SCOTT RIVER HYDROLOGY AND INTEGRATED SURFACE WATER / GROUNDWATER MODELING

1.0 Study Goals and Objectives

The overall goal of the Scott River hydrology and integrated surface water / groundwater modeling study plan is to: 1) quantify unimpaired[1] and regulated flows in the watershed; and 2) further refine the Scott Valley integrated surface water / groundwater model (SVIHM). The unimpaired hydrology developed under this study will be integrated with existing groundwater models to allow evaluation of operational alternatives. The unimpaired hydrology model will integrate rainfall and snowpack measurements, infiltration and evapotranspiration from the watershed soils and vegetation, watershed percolation to the shallow groundwater and subsequent baseflow discharge, stream diversions and irrigation return flows. The seasonal groundwater storage and pumping for irrigation is a major component of the water balance in the Scott River basin. The daily natural and regulated flows for each major tributary and river segment will be modeled for the 21-year period of water year 1991-2011.

The specific objectives of the study include:

1) Estimate the unimpaired daily streamflow in each tributary and main river reach as a function of the rainfall and snowmelt runoff using a daily hydrologic model (e.g. HEC-HMS). The hydrologic model will apply daily rainfall and snowpack data from two or more precipitation stations (one for valley rainfall and one for higher elevation rainfall with snowpack) and will include representations of the soil moisture capacity (depth of water) and evapotranspiration losses so that the direct surface runoff can be estimated. The hydrologic model will be divided into tributary watersheds, so that the runoff from each tributary can be estimated. Tributary reach flow estimates will be provided at the upstream boundary of the alluvium, the upstream extent of fisheries habitat, the downstream confluence with another tributary reach or with a main river reach, and the location of each diversion. In addition, unimpaired flows will be estimated for the reach downstream of the Scott River Valley alluvium (i.e. below USGS 11519500 Scott River at Fort Jones). These estimated flows will be referenced with river mile locations.

2) If necessary, estimate the percolation losses from each tributary to the riparian groundwater (in the downstream alluvial deposits) as a function of streamflow (fraction of flow, which may increase at higher flows)[2]. Distinguish between subsurface gravel flow and percolation to the groundwater basin. Estimate the groundwater discharge to the main river reaches as a function of groundwater elevation and streamflow.

3) Refine the SVIHM (i.e. MODFLOW SFR2) in collaboration with the North Coast Regional Water Quality Control Board, UC Davis, and the Scott Valley Groundwater Advisory Committee using the unimpaired flows. The refined SVIHM will allow interested parties to evaluate alternative water management scenarios within the basin.

---

[1] "Unimpaired Flow" represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. Gauged flows at the given measurement points are increased or decreased to account for these upstream operations.

[2] This information may be developed as part of the groundwater modeling studies that are currently in progress.

2.0 Existing Information/Literature Review

Measurements of flows in the Scott River watershed are described in a series of reports by Deas and Tanaka (2004, 2005, 2006, 2008). Researchers at the University of California Davis (Foglia et al. 2013a, 2013b) have recently completed data analysis of streamflow records in the Scott River basin to support the development of a Scott Valley integrated groundwater model and a similar effort has been undertaken on behalf of the Karuk Tribe (Papadopolus & Associates 2012). The location of the historical streamflow stations used in the Foglia et al. 2013b study are presented in Table 1, and a summary of stream gages and flow data from is provided in Table 2. Additional data on groundwater levels from monitored wells and well pump test data are also contained in Papadolulos & Associates (2012), and additional data are in Harter and Hines (2008). The USFS weather station at Scott Mountain (elevation 5,500 feet) provides daily precipitation and daily snowpack depth, and daily weather stations near Callahan (elevation 3,100 feet) and Fort Jones provide valley (low elevation) rainfall estimates. Other flow measurement stations have been operated for various periods by Scott River Watershed Council (SRWC), North Coast Regional Water Quality Control Board (NCRWQCB), US Forest Service (USFS) and Quartz Valley Indian Tribe (QVIT).

Table 1. Dates of available tributary streamflow data used for the regression analysis, including the east and south fork of the main stem Scott River. (Source: Foglia et al. 2013b, Table 5)

	Pre-WY1972 Data Range	Post-WY1972 Data Range
Kidder	4/72-9/72	10/02-9/11
Mill	-	12/04-9/05
Shackleford	10/56-9/60	10/04-9/11
Sugar	9/57-9/60, 5/72-9/72	10/09-9/11
Moffett	10/58-9/67, 4/72-9/72	-
East Fork	10/59-9/72	10/72-9/74, 7/02-9/11
South Fork	10/58-9/60, 4/72-9/72	7/02-9/11
French	-	10/04-9/11
Etna	4/72-9/72	-
Patterson	4/72-9/72	-

Table 2. Summary of stream gages and flow data for the Scott River watershed

Station Name	Data Source (Type)	Station ID	Period of Record
Scott River near Fort Jones, CA	USGS (stream flow)	11519500	10/1/1941 – Present
Scott River near Scott Bar	WDL (stream flow)	F25040	10/1/2004 – 9/30/2005 10/1/2006 – 9/30/2007
Mill Creek near Mugginsville	WDL (streamflow)	F25480	11/10/2004 – 9/29/2005
Shackleford Creek near Mugginsville	WDL (stream flow)	F25484	10/1/2004 – 9/30/2014
French Creek at Hwy 3 near Callahan	WDL (streamflow)	F25650	10/1/2004 – 9/30/2014
Sugar Creek near Callahan	WDL (stream flow)	F25890	10/1/2009 – 9/30/2014
Scott River, East Fork, at Callahan	WDL (stream flow)	F26050	10/1/2006 – 9/30/2013

Scott River, South Fork, near Callahan	WDL (stream flow)	F28100	4/25/2007 – 9/30/2013
Collins Baldy (5493 ft)	CDEC (hour precip.)	CLB	7/9/1990 – Present
Darbee Ditch near Callahan	CDEC (diversion)	DDC	9/20/2010 – Present
Fort Jones Research Station (2725 ft)	CDEC (mon. precip.)	FJN	10/1/1935 – Present
Log Lake (5300 ft)	CDEC (mon. snow)	LOG	4/1/1951 – 12/31/1978
Marble Valley (5900 ft)	CDEC (mon. snow)	MBV	4/1/1951 – 12/31/1982
Quartz Hill (4238 ft)	CDEC (hour precip.)	QTZ	1/1/1984 – Present
Sugar Creek below Darbee Ditch near Callahan	CDEC (streamflow)	SDA	5/12/2010 - Present
French Creek above NF French Creek	DWR Watermaster	n/a	Daily data during diversion season through 1998

The Scott River has been declared “fully appropriated” by the California State Water Resources Control Board (SWRCB 1998). Water rights are currently managed under three separate judicial decrees (described below). The amount of water allocated under the three decrees is generally greater than streamflow sources during the summer and fall. During many years, surface diversions cease in the late summer months and diverters rely on groundwater for the remainder of the irrigation season. The irrigation season under the decrees begins on April 1 and continues through October 31, with additional stockwater demand through the winter. The irrigation demand pattern increases to a maximum in July and August and then decreases through October.

Stream diversions from Shackleford Creek are defined by the 1950 Shackleford Creek Decree. This decree covers Shackleford Creek and all tributaries (including Mill Creek) and springs draining to Shackleford Creek. The decree allots a total of 69.55 cfs from Shackleford Creek and its tributaries (in priority). Stream diversions from French Creek (including Miners Creek) are defined by the 1958 French Creek Decree. The decree allots a total of 36.5 cfs from French Creek and its tributaries (in priority). The 1980 Scott River Decree (1980 Decree) allocates (with priority) water rights for the Scott River, South Fork Scott River, East Fork Scott River, Wildcat Creek, Oro Fino Creek, Sniktaw Creek, and several small streams and lakes.

The two largest diversions (and allotments) on the Scott River are the Farmers Ditch and the Scott Valley Irrigation District (SVID) ditch. The Farmers Ditch is located just downstream of the Sugar Creek confluence. The Farmers Ditch Company owns and operates the ditch to supply 10 users and most of the water is applied to irrigated pasture. The 1980 Decree allocates 36.0 cfs to the Farmers Ditch (22.3 cfs for consumptive use and 13.7 cfs for ditch losses). Typically, in August and September the ditch capacity is greater than the natural flow of the Scott River. The SVID ditch diverts flows from the river downstream of French Creek confluence. The 1980 Decree allocates 62.5 cfs to the SVID at this diversion, although this was later reduced by SWRCB to 43 cfs.

The Scott River Valley Groundwater Basin underlies the alluvial floodplain and is approximately 28 miles long, 0.5 to 4 miles wide, and nearly 100 square miles in surface extent. Quaternary stream channel, floodplain, and alluvial fan deposits are the primary water-bearing formations. Groundwater storage capacity of the basin (to a depth of 100 feet) is estimated to be 400,000 acre-feet. This large aquifer is recharged annually by the Scott River, tributary streams, and by infiltration of precipitation and snow melt. In the Valley, groundwater exerts a strong influence on the volume and temperature of Scott River flow. The seasonal fluctuation of the groundwater table locally determines the exchange of water between the Scott River and the aquifer.

The stream flow connections with the groundwater for the Scott River are also very important for understanding the water management and recharge from streamflow diversions. Because groundwater pumping is a major source for irrigation water, there is great interest in determining the tributary recharge component for the Scott Valley groundwater basin. If the stream percolation to the groundwater is high, the stream flow will decrease along the alluvial fan, from the mountain canyon mouth to the confluence with the Scott River. This should be measured directly in the early spring before irrigation diversions begin. A general indication of the fraction of the combined tributary flow that percolates to the groundwater potentially could be estimated from historical flow measurements and groundwater recharge (increase in groundwater elevations) during the winter-spring high flow periods. The possible effects of groundwater pumping on lower groundwater elevations and higher streamflow recharge is a topic of interest, but this secondary effect on stream recharge of the groundwater will be more difficult to estimate. Recent study efforts by the Karuk Tribe (Papadopulus 2012) and UC Davis (Foglia et al. 2013a, 2013b) to develop groundwater models for the Scott River basin provide a good start for quantifying the seasonal irrigation, diversions, groundwater use, and groundwater recharge. They estimated the total irrigation as about 70,000 acre-feet (af), with about 25,000 af from surface diversions and about 45,000 af from groundwater pumping. They estimated the total recharge necessary to balance the groundwater pumping, but have not yet estimated the recharge from rainfall infiltration, streamflow percolation, and irrigation infiltration from the tributary streams.

Groundwater use in the Scott Valley has increased dramatically over the last few decades. In the year 2000, DWR estimated that 45 percent of the irrigated acres in the Scott Valley were using groundwater, compared to 2 percent just over 30 years ago. Although there is no regulation or quantification of the extraction of water from wells, groundwater levels have remained fairly constant over the last 40 years and have recharged for the most part each year. Because the demand for irrigation water is greater than surface flows during the summer and fall, diverters must rely on groundwater for the latter part of the irrigation season.

3.0 Study Areas

The study areas for the Scott River hydrology and water balance modeling are presented in Table 1 (see Scott River Potential Studies Matrix; http://www.normandeau.com/ scottshasta/ project materials.asp). The Scott River study area includes both mainstem (Figure 1) and tributaries (Figure 2), because rainfall and snowmelt runoff originate from the entire watershed area. The Scott River watershed is about 812 square miles at the confluence, and about 650 square miles at the USGS streamflow measurement station (gage) at Fort Jones.

Table 1. Reaches of the Scott River and tributaries where hydrology and water balance need to be evaluated.

REACH DESCRIPTION	Reference(s)	Studies Status
Mainstem Scott River	Deas & Tanaka 2004; NCRWQB 2005; NMFS 2012; SRWC 2006	Needed
Scott River Tributaries	Deas & Tanaka 2004; NCRWQB 2005; NMFS 2012; SRWC 2006	Needed

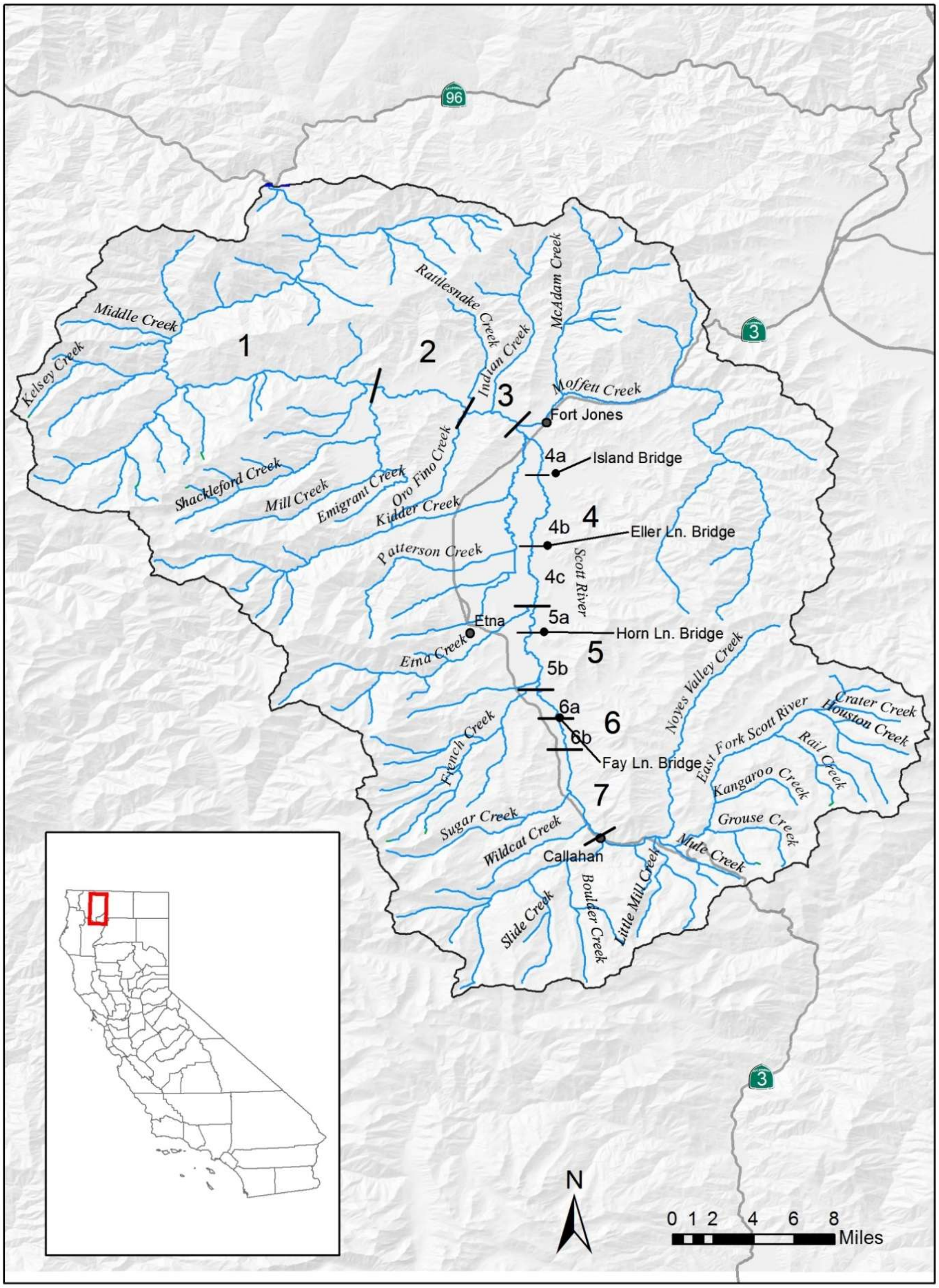

Figure 1. Scott River Mainstem Reaches.

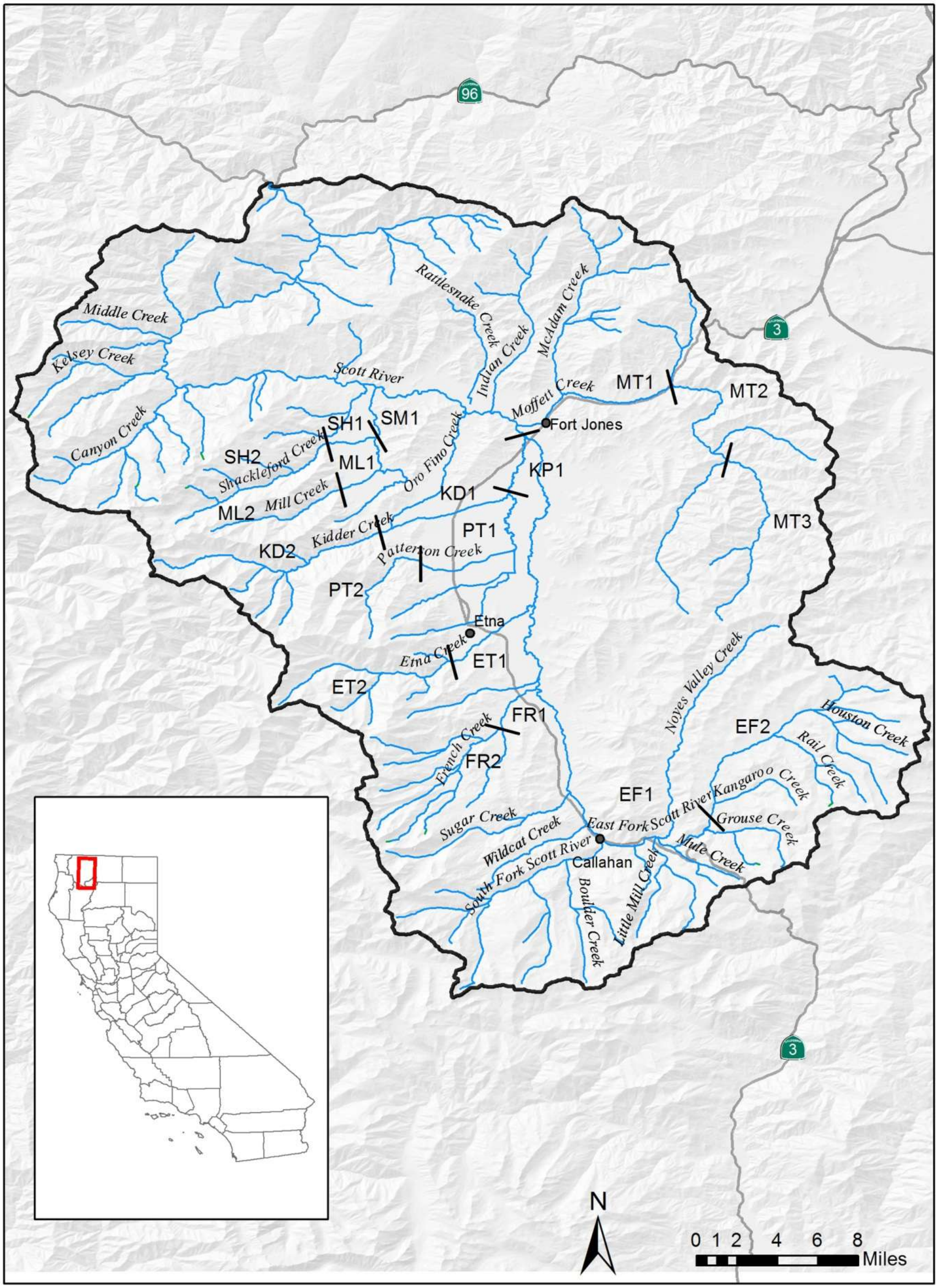

Figure 2. Scott River Tributary Reaches.

4.0 Study Methods

Task 1. Develop Unimpaired Hydrology

1) Review the previous reports on hydrology and water measurements for the basin, including SWRCB (1974) and particularly the streamflow component of Foglia et al. 2013b, which developed statistical regression analysis for the Scott River and most major tributaries. Compile all publically available streamflow, precipitation, snowpack, and meteorological data appropriate for use in a hydrologic model within the Scott River watershed. Obtain or prepare maps with streams and watershed areas and elevation contours and gaging stations.

2) Compare historical hydrology data with the reach descriptions (Figures 1 and 2) to identify the upstream watersheds for each reach boundary.

3) Identify all springs, stream inflows, and diversions along each reach, so that the flows can be accurately estimated along the stream channel (with river mile locations).

4) Identify the connections with the basin groundwater, such as a) stream infiltration to the groundwater along the alluvial fan sections of tributary streams, b) recharge from irrigation water canals, and c) seepage from the shallow groundwater to the river channel in the irrigated valley reaches. Estimate the magnitude of these connections as a function of the stream flow (depth) and river gains as a function of the river flow (elevation) and shallow groundwater elevation (index wells). This information will require a series of streamflow measurements along the alluvial fan of the Scott River tributary streams at a range of flows (e.g., March-May, before major diversions).

5) Develop a daily rainfall-snowmelt-runoff hydrologic model using HEC-HMS (Scharffenberg 2013), or similar model, that includes soil moisture, evaporation and shallow groundwater infiltration and seepage (baseflow, springs) for the basin. The hydrologic model should include specific representations of the surface water inflows at the following locations:
    a. Downstream of each reach break depicted in Figures 1 and 2;
    b. The upstream boundaries of the alluvium for each tributary;
    c. The reach below the Scott River Valley alluvium (i.e. below USGS 11519500); and
    d. The diversion locations identified in the 1950 Shackleford Creek Decree, the 1958 French Creek Decree; and the 1980 Scott River Decree.

6) Calibrate the model against an appropriate dataset, and subsequently validate the model against a separate, recent, dataset. Apply the hydrologic model to estimate the streamflow for the locations identified above for the 21-year period of water year 1991 to 2011.

7) In addition to applying the hydrologic model to estimate unimpaired flows as specified in the preceding step, apply the model to support various scenarios of interest, including one or more scenarios that reflects the hydrologic impacts of climate change on Scott River flows.

Task 2. Refine the Integrated Surface Water / Groundwater Model

1) Collaborate with the North Coast Regional Water Quality Control Board, UC Davis, and the Scott Valley Groundwater Advisory Committee on the refinement of the SVIHM (i.e. MODFLOW SFR2) using the information developed in Task 1.

    a. Using the FLIR and water temperature data collected pursuant to the Scott River Water Temperature Assessment study plan, apply the methods articulated in Loheide and Gorelick (2006) to refine the estimates of groundwater discharge and hyporheic flow.

2) Develop and apply operating rules for each diversion that reflect recent historic conditions, if known, or the water rights decrees if recent historic operations are not known.

3) Validate the model against the observed record compiled in Task1.

4) Develop a base-case simulation in consultation with interested participants.

5.0 Deliverables

Deliverables from this study plan include:

1) Estimates of the regulated an unimpaired flow at the following locations:
    a. downstream of each reach break depicted in Figures 1 and 2;
    b. the upstream boundaries of the alluvium for each tributary;
    c. the reach downstream of the Scott River Valley alluvium (i.e. USGS 11519500), and
    d. the diversion locations identified in the 1950 Shackleford Creek Decree, the 1958 French Creek Decree, and the 1980 Scott River Decree;
2) A refined SVIHM that can be used to evaluate flow management alternatives; and
3) A Final Report that: documents the development of the hydrology day and the SVIHM, including calibration and validation efforts.

6.0 Literature Cited

California Department of Fish and Game (CDFG). 2004. Recovery Strategy for California Coho Salmon. Report to the California Fish and Game Commission, Species Recovery Strategy 2004-1. California Department of Fish and Game, Native Anadromous Fish and Watershed Branch. Sacramento, CA.

California Department of Fish and Game. 2009. Scott River Watershed-Wide Permitting Program. Final Environmental Impact Report. Available at: https://r1.dfg.ca.gov/portal/NorthernRegionHome/ShastaScottRiversPermitting/ScottRiverPermittingEIR/tabid/853/Default.aspx

California Department of Water Resources (DWR). 1991. Scott River Flow Augmentation Study. Northern District.

Deas, M.L., and S.K. Tanaka. 2004 . Scott River Water Balance Study: Data Analysis and Model Review. Watercourse Engineering, June 2004.

Deas, M.L., and S.K. Tanaka. 2005. Scott River Runoff Forecast Model: Investigation of Potential Formulation. Watercourse Engineering, December 2005.

Deas, M.L., and S.K. Tanaka. 2006 . Scott River Water Supply Indices: Year Types for the Scott River Basin, prepared for the Siskiyou RCD.

Deas, M.L., and S.K. Tanaka. 2008. Scott River Water Balance-Streamflow and Precipitation Gauging, prepared for the Siskiyou RCD.

Foglia, L., A. McNally, and T. Harter. 2013a. Coupling a spatiotemporally distributed soil water budget with stream depletion functions to inform stakeholder-driven management of groundwater-dependent ecosystems, Water Resources Research, 49, 7292–7310, doi:10.1002/wrcr.20555.

Foglia, L., A. McNally, C. Hall, L. Ledesma, R. J. Hines, and T. Harter. 2013b. Scott Valley Integrated Hydrologic Model: Data Collection, Analysis, and Water Budget, Final Report. University of California, Davis. April 2013. 101 p. Available at: http://groundwater.ucdavis.edu.

Harter, T., R. Hines. 2008. Scott Valley Community Groundwater Study Plan. Final Report, Version 11, February 11, 2008 Available online at:http://groundwater.ucdavis.edu/ScottValley.htm

Loheide, S., S. Gorelick. 2006. Quantifying Stream – Aquifer Interactions through the Analysis of Remotely Sensed Thermographic Profiles and In Situ Temperature Histories. *Environment, Science and Technology, 40*(10), 3336-3341.

Mack. S. 1958. Geology and Ground-Water Features of Scott Valley, Siskiyou County, California. U.S. Geological Survey Water Supply Paper No.1462. 115 pp. Available online at: http://pubs.usgs.gov/wsp/1462/report.pdf

National Marine Fisheries Service (NMFS). 2012. Recovery Plan for the Southern Oregon Northern California Coast Evolutionary Significant Unit of Coho Salmon (Oncorhynchus kisutch). Volume II, Chapter 36, Scott River Population.

National Research Council. 2004. Endangered and Threatened Fishes in the Klamath River Basin. Available at: http://www.krisweb.com/biblio/klamath_nsa__nrc_2003.pdf

North Coast Regional Water Quality Control Board (NCRWQCB). 2005. Staff Report for the Action Plan for the Scott River Watershed Sediment and Temperature Total Maximum Daily Loads. 472 pp.

North Coast Regional Water Quality Control Board (NCRWQCB). 2006. Action Plan for the Scott River Sediment and Temperature Total Maximum Daily Loads, September 2006. Available at: http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/scott_river/staff_report.shtml

North Coast Regional Water Quality Control Board. 2011. Staff report for the action plan for the Scott River Watershed Sediments and Temperature TMDLs. Available at: http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/scott_river/staff_report.shtml

Papadopulos & Associates. 2012. Groundwater conditions in Scott Valley. Report prepared by S.S. Papadopulos & Associates, Boulder, Colorado, for the Karuk Tribe, March 2012.

Scott River Watershed Council (SRWC). 2006. Initial Phase of the Scott River Watershed Council Strategic Action Plan. October 2005 Update. 5/2/2006. 249 pp.

State Water Resources Control Board (SWRCB). 1974. Report on water supply and use of water: Scott River system, December, 1974: Division of Water Rights, 34 p. plus appendices.

State Water Resources Control Board. 1998. Water Right Order 98-08 Order Revising Declaration of Fully Appropriated Stream Systems. November, 1998.

Sharffenberg, W.A. 2013. HEC-HMS hydrologic modeling system user's manual, version 4.0, December 2013. US Army Corps of Engineers Hydrologic Engineering Center, Davis, CA. 426 pp.

Yokel D., and E. Yokel. 2007. Scott River Flow Measurements & Report – Evaluation of gaining and losing reaches of the Scott River. Completed by the Siskiyou Resource Conservation District for the North Coast Regional Water Quality Control Board.