnected groundwater supplies near the river (the latter for the Scott River only); 2) the area where such water may be used; 3) the priority of each water right as it relates to other water rights on the same source; 4) the purpose for which the water is used (e.g., irrigation, municipal, domestic, stock water); and 5) the diversion season. Riparian, pre-1914 claims, and appropriative rights are included in all of these decrees. Use of groundwater, where not considered interconnected with the Scott River, does not currently require state water rights permits and is not adjudicated.

In 1980, the Scott River Adjudication was decreed by the Court. It was based on a legal determination by the Division of Water Rights, of the State Water Resources Control Board. This adjudication applied to all water right holders in Scott Valley, with the exception of those in the Shackleford/Mill Creek and French Creek drainages. Separate adjudications were previously decreed for these two watersheds in 1950 and 1958, respectively. The Scott River Adjudication recognized 680 diversions, which could cumulatively divert 894 cfs from the Scott River and its tributaries (CH2M-Hill, 1985). Riparian, pre-1914 claims, and appropriative rights are included in all of these decrees.

Since 1989, Scott River, French Creek, Kidder Creek, Shackleford Creek, and Mill Creek have been considered "fully appropriated" by the SWRCB. As a result, no new water appropriation permits for additional surface or interconnected water can be issued for the period of April 1, to November 30, except Mill Creek, by order of the State Board. Even though the adjudications specify a right to use a certain amount of water, this amount is not always naturally available, particularly in below-average runoff years.

During the non-irrigation season, defined as "from about October 15 to about April 1" for most water users, water right holders in the 1980 Decree are allowed to divert, for domestic and stock watering uses, a "sufficient amount of water, in their priority class, to offset reasonable conveyance losses and to deliver 0.01 cfs at the place of use" (Para. 36). The statement on reasonable diversion and use (Para. 15) states:

> "Nothing herein contained shall be construed to allot to any claimant a right to waste water, or to divert from the Scott River stream system at any time a quantity of water in excess of an amount reasonably necessary for his beneficial use under a reasonable method of use and a reasonable method of diversion, nor to permit him to exercise his right in such a manner as to unreasonably impair the quality of the natural flow" **.**

Watermaster Service: To help assure water right holders that the adjudicated amounts are fairly distributed each year, the Scott Valley Service Area was created to administer Watermaster Service. The legislation to create the Scott Valley Watermaster Service also allowed the district to charge the affected landowners to recover the costs associated with the service. Watermaster service is presently used for 102 decreed water right holders in French Creek, Oro Fino Creek, Shackleford Creek, Sniktaw Creek, and Wildcat Creek.

In-stream flows: The USFS was designated a priority one user in the Scott River and as such was allotted minimum flows (in the 1980 adjudication) for the Scott River, at the USGS Gage Station, to protect the fishery resource. However, during the period of 1980 to 1995, summer and fall flow minimums have only been met for 3 years, 1982 through 1984 (Power, personal communication). Prolonged drought from 1987 through 1994, excluding 1993, has exacerbated this deficiency. It is not known whether other priority one, or lower priority, water users in this reach obtained their adjudicated allowable flows during this period**.**

Another streamflow requirement comes from Section 5937, of the State Fish and Game Code, which states that the owner of any dam must "allow sufficient water to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam." This regulation is applicable to permanent dams and may also be to seasonal gravel diversion dams in the Scott River and its tributaries.

3.5.2 Scott River Dry and Critically-Dry Year Plan

The RCD and SRWC are developing a detailed Contingency Plan for Dry and Critically-Dry water years at the request of the CDFG's Coho Salmon Recovery Plan. The contingency plan shall identify the criteria used to determine when a water year meets the definition of "dry" or "critically-dry" and describe a process by which the Grantee shall coordinate with landowners to augment streamflows and/or ramp up diversions during rearing and spawning seasons. In addition, the contingency plan shall identify data gaps. The plan will identify ways to augment stream flows during critical times of the year and work with the Department of Water Resources or a functional equivalent to develop a Diversion Ramp-up Management Plan to coordinate and monitor irrigation so as to minimize rapid reductions of in-stream flows and the possible stranding of coho salmon juveniles and adults. The Scott River Water Trust is also an identified tool to help with dry and critically dry year flow improvements. The development of the plans shall include the participation of water users, the Scott River Watershed Council, the Scott River Water Trust, appropriate government agencies, and technical experts.

3.5.3 Scott River Water Trust

In July 2002, the SRWC and RCD developed a concept paper for the development of a water leasing program. The Scott River Water Trust Program's goal is "to foster transactions which will provide improved streamflow for salmon and steelhead at critical periods of their habitat needs in the Scott River system by exchanging fair compensation to water right holders for the temporary or permanent in-stream use of their water allocation and the value foregone of the applied water." Phase I of the program identified the legal conditions of the three adjudications existing in Scott Valley and how such an effort could fit into the State's water rights procedures (Ellison, Schneider & Harris 2004). Phase II evaluated the financial, institutional, economic, biological, and monitoring needs and options for the program.

Implementation, or phase III, of the Water Trust Program, actively began during the summer of 2007 with successful water leasing transactions occurring on French Creek and Shackleford Creek to improve in-stream flow conditions for juvenile coho salmon and steelhead. Another proposed effort is to lease livestock water to increase flows in October and possibly November for adult Chinook salmon spawners in the mainstem Scott River, where low flows can block adult access to good spawning habitat in the valley (Sari Sommarstrom, Scott River Water Trust, personal communication.)

4 GROUNDWATER DYNAMICS IN THE SCOTT VALLEY

4.1 The Scott River as Groundwater Dependent Ecosystems (GDE): Basic Concepts of Groundwater – Surface Water Interactions and their Ecological Importance

Streams are a complex and diverse expression of the interplay between climate, precipitation, snowmelt, vegetation, ecosystem functions, soil, runoff, watershed properties, landscape forms, geology, and groundwater. Within that framework, streams have hydrological, physical, chemical, and biological functions. Therefore, a stream such as the Scott River cannot be viewed isolated from these or other elements of the Scott Valley watershed environment.

Within the context of the hydrologic cycle, the Scott River's main function is to convey runoff, generated by precipitation or snowmelt through Scott Valley and into the Klamath River, from where it is ultimately discharged to the ocean. Precipitation or snowmelt may be generated locally (within the valley) or throughout the watershed, for short periods of time, or over longer periods of time. During periods of no precipitation and no snowmelt (during cold winter-spells and in the summer and early fall months from June through October), the Scott River functions as the main drainage of the various groundwater reservoirs located within the headwaters and along the stream courses of the tributaries and mainstem of the Scott River. These groundwater reservoirs include the Scott Valley aquifer described above. Hydrologists refer to the discharge of a stream during periods of no precipitation or snowmelt as "base-flow". In contrast, stream flow during rainstorms generates "direct runoff" from overland stormflows and from so-called "interflow", which is a hydrologic term denoting water flowing laterally in the shallow soil subsurface towards a stream, without either being observable as surface runoff or becoming part of the larger groundwater aquifer system.

Direct runoff is a key hydrologic concern for predicting and managing floods and for managing reservoirs and water supplies. In contrast, the temporal and spatial characteristics of base-flow and its dependency on the complex interaction between the stream and nearby groundwater is critical for our understanding of the ecological function of a stream. Because base-flow is essentially an expression of groundwater flows into a stream, the ecological importance of the groundwater-surface water connection cannot be overstated.

Groundwater-dependent ecosystems (GDEs) are increasingly recognized as an important category of ecosystems with an often high degree of diversity, complexity, and biodiversity (Boulton and Hancock, 2006). The Scott River, one of the few remaining streams in California that is not managed by dams or reservoirs, is in "base-flow" mode for many months of the year, particularly during the ecologically critical summer and early fall months, when stream flows are lowest.

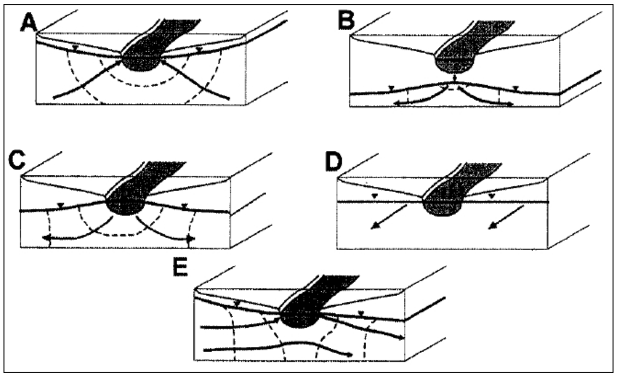


Figure 4-1: Basic Principle of Groundwater-Surface Interactions

A – gaining stream (upward seepage); B, C – losing stream (downward seepage); D – parallel flow; E – transverse through-flow. The Scott River is thought to be primarily a gaining stream (A). (*from*: Woessner, 2000).

Base-flow contributions from groundwater to the stream may occur continuously or intermittently along all or some reaches of the stream. In some locations or along some stream reaches, the reverse process of stream water infiltration into groundwater may occur (Woessner, 2000). Groundwater inflow to the stream may occur in individual, highly localized seeps or springs, or more broadly through lateral inflows from the so-called "parafluvial" zone immediately adjacent to the wetted stream channel, or from groundwater flow through the hyporheic zone underneath the stream into the stream itself (Fig. 4-2).

The hyporheic zone of the stream is generally defined as that zone of groundwater-filled streambed sediments that is effectively an extension of the stream itself in that the hyporheic zone conveys groundwater that has been recharged by the stream nearby and will be discharged a shorter or longer distance downstream back into the stream. Some define the hyporheic zone as the saturated zone below the stream in which groundwater and surface water mix (Woessner, 2000). This may happen particularly in braided streams and meandering streams, where hyporheic water flows are an essential, albeit invisible portion of streamflow. While the exchange of water, nutrients, and heat between the stream and the hyporheic zone is not necessarily dependent on groundwater from a nearby aquifer, it serves an important ecologic function and may be strongly controlled by the hydraulic properties and the pressure or water level status of the surrounding aquifer. According to Woessner (2000), hydrologic research at the aquifer-stream interface and in the hyporheic zone is a new area of hydrogeologic research: while hydrogeologists have long considered the stream-aquifer as a simple one-dimensional connection (Fig. 4-1), new research and interdisciplinary work with ecologists and stream hydrologists suggests that this zone has a high degree of complexity.

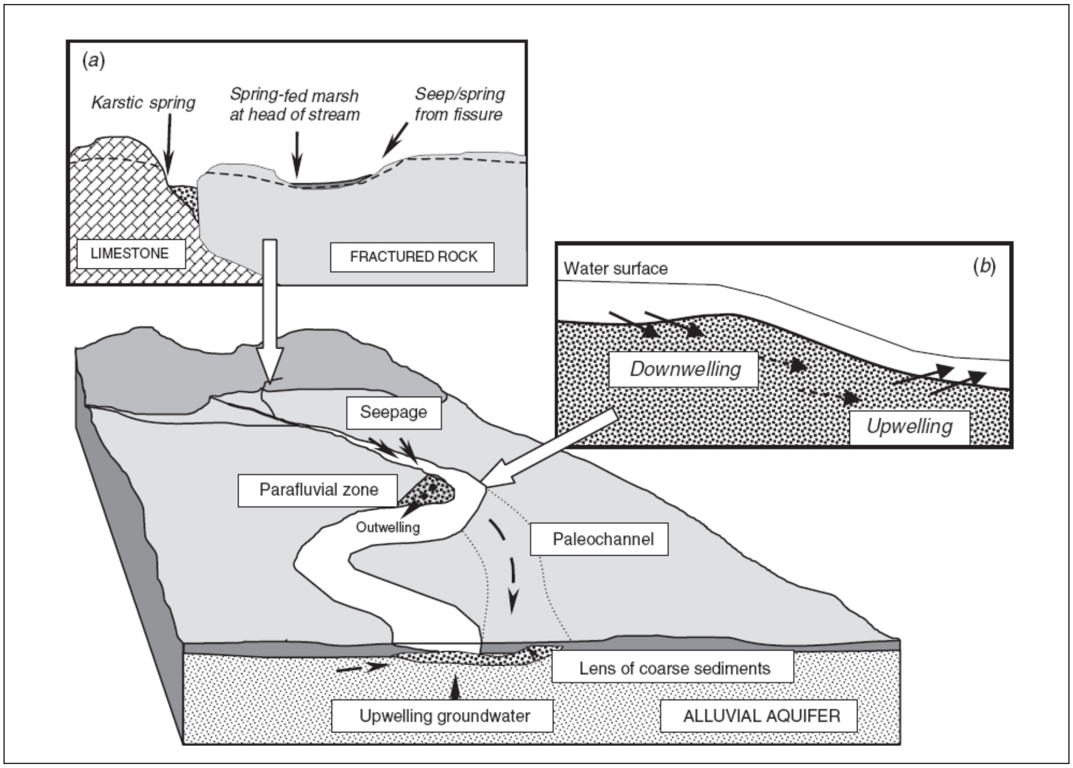


Figure 4-2: Common river base-flow system in a typical catchment. (a) In the bedrock-controlled reaches of the headwaters, seeps, springs and spring-fed marshes may be common, whereas (b) parafluvial and hyporheic zones where water upwells and downwells during its passage downstream are more common in the middle reaches. Lateral paleochannels may carry water in lenses of coarser sediments in the lower reaches (*from*: Boulton and Hancock, 2006).

Support of the various salmon spawning grounds and salmon migrations in the tributaries and in the mainstem of the Scott River (together here referred to as the “Scott River System”) has been recognized as an important ecological function of the Scott River System. Sufficient base-flow and water quality (including temperature) during the summer and early fall months are critical to maintaining these anadromous fisheries (see below). For the stream reaches of this system that are located on the alluvial fans and sediments of Scott Valley, base-flow is currently thought to be significantly controlled by the within-valley interaction of groundwater with the stream and by the functionality of the hyporheic zone below the Scott River System.

Stakeholders at the local and state level are seeking input to develop proper management practices to protect beneficial uses of Scott Valley including the Scott River System during the critical summer and early fall months. However, the development of such management practices is highly dependent on a thorough understanding of:

- Ecological functions of the Scott River System base-flow regime;
- Hyporheic zone processes; and
- Groundwater-surface water interactions.

The complexity and diversity of the Scott River System base-flow, its connection to the Scott Valley groundwater system, and the importance of these connections to the ecosystem function of the Scott River System (including its anadromous fishery) can be better understood by clarifying that groundwater – surface water interactions have the following four components:

- Hydrological (flow rates, pressure, hydrogeological characterization, water level);
- Physical (temperature, sediment transport);
- Chemical (solute transport, nutrient transport, contaminant transport, dissolved oxygen); and
- Biological (fauna and flora).

The spatio-temporal complexity of hydrological, physical, chemical, and biological functions of groundwater – surface water interaction occur at several spatial scales: the local or channel unit scale (channel bedforms, e.g., a spring or small seep of one to a few meters in diameter, pool-riffle), the stream reach scale (section of a stream, from several tens of meters to a few kilometers long), the sub-catchment or valley segment scale (Scott Valley, the various sub-watersheds of the Scott River Watershed), and the Scott River Watershed scale (watershed scale, regional scale). Similar hierarchical scales have been suggested, e.g., by Baxter and Hauer (2000) and Boulton and Hancock (2006).

At the watershed scale, we compute the overall water balance of the Scott River Watershed, we analyze inter-annual trends in precipitation and stream-flow (Drake et al., 2000), and we characterize seasonal variations (e.g., summer vs. winter flows).

At the sub-catchment or sub-watershed scale, we identify various tributary watersheds with their specific hydrologic properties. Large-scale differences in the groundwater – surface water connections can also be distinguished at this scale: headwaters of the streams in the Scott River Watershed primarily interact with fractured rock groundwater aquifers of very limited spatial extent and storage capacity. The stream channel is constrained by bedrock geology. As the streams emerge onto the alluvial fans of the Scott Valley, coarse sediments make up the stream channel in the steeper sections. Further downstream, particularly along the mainstem Scott River, the slope of the streambed becomes significantly smaller and the stream-bed sediments are much finer textured. Such spatial differences in the sediment texture of the stream-bed have major impacts on the dynamics of the flows between groundwater, hyporheic zone, stream bed, and the stream itself. Also, in the lower reaches of the Scott River and some of its tributaries, we may observe paleochannels, anabranches, and similar river channel features not observed in the stream channels near the margins of the valley. These features play a critical role in the hyporheic exchange with the stream.

Much of the stream flow hydrograph history has been collected at the sub-catchment scale (rather than at the reach scale), with continuous records of stream flow that are representative of entire sub-catchments. Hence, it is possible to define, at a relatively large scale, the net groundwater-surface water seepage rates (upward or downward) during base-flow periods.

While existing gaging stations may define the net contribution of groundwater to base-flow within a few sub-catchments of the Scott Valley, actual seepage rates to or from groundwater and actual exchange rates between the stream and the hyporheic zone may exceed the average contributions by orders of magnitude locally or even within specific (losing or gaining) stream-reaches, only to be neutralized by equal contributions into the other direction (e.g., upwards instead of downward) some distance downstream.

Ultimately, the survival of the anadromous fishery in the mainstem of the Scott River during summer months will largely depend on highly localized expressions of groundwater – surface-water interactions, for example by the function of a localized groundwater spring within the stream that locally provides a thermal refugium for the fishery to survive. To a large extent, much of this functionality of and interplay in the hyporheic zone is not known for any of the reaches of the Scott River. It is an open question, to which degree the dependency of the Scott River System, and its salmon fishery, on groundwater is obligate or facultative. This latter question, however, is not addressed by the groundwater study plan. The study by Baxter and Hauer (2000) is an illustrative example of the importance of a hierarchical approach to investigating groundwater - surface water interactions. They showed that Redds of Bull trout in Montana, at the reach scale, are preferably located in gaining reaches of the stream; yet, at the local, bedform scale, Redds were located in gravel bed features with more downwelling and substantial gravel bed flow rates.

Temporal variations in exchange of water, heat, and solutes across the groundwater – stream interface also play a significant role, particularly changes in stream temperature and stream water quality. Such changes occur at decadal scales (climate change), seasonally (e.g., seasonal variations in mean monthly stream temperature), and diurnal (e.g., temperature and dissolved oxygen changes between daytime and nighttime). Long-term and seasonal variations are closely linked to climate, climate-change, vegetation (e.g., increase in flow after first fall frost due to sudden drop in evapotranspiration), and anthropogenic practices (e.g., summer irrigation). Diurnal variations, e.g., in stream temperature during the summer, are related to evaporation and evapotranspiration from the stream, riparian vegetation, direction and strength of groundwater seepage, and groundwater quality.

The GW Study Plan will address groundwater – surface water interactions at all scales and encompass investigations of the hydrological, physical, chemical, and biological functionality of these interactions to the degree that they influence the well-being of the salmon fisheries in the Scott River System. Seasonally, groundwater contributions to the Scott River System are most important during the late spring, summer, and early fall months (most associated with base-flow condition) and will therefore be the focus of the GW Study Plan.

4.2 Groundwater Flow and Heat Transport – A Preliminary Conceptual Outline

Some preliminary estimates of groundwater flow and properties in the Scott Valley aquifer system are obtained by applying a very simple conceptual model to a cross-section of the Scott Valley aquifer (Fig. 4-3). In the first step, we consider the possibly highest regional aquifer hydraulic conductivity that represents the Scott Valley aquifer. This estimate is obtained from the following considerations:

The highest level (upper limit) of groundwater accretion to the Scott River main stem occurs during the time with highest regional water level and steepest possible groundwater gradient from the margins of Scott Valley towards the Scott River. This would typically be in the late spring or early summer, following the seasonal snow melt. At that point, most groundwater discharges from Scott Valley to the Scott River would occur between the bottom of the dredge tailings (at the south end of the valley), the Scott Valley Irrigation District diversion, and Highway 3. If all surface water inflows were measured between Callahan and the USGS gage just below Scott Valley, the difference between all surface water contributions to the Scott River in Scott Valley and the actual discharge at the USGS gage would represent an estimate of groundwater discharge from Scott Valley to the River System.

However, in practice that amount is too small to be easily observable. That means, it is unlikely to be as large as 500 cubic per second (cfs) or 1,000 cfs and probably more on the order of 100 cfs or less. With that number in mind, we can determine an upper limit for the regional average aquifer hydraulic conductivity based on the fundamental physical law governing groundwater flow, called Darcy's law:

groundwater flow per unit area = hydraulic conductivity X hydraulic gradient

which engineers and groundwater hydrologists write mathematically as:

$$Q/A = K \times i$$

- We know that a regional west to east gradient, based on land surface elevation slope is on the order of 0.33% (60 ft over 3 miles) or less, probably as little as 0.1% near the Scott River. The average land surface gradient is 60 ft (Hwy. 3 S of Greenview: 2800', SR due E of there: 2740') over a distance of 12,000 ft, or approximately 0.5%.

- Let's say, the groundwater accretion were indeed 100 cfs over a distance of approximately 20 river miles. That is 100 cubic feet per second discharged along 100,000 feet or approximately 10 million cubic feet per day per 100,000 feet, which amounts to 100 cubic feet per day per foot of river length.
- Now let's further assume that most recharge is from the Westside (and not from the eastside), and that the effective, average aquifer thickness is 100 feet.
- Then we can quickly compute that the aquifer flow rate, *Q/A*, is not larger than 100 cubic feet per foot river length and 100 feet aquifer thickness (100 ft^3/d/ (1 ft * 100 ft). That yields a maximum aquifer flow rate, *Q/A*, of 1 ft/d.
- The maximum possible regional *K* value is 1 ft/d divided by 0.5% = 200 ft/d (see Figure below). That is in fact a typical hydraulic conductivity for coarse sands and gravels. For a regional aquifer *K* value, this is relatively high number.

Here is another example of the same scenario, but this time for the summer, where we do know the amount of groundwater accretion to the Scott River:

- Let's assume that the Scott River currently gains 20 cfs between the Callahan and Hwy. 3 (about 20 miles) during typical spring conditions. That is 2 million cubic feet per day over 100,000 feet river distance or 20 cubic feet per day per foot river length.
- Now let's again assume that all groundwater accretion is from the western part of the Scott Valley and that the aquifer thickness is 100 ft. Then the groundwater discharge, *Q/A*, is 0.2 ft/d. We need to also know the gradient, *i* : The water table is 30 ft below ground surface at Hwy.3 & Etna/Greenview or at 2770 ft, 12,000 feet from the Scott River, which is at 2740 ft. That is a gradient of 30' per 12,000' or 1' per 400' or *i* = 0.25%. Hence, the regional hydraulic conductivity, *K*, is 0.2 ft/d / 0.25% = 80 ft/d.

These estimates are, what engineers and scientists call an "order of magnitude" estimate of the "upper limit" of the hydraulic conductivity in the Scott Valley aquifer system. If we had assumed slightly different numbers, the results would be equally different. What this simple model says is that the aquifer cannot possibly have a hydraulic conductivity that is much more than few hundred feet per day. This is indeed consistent with the type of aquifer material found in Scott Valley. What this simple model also says, is to look for regionally averaged hydraulic conductivity values on the order of a few tens of feet per day. Estimates such as these are important to constrain future modeling efforts.

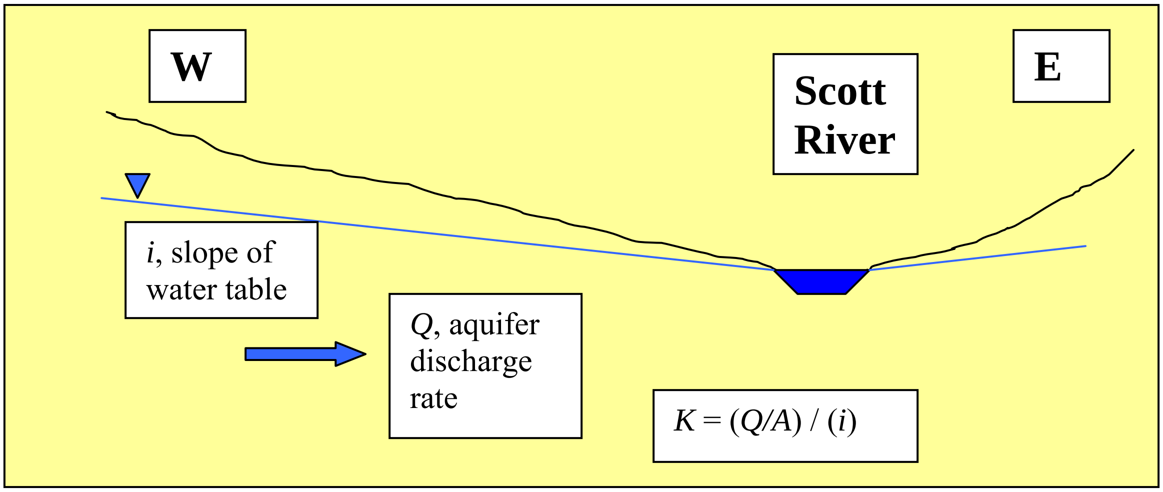


Figure 4-3: Preliminary Groundwater Flow Representation

4.3 Flow and Heat Transport at the Groundwater-Stream Interface

Flow and heat transport at the groundwater-stream interface has recently become a renewed subject of research, as better and less expensive instrumentation becomes available to measure flow, tracers, and temperature in much more detail than in the past. This research has allowed scientists to demonstrate some of the complexities in the groundwater – surface water interface and provided a new understanding. A few examples that are relevant to the Scott River are given here:

Constantz et al. (1994, 1998) show that, during summer months, losing streams with low flows are subject to large diurnal temperature variations that lead to large variations (30% and more) in the infiltration rate through the stream-bed, primarily due to changes in hydraulic conductivity (increased viscosity of water at higher temperatures). In one study, only 5% of the total increase in streambed infiltration was due to increased ET by riparian vegetation (Constants et al., 1994; Ronan et al., 1998). Conversely, gaining streams with low flows are highly dependent on the groundwater discharge to the stream. Diurnal variations in groundwater discharge are observed due to increased ET from riparian vegetation in the afternoon. Lower discharge to the stream leads to lower stream-flows and quicker rise in stream temperatures in the afternoon. Long-term annual and short-term diurnal temperature variations, together with flow data can be used to discern losing and gaining stream dynamics and their controls.

Ronan et al. (1998) used the unsaturated zone flow and heat transport model VS2DH to compute infiltration from the stream into the subsurface. But that approach only worked for regions with significant unsaturated zone and a lower conductivity streambed and would not be applicable to Scott Valley.

Loheide and Gorelick (2006) use FLIR data, taken 4 times in one day on a 1.6 km stream, to match to a model (“Heatsource”, a 1D stream flow and heat transport model) to identify local seeps due to hyporheic flow and also base-flow contributions from groundwater. This reference contains a valuable summary of the physical background of coupled heat and flow at the stream-aquifer interface. A similar approach has been employed in a recent survey of stream temperature on the Scott River, implemented by RWB. The RWB survey provided a fully two-dimensional map of stream temperature during a single fly-over in August 2004. Estimates of groundwater seepage were obtained using "Heatsource" (Bryan McFadin, *personal communications*). Another model, the Continuous Time Random Walk (Emmanuel and Berkowitz, 2007) modeling method has recently been show to be a useful tool to evaluate the role of thermal (non-)equilibrium in the stream, but its practical applicability remains to be evaluated.

5 STUDY PLAN ELEMENTS (RESEARCH METHODS)

5.1 Field Data Collections and Field Data Analysis

5.1.1 Groundwater Level Observations

Groundwater level observations over both, short-term and long-term periods are critical to understand groundwater resources and their response to groundwater development within the Scott Valley. For an evaluation of decadal and even longer-term effects, a multi-year to multi-decadal observation record is needed. A comprehensive water-level monitoring program for the Scott Valley considers the fully three-dimensional groundwater flow system, its recharge and discharge mechanisms, and its interface with surface water features (Alley and Taylor, 2001). This groundwater level observation program (beyond the scope of existing groundwater level monitoring programs) is designed to determine the large scale, valley-wide distribution of groundwater flow paths, from the mountain front towards the valley bottom, on the alluvial fans around the various tributaries, especially on the Westside of Scott Valley. The main objectives of this monitoring program will be:

- to help identify the reach and sub-catchment scale groundwater contribution areas in the Scott River System.
- to identify seasonal and long-term changes in groundwater storage
- to provide a multi-year time-series of water level fluctuations that can be used towards calibration of groundwater modeling efforts

Another objective that can be met with such a monitoring network is to determine seasonal and long-term fluctuations in groundwater temperature and shallow groundwater quality.

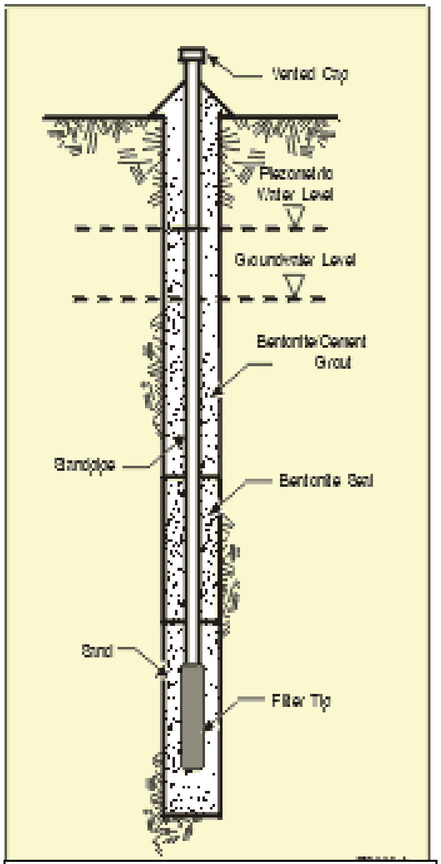


Fig 5-1: Schematic diagram of a simple standpipe piezometer installation. The standpipe is typically a 1" or 2" PVC pipe (*from*: www.slopeindicator.com)

We propose that a detailed network plan be developed that meets the above objectives, and provides for a network of observation wells that is accessible to monitoring personnel (e.g., from the RCD) for monthly, quarterly, or twice-annual sampling. We propose a phased program. In phase I, a sparse water level observation well network will be installed consisting of approximately 140 observation wells or piezometers, drilled to a depth of ten feet below deepest anticipated water level. This provides for an observation well density of at least 1 well per section (square mile). Monitoring wells shall be screened for 20 feet, but never in the uppermost ten feet below ground surface (for protection purposes). This network will provide a minimum coverage of the Scott Valley necessary to measure large-scale fluctuations and groundwater flow directions including those near the Scott River. However, this phase I network may not be sufficient to identify major gaining and losing reaches of the Scott River System. For that, and to better identify total groundwater storage changes and more localized features of groundwater flow, the phase I network will be expanded in phase II as needed. The final network density may be as much as one well per quarter-section (one well per half-mile), in particular near the Scott River and its tributaries.

Observation wells may be constructed of 1” or 2” PVC pipe. The anticipated average depth of each well or piezometer is 30 feet. Any such wells will be constructed in accordance with a standard operating procedure and to an accepted engineering standard. The wells will be provided with locks to prevent intrusion and will be abandoned when no longer being utilized. The anticipated planning and construction cost for the entire phase I+II network is approximately $300,000 (~$500 per piezometer for installation plus cost of network planning and design).

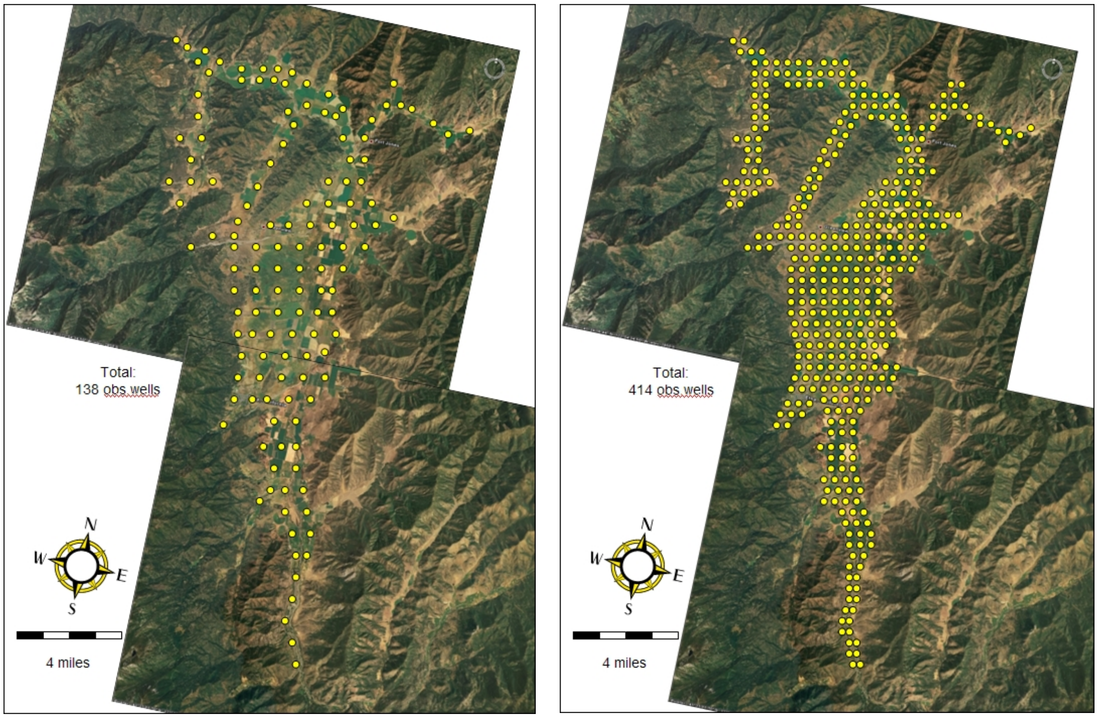


Figure 5-2: Example Phase I (left) and Phase II (right) water level monitoring well networks for Scott Valley. The networks shown consist of 138 and 414 wells with an average spacing slightly less than one half mile and slightly less than one mile,

respectively. The network will consist of shallow piezometers or screened monitoring wells.

5.1.2 Surface Water Discharge Monitoring

Currently, there are seven stream gages installed in the Scott River System including 3 gages on the Scott River itself. These gages are located at East Fork and South Fork Scott River near Callahan, and on the Scott River west of Ft. Jones. Gages are located at the valley margin on French Creek, Kidder Creek, Shackleford Creek above the falls, and Shackleford Creek at Mill Creek. For better understanding of groundwater-surface water interactions during the summer months, we propose to install additional stream discharge measurement capacity above and below critical reaches of the Scott River System. Deas (2004) suggested the installation of at least three additional continuous measurement gages on the Scott River at Youngs Dam, immediately above Moffett Creek, and at the mouth of the river. Additional event-specific stream flow measurements shall be conducted using flowmeters to map the cross-sectional velocity profile of the stream or using the tracer-dilution method (see below). Additional flow measurements are critical to define spatial variations in stream-flow rates along the Scott River and its tributaries, but also diurnal variations during the critical low flow period. These are important to understand variations in local groundwater contributions to stream-flow. The following tasks shall be accomplished:

1. Stream gages. Additional stream gages will be installed on the main-stem of the Scott River at major stream reach boundaries that have been identified as relatively strongly losing/gaining stream reaches. Stream gages will be installed primarily to accurately monitor summer discharges, which are significantly lower than winter/spring discharges. Stream gages could be temporarily set up during summer months along the chosen stretches of the river and connected to a datalogger which would record measurements at set intervals.
2. Cross-sections of stream flow velocity are obtained using a flow velocity meter at certain depth and distance intervals across a well-defined cross-section of the stream. Stream velocities and the cross-sectional area represented by each measurement are intergrated to obtain a total stream discharge. This method can be used for preliminary surveys of stream discharge, to identify gaining and losing stream reaches along the main-stem Scott River , and to gage tributaries from time to time (see, for example, http://ga.water.usgs.gov/edu/measureflow.html).
3. The tracer-dilution method is primarily applicable to smaller, relatively turbulent streams such as the tributaries to the main-stem Scott River. The basic principle of the method is to inject a known amount of tracer into a stream over some period of time. Typically, fluorescent dye-tracer are used, which can be accurately measured downstream, at very low concentrations using a fluorometer. Downstream of the injection point, after a sufficient in-stream mixing distance, the diluted concentration of the tracer is measured. From the dilution ratio, the total stream discharge can be computed (Kilpatrick and Cobb, 1985).

Importantly, any surface water diversions from critical stream reaches monitored by stream gaging or other methods, must be monitored separately to obtain proper mass balance. This would typically be done using in-line flowmeters on the discharge pipe of each water diversion or with a flume and automatic gage, where the diversion by gravity flow into a surface canal. If surface water diversions are constant over long periods of time, individual diversions may be measured once with a portable flow meter (rather than continuously). An updated assessment of these diversions shall be conducted as part of the early discovery work in Phase I.

5.1.3 Mapping Stream Topography and Morphology

Stream geomorphology, that is, the topography and sediment distribution within the stream channel, the occurrence of pools, riffles, channel-bars, alcoves, etc., exerts a major control not only on the stream flow itself, but also on the hyporheic flows, the depth of the hyporheic zone, and on the spatial distribution and dynamics of groundwater flows underneath and near the stream. Stream geomorphology also is a critical factor in understanding stream ecology and for identifying critical spawning and rearing habitat of salmon and steelhead. We recall that the main goal of the RWB TMDL process is to achieve the water quality objective for temperature throughout the Scott River system; and additionally a major goal for Siskyou RCD is to improve the summer rearing habitat for juvenile coho salmon and steelhead in the tributaries..

A complete map of the current Stream River System geomorphology and a monitoring system to record its dynamics are therefore essential for monitoring its salmon habitats and understanding groundwater – surface water interactions.

To date, cross-sections of the Scott River main stem have been mapped as part of an effort to create a geomorphic indexing system. These efforts are led by Siskiyou RCD, often in cooperation with the NRCS (Sommarstrom et al. 1990). Furthermore, the RWB, as part of the 2004 infrared thermal survey (see above) has generated rectified GIS maps of the Scott River banks and the boundaries of the low flow channel within the Scott River, along its mainstem from the USGS gauging station to Callahan.

The following field work is proposed to take place in support of not only better understanding salmon habitats in the Scott River System, but especially to better understand groundwater – surface water interaction:

Ground-based, high density point survey of a stream reach: Major groundwater discharge reaches in the Scott River are selected for complete mapping of the stream channel in these reaches. Topographic data can be obtained using specialized GPS equipment (e.g., Topcon GTS-802A, LEICA TPS1100, TPS1200 robotic total station, RTK GPS). Topographic data are digitized to create each baseline DEM. The four iterative stages of DEM development as described by French and Clifford (2000) will be implemented: interpolation, visualization, editing, and augmentation. First, survey data are interpolated and a surface defined respecting breaklines. Next, the surface is visualized as a map and edited to remove obvious interpolation errors. The revised surface is visually verified in the field to check for poorly represented areas in the DEM. Further iteration was done as needed.

Remote sensing survey methods: Alternative methods should be considered that have somewhat less accurate resolution, but are possibly adequate for modeling and understanding groundwater-hyporheic zone-stream exchanges of water and heat. These methods are remote sensing methods using aerial photography, ground-based LiDAR, or aerial LiDAR, the latter of which can be made available through NCALM at the University of Florida, which is funded by the National Science Foundation (www.ncalm.ufl.edu).

The detailed topographic maps of the stream channel in a few critical reaches of the Scott River will be used for geomorphologic classification of the individual river elements and prioritization of primary potential salmon habitats and primary potential groundwater discharge areas. The data will also provide a critical basis for detailed near- and in-stream modeling of groundwater-stream water exchanges and the role of the hyporheic zone vs. groundwater in mitigating temperature degradation of the stream flow.

5.1.4 Near- and In-Stream Monitoring Well- / Piezometer Nest-Network

Groundwater monitoring wells and shallow piezometer nests near and in the stream are the key tools to measure groundwater gradients and to determine water quality and temperature changes in the immediate vicinity of the stream. Transient water level information obtained from monitoring well and piezometer nest networks are essential to map pressure heads in the subsurface, which is the driving force for groundwater discharge to the Scott River System throughout Scott Valley. These networks are also used to collect data on the transient dynamics of groundwater chemistry and temperature data. These latter are compared to the transient dynamics of chemistry and temperature in the stream discharge. Such a network would consist of monitoring or observational wells/piezometers only and would be supplied with locked caps in order to protect the groundwater and surface water resource from being contaminated. With sufficient spatial coverage and adequate temporal resolution, the analysis of such datasets provides a tool to determine groundwater discharge and groundwater recharge areas, and to determine the rate of water and heat exchange across the stream-groundwater interface. This network, when installed in a reach with riparian vegetation, also provides data that are useful to determine the effect of riparian vegetation on groundwater usage.

Specifically, we propose that two types of networks be installed:

1. Regional Near-Stream Piezometer Network (ReNSPiN). ReNSPiN will consist of ten to twenty cross-sections of piezometers installed every one to two miles along the main-stem of the Scott River. At each cross-section, from 4 to 8 piezometer nests, each with 2 to 4 piezometers shall be installed, with piezometers at depths of zero m to 5 m below stream water level. Piezometers are constructed either with mini-piezometers (Baxter et al., 2003; Horner, 2005) or of 2” Schedule 40 PVC pipe with screened lengths of approximately 10 cm - 30 cm. These (mini-) piezometers will be used to measure water level, temperature, dissolved oxygen

level, and general water quality parameters for comparison with stream stage, temperature and water quality. During the low-stage late spring/summer/early fall months, the ReNSPiN will be used to identify major losing and gaining stream reaches based on water level, temperature, and geochemical data interpretation.

2. Local Near-Stream Piezometer Network (LoNSPiN). Two to three LoNSPiNs will be constructed around selected ReNSPiN cross-sectional sites. Examples of three representative site groups are one site in the upper Scott River main stem between the tailings and Youngs Point, one site in the incised channel of the Scott River main channel between Horn Lane and Hwy. 3, and potentially a third site near the confluence of the Scott River with Shackleford Creek.. The LoNSPiN will be used to further investigate groundwater-surface water interactions at sites where significant groundwater discharge is observed in the ReNSPiN and using other tools (e.g., temperature surveys). The LoNSPiN data are used to better understand the within-reach and local-scale heterogeneity of groundwater – surface water interaction and the role that heterogeneity plays in controlling the exchange between groundwater and surface water (e.g., Baxter and Hauer, 2000). Again, water level, temperature, and water quality data will be collected from the LoNSPiN.

5.1.5 Tracer and Isotope Studies to Quantify Groundwater-Surface Water Interactions

Tracer studies shall be implemented to complement hydraulic and temperature monitoring in the LoNSPiN and in the ReNSPiN. The primary use of tracer studies is to investigate the groundwater-surface water or surface water-groundwater connectivity. This is done by injecting a tracer into surface water (where the stream is thought to lose water to groundwater) or into a groundwater well or piezometer (where the stream is gaining groundwater), and then measuring the tracer breakthrough at various locations in the stream and in near-stream groundwater.

The most common tracers used in quantifying groundwater-surface water interactions in an alluvial setting such as the Scott River System are chloride, bromide, and fluorescent dye tracers. These are conservative tracers that are not subject to significant sorption or degradation in the stream. Dye tracers may be subject to strong interaction (sorption, degradation) in the streambed sediments and have to be carefully selected if the tracer study includes monitoring of subsurface (e.g., hyporheic zone) transport. It should be noted that other environmental factors will be considered when choosing any tracer to be used as a study element. The advantage of dye tracers is that these can be detected easily and accurately over a wide dynamic range (concentration range) using field-detectors. Bromide and chloride tracers require the collection of water samples that are shipped to analytical laboratories. The advantage of the latter two tracers is that they are known for their outstanding conservative transport behavior within and below the stream.

Isotopes have also been used to study groundwater-surface water interactions. In particular the isotopes of the water molecule, ^{2}H (deuterium) and ^{18}O (heavy oxygen) have been used to trace the origins of groundwater in close proximity to streams (fraction of regional groundwater vs. stream recharge) and the fraction of groundwater contributing to stream discharge. The relative abundance of the heavier isotopes, deuterium and ^{18}O, in precipitation is primarily a function of the time of year and elevation (temperature), at which the precipitation occurs. Hence, runoff in streams vary with season and weather conditions depending, for example, whether runoff is generated by warm convective storms, by cold winter storms, or by snow-melt. If precipitation or snow is subject to significant evaporation, this will further modify the heavy isotope signature of water. Groundwater produced from the alluvial aquifer of the Scott Valley is likely to have an isotopic composition that is close the annual average isotopic composition of precipitation in the Scott Valley watershed. Unlike stream runoff, the isotopic composition of groundwater is relatively constant throughout the year, except in very shallow wells with very young recharge (upper 10 - 30 feet of the aquifer).

The different dynamics of the ^{2}H and ^{18}O composition of groundwater and stream runoff can be exploited to study groundwater-stream interactions in the hyporheic zone and in near-stream groundwaters of the Scott River.

As a first step towards analyzing isotopes at the groundwater-stream interface, we propose to implement a two-year program that identifies the basic water-isotopic information for the various components of the hydrologic cycle in the Scott River watershed:

1. Identify the Scott Valley Meteoric Water Line (SVMWL), that is, the characteristic ^{2}H and ^{18}O composition of precipitation and its seasonal variations. Weekly samples from various rain gauges at varying altitudes and selected samples from the snow-pack will be collected over a two-year period.
2. Collect 24 monthly samples from ten deeper groundwater wells for water isotope analysis. If large variations are observed between the groundwater samples, a broader sampling plan for the deeper aquifer shall be developed.
3. Identify the seasonal and diurnal variation in water-isotopic composition of runoff in the Scott River and its tributaries at key locations in the Scott Valley (approximately 10 locations initially). For this, we anticipate to collect weekly samples at identical time-of-day. Additionally, over a one-week period in August, January, and early June of each of two years, three-hourly samples shall be collected to characterize the extend of diurnal variations.

Results from this first isotopic survey, together with the water quality survey, shall be used to evaluate the potential for using water and other isotopes to improve the characterization of the groundwater-streamwater interface in the Scott Valley. The usefulness of further isotopic monitoring will be evaluated and compared to using temperature and hydraulic data only (without the more expensive isotope monitoring) for intermediate and long-term monitoring (see below).

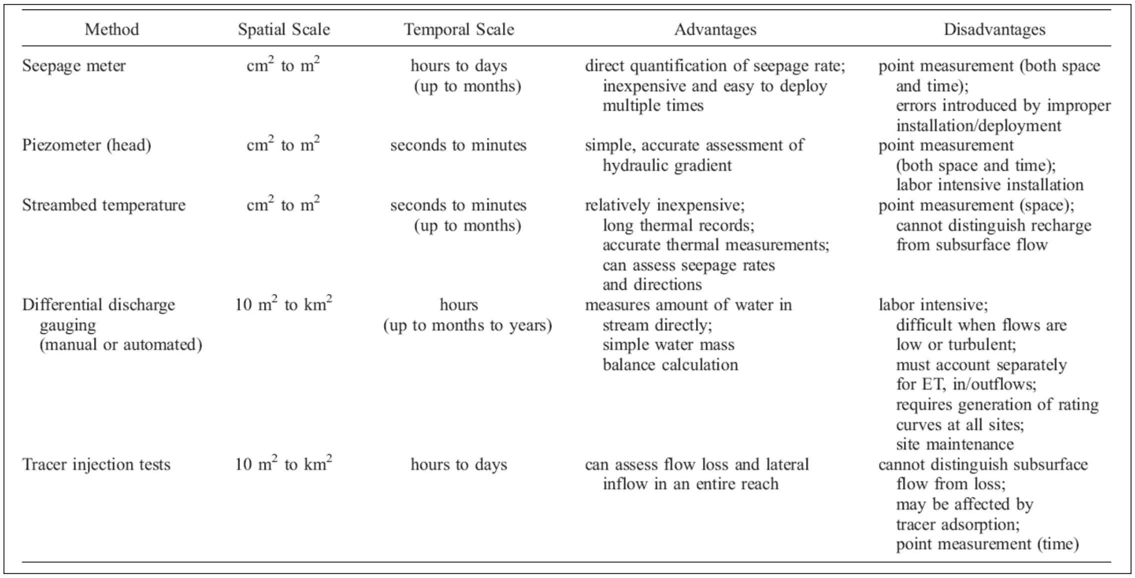
5.1.6 Monitoring Groundwater Temperature in/near Streams

The LoNSPiN and ReNSPiN systems are used to measure transient groundwater temperature during summer months. Diurnal temperature variations in the stream and the atmosphere are transmitted to piezometers located either in the streambed or within a short distance from the stream (a few feet to tens of feet) by heat conduction (through the solid materials, i.e., sand grains, cobblestones, soil particles), by heat diffusion (through both, the solids material of the subsurface and through subsurface water), and by heat conduction with subsurface flows. Temperature variations in the stream and at nearby land surfaces therefore affect the groundwater temperature that is observed in temperature sensors that will be deployed in the piezometers of the LoNSPiN and ReNSPiN. Significant diurnal temperature variation in piezometers located in or near a stream channel are potential indicators for seepage from the stream. Temperature differences, and the attenuation and delay of the diurnal temperature variation in near-stream groundwater relative to diurnal temperature variations in the stream itself are used to determine subsurface hydraulic properties and flow velocities (see below). Temperature sensors and loggers are relatively inexpensive (compared to chemical or other sensors), are widely available and can be easily deployed, especially during the non-flooding summer months. Not all piezometers need to be equipped with temperature sensors. Observations will be made sequentially in various subsets of piezometers.

Several methods can be employed to interpret these type of data (see Table 5-1). Constantz et al. (Ground Water, 2003) showed that heat and temperature provided comparable information about streambed hydraulic conductivity (using the USGS models VS2DT, VS2DH, cross-sections of piezometer nests at 1.5 m depth near the stream).

Su et al. (Ground Water, 2004) used six near-stream observation wells and VS2DHI to obtain hydraulic properties (Kh and Kv) from temperature data in monitoring wells near streams. Model much less sensitive to river stage changes and well water level than to K, hence steady-state model with average conditions was used. Table 1 shows depth and distance of MWs from river (3.5 m to 7.1 m deep and 21 m to 62 m distant).

Hatch et al. (WRR, 2006) used time series analysis of temperature data obtained from piezometer nests to determine seepage rates. The method is reportedly sensitive to seepage rates ranging from 0 to 15 ft/d either upwards (to the stream) or downwards (from the stream). The method has some limitations common to others. For example, it assumes that the material between the vertically separated streambed sensors is homogeneous. For this method, relatively long time series are needed, on the order of several months.



Method	Spatial Scale	Temporal Scale	Advantages	Disadvantages
Seepage meter	cm^2 to m^2	hours to days (up to months)	direct quantification of seepage rate; inexpensive and easy to deploy multiple times	point measurement (both space and time); errors introduced by improper installation/deployment
Piezometer (head)	cm^2 to m^2	seconds to minutes	simple, accurate assessment of hydraulic gradient	point measurement (both space and time); labor intensive installation
Streambed temperature	cm^2 to m^2	seconds to minutes (up to months)	relatively inexpensive; long thermal records; accurate thermal measurements; can assess seepage rates and directions	point measurement (space); cannot distinguish recharge from subsurface flow
Differential discharge gauging (manual or automated)	10 m^2 to km^2	hours (up to months to years)	measures amount of water in stream directly; simple water mass balance calculation	labor intensive; difficult when flows are low or turbulent; must account separately for ET, in/outflows; requires generation of rating curves at all sites; site maintenance
Tracer injection tests	10 m^2 to km^2	hours to days	can assess flow loss and lateral inflow in an entire reach	cannot distinguish subsurface flow from loss; may be affected by tracer adsorption; point measurement (time)

Table 5-1: Methods for estimating streambed seepage (from Hatch et al., 2006)

5.1.7 Monitoring Stream Temperature

Stream temperature can be an excellent signal to indicate the degree of local groundwater influence on stream flow. During the hot summer months, stream temperatures that are not influenced by groundwater tend to fluctuate with a daily (diurnal) cycle: late in the afternoon, stream temperatures are highest due to high ambient temperature and direct radiation from sunshine. At night, stream temperatures cool off and reach a minimum in the early morning hours.

Groundwater temperatures, as indicated above, fluctuate significantly less or not at all. Deeper groundwater has nearly constant temperature year-round. When groundwater discharges to a stream in the summer, several impacts are imparted on the stream: at and nearby the location of groundwater discharge (at the seep or subaqueous spring, if it is a local in-stream feature), temperatures tend to be cooler (groundwater being close to an annual average temperature is much cooler than stream temperature during the summer). Also, if groundwater flow towards the stream is intercepted by riparian vegetation, groundwater discharge to the stream is reduced during the day (when plants transpire), leading to lower stream flow during the day and higher stream flow at night. Lower stream flow rates due to groundwater uptake by riparian vegetation may lead to faster heating of stream temperatures during the day, where canopy does not cover stream flow. This may mask the (cooling) discharge of groundwater during the day, but not at night.

A network of temperature sensors or other tools that can provide both, high spatial resolution along the stream, and high temporal resolution (nearly hourly temperature measurements) are therefore needed. We propose three separate methods, which complement each other in the space-time continuum of such a hierarchical measurement network:

1. Portable temperature probes with loggers are relatively inexpensive (Johnson et al., 2005) and simple to deploy in streams or in the streambed (via piezometers, see above). Temperature loggers can be set to measure temperatures at a

reasonable time interval (e.g., 1 hour) for long periods of time in stand-alone mode (e.g., Hatch et al., 2006). The sensitivity of inexpensive temperature loggers is b0.5 ºC

2. Fiber optic cable method. This new technology is one of the most promising advanced tools in stream ecology and groundwater-stream interaction research (Selker et al, 2006). The principle of this method is as follows: a fiber-optic cable with a length up to 10 km (6 miles) is deployed in the stream (linearly or in a well-defined, surveyd zig-zag pattern). A laser-beam is sent into the cable. The reflections of the laser-beam along the fiber-optic cable are measured by a detector. Since the reflections are temperature-dependent, the signal can be deconvoluted to determine the temperature at better than 1 m intervals along the cable with an accuracy of ±0.01ºC. The system can repeat temperature measurements up to four times per minute. This tool is an excellent survey system to obtain spatio-temporal temperature data in streams at very high spatial AND temporal resolution. We propose that UCD work with UNR (Reno, Nevada) on a preliminary stream survey at select sites as the basis for further planning.
3. Forward-Looking Infrared Radiometry (FLIR) or Thermal Infrared Radiometry (TIR) imaging can be used to map the spatial pattern of temperature variability in rivers. The remote imagery is obtained from a sensor mounted on the underside of an airplane or helicopter, which is coupled with a digital camera and a global positioning system (GPS) to provide accurate spatial location. The sensors translate the infrared radiation of a given ground surface-area and convert that to radiant temperatures which are then plotted as surface temperatures along the course of the river. Temperature measurements of approximately half-meter resolution at an accuracy of better than +/- 0.5°C are able to be obtained through the use of infrared imaging. The remote sensors are able to identify the location and thermal influence of point sources, tributaries, and surface and subsurface fluxes (including groundwater accretion and hyporheic exchages). Since the remote sensing is only able to provide data on the surface of the river, data loggers are usually deployed in the field in order to verify and calibrate the results both at the surface and at greater depths. The benefit of this type of temperature survey is the bulk of data that is able to be quickly obtained over the entire course of the river which can be used to determine critical reaches within the river. To date, two such surveys have been implemented on the Scott River.

5.1.8 Monitoring Groundwater Pumping

Groundwater pumping is thought to have significant impact on the flow dynamics of the groundwater system in Scott Valley and it is a major component of the Scott Valley water balance, particularly during the summer months (June through mid-September). Knowledge of the spatio-temporal distribution of groundwater pumping and its magnitude within the Scott Valley is important to understand water use needs, to provide a basis for studying groundwater flows, to develop appropriate groundwater models, and to develop and assess potential groundwater management alternatives with respect to their impact on Scott River System flows and temperature. A determination of groundwater pumping can be achieved by various methods with various degrees of accuracy:

1. Metering of all groundwater use on wells pumping more than 0.2 cfs (90 gpm). There are approximately 350 to 500 groundwater wells that are equipped to pump 0.2 cfs (90 gpm) or more from the alluvial aquifer in Scott Valley, primarily for agricultural uses. A metering program requires the cooperation of landowners, a centralized data collection infrastructure, annual to triennial inspection and possibly maintenance of the metering system, to ensure proper data accuracy. This method allows for an accurate estimate of groundwater pumping, but does not account for groundwater recharge from over-irrigation or for return flows to surface water channels. Currently, a majority of land owners with medium to large sized pumping wells are not interested in and politically opposed to such a metering approach. A survey of the number of wells and the size of their pumps would be useful information to obtain a preliminary, rough estimate of groundwater pumping within Scott Valley and geographic differences between sub-basins of the Valley.
2. Estimation of groundwater pumping by closure of the field-by-field water balance ("water balance method"). This method requires detailed mapping of the Scott Valley cropping patterns including annual changes in cropping patterns, e.g., by a combination of aerial photography and ground-based data collection. A water balance is computed for each field on a daily or monthly basis that accounts for precipitation, surface water applications, soil water storage and changes therein, soil water field capacity, groundwater use by crops, and crop water use (evapotranspiration). Groundwater pumping is estimated as the difference between crop water demand (including surplus demand due to irrigation inefficiency) and available water from precipitation, surface water deliveries, and soil water/groundwater (e.g., Ruud et al., 2004). In the Scott Valley, the most significant limitations to applying the water balance method include lack of data to estimate crop water use (Deas, 2004), a lack of data to account for all surface water diversions along the Scott River, although significant historic data exists (For diverters who participate in the Watershed-Wide Permitting Program being developed by DFG and the Siskiyou RCD their diversion rates will have to be verified by a watermaster or other means acceptable to CDFG.) A model will need to be used to estimate direct groundwater use of deep-rooted crops in areas of shallow groundwater. At the basin (Scott Valley) scale, this method may currently be used to obtain rough estimates on overall groundwater usage in the valley.
3. Estimation of groundwater pumping from water level measurements ("water table method"). This method is based on frequent (at least twice annual) observations of the water level in the upper unconfined portion of the Scott Valley aquifer. With a fully built-out phase II groundwater level monitoring program (see above), local changes in water level can be used to determine the net change in groundwater storage. The net change in groundwater storage per unit area is the product of the change in water level multiplied by the specific yield of the unconfined aquifer at that location. Detailed information on the specific yield and related hydraulic properties of the Scott Valley aquifer as well as their spatial distribution may be obtained, e.g., from pumping and slug tests, see above, or from geologic logs obtained during well drilling. This method is limited to

> estimate groundwater usage by sub-basin only (it cannot be applied to the field scale) as water level changes are significantly affected by upgradient and downgradient changes in groundwater fluxes. Currently, neither sufficient water level data nor sufficient data on the specific yield of the Scott Valley aquifer are available to accurately estimate groundwater pumping and its spatio-temporal distribution, even at the sub-basin level. Current data may be used to constrain estimates of overall basin-wide groundwater usage in the basin.

For the groundwater study, we recommend to further investigate the possibility of implementing either method 1 (totalizing meters) or method 2 (water balance method).

5.1.9 Hydraulic Groundwater Tests: Pumping Tests and Slug Tests

A series of pumping tests will be implemented to obtain values of hydraulic conductivity that are representative of the various alluvial sediments in Scott Valley. Pumping test locations shall include upper alluvial fan locations, lower alluvial fan locations, and several valley bottom locations. For the pumping tests, existing production wells with known construction records (perforation interval, diameter of the well and gravel pack) and nearby observation wells (from either the near-stream piezometer nest network or the groundwater level network) will be selected.

At some locations, piezometers intersecting important deeper sections of the alluvial aquifer may be installed either temporarily or permanently to assess the hydraulic conductivity distribution with depth. Pumping tests will be evaluated using standard pumping test analysis for unconfined and leaky aquifers (Dawson and Istok, 1991).

A select number of observation wells in the groundwater level monitoring program or the LoSPiN/ReNSPiN program will be selected to perform slug tests. These slug tests provide estimates of the hydraulic conductivity of the specific sediments, in which these observation wells or piezometers are screened/completed. Standard slug test analysis will be performed (Butler, 1997; Baxter and Hauer, 2000).

5.1.10 Geophysical Surveys

Geophysical methods are used to “image” the structure of the subsurface. Currently, there are only rough estimates of the thickness of unconsolidated sediments in the Scott Valley. The Phase I modeling will be based on these estimates (e.g., Mack 1958). If the modeling results show that the response of groundwater-stream interactions to aquifer pumping is significantly sensitive to the thickness of the aquifer, it may be necessary to consider methods for estimating the thickness of the alluvium in the Scott Valley. Young et al. (1999) found that transient electromagnetic sounding (TEM) was a rapid method to identify alluvial aquifer thickness, especially over shale and mudstone bedrock. Thickness was computed by resistivity-depth modeling of the TEM data. Other methods to be considered for mapping the depth of the aquifer are gravity survey, seismic refraction survey in combination with vertical electrical sounding, or seismic reflection (Keiswetter et al., 1994; Hunter et al., 1998).

Geophysical surveys will need to be interpreted in conjunction with an analysis of existing well- and other borehole-logs, including geologic logs and E-logs typically generated during the construction of a water well. For the phase I groundwater model, we plan to use existing E-logs and geologic logs to determine the fraction and distribution of highly permeable sands and gravels within the Scott Valley aquifer system. Currently, the density of these logs is very low. In subsequent study phases, additional boreholes may have to be drilled in support of the geophysical data interpretation.

5.1.11 Groundwater Recharge

Changes in groundwater levels and groundwater fluxes to or from the Scott River System are controlled by groundwater recharge, groundwater pumping, and groundwater exchange with the stream system. For purposes of establishing a groundwater-surface water model of the Scott Valley that can be used to evaluate the overall role of groundwater and water management in sustaining sufficient stream flow and also control stream temperatures in the summer and in early fall, we need to quantify and map reach-, and subcatchment-scale recharge, groundwater pumping, and discharge to streams across the Scott Valley.

5.1.11.1 Stream Recharge

Groundwater exchange with the stream system will be the subject of various study components that are designed to quantify and map groundwater exchange with streams at the local scale (stream bed forms), at the reach scale, and at the basin scale (see above). Results from these studies will be used in the development and updating of a Scott Valley groundwater model.

5.1.11.2 Mountain Front Recharge

Mountain front recharge includes recharge of water from small ephemeral streams and tributaries of the Scott River System, as these streams enter the highly permeable upper alluvial fans that skirt Scott Valley. Mountain front recharge also includes spring discharges at and immediately above the bedrock-alluvial boundary in the foothills around Scott Valley. Springs may create short-distanced, small discharges that readily disappear in the alluvial sediments below the springs. Currently, there are no data for the amount or magnitude of mountain front recharge. It is thought that a predominant portion of that recharge comes from recharge in the alluvial stream channels on the upper alluvial fans of the various tributaries to the Scott River, particularly along the Westside of the Scott Valley. Stream discharge monitoring at various locations on these tributaries will provide the necessary data to estimate mountain front recharge across the basin (see above). Spring discharges will be measured using portable flumes once per summer over a five-year period.

5.1.11.3 Irrigation Return Water Recharge

An important source of groundwater is recharge from irrigation water applied to fields, but also recharge directly from irrigation canals, which are all unlined in Scott Valley. Knowledge of the magnitude of this recharge is critical in developing water management practices. Much of the predominantly pasture-based agriculture in Scott Valley uses flood irrigation, a method by which relatively large amounts of water are run across a field.

Return water at the bottom of the field is rerouted into a canal, rerouted towards another irrigation, or released to a network of surface water features that discharge into the mainstem of the Scott River.

We propose to estimate canal water recharge based on measurements of hydraulic properties of the canal beds at various representative locations. Specifically, we propose to perform recharge tests using standard infiltrometers (Hvorslev, 1951). The number of tests may be adjusted depending on the amount of variability found.

Groundwater recharge from irrigation will initially be estimated based on irrigation records, surface water supply records, and estimates of groundwater pumping, which in turn may be based on comparing surface water supplies and an estimate of the irrigation efficiency of the systems used in the past and currently in Scott Valley. Recharge will be computed as the monthly difference between water supply, crop water uptake, and change in soil moisture within the root zone (Ruud et al., 2004). We propose that field studies be implemented to verify these estimates of groundwater recharge: a number of representative fields will be selected for which all components of the water balance are monitored at the field scale: water applications (groundwater or surface water), precipitation, evapotranspiration, and changes in root zone soil moisture. The amount of recharge will be estimated by closing the water balance at the field scale (difference between measured inputs and outputs).

5.1.12 Valley Water Balance: Groundwater and Surface Water Use

Water management is the decision making process – private or public, individual or communal, incidental or intentional – that allocates water use over space and time. In Scott Valley, more than 90% of all human water use is for agricultural purposes, primarily irrigation. The remainder is for municipal, domestic, public, or industrial water uses.

Except for limited reporting by the two municipalities, water use by agricultural or domestic users is not reportable and specific measurements of water use have not been implemented in Scott Valley except the diversion amounts reported by the Watermaster for 5 tributaries. Also, little is known about water uptake and transpiration of riparian vegetation, although mapping of riparian vegetation along the Scott River System has been partly done (Lewis 1992; RWB 2005) . In the past, some water use estimates for these various categories have been made based on land use, population, and number of animals in Scott Valley (e.g., Mack, 1958; CDWR 2003; Deas, 2004). The following elements may be added as part of a groundwater study.

5.1.12.1 Agricultural Water Uses

If a metering program which totals flows is implemented, the annual total usage at each agricultural well would be known. It is understood that this type of program may not be acceptable to all of the stakeholders located within the Valley. However, this type of information is critical in development of the Groundwater Study Plan and would be determined from other information (see above), e.g., by estimation of the seasonal evapotranspiration distribution based on information about crop planting and harvesting.

This information would be collected either based on information about common practices, by annual grower survey, by reporting associated with reporting the well water use, or through monthly aerial surveys of Scott Valley in at least a number of typical water years.

5.1.12.2 Municipal, Domestic and Industrial Water Uses

Municipal and industrial water uses are determined through direct cooperation with such users in Scott Valley. Domestic water use will be estimated based on typical California per-household annual water use and based on a geographic information system (GIS) analysis of Scott Valley residences outside the service area of municipal water companies.

5.1.12.3 Riparian Vegetation Water Use

Riparian vegetation water use (evapotranspiration) will be estimated through calculations of average uptake and transpiration of the vegetation identified within 300 feet of the centerline of the stream, which was mapped as part of the temperature TMDL analysis. In addition, a visual verification of current conditions will be completed to determine the accuracy of the 2003 vegetation data. If significant differences are observed during the visual field inspections, a newer inventory will be obtained from analysis of remote sensing data including available aerial photography. Initially, riparian vegetative water use will be assigned per literature information for specific riparian plant species, adjusted for Scott Valley climate conditions. If this information is insufficient, a more detailed riparian vegetative water use study may be necessary. The effect of water table depth (as influenced by pumping, stream-flow) on the establishment and support of riparian vegetation shall be evaluated using the groundwater modeling efforts (see below) and an appropriate conceptual model of riparian water use.

5.1.13 Spatio-temporal Distribution of Up-/Downward Seepage in Streambeds

The temperature, tracer, and water level information collected from the ReNSPiN and LoNSPiN systems, the stream gaging data, the thermal surveying data obtained from fiber optics cable studies and from infrared thermal mapping, and the stream geomorphology survey provide, at various scales, the necessary information to map the spatio-temporal distribution of up-/downward seepage in the streambeds of the Scott River System at a high resolution. The individual tools are described above. For this task, the information gathered from these separate study elements will be integrated into a well-informed, hierarchical, and spatio-temporal distributed analysis of measured groundwater-stream interactions in the Scott River System. The analysis provides key insights into the dynamics of this interface and the linkage to the aquatic ecosystem. It is a critical element for the development of future conceptual and quantitative modeling approaches to be developed for assessing the impact of Scott Valley water management options on the groundwater-stream interface.

5.2 Groundwater Modeling Approaches

5.2.1 Model Design and Objectives

An integrated groundwater-surface model is a scientifically defensible representation of our conceptual understanding of the hydrogeology of Scott Valley, of the various sources of groundwater recharge, the distributed pumping, the linkage of groundwater with surface water, the linkage of groundwater and soil water with vegetation and plant water uptake, and an adequate representation of the surface water features of Scott Valley that are directly connected to groundwater. The model mathematically represents the important physical processes governing groundwater flow, stream flow, plant water uptake (especially near the stream), and thermal exchange processes. Such a model can be relatively simple or relatively complex, depending on the degree of detail with which the model represents various physical elements controlling groundwater flow and thermal exchange processes with the stream, and depending on the spatial and temporal resolution of the model.

Importantly, we distinguish between models representing the watershed /groundwater basin hydrology (e.g., models of the entire Scott River watershed, or of the entire Scott Valley groundwater basin), models that represent specific sub-watershed / groundwater sub-basins, and models that represent the details of groundwater-surface water exchange or groundwater-soil-plant-atmosphere exchange at the stream-reach, field, or localized stream-section scale.

Models are like cars: there is not one car that fits every purpose. We buy a specific car to meet specific needs. Models must be designed to meet specific objectives. The model software choice and the design of the model is driven by the objectives of the project and the amount of data available. As new data become available, and as objectives change, the model must be adjusted, or even a new model may have to be developed that represents additional processes not considered in an earlier model. Sometimes one model may not suffice and several models are created to meet specific sub-goals within an overarching study framework (like the mini-van, the sub-compact car, and the tractor at home).

Regardless of the spatial or temporal scale that a model represents, it must also be tested against reality and the test has to be consistent with the objectives and conceptual basis of the model. This process is usually referred to as model validation. For model validation, a real world scenario with known outcome is simulated with the model. The model results are compared to the known outcome. Once the model has succeeded in predicting this known outcome with sufficient accuracy, the model can be used to predict future events or to evaluate connections between various elements of the hydrologic cycle that are not otherwise obvious.

For the purposes of this groundwater study, the two major modeling objectives are:

i. to determine the most likely historic groundwater flow conditions that are the basis for the TMDL regulation (**pre-development basin scenario**)

ii. to investigate the usefulness of various conjunctive use groundwater and surface water management approaches in the Scott Valley with respect to preserving and improving the Salmon fisheries and meeting TMDL water quality objectives along with sustaining a healthy economy and historical family farms by supporting proper conjuctive uses in the Scott River System (**current and future basin scenario**).

As discussed above, it is likely that much of the benefits to salmon fisheries are controlled by local scale features, that is, features of the hydrogeology, the stream bed geomorphology, and groundwater-surface interactions that are only a few tens of feet to a few hundreds of feet in size (stream bed channel element scale). We anticipate that only models that accurately represent this (local) scale will ultimately be useful in assessing the impact of water management changes on the salmon fisheries. But it is unlikely that these local scale features operate outside the context of larger scale (reach scale, sub-catchment scale, and basin-scale) effective processes that are sufficiently well captured with models that represent the Scott Valley hydrology as a whole (including all recognized beneficial uses) without accounting necessarily for all local details. These larger scale processes need to be equally well understood and are thought to provide the framework for understanding the local scale processes.

We therefore suggest implementing a hierarchical, phased approach to modeling groundwater and groundwater-surface water interactions in the Scott Valley. The first modeling step ("Phase I Modeling") will be to put together a three-dimensional groundwater model that:

- represents the hydrogeology of the Scott Valley groundwater basin according to our current conceptual understanding (see above)
- includes a basic groundwater-surface water interface representing details at the reach-scale to sub-catchment scale
- and that includes a simple, but effective and physical representation of the thermal processes at the groundwater-surface water interface at the reach to sub-basin scale.

The phase I model will have to be developed based on the limited amount of existing data and based on best estimates of values (or range of values) for key parameters such as hydraulic conductivity, specific yield, recharge, etc. This model will be used to meet several objectives (see "Goals & Objectives"):

1. define and validate our current conceptual understanding of the major hydrogeological processes in the Scott Valley and provide some insights in the fundamental, large-scale functioning of the groundwater-stream connection along the Scott River System.
2. calibrate and validate the model against existing measurement data representing pre-development and recent conditions to provide a measure of confidence.
3. define approximate groundwater-surface water interactions under historic, pre-development environmental conditions and under current and future conditions.

4. test some key water management scenarios and outline their potential impacts on the Scott River System summer discharge and temperature and include estimates of prediction uncertainty.
5. identify data-gaps that are critical to better understand the groundwater-surface water interaction at a scale that is relevant to the salmon fishery ecosystem (reduce prediction uncertainty).
6. define specific goals and identify specific approaches for subsequent modeling phases that will be used to process data collected as part of the above listed field reconnaissance work, identify potential improvements in prediction uncertainty for the water management scenarios that these future models address

Based on the result from the phase I model outcome and other phase I study elements, additional modeling efforts will be defined, which may include some of the following options:

- reach-scale or local scale models to interpret the data obtained from the detailed temperature, tracer, and water level measurements in the in-stream/near-stream monitoring network at the selected site(s).
- a refinement/improvement of the phase I Scott Valley groundwater basin model to incorporate new data collected and new scientific insight gained that will lead to:
  - improved representation of aquifer parameters
  - improved representation of pumping stresses
  - improved representation of aquifer-stream interaction
  - improved representation of groundwater-riparian vegetation-stream interaction
  - improved representation of aquifer heterogeneity
  - improved representation of land use and groundwater recharge
  - reduced uncertainty in the forecasting capability of the model

The Background Section summarizes some of the current research modeling approaches to better understand the surface water – groundwater connection at the local to reach scale.

5.2.2 Phase I Groundwater Flow Model

5.2.2.1 Software

Deas (2004) identified seven software packages available to model various aspects of surface water and groundwater flow in the Scott River watersheds. Five of the seven models represent basin-wide planning models that represent both, surface water and groundwater. In these management models, however, groundwater is represented as a "storage box" similar to a bank account, without much attention to the details of groundwater flow. A sixth model is primarily intended to determine runoff amounts from rainfall distribution. Only one model (the U.S. Geological Survey "MODFLOW" software) was reviewed that explicitly represents the physics of groundwater flow.

Recent updates to several of the software packages reviewed by Deas (2004) have provided better integration of surface water and groundwater flow aspects (see http://groundwater.ucdavis.edu/gwmodelingcourse.htm for more information and internet links):

MODFLOW has improved capabilities for simulating farm-type settings with irrigation, crop water use, and groundwater recharge; commercial upgrades to MODFLOW (MODFLOW-SURFACT, MODHMS) also include improved representation of unsaturated zone flow, which may be important for simulating riparian vegetation water use.

The same company that markets the GIS-based software “MIKE BASIN” also produces a software package called “MIKE SHE”, which has recently been upgraded to include MODFLOW to simulate groundwater aquifers. However, it remains primarily a surface water/watershed oriented modeling tool.

IGSM2 has been renamed “Integrated Water Flow Model” (IWFM), maintained by the California Department of Water Resources. It is specifically designed to model agricultural and urban water demands. Water re-use is also modeled as well as tile drains and lakes or open water areas.

The commercial software package FEFLOW is another software package that is similar in its basic capabilities to MODFLOW, MIKESHE, or IWFM. It is an integrated surface water, unsaturated zone, and groundwater flow and transport model that has found widespread application in Europe but also in the United States.

Importantly, all four software packages (MODFLOW, MIKE SHE, IWFM, FEFLOW) have been used in a wide variety of hydrogeologic and engineering applications and have gained a respectable, international audience. These software packages have withstood, to a large degree, the test of time, professional scrutiny, and legal scrutiny by a relatively large user audience (except, perhaps, IWFM, which has the smallest, mostly California-limited user base). MODFLOW, MIKE SHE, and FEFLOW are likely to be available and supported for many years due to their large customer base. Another research code that provides a fully three-dimensional, fully-integrated approach to modeling runoff, interflow, infiltration, groundwater flow, and stream flow is the code InHM (Integrated Hydrologic Model (VanderKwaak and Loague, 2001).

Much of the data needed for modeling is or will be compiled in GIS format. Hence, the choice of groundwater modeling software must support a strong interface with commonly used GIS software (e.g., ESRI ArcGIS®). For MODFLOW that interface is achieved through third party visualization software (e.g., “Argus ONE”, “Visual MODFLOW”, “Groundwater Vistas”, or “GMS”). MIKE SHE and FEFLOW have a GIS-support built-in.

We recommend to use either MODFLOW or FEFLOW for phase I modeling, although other codes may be considered (such as MIKE SHE, InHM). We also recommend that all input and output data be managed in a ESRI ArcGIS® database. This provides the most flexible data and modeling result transfer platform between model developers and model result users. A GIS system as data archive also allows for the same data to be shared between multiple modeling platforms, as needed.

5.2.2.2 Data Availability

Deas (2004) listed the availability of various data types needed for implementing a modeling study. The author concluded (and we concur) that sufficient data are available to begin a preliminary or phase I modeling effort focused on the role of groundwater in the Scott Valley's hydrology. Data identified by Deas (2004) as missing include agricultural diversions, tail water, transit losses, and crop water use, updates of municipal and industrial water use, identification of intermittent stream reaches, additional stream flow gaging, and groundwater level monitoring. For missing data, best available estimates will have to be substituted. The model will need to be tested for the effect of data uncertainty on its predictive capabilities. The following outlines some key features to be represented in the phase I groundwater model.

5.2.2.3 Aquifer Dimensions, Properties, and Heterogeneity

Aquifer dimensions and aquifer materials will be identified based on the hydrogeologic investigation by Mack (1958), SWRCB (1975), and by inspection of borehole logs available at the California Department of Water Resources. The aquifer will initially be modeled as a single unconfined aquifer with several major alluvial hydrogeologic units as identified by Mack (1958): the streambed and fluvial floodplain deposits along the Scott River mainstem, the younger alluvium of the alluvial fans skirting the margins of Scott Valley, and the older alluvial fans forming some of the terraces at the rim of the Scott Valley. Groundwater flow in the bedrock below and around the unconsolidated sediments of Scott Valley is considered negligible (Mack, 1958). The transition from the unconsolidated tertiary and quaternary alluvial deposits to the consolidated bedrocks will be treated as an impermeable boundary.

Aquifer properties will be assigned to the major hydrogeologic units identified by Mack (1958) based on textural classes and their volume proportions, which will be obtained from borehole logs and as described in Mack (1958). Using standard values of hydraulic conductivity and specific yield reported for various texture classes in the literature, we will determine the horizontal and vertical hydraulic conductivity as the arithmetic and harmonic mean, respectively, of the hydraulic conductivity associated with each texture class. The specific yield will be computed from the arithmetic mean of each texture class, weighted by their respective proportions. As a range of hydraulic conductivities and specific yields is typically given for each texture classes (e.g., Todd, 1980; Johnson, 1990), we will use this procedure to define a range of possible hydraulic conductivity and specific yield values for each of the three hydrogeologic regions. Model calibration will be used to determine, whether these ranges can be further refined based on existing aquifer response data (water level information).

We propose to evaluate the use of an alternate model explicitly accounting for the large amount of textural heterogeneity typically observed in these alluvial sediments and described by Mack (1958). Use of that approach will depend on the availability of sufficient borehole log data to develop a geostatistical model of the alluvial deposits.

Specifically, we suggest to apply the Transition Probability-Markov Chain (TPMC) approach, as used, for example, by Weissmann et al. (1999a,b) for describing heterogeneous patterns on alluvial fans in the Central Valley of California. Fleckenstein et al. (2004, 2006) have recently shown the importance of aquifer heterogeneity in the dynamics of the stream-aquifer connection. A potential issue to address in this study is the connectivity of coarser sand and gravel deposits within an alluvial aquifer, particularly between the recharge areas of the alluvial fan apex and the high permeability areas of the fluvial plain near the Scott River. The TPMC approach, conditioned on existing borehole and soils data, is able to address the issue of connectivity (Harter, 2005).

Aquifer stresses (spatiotemporal distribution of aquifer recharge and pumping) will be defined based on existing knowledge of recharge and groundwater use, using some of the approximation techniques described above (also see Deas, 2004). As additional data become available, data will be incorporated into the model to improve its predictive capacity.

5.2.2.4 Surface Water and Surface Water-Groundwater Connection

For the Phase I groundwater flow model, surface water will be represented as an external sink/source to the aquifer system defined by a spatiotemporally distributed network of nodes with specific stream stages and specific streambed conductivities that correspond to the sediment textures observed at the streambed surface. In MODFLOW, for example, this conceptual model is implemented by the so-called “River Package”. Similar physical models are incorporated into FEFLOW and MIKE SHE. The approach does not account for flood-routing or runoff generation during rainfall events. Rather the stream is explicitly represented by time-varying stream water levels obtained from existing stream-gage information and stream morphology. This simplified stream approach is justified since our focus is on groundwater-stream discharge during the summer and early fall months which are characterized by a lack of storm-driven runoff events and by relatively constant base-flow conditions. Instead of a dynamic streamflow/flood routing model, base-flow contributions in the Scott River System will be computed by integrating all modeled groundwater inflows (positive or negative) along the stream network in the Scott Valley, from the mountain front to the valley outlet. For a basin-scale phase I model, this approach is anticipated to be sufficiently sensitive to identify the relative role of what are thought potentially to be major regional controls on groundwater-stream discharge, including summer irrigation, summer groundwater pumping, intentional winter-/spring-recharge of the groundwater aquifer, and riparian vegetation consumptive water use.

5.2.3 Thermal Fluxes and Linkage to Flow Models

Groundwater models are able to account not only for flow, but also for heat/coolness transport in the subsurface (either by convection with groundwater flow or by conduction through water or porous material). As an initial step in the phase I model, we propose to use a simple mixing model for stream temperature, based on stream-flow and temperature and the net reach-scale groundwater inflow to the stream and its associated groundwater temperature. The interpretation of any of the reach-scale or local scale temperature-, tracer-, or water level-data at the stream-aquifer interface will likely necessitate the use of a model that is capable of the simultaneous simulation not only of flow processes, but also flow-coupled solute transport, and heat advection and conduction in the subsurface and at the aquifer-stream interface. For the latter, advanced software packages such as HST3D (USGS), SUTRA (USGS), or FEFLOW® are available. Alternatively, the generic engineering and physics modeling platform COMSOL® (formerly "Femlab") can be used to model coupled flow, heat, and/or transport processes, especially at the local/reach scale (for more information and internet links, see http://groundwater.ucdavis.edu/gwmodelingcourse.htm). All of these models are highly specialized and are primarily used within a research context. Specific objectives for the application of these models will be defined based on the phase I model results and based on the field results of the local-/reach-scale stream-aquifer monitoring network.

5.3 Assessment of the Impact of Various BMPs to Beneficial Uses

5.3.1 Definition of BMPs and Management Approaches

Over the next two years, best management practices and various conjunctive use water management approaches will be developed jointly to be voluntarily implemented on a test basis between the research team at University of California, Davis, the Siskiyou RCD, the Scott River Watershed Council, Siskiyou County, and the North Coast Regional Water Quality Control Board. Some of the potential practices and management decisions to consider include:

- flood irrigation vs. sprinkler (pivot) irrigation
- unlined irrigation canals vs. lined/piped irrigation canals
- recharge of winter stream runoff via filling irrigation canals
- recharge of winter stream runoff via extensive field irrigation including optimal spatial and temporal distribution
- decrease in groundwater pumping during various time periods
- stream bed restoration
- building several weirs (low dams) across main stem Scott River, with fish ladders
- reintroduction of beaver dams
- increase/decrease in riparian vegetation

5.3.2 Evaluating Water Management: Dealing with Data Paucity and Uncertainty

The various model components that will be constructed to support the development of water management alternatives for Scott Valley to assess their potential impacts on stream ecology, specifically salmon habitats ("assessment"), rely on a good conceptual understanding of the hydrological processes in Scott Valley and on data that represent the specific nature of Scott Valley hydrogeology and hydrology.

Inevitably, any model will be only an approximation of reality, reflecting uncertainty about the exact place, time, and magnitude of the various processes affecting groundwater-surface water fluxes and Scott River System stream ecology. This uncertainty arises from the limited amount of data about the Scott Valley alluvial aquifer hydrogeology (including the spatial distribution of high permeable versus low permeable alluvial sediments within the aquifer), the limited amount of data about the actual four-dimensional spatio-temporal distribution of groundwater pumping, and about the actual spatio-temporal distribution of groundwater recharge and stream-discharge. The various elements of this groundwater study are designed to increase the amount of data, and thereby decrease some of the uncertainty about the hydrologic system by specifc, targeted field surveys and examination, which is partially guided by the initial modeling efforts that reflect our current knowledge of Scott Valley hydrology.

Uncertainty about the system parameters leads to uncertainty in the assessment of future water management scenarios. This is not a weakness of the model or the modeler, it is inherent to the lack of data in the face of the natural complexity an environment such as Scott Valley. Ideally, the assessment includes explicit information about the uncertainty in the input parameters to the hydrologic model and in the stresses that define the hydrologic dynamics; then carries that uncertainty forward into a quantitative description of the uncertainty about the assessment's predictions. This is not unlike meteorologists explicitly including the uncertainty about inputs to their weather models, which then yield not a definitive prediction of the weather, but rather a statistical description of what is most likely to happen ("80% chance of rain"). An analogous procedure will be employed in the development of the model(s) used to assess impacts from various, alternate water management practices (stochastic modeling, statistical analysis).

This stochastic approach to evaluating management alternatives provides a more realistic and honest assessment of what we can say about the future state of Scott River stream flows and temperatures, and hence of fishery health. It provides decision makers and the public with more information, equally understandable, about the likely benefits and drawbacks of specific options and about the likelihood of success of specific options, relative to each other.

Moreover, a stochastic/statistical approach to assessing water management scenarios is ideally suited to evaluate the potential gains from various field measurement and monitoring approaches. For example, the approach would allow us to compare uncertainty in our future predictions given the current level of groundwater monitoring against the uncertainty in future predictions if a Valley wide groundwater level monitoring program were implemented. Thus, we would be able to gage the direct benefit, or lack thereof, of implementing such a monitoring system.

Table 5-2: Overview of each proposed groundwater study element (described in this chapter), the associated methods, the purpose of the study element, and the applicable phase and task in the roadmap (see next chapter).

GW STUDY ELEMENT	METHODS	PURPOSE	PHASE / TASK
Groundwater level monitoring	Installation of a piezometer network; frequent monitoring of piezometer network and existing wells.	Define long-term groundwater flow dynamics throughout Scott Valley; provide calibration and validation data for future groundwater-surface water models.	I / 2 II / 6 III
Surface water discharge	Installation of additional	Obtain reach-scale and sub-reach	I / 3

GW STUDY ELEMENT	METHODS	PURPOSE	PHASE / TASK
monitoring	stream gages; stream gage monitoring; flow metering at established cross-sections; tracer-dilution method (small streams)	scale stream flow data to estimate groundwater contributions during low-flow period (July-Sept).	II / 2e, 3 III
Mapping stream topography/morphology	Cross-sections and longitudinal GPS-based surveys; remote sensing surveys.	Define streambed topography which is thought to exert major control on the local exchange of water between the stream, the hyporheic zone immediately below the stream and underneath gravel bars, and groundwater.	II / 10 (III as needed)
Near-/Instream groundwater level monitoring.	Dense near-/in-stream piezometer network at selected sites to be used for: • water level measurements; • tracer and isotope studies • temperature sensing	The water level / pressure / heat / tracer distribution in the subsurface near a stream provides important clues about the dynamics of groundwater-stream interactions.	I / 3, 4 II / 2a, 2b, 2c, 2d, 9
Stream temperature monitoring	Portable temperature probes; fiber optic cable methods; aerial infrared survey.	Stream temperature is one of two major factors driving the TMDL. It provides important clues towards identifying localized groundwater contributions to stream flow	I / 3 II / 2b III
Groundwater extraction monitoring	Well metering; water balance method; water table method.	Groundwater extraction is a major element of Scott Valley's groundwater flow dynamics. Exact groundwater extraction, and its spatial and temporal distribution is an important input to drive the groundwater model.	I / 1a, 1b II / 1, 5 III
Aquifer property measurements	Water well logs; pumping tests and slug test; geophysical surveys.	The spatial distribution of hydraulic conductivity, specific yield, and porosity in the Scott Valley aquifer is a critical groundwater modeling parameter. It is particularly important to characterize the degree of spatial variability and consider that in future groundwater models. The depth of the aquifer (depth to bedrock) is also an important model parameter.	I / 1a, 1b II / 1, 5, 11, 12 (III as needed)
Recharge Estimation	• stream: see above • irrigated crops: field water balance analysis • mountain front: stream gages • precipitation: soil root zone water model	Like pumping, recharge is a major driver of the groundwater model. The better its spatial and temporal distribution can be "measured" (estimated), the higher the confidence in the resulting groundwater model.	I / 1a, 1b II / 1, 5

GW STUDY ELEMENT	METHODS	PURPOSE	PHASE / TASK
Groundwater modeling	• regional scale vs. reach scale vs. local scale • historic vs. present vs. future scenarios	Provides a physical representation of our conceptual understanding of groundwater flow in the Scott Valley aquifer. Used to test various study hypotheses.	I / 1a,b II / 1, 5 (III as needed)
Identifying and implementing best management practices	Community feedback, stakeholder feedback.	Evaluate various options to improve water quality in the Scott River (Phase I, II). Implement and evaluate trials in Phase II. Full implementation of preferred option(s) in Phase III.	I / 5 II / 4 III

6 ROAD MAP AND COST ESTIMATES

In order to meet the goals and objectives of this GW Study Plan, the following timeline or "Road Map" is proposed to implement the various potential groundwater study elements described in Section 5. The "Road Map" is divided into short-term (Phase I, years 1 – 3), intermediate term (Phase II, years 3 – 8) and long-term (Phase III, years 8 – 20) projects. For Phase I and Phase II, we propose individual project tasks (these are really complete projects in themselves) such that individual project proposals can be written for each Task and submitted by county agencies to state and federal funding sources. This groundwater study plan provides much of the material and lists all of the relevant resources necessary to complete these proposals. Phase I and Phase II projects are considered high priority projects with high likelihood of significant impact, as measured by addressing the goals, objectives, and working hypotheses listed in Section 2. We strongly suggest to the County that funding for Phase I projects be obtained as soon as possible in conjunction with current project partners. Funding for Phase II projects shall be developed within two years after this Study Plan has been approved.

The "Road Map" is open for detours that will invariably come up along the way. At those times, if data and information collected during the course of the study indicate that it would be more important to deviate from the below plan the implementation schedule should remain flexible to account for such deviations.

Phase I (Years 1 - 3):
Phase I incorporates the most immediate study needs, which will be primarily based on using existing data, existing conceptual understanding of groundwater, stream flow, and stream ecology. With these existing data, phase I projects seek to address the most important research questions regarding groundwater-stream interactions in the Scott Valley:

Task 1. Develop groundwater model of Scott Valley (predevelopment, current, and future scenario conditions) to direct future field monitoring and investigation programs and future modeling efforts needed:

   a. Evaluate existing data (hydrogeologic reports, TMDL development related literature, water budget related work, Ca. DWR well records, water level data) to evaluate historic trends in the Scott Valley water budget (including stream-flow, tributary diversions, and groundwater levels). Develop conceptual framework based on existing literature and field data, collate existing data into a GIS database, and prepare initial model of predevelopment and current conditions, preliminary calibration, address the questions/hypotheses listed in Section 2 to the degree possible, define follow-up field sampling and modeling strategies, and communicate with clients [currently funded].

b. Refine groundwater model as needed to address questions/hypotheses listed in Section 2 that cannot be answered from Task 1a. Refine groundwater model also for improved calibration; define and simulate future scenarios; perform sensitivity analysis; complete model calibration and validation; apply to define future study needs; communicate with clients [1,000 hours@ $200/hr including travel, admin, overhead, etc. Total: $200K].

Task 2. Expand voluntary groundwater level monitoring program to include at least one piezometer per square mile and implement regular (at least twice annual) groundwater level monitoring [150 piezometers@$1,000/piezometer including planning and installation, plus 400 hours/yr for twice annual monitoring, data entry, and reporting @ $100/hour; Total for Phase I network and 3 years of monitoring: $270K].

Task 3. Identify major groundwater discharge locations and their diurnal dynamics during base-flow conditions along the Scott River using stream temperature methods (existing FLIR data, application of the fiber-optic cable method, Summer 2008 and 2009), and install a preliminary stream piezometer network with select near-stream and in-stream piezometers at up to five key cross-sections of the Scott River considered to be major groundwater discharge areas [5 x 5 triple-nested (multiple depth) piezometers@$2,000/piezometer-nest including planning and installation, SWRCB funded internship programs, lead consultant for management, analysis, report writing, 500 hours@$200/hr including travel, admin, overhead, etc. Total: $150K]

Task 4. Develop funding to study groundwater-stream interaction for at least two representative groundwater discharge sites [grant writer, 100 hours@$200/hr. Total: $20K] (see details in Phase II)

Task 5. Identify BMPs and Management Approaches to be evaluated for support of TMDL goals during the modeling analysis [cost included in Task 1.]

Phase II (Years 3 – 8):

Results from Phase I studies are used to refine the specific goals for Phase II studies and to propose specific tools needed to further refine our understanding of groundwater-stream interactions:

Task 1. Complete Phase I modeling efforts (especially those currently unfunded) [under Phase I funding].

Task 2. Implement a five-year groundwater-stream interaction monitoring network and observation program along the entire Scott River (ReNSPIN) and (intensively) at a minimum of two representative groundwater discharge sites

(LoNSPIN) [ReNSPIN: at least 10 sites x 6 triple-nested piezometers@$2,000/ piezometer nest; LoNSPIN: 2 sites x 5 cross-sections x 8 triple-nested piezometers @$2,000/ piezometer nest, chemical analysis: $350K, instrumentation (temperature probes, additional FDIR, fiber-optic cable) and travel: $200K, field and data analysis personnel, computer modeler $300K/yr for 5 years $2,000K]:

  a. installation of complete in-/near-stream piezometer network;
  b. temperature surveys in a network of in-/near-stream piezometers;
  c. tracer studies in a network of in-/near-stream piezometers;
  d. water level monitoring in a network of in-/near-stream piezometers;
  e. measure stream discharge at select locations

Task 3. Identify, construct, and monitor important additional stream gage locations, primarily on tributaries at the edge of the Scott Valley [10 gages @$20,000/gage; annual maintenance for 5 years @$12,000/gage per year. Total: 800K]

Task 4. Decide on key management practices to be tested at the field / basin scale (e.g., intentional spring recharge, modification of pumping schedule, stream shading) and implement trials, perform trial monitoring and evaluation [$500K for irrigation canal modification, water trust purchases etc.].

Task 5. Define and implement additional modeling efforts needed to evaluate the various monitoring programs, analyze the incoming monitoring data, and come to an increased understanding of groundwater-stream interactions (water, heat) that tightly links local-, reach-, and regional-scale processes. This may include additional modeling studies at the redd / reach/ basin scale; possibly in conjunction with the implementation of management trials. Include formal uncertainty assessment (statistical/stochastic methods) [2,000 hours@ $200/hr including travel, admin, overhead, etc. Total: $400K]

Task 6. Continue monitoring of basin-wide piezometer network; Identify additional basin groundwater piezometer locations to be monitored and install, compile and analyze monitoring data, provide summary reports; [up to 150 additional piezometers@$1,000/piezometer including planning and installation, 600 hours/yr @ $100/hour for twice annual monitoring over five years, data entry, and reporting of the expanded piezometer network, Total for enlargerd Phase II network: $450K].

Task 7. (This task is outside the core Scott Valley Groundwater Study, but is assumed to continue current efforts as it provides significant guidance for the Groundwater Study): Continually monitor and determine the status of salmon in the Scott River basin; evaluate the effects of low stream flow and altered stream-flow under new BMP scenarios; evaluate risk of extinction under various BMP scenarios (including no action scenario). [5 years, 2,000 hours/yr @ $100/hour for monitoring, travel, admin, data entry, analysis, and reporting. Total: $1,000K]

Task 8. Identify potential follow-up work in the latter part of Phase II, which may lead into Phase III (all of the following tasks):

Task 9. Additional reaches to be studied for intensive groundwater-stream interaction monitoring [pending funding availability and results from 2.];

Task 10. Additional stream geomorphology mapping needed [pending results from

Phase I and from Phase II – Task 2];

Task 11. Additional water chemistry/tracer/isotope surveys, as needed;

Task 12. Geophysical surveys as needed [pending results of Phase I groundwater modeling studies]

Task 13. Additional hydrogeologic information and water budget information that needs to be collected/measured/monitored; and

Task 14. Need for additional BMPs to be developed and evaluated [based on Phase I and early Phase II results].

Phase III (Years 8 – 20):

We anticipate that the modeling and research results from Phase I and Phase II will lead to a combination of gradual and staged adjustments in water management practices, stream restoration, and revegation of the riparian corridor. Both, the beneficial effects of these efforts will need to be monitored, while concurrently monitoring water use and water quality data that will confirm model predictions. Activities during Phase III include water level monitoring in all or selected piezometers of the regional and stream networks and any follow-up research and monitoring work to the study plan elements listed under Phase II. We expect that the initial research implemented in Phase I and II will raise additional questions. Global climate change issues will become even more important to address as part of Phase III work.

Cost Estimates, Responsible Parties, and Financial Resources

Preliminary cost estimates are given for the individual plan elements of Phase I. Cost estimates are approximate to within a factor two (+/- 50%) and depend strongly on the number of sites chosen for field investigation, the number of parameters to be observed, the frequency of observation, and the degree of complexity used for the modeling analysis. The University of California, Davis, has been contracted to develop the Groundwater Study Plan; and to develop the framework for and implement an initial groundwater model of Scott Valley with the data that are currently available (Phase I – Element 1a). The contract includes model selection, data preparation, model development, and preliminary calibration. Detailed model calibration and a more extensive future scenario analysis, which is also part of Element 1, will be implemented under a separate future contract.

Currently, no funding has been secured for any task but development of a Groundwater Study Plan and Element 1a ($70K). Siskiyou County will be the primary responsible party to secure future collaborators and funding, for example, through the Proposition 84 and AB303 grant process. Siskiyou County will work closely with RWB, the University of California, and third parties to develop funding sources and contracts.

7 SCOTT VALLEY ENVIRONMENT: LIST OF AVAILABLE RESOURCES

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9 GLOSSARY

- Aggradation: The process by which a Stream's gradient steepens due to increased Deposition of sediment
- Alluvial: Process where transported chiefly by water and is sorted.
- Alluvial Fans: A triangular deposit of sediment left by a Stream that has lost velocity upon entering a broad, relatively flat Valley
- Alluvium: Transported chiefly by water and is sorted.
- Bankfull: This stage is delineated by the Elevation point of incipient flooding, indicated by deposits of sand or silt at the active scour mark, break in Stream bank slope, perennial vegetation limit, rock discoloration, and root hair exposure
- Bankfull Depth (dbkf):. The average depth measured at Bankfull Discharge.
- Bankfull Discharge (Qbkf): The dominant channel forming flow with a recurrence interval seldom outside the 1 to 2 year range.

- Bankfull Width (Wbkf): Channel width at Bankfull Discharge.
- Base-flow: Stage at Average Low Flow
- Base-flow Width: Wetted width at Base-flow. Critical for fisheries passage and other biotic indices.
- Channel Length: Curvilinear distance measurement along the center of the channel
- Channel Slope: Change in Elevation divided by the length of channel along a channel distance of 20-30 riffle/pool sequences or 2 Meander lengths. Valley Slope/Sinuosity.
- Colluvial: Process where transported chiefly by gravity and is unsorted. It may travel within water
- Colluvium: Transported chiefly by gravity and is unsorted. It may travel within water
- Competence: A Streams ability to transport sediment. The diameter of the largest sediment grain transported
- Datum: An arbitrary Elevation from which all vertical measurements are taken in a design
- Degradation: The process by which a Stream's gradient becomes less steep, due to the Erosion of sediment from the Stream bed. Such Erosion generally follows a sharp reduction in the amount of sediment entering the Stream
- Delta: An Alluvial fan having its apex at the mouth of a Stream
- Deposition: The terminus of Erosion - the settling of particles
- Elevation: Measure of vertical length relative to a Datum
- Entrenchment Ratio (ER): The channel width at two times the Bankfull Depth divided by the channel width at Bankfull.
- Erosion: The process by which particles of rock and soil are loosened, as by weathering, and then transported elsewhere, as by wind, water, ice, or gravity
- FGM: Fluvial Geomorphology
- Flood-Prone Area: A relatively flat lowland that borders a Stream and is covered by its waters at flood stage of twice the maximum Bankfull Depth.
- Flood-Prone Width (WFP): The Stream width at a discharge level defined as twice the maximum Bankfull Depth.
- Floodplain: Land that is actively (flooded beyond Bankfull once every 1-2 years), generally broad, gently sloped Valley floor, often bounded by a Terrace (abandoned Floodplain) or encroaching side slope
- Geologic Material: Solid inorganic substratum of the earth and all possible derivatives
- Landforms: Natural features of a land surface
- Low Flow: Groundwater fed flow
- Meander: Curves deviating from a linear course. Components of Meander geometry include length, amplitude, belt width.
- Meander Width Ratio: Meander Belt Width divided by the Bankfull Width
- Reach: A channel type unit length with the same channel type existing for a length over twenty Bankfull channel widths (Rosgen). The length of channel uniform with respect to discharge, depth, area, and slope. The length of a channel

for which a single gage affords a satisfactory measure of the stage and discharge. The length of a river between two gaging stations. More generally, any length of a river.

- Sinuosity: Ratio of Channel Length to Valley Length. Ratio of Valley Slope to Channel Slope.
- Stream: A body of water found on the Earth's surface and confined to a narrow topographic depression, down which it flows and transports rock particles, sediment, and dissolved particles. Rivers, creeks, brooks, and runs are all Streams
- Terrace: An abandoned Floodplain, due to river incision or downcutting, etc
- Thalweg: Longitudinal outline/trace/survey of a deepest part of riverbed from source to mouth (upstream/downstream). Line of steepest descent along the Stream.
- Valley: A depression on the earth surface drained by, and whose form is changed by, water under the attractive force of gravity, between two adjacent uplands
- Valley Length: Horizontal distance measured in the Thalweg of two cross sections in a linear depression between two adjacent uplands
- Valley Slope: Slope of a Valley for a given Reach where Valley and Reach intersect for some longer distance (several Meanders or step pools)
- Wetted Width: The width of the wetted Stream at the time of the survey. Wetted Width is generally less than Bankfull Width. Wetted Width is also referred to as "low flow channel

Sources for the Glossary:

http://www.fgmorph.com/showglossary.php (Dr. Theodore Endreny at SUNY ESF)

APPENDIX A

SCOTT VALLEY'S GROUNDWATER ASSESSMENT: HISTORY

Scott Valley's Groundwater Assessment History (1952-1991)

- 1952-1958: Scott Valley's groundwater was studied by U.S. Geological Survey (Seymour Mack) and report with maps was published.
- 1970: California Water Code was amended to allow water law to address groundwater as interconnected with surface water in the Scott Valley.
- 1970-1975: Scott Valley's groundwater was reevaluated by State for Scott River Adjudication, which was requested by local farmers to protect their water rights.
- 1980: Scott River Adjudication became decreed by the County Superior Court: it included an "interconnected" groundwater and surface water zone on the map.
- 1990-91: Groundwater assessed by the California Dept. of Water Resources (DWR) as part of a Scott River Flow Augmentation Study (for the Siskiyou RCD).
- 1955-present: DWR measures groundwater fluctuations twice a year at 5-7 wells.

Scott River Watershed CRMP & Water (1992-1999)

- In 1992, the Scott River Watershed Coordinated Resource Management Planning (or CRMP) was created as a local volunteer effort by landowners, agencies, and others to work together to solve some of our local natural resource problems. Dave Black was our first Chair, with 16 people from diverse backgrounds being voting members.
- A prolonged drought beginning in 1987, combined with declining fall chinook numbers, brought WATER to the front as a resource problem to be considered.
- In November 1993, a workshop called "Agriculture and Salmon in Scott Valley: Meeting Their Water Needs" was conducted. Additionally, a Water Law Symposium was held in March 1995.
- After many committee meetings, a Scott River Fall Flows Action Plan was adopted in 1995 as a Working Plan, to be updated regularly.

Scott River Watershed CRMP's Fall Flows Action Plan (1995):

Goal**:** *Work for adequate water flows in the Scott River system to protect the migration, spawning, and rearing needs of the salmon and steelhead stocks, while also protecting other beneficial uses.*

A. Improve our understanding of the hydrology of the Scott River system.

1. Develop a water budget to graphically map where the water comes from and where it goes.
2. Evaluate the groundwater and surface water recharge effects of irrigation ditches. More information is needed on the return rate, quantity, and location of ditch seepage to streams during the fall months and the effect on spawning conditions.

B. Evaluate existing and potential projects through water monitoring, using landowners who volunteer sites.

1. Monitor fall well levels to measure changes in water table after irrigation season and during salmon spawning season.

2. Test the effect of temporarily stopping diversions into ditches for stockwater use in fall to see if it will help fish flows, or just recharge ground water adjacent to the stream. Only ditch systems that have alternative stockwatering methods already in place should be used. Monitoring of before and after streamflow and adjacent groundwater conditions will be needed.

The Fall Flows Action Plan was updated in 1999.

Scott River Watershed Council & Water (1999-present)

- The CRMP was transformed into the Council in 2000, and the Council continued implementing the Fall Flows Action Plan.
- In 2003, the Council and the Siskiyou RCD prepared the "Scott River Fall Flows Action Plan Accomplishments, 1995 to 2003" to share what was done and not done.
- In 2004, it adopted its Strategic Action Plan (2004), which includes the same Water Goal, but also a Water Objective and Tasks:
  http://www.scottriver.org/SRWPlans.html
  1. Improve our understanding of the hydrology of the Scott River system and the relationship to water use.
  Task A: Evaluate the ground and surface water recharge effects of irrigation ditches. More information is needed on the return rate, quantity, and location of the ditch seepage to streams.
  Task B: Investigate feasibility and effectiveness of various water recharge methods.
  Task C: Conduct a groundwater study including connectivity of groundwater to streams.

- Water Budget / Balance work is continuing, with a spreadsheet model in use developed by Dr. Michael Deas of Watercourse Engineering. Groundwater data remain the biggest gap in making the model useful.
- Water Committee of 7-9 members is actively pursuing these tasks.
- In April 2006, a MOU for the Scott Valley Community Groundwater Measuring Program was signed among SRCD, SRWC, County, NRCS, and U.C., with the objective of the program: "to understand changes in the recharge/discharge balance of the Scott Valley aquifer, particularly how this balance changes by location in the valley, by season of year, and as a result of inter-annual variations in precipitation and climate."
- Since April 2006, monthly groundwater measurements are taken by RCD staff at over 30 wells in Scott Valley, with data sent to UC Davis for storage and analysis.

Recent Regulatory Requirements for Scott Valley's Groundwater

California Dept. of Fish and Game & State Endangered Species Act – Coho Salmon:

- Shasta-Scott Coho Salmon Recovery Team prepared a Pilot Program relating to agricultural water use in 2003.

- DFG’s Incidental Take Permit (ITP) will take effect in 2008 and includes a mitigation action to develop a Dry and Critically Dry Year Contingency Plan to be implemented during those types of water years to benefit coho salmon rearing and spawning.

<u>North Coast Regional Water Quality Control Board & Clean Water Act – TMDL:</u>

- Scott River’s water quality was listed as “impaired” for temperature and sediment in the mid-1990s.
- A Total Maximum Daily Load (TMDL) was adopted by the Regional Board to address these two impairments in December 2005 and by the State Water Board in June 2006.
- Groundwater’s effect on stream temperature was identified to be important and specific tasks are listed in the Action Plan and Work Plan. Siskiyou County is requested to study the connection between groundwater and surface water, in cooperation with other appropriate stakeholders.