Appendix C:
Temperature TMDL Supplemental Information: Geomorphology and Groundwater Connectivity Assessment

THIS DOCUMENT IS SUPPLEMENTAL TO THE ROGUE RIVER BASIN TEMPERATURE TMDL (CHAPTER 2)

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Rogue River Tributary – Little Butte Creek Geomorphology and Groundwater Connectivity Assessment

Final Report

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Prepared for:

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Seattle, Washington

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1. Introduction

1.1 Background

The Rogue River is listed as impaired on the State of Oregon's 2004/2006 303(d) list due to excessive water temperatures. Oregon Department of Environmental Quality (ODEQ) has observed exceedances in both the summer juvenile rearing and the spawning temperature standards in the river. ODEQ is currently modeling temperatures in the mainstem and several tributaries of the Rogue River to determine the natural thermal potential of these waterbodies.

ODEQ has identified several sources of thermal impairment in the Rogue River watershed. These include point source dischargers (e.g. industries and wastewater treatment plants) and nonpoint sources (e.g. lack of riparian shading). To date, the impact of geomorphological changes on Rogue tributaries has not been assessed. It is believed that geomorphological and related changes to Little Butte Creek may be impacting instream temperatures. ODEQ would like to compare the current river morphology to the historic or natural morphology to assess (1) where changes have occurred, (2) the types of changes that have occurred, (3) when changes occurred, (4) the magnitude of those changes, (5) possible causes of the changes, and (6) the impacts of the changes on stream temperatures of Little Butte Creek.

Stakeholders of the Rogue River TMDL project suggested improving the understanding the impacts of changes in geomorphology and related groundwater connectivity that have occurred in the Rogue River Basin through development that has occurred over time. The Little Butte Creek tributary to the Rogue River near Eagle Point, Oregon was identified as a candidate for further investigation of these impacts. The US Environmental Protection Agency (US EPA) has offered to assist ODEQ in characterizing these impacts on water temperatures by funding this study of changes in geomorphology and groundwater connectivity in Little Butte Creek.

1.2 Purpose

The main purpose of this study is to characterize the changes in geomorphology and associated groundwater connectivity within the Little Butte Creek watershed. Based on these estimated changes, input parameters to the ODEQ temperature model such as bankfull width and percent hyporheic flow exchange can be made. Thus the impacts of changes to the stream channel relative to natural, pre-development conditions on instream water temperatures can be predicted.

1.3 Scope of Study

This geomorphology and groundwater system connectivity assessment focuses on the mainstem of Little Butte Creek (mainstem), the South Fork of Little Butte Creek (South Fork), and Fish Lake. The North Fork of Little Butte Creek (North Fork) is not included in this analysis due to funding limitations and necessary prioritization. It is generally believed that land use changes, development and associated impacts on stream geomorphology and groundwater connectivity along the North Fork are less significant than those along the Mainstem and the South Fork.

Thermal imaging analysis, previously conducted by ODEQ, has confirmed this and indicated that groundwater-surface water interactions may be more significant on the South Fork. Fish Lake analysis was included to support estimates of the natural conditions of the North Fork in the temperature model. These reaches and their proximity to Medford, Eagle Point and the Rogue River are shown in Figure 1-1.

This report also identifies and briefly describes general restoration actions that may potentially address the stream channel and related water quality degradation in Little Butte Creek. These actions include conservation and land use management approaches intended to protect stream resources from new impairments and also prevent further degradation of reaches already impacted. Stream restoration measures may be one avenue through which stakeholders move toward the required TMDL allocations.

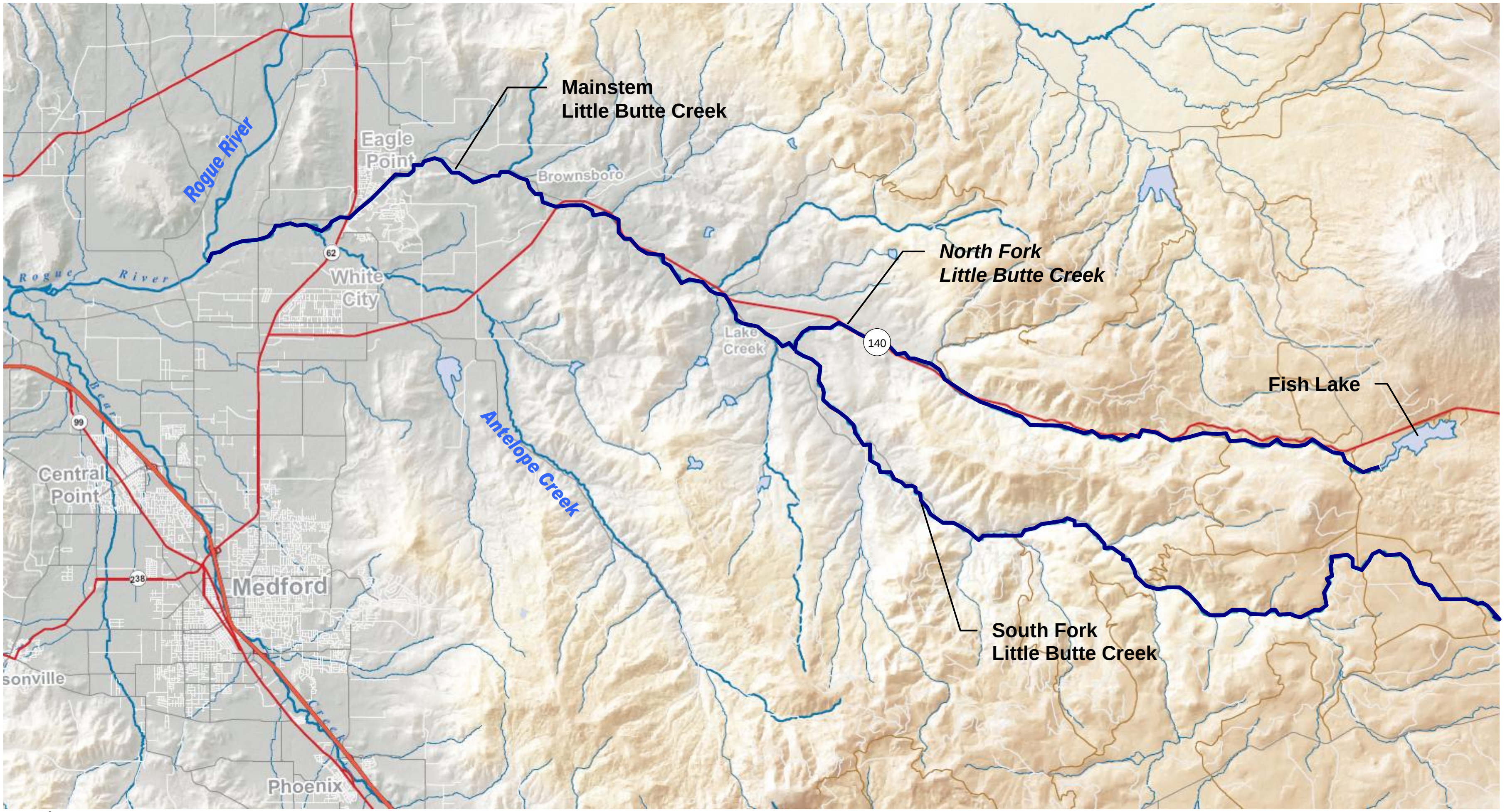

Figure 1-1
Little Butte Creek Vicinity Map Showing the Mainstem, North Fork, South Fork, and Fish Lake.
(Not to scale - Jackson, 2008)

2. Data and Literature Review

2.1 Watershed Characteristics and History

The Little Butte Creek Watershed encompasses nearly 400 square miles in southern Oregon, primarily east of the town of Medford, within Jackson and Klamath Counties. This drainage system is classified as a 5th field tributary of the Rogue River watershed. Little Butte Creek flows primarily east to west over approximately 43 miles off the slopes of the Cascade Mountain Range and through the town of Eagle Point before its confluence with the Rogue River. The main tributaries to Little Butte Creek are Antelope Creek, the North Fork, and the South Fork (see Figure 1-1, Little Butte Creek Watershed Council (LBCWC), 2003).

The watershed topology varies significantly along the main drainage profile. Elevations range from 9,300 feet above mean sea level at the headwaters to approximately 1,200 feet mean sea level at the Rogue River confluence. The headwater regions of the watershed are located on the relatively mild-sloping High Cascade Plateau. From there the stream enters a steeper profiled transition, before returning to a lower gradient reach over the remaining approximately 20 miles (LBCWC, 2003).

Various communities are located along Little Butte Creek. The largest and only incorporated city in the watershed is Eagle Point (incorporated in 1911), located approximately three miles from the Rogue River confluence. Other smaller rural communities in the watershed include Brownsboro, Lake Creek, White City, and Climax. Early settlement began in the 1850s and was driven by agriculture and nearby gold mining activities. Forest lands in the upper watershed were also the source of timber for home and building construction as the gold mining era continued (LBCWC, 2003).

2.2 Existing Channel Classification

The 2003 Little Butte Creek Watershed Assessment evaluated variations in channel forms throughout the watershed (channel habitat types, Chapter II). The purpose of the channel type evaluation was to determine the impacts of land uses on geomorphology and physical stream processes (LBCWC, 2003). This evaluation was based on geomorphic parameters such as stream gradient and valley type (i.e., channel confinement).

The results of this evaluation indicated that the Mainstem, North Fork and South Fork are largely confined throughout their respective high, moderate and low gradient reaches. Only 19% of the Mainstem (presumably near the Rogue River confluence but not specified in the report) was considered unconfined (not channelized). A summary table (revised from Table CT2 in LBCWC, 2003) is repeated as Table 2-1 below. The green shaded columns in the table indicate unconfined reaches, and the orange shaded columns indicate various confined channel types. The high levels of confinement are likely the result of development related to road construction near the stream, modifications to stream banks in agricultural regions to facilitate diversions, the actual diversion structures itself, livestock access, and other types of development.

Table 2-1
Channel Type Distribution Showing Percentages of Channel Confinement in Little Butte Creek.

Subwatershed	FP1	FP2	FP3	LM	LC	MM	MC	MH	MV	SV	VH	Stream Dist (km)
Mainstem	19	0	0	**39**	0	13	0	0	**21**	8	0	73
South Fork	0	0	0	0	8	**26**	12	6	13	**27**	9	54
North Fork	0	0	0	5	**17**	7	**17**	7	**22**	18	5	52

Notes: *1. Green shaded channel types FP1, FP2, FP3 indicate unconfined reaches.*
2. Orange shaded channel types (remaining) indicated confined reaches.
3. Values in bold are the highest percentage channel types.
4. Channel types: FP – low gradient large (1), medium (2) and small (3) floodplain; LM – low gradient moderately confined; LC – low gradient confined; MM – moderate gradient moderately confined; MC – moderate gradient confined; MH – moderate gradient headwater; MV – moderate steep narrow valley; SV – steep narrow valley; VH – very steep headwater.

Another finding of the watershed assessment was that approximately 50% of the stream network is in close proximity to a road. From this it is plausible that about half of the channels and adjacent floodplains in the watershed (Mainstem, North Fork, and South Fork) have been filled, channelized or otherwise modified to accommodate a roadway. This result is shown in Table CM3 (LBCWC, 2003). Approximately 41% of the Mainstem is within 10 meters of a road, and 61.8% and 49.2% of the North Fork and South Fork, respectively, are in proximity to a road. Thus a significant portion of the watershed has likely experienced significant changes in geomorphology and floodplain connectivity due to road construction alone.

Similarly, Little Butte Creek has undergone a significant degree of channel and flow regime modification due to instream diversions and associated withdrawal and return structures. These structures include diversion gates, push up dams, mined or excavated channels, dikes and levees, among others. Throughout the watershed, there are a total of 466 instream diversions as reported by the Little Butte Creek Watershed Council Watershed Assessment (2003). In the Mainstem, there are 171 reported diversions (approximately 1.3 diversions per stream mile). In the North and South Forks, there are 32 and 51 diversions, respectively. Although the watershed assessment implies that these diversions are points of withdrawal, it was not confirmed if this number refers to actual diversions or the total number of water rights along the creek system.

2.3 Geology and Soils

The general geology of the Little Butte Creek Watershed region is characterized by extensive lava flows underlying the present land surface. The lava flows are the result of geologically recent activity of the nearby volcanic cones and vents. The drainage pattern over the watershed area is generally dendritic as the drainage flows relatively slowly over the upland plateau region. From there it descends more rapidly through the transition region of the western slopes before reaching the flatter grades along the Mainstem (LBCWC, 2003).

The upper reaches of the North and South Forks are steep, on the order of 200 to 300 feet per mile (slopes of approximately 0.04 to 0.06). The resulting canyons are cut deeply into the jointed lava along the western Cascade Range. Some locations where erodible soils such as tuff-breccia exist have developed more mildly sloped canyon walls. The lower gradient reaches of Little Butte Creek have an average slope of approximately 0.005 or 0.5% (LBCWC, 2003).

Soils throughout much of the lower watershed are derived from volcanic alluvium that is generally very deep. A layer of clay hardpan is also prevalent intermittently near the surface, and this layer can act to restrict drainage. Consequently drainage tiles and other changes in irrigation practices have been required to reduce excess standing water in agricultural areas. Moreover, this clay layer has also restricted the used of septic tanks in many areas because rates of percolation are not sufficient (LBCWC, 2003).

2.4 Groundwater Connectivity and Hyporheic Flows

The state of Oregon Water Resources Department (WRD) has made available monitoring data and other information related to groundwater levels. These data are primarily in the form of well logs and studies for regions throughout much of the state including the Rogue River Basin (WRD, 2008; USGS, 1959). However, there is no available data characterizing groundwater conditions specifically within the Little Butte Creek drainage. The earlier USGS report extensively characterizes groundwater within Bear Creek and adjacent areas, but it is not easy to distinguish or pull out information specifically pertaining to Little Butte Creek.

Local experts were also queried regarding the availability of groundwater profile data near Little Butte Creek and its floodplain (Menteer, 2008; Lane, 2008). Correspondence confirmed that some groundwater monitoring studies have been performed nearby such as at North Mountain Park, Ashland (Lane, 2008). In addition, relevant and ongoing geomorphic analysis is being conducted along Little Butte Creek to characterize year to year changes, measured at a series of monumented cross section locations (Lane, 2008). However, there has not been a groundwater well or piezometer monitoring study that has characterized the relationship between creek water surface levels and adjacent groundwater levels.

Hyporheic Flows

One type of stream-groundwater flow interaction is known as hyporheic flow exchange. Hyporheic exchange is the inter-mixing of stream flows and shallow groundwater flows that are conducted through relatively porous substrates common along stream bottoms, banks and bars. Hyporheic flows occur through channel islands, across point bars, and across bar deposits that separate alcoves from the main channel. Schematic cross sections depicting different channel types with and without hyporheic flow are shown in Figure 2-1 (White, 1993).

Hyporheic flows can have significant cooling effects on instream water temperatures. As flows in the stream enter the gravel deposits they can be cooled through ground conduction, and they are also insulated from the atmospheric heating mechanisms (short wave radiation, long wave radiation, conduction, etc.). The resulting flows return to the stream cooler and/or out of phase with the water temperature of the surface water.

Various studies have investigated hyporheic flow in relation to various geomorphic stream characteristics and/or its impacts on water temperatures and fish spawning habitat (Rothwell, 2005; USGS, 2002; Evans, 1998; Douglass, 2006). Moreover, many of these have been conducted in streams and rivers in Oregon such as the Willamette River and its tributaries, the Clackamas Rivers, and others (Fernald, 2001; Kasahara, 2003; Grant, 2006; CTUIR, 2007). These studies described measured or estimated hyporheic flow exchange at various bedform and planform channel types (gravel bars, riffles, mid-channel islands, side channels, meander belts, etc.). These studies have found decreases in stream temperatures due to even low hyporheic flow exchange levels. For example, in the Willamette River, decreases in water temperature of approximately 1 to 2 degrees Celsius were noted at locations that experienced hyporheic flow exchanges of only approximately 2% (Fernald, 2001). Studies cited by Grant (2006) showed common instream temperature decreases ranging from 2 to 3 degrees Celsius, with some decreases as high as 6 to 8 degrees Celsius.

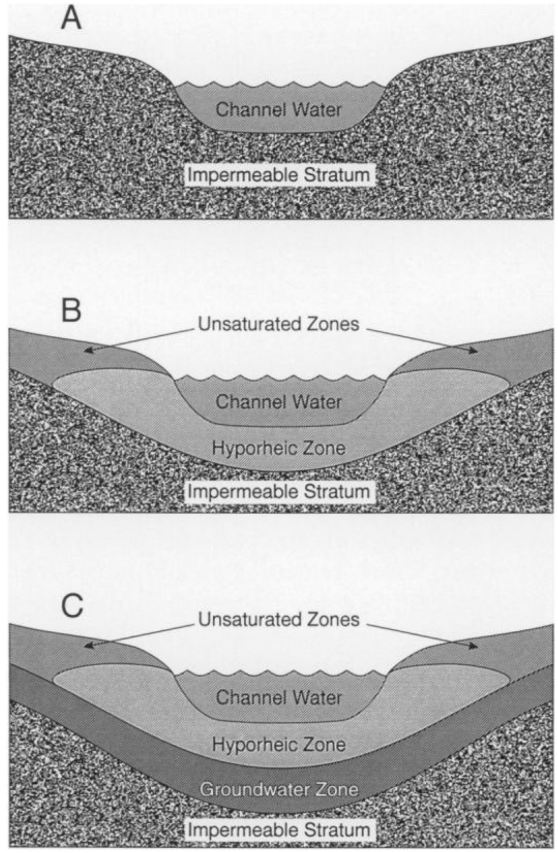

Figure 2-1
Conceptual Cross Sections Showing Surface Water-Groundwater Interaction Zones:
A – No Hyporheic Zone, B – Hyporheic Zone Due Only To the Steam Flow, and C – a Hyporheic Zone Created by Both the Stream and Groundwater (White, 1993).

The impacts of hyporheic flows on stream water quality have been recognized and documented for at least the last few decades. Although numerous studies exist, the state of the science hyporheic flows is relatively new. Accordingly there are no well known or widely applied numeric correlations, quantitative relationships, or other models relating observable stream features and levels of hyporheic flow. Assessments of hyporheic flow for a particular stream system should be based on site-specific knowledge of the stream and knowledge of how geomorphic parameters affect hyporheic flow.

2.5 Field Reconnaissance - May 2008

A one-day watershed visit was conducted on May 8, 2008 to generally assess stream and watershed conditions. Bill Meyers from ODEQ led the tour for Curtis Loeb of Tetra Tech. Approximately 11 locations along the Mainstem, and North and South Forks including Fish Lake were visited. Although the North Fork was not the focus of the tour or of this study, one location on the North Fork near Heppsie Mountain Road was documented for reference. Brief field notes and photos were documented at each location. A copy of the field notes, a series of maps with location notes, and selected photographs taken by Tetra Tech are included in Appendix B.

At the time of the site visit, the watershed was generally characterized by flows that were atypically high for mid- to late spring. Though the weather was warm and there was no precipitation in the days leading up to the site visit, flows throughout the creek were relatively high. High flows were the result of the late and substantial snowfall and subsequent snowmelt/runoff in April. Flows seemed to be near bankfull depth at most or all locations along the Mainstem and North and South Forks. Although bankfull depth was generally difficult to discern because channelization of the creek was typical, flow depths were judged to be near bankfull as vegetation at the lower stream bank was mostly underwater (see Appendix B, page B-7 Harnish Park, and page B-8 Agate Road Bridge).

The measured flows at the gaging station at Highway 62 Bridge in Eagle Point was reportedly in the range of 650 to 700 cubic feet per second (cfs) during the time of the site visit. Figure 2-2 shows stream flows at this location for the available period of record of the USBR Hydromet data, from January 2006 to present. In 2007 flows in May had already dropped to less than 100 cfs; however, in 2006 the flows in early May were similar to those this year, ranging from approximately 600 cfs to 800 cfs.

Excessive suspended sediment loading was also observed throughout the Mainstem and South Fork reaches. It was hypothesized that a landslide, bank failure, or similar mass wasting event had occurred somewhere in the upper watershed. The high sediment loads were not seen on the North Fork. After driving up the South Fork as far as Camp Latagawa (near Dead Indian Soda Springs), the bankslope failure event was not observed and was presumed to have occurred farther upstream because high sediment loads were visible at this location.

ODEQ staff has in the past observed other similar large-scale mass wasting events that cause high suspended sediment pulses in the South Fork. To date the source or specific location of the high sediment loads during the site visit has not been confirmed. The photos on page B-11 show the contrasting turbid waters of the South Fork and the Soda Creek tributary, which was not influenced by the erosion event. In this series of photos, the South Fork is on the left (looking upstream), and Soda Creek is on the right.

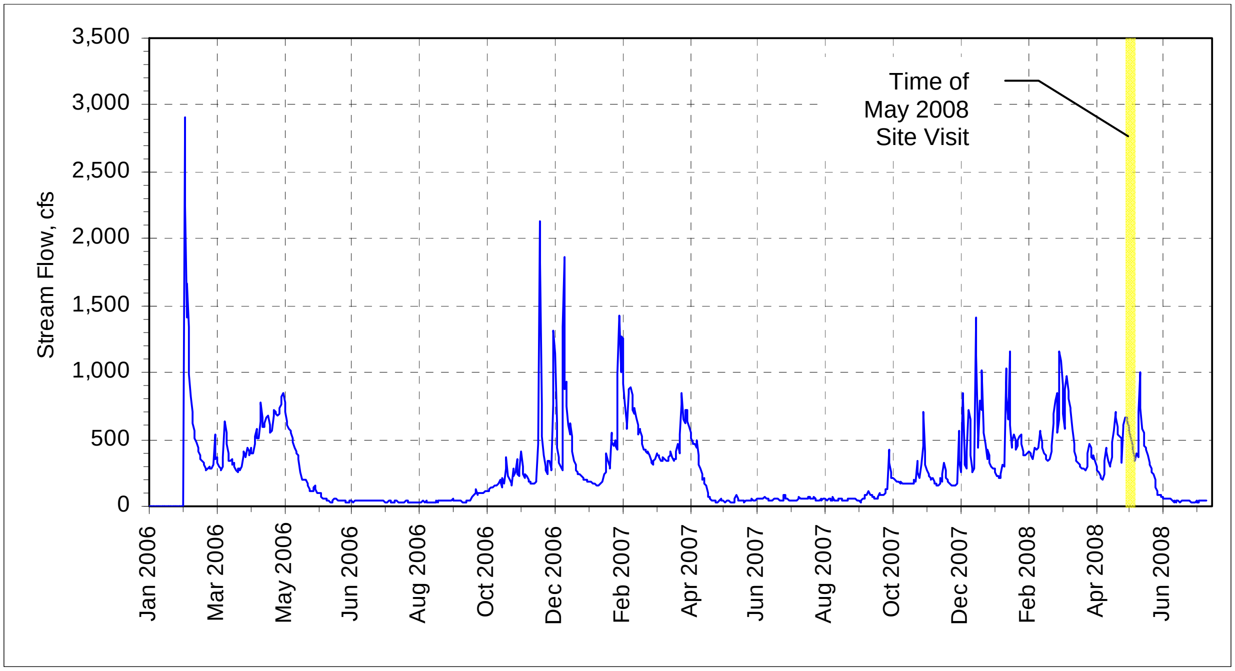

Figure 2-2
Recent Stream Flows of Little Butte Creek at Eagle Point.
(USBR, 2008)

The particularly cold spring and late snowfall was also apparent at Fish Lake where a large portion of the lake was covered with ice (Appendix B, page B-12). During the visit, the resort maintenance manager commented that they had only recently gained access to the floating boat and fishing docks because of the late-season ice.

3. Geomorphology and Groundwater Connectivity

3.1 Approach and Assumptions

The geomorphology and groundwater connectivity analysis is based primarily on available sets of aerial photographs of Little Butte Creek. Aerial photographs of the Mainstem were obtained from the US Army Corps of Engineers (Corps) Portland District in the form of digital images. The Corps photo catalogue included flight lines of the watershed from three time periods: 1939, 1957, and 2005. For this analysis, the 2005 photographic set is taken to reflect current conditions, the 1939 photo-record is referred to as the “historic” conditions, and the “natural” conditions are those that pre-date any development along the creek system—in some cases even predating the 1939 conditions. The 1957 photo-record is an intermediate snapshot that can be used to characterize the variability of changes in geomorphology over time.

Historical flight lines were available for the Mainstem and the North Fork, but only current flight lines (2005) were available for the South Fork. An unsuccessful search of various sources was conducted to obtain historical photos of the South Fork. These sources included: Jackson County Court House (Assessors and Surveyors - JCC, 2008), Southern Oregon University (SOU, 2008; SODA, 2008), the Eagle Point Historical Society and Museum (Eagle Point, 2008), the Southern Oregon Historical Society (SOHS, 2008), and Jackson County Soil and Water Conservation District (JCSWCD, 2008). No pre-dam photographs were available for Fish Lake. A summary of available photographic records is listed in Table 3-1.

Table 3-1
Summary of Available Aerial Photograph Records Used in the Analysis.

Little Butte Creek Reach	Year(s) Available
Mainstem	1939, 1957, 2005
North Fork	1939, 1957, 2005
South Fork	2005
Fish Lake	None (pre-dam)

Despite the availability of photographs of the North Fork (and the lack of those of the South Fork), analysis was carried forward on the South Fork instead of the North Fork. This was decided because the South Fork is believed to be more impacted by development (roadways, diversions, agriculture, etc.) than the North Fork. The North Fork is somewhat naturally confined by the canyon through which it flows. Roadways, for example, are prominent along the North Fork, but because of its high degree of natural confinement the North Fork is believed to be impacted less by roads and other types of development. The roads along the North Fork, while near the creek, are generally cut into the steep, adjacent hillsides outside of (and above) the naturally narrow floodplain of the creek. This is generally less true along the South Fork

The aerial photo-records are shown in series of plates in Appendix A. The plates are organized by time period, beginning with the most recent period and progressing backwards in time. This convention is followed because changes in the stream are recorded relative to the baseline condition which is the current condition (2005 photographs). For each time period, the plates are organized from upstream to downstream. For example "Plate I-2005" is the first series of photographs for 2005 beginning at the Rogue River Confluence, and Plate II-2005 is the second and downstream series of photographs, etc.

3.1.1 General Methodology

One finding of the data search was that very little groundwater well information was readily available and suitable for a groundwater connectivity analysis. A groundwater-surface water connectivity analysis typically involves monitoring of a matrix of wells located both parallel and perpendicular to the stream to capture groundwater flow paths in these two directions. This type of data was not available to the study. Consequently, geomorphic parameters as described below were used to estimate hyporheic flow exchange, which by definition is a measure of surface-groundwater connectivity that has direct influences on stream water temperatures.

The following steps describe the general process followed to estimate changes in hyporheic flows.

Step 1 – Geo-reference Aerial Photographs

Images from each period were brought into a GIS database and georeferenced. Georeferencing the series of photographs for each year-period was necessary to establish common locations of comparison. Meander migrations and other changes in channel position can be significant, making comparisons over long periods of time difficult.

Along with the aerial photo-records in Appendix A, the channel centerline positions for each year-period are shown. The 2005 channel centerline is shown as a blue line, the 1957 channel centerline is shown as a red line, and the 1939 channel centerline is shown in green.

Step 2 –Characterize Geomorphology

For a particular photographic year-period, geomorphic parameters such as floodplain connectivity (entrenchment or ratio of floodplain-to-bankfull widths), channel complexity, presence of gravel bars, sinuosity, and riparian vegetation and condition were qualitatively noted. These parameters are typically apparent in aerial photographs and are commonly cited in the hyporheic literature (see Section 2.4). A stream network overlay provided by the ODEQ modeling team was used to establish common reference locations along the creek at which observations were made. A general characterization was made at intervals of approximately 200 meters on the Mainstem and larger intervals on the South Fork according to where channel changes were observed.

Step 3–Establish Correlations Between Geomorphology and Hyporheic Flow

As described in Section 2.4, a review of hyporheic flow studies was conducted. This review was done in part to correlate stream features such as those observed in ***Step 2*** to levels of hyporheic exchange and associated changes in stream water temperature. According to the literature, a stream section observed to have relatively high sinuosity, notable gravel bars, good channel complexity and connection with its floodplain, and/or similar features was estimated to have high hyporheic flow exchange. Similarly, a channel section that was straightened, confined, and/or incised was judged to have a low level of hyporheic flow.

From literature as well as a general assessment of the creek and overall watershed, it was estimated that hyporheic flows in the Little Butte Creek system could likely vary between 2 and 12 percent. This range served as relative "bookends" for estimates over the various year-periods and over the various reaches of the creek. Review of the literature also shows that hyporheic flows have only recently been studied in detail, likely because they are difficult to measure directly. Correlating hyporheic flow to individual and specific stream features is also difficult because of the myriad variations in stream conditions, even within the same watershed. The "bookend" approach used in this study is likely appropriate given these difficulties as well as other uncertainties and simplifications made in this analysis, including those inherent in estimating the natural, pre-development conditions of the creek system.

Step 4 – Map Changes in Hyporheic Flow

Based on the observations from ***Step 2*** and the trends between geomorphology and hyporheic flows noted from ***Step 3***, hyporheic flows (as a percent of total stream flow) were mapped at each observation location. Hyporheic estimates were made for each year-period, and changes over time were simply calculated as differences between these values.

Step 5 – Confirm Hyporheic Estimates using Temperature Model

The last step involved verifying the hyporheic estimates using results from the temperature model. Changes in simulated stream temperatures (due to the estimated hyporheic flows) were compared to temperature changes reported in the literature. Hypothetically, if the range of hyporheic estimates demonstrated significant error, the model would indicate this through an unreasonable temperature result. Deterministic, process-based computer models are often used to check hypotheses, and they are often a good means of verifying estimated inputs because errors in inputs commonly show in simulation results.

3.1.2 South Fork Little Butte Creek

Only current aerial photographs were available on the South Fork. Consequently estimates of changes in hyporheic flows within this reach were based on a similar location(s), i.e. a "reference location," on the Mainstem. For example if a roadway had been constructed in the floodplain of the South Fork, a location on the Mainstem where road construction had apparently encroached into the floodplain was found. The level of estimated change in hyporheic flow for the Mainstem was used to judge the estimated impacts on the South Fork. In determining appropriate reference locations, effort was made to find not only comparable types and magnitudes of channel impacts, but also similar stream reach types.

3.1.3 Natural Conditions

The oldest available photo record was 1939 (also referred to as “historic conditions”), at which time some development including roads and farms pre-existed in parts of the basin. Along the creek where development pre-dated 1939 such as in Eagle Point, another step was needed to “back-out” the “natural conditions.” Similar to estimating conditions along the South Fork described in Section 3.1.2, this was done by using reference locations and nearby undeveloped reaches. An incremental change was applied to the historic condition to back-out the natural condition. The overall result was a total change from the current conditions to the natural, pre-development conditions throughout the Mainstem and South Fork reaches.

A common example of early development is road construction because several roadways adjacent to the creek are visible in the 1939 photo sequence, most prominently near Eagle Point. The impacts of confinement, channelization, loss of channel complexity and floodplain connection, etc., on these sections of the creek were estimated by observing other sections of the creek where development had occurred after 1939. The level of channel changes at these locations could be seen by comparing the 1939 and either 1957 or 2005 photographs. These ‘observable’ changes were used to judge those that had taken place before 1939. Thus reference locations were used to estimate the “natural conditions” of the stream.

3.2 Results

Results of the geomorphology and groundwater connectivity assessment are listed in Table 3-2 (Mainstem) and Table 3-3 (South Fork). These results are also shown graphically in Figure 3-1 (Mainstem including the South Fork). The tables list the stream reach beginning at the Little Butte Creek mouth (confluence with the Rogue River). The extents of the South Fork include over 21 km, up to approximately the confluence with Soda Springs near Camp Latagawa. The point ID number refers to ODEQ temperature model segments and is included for reference. Bankfull widths were calculated for possible use by the ODEQ modeling team in case they were needed and are shown for reference. Bankfull values for the current conditions (2005) were calculated by ODEQ and are also shown in the tables.

The percent hyporheic flow exchange values are listed in the columns to the right. Hyporheic exchange values for the natural conditions are shown in the right-most column. The natural conditions are estimated to be representative of pre-development conditions, and these values were provided as input into the temperature model. Blank table values indicate that data (aerial photo coverage) is unavailable for a particular location and time period.

Figure 3-1 displays the longitudinal variation of ***changes in hyporheic exchange*** for the various periods of comparison. This figure corresponds to but is different from Table 3-2 and Table 3-3 in that it shows changes in hyporheic exchange, rather than the hyporheic flow percents at a particular snapshot in time as do the tables. Changes in hyporheic flow can be either positive (increase in historical flow exchanges relative to current conditions) or negative (decrease in flow exchanges relative to current conditions). The red line in the figure indicates the relatively recent comparison to 1957 conditions; the darker blue line represents changes relative to 1939; and the green line indicates the change relative to natural conditions.

Results show that on average the hyporheic exchange of the natural conditions (pre-development) ranges from -2% to 10% higher than current conditions (see Table 3-4 or Figure 3-1). The negative value in the range indicates a particular location where flow exchange was estimated to be greater today than what occurred naturally. This is a plausible result and could be caused for example by a relatively intact channel-floodplain connection that exists today, or by a particularly incised or eroded reach of stream that was visible in the historic aerial photos.

Figure 3-1 also shows the total percent hyporheic exchange of the natural conditions (light blue line) for reference. These values were provided as input to the temperature model to simulate the Natural Thermal Potential (NTP) scenario. It is important to note that this curve does not represent the change in flows relative to current conditions as do the other curves; rather, it represents the total magnitude of flows.

In general the curves in the figure appear segmented instead of smooth. This is a result of the 200 m discretization used in estimating geomorphology parameters and hyporheic flow values (as well as the exaggerated X- and Y-axes that are scaled for clarity). In reality these values transition smoothly along the stream profile.

On average the hyporheic exchange of the natural conditions was 5.7% greater than it is today. The rate of change was not constant over time however. For example, the increase in exchange measured in 1957 was on average 1.8%, while the increase in flows earlier in 1939 was only 1.4%. Thus the channel experienced both increases and decreases in hyporheic exchange. It is not uncommon for dynamic stream channels to experiences both spatial and temporal changes in its sinuosity, floodplain connection, and other geomorphological parameters. This appears to be one such instance. The specific reasons for these particular variations are not known at this time; they could be a result of natural causes such as erosive high flow events, anthropogenic causes such as roadway construction, or some combination thereof.

Table 3-2
Estimated Hyporheic Flow Exchanges Over time (Mainstem).

		Bankfull Width (Feet)			Hyporheic Exchange, %			
Point ID	Dist. From Mouth (m)	2005	1957	1939	2005	1957	1939 (Historic Conds.)	Natural Conds.
4	200	36.4			2			12
8	400	53.0			2			12
12	600	22.0			2			12
16	800	17.9			2			12
20	1000	25.9			2			12
24	1200	13.4			2			12
28	1400	28.2			2			12
32	1600	14.4			2			12
36	1800	19.0			2			12
40	2000	21.1			2			12
44	2200	15.3			2			12
48	2400	17.2			2			12

Point ID	Dist. From Mouth (m)	Bankfull Width (Feet) 2005	1957	1939	Hyporheic Exchange, % 2005	1957	1939 (Historic Conds.)	Natural Conds.
52	2600	16.7			2			12
56	2800	20.3			2			12
60	3000	19.5			2			12
64	3200	16.3			2			12
68	3400	21.3			2			12
73	3650	12.4	34.3		10	5		12
77	3850	29.4	77.3		10	10		12
81	4050	17.7	34.5		10	10		12
85	4250	22.2	32.6		5	10		12
89	4450	31.3	62		5	10		12
92	4600	17.2	9.4	11.5	5	10	10	12
96	4800	19.5	42	16.8	10	10	10	12
100	5000	14.2	40.8	20	10	10	10	12
104	5200	18.5	58.1	19.9	10	10	10	12
108	5400	13.3	34	12.2	5	10	10	12
112	5600	23.0	27.9	20.6	5	5	10	12
116	5800	12.5	12.7	11	2	5	5	12
120	6000	12.2	7.7	6.7	2	5	5	12
124	6200	11.8	11.2	10.7	2	10	5	12
128	6400	14.9	21.5	12.5	5	10	10	12
132	6600	13.4	12.7	15.4	2	10	5	8
136	6800	11.6	14.7	14.9	2	5	2	8
140	7000	9.7	16.8	11.8	2	5	2	8
144	7200	11.2	13.9	14.3	2	5	2	8
148	7400	10.7	7.5	11.1	2	5	2	8
152	7600	9.7	13.1	15	2	2	2	8
156	7800	12.3	14	18.2	2	2	2	8
160	8000	14.7	16.8	15.6	2	2	2	8
164	8200	10.1	15.7	7.7	2	2	2	8
168	8400	8.8	16.5	10.3	2	5	5	8
172	8600	20.2	26.9	11.8	2	5	10	8
176	8800	36.2	4.9	16	10	10	5	8
180	9000	12.6	25.5	23.4	5	5	5	8
184	9200	14.9	24	21.5	5	10	10	8
188	9400	12.3	23.5	21.3	2	10	10	10
192	9600	11.1	19.2	16.7	2	5	5	10
196	9800	14.0	20.9	16.8	5	10	10	10
200	10000	15.0	14.8	16.3	2	5	5	10
204	10200	12.6	34.7	25.2	10	10	5	10
208	10400	13.1	8.2	11	2	2	2	10
212	10600	18.3	19.9	18.4	5	2	5	10
216	10800	8.2	14.5	12.2	2	5	2	10
220	11000	9.0	11.8	7.4	2	5	5	10
224	11200	10.0	13.5	10.1	2	5	2	10
228	11400	7.4	15.3	9.8	5	5	5	10
232	11600	9.0	19.4	13.6	5	5	5	10

Point ID	Dist. From Mouth (m)	Bankfull Width (Feet) 2005	1957	1939	Hyporheic Exchange, % 2005	1957	1939 (Historic Conds.)	Natural Conds.
236	11800	8.5	7	8.4	2	5	5	10
240	12000	7.9	13.6	13.1	5	5	5	10
244	12200	8.8	23.6	11.8	5	5	5	10
248	12400	9.3	17	10.1	5	5	5	10
252	12600	8.4	18.9	14.2	2	5	5	10
256	12800	10.6	19.9	13.5	2	5	5	10
260	13000	7.3	16.8	8.7	2	5	5	10
264	13200	6.2	23.3	18.3	5	5	5	10
268	13400	6.5	22.3	23.8	5	5	5	10
272	13600	17.3	23.4	31.5	2	5	5	10
276	13800	13.8	19.5	19.5	2	5	5	10
280	14000	13.2	18.5	23.3	2	5	5	10
284	14200	9.9	28.5	38.5	2	10	5	10
288	14400	10.7	23.1	22	5	10	10	10
292	14600	9.2	13.5	11.7	2	5	2	10
296	14800	7.5	9.3	6.8	5	5	5	10
300	15000	10.0	14.3	9.8	5	5	5	10
304	15200	10.0	17.3	14.6	2	10	2	10
308	15400	12.6	19.7	11	5	5	5	10
312	15600	10.8	13.5	7.5	5	5	5	10
316	15800	15.6	8.6	8.2	10	5	10	10
320	16000	7.7	23.1	11.5	5	10	5	10
324	16200	8.1	11.3	17.9	5	5	5	10
328	16400	12.5	21.3	14.8	5	10	5	10
332	16600	11.7	13.8	9.6	5	5	10	10
336	16800	9.6	8.3	15.7	5	5	5	10
340	17000	9.7	13.1	10.5	5	10	10	10
344	17200	5.5	14.2	8.5	10	10	5	10
348	17400	7.2	32.7	29.1	10	10	10	10
352	17600	7.4	16.1	13.7	5	10	5	10
356	17800	8.5	18.3	12.7	5	5	5	10
360	18000	8.4	10.5	13	2	5	5	10
364	18200	11.0	17.5	16.8	2	10	2	10
368	18400	9.9	18.8	17.6	5	10	5	10
372	18600	7.1	15.2	12.4	5	10	10	10
376	18800	9.1	19.6	9.5	2	5	5	10
380	19000	6.4	15.3	11.7	2	5	2	10
384	19200	6.2	12.2	9.2	2	2	2	10
388	19400	9.9	16.3	7.2	2	5	2	10
392	19600	13.0	8.4	10.5	5	5	5	10
396	19800	21.6	9.4	12.4	5	10	10	10
400	20000	7.1	7.2	10.5	5	2	2	10
404	20200	7.3	7.9	10.1	2	5	2	10
408	20400	10.5	6.5	6.4	5	5	5	10
412	20600	7.5	10.3	9	5	5	10	10
416	20800	10.2	23.1	23.7	5	5	5	10

		Bankfull Width (Feet)			Hyporheic Exchange, %			
Point ID	Dist. From Mouth (m)	2005	1957	1939	2005	1957	1939 (Historic Conds.)	Natural Conds.
420	21000	7.4	12.8	10.3	2	2	5	10
424	21200	11.6	7.8	7	5	5	5	10
428	21400	12.5	16.4	16.3	5	10	10	10
432	21600	15.5	16.1	15.9	2	5	5	10
436	21800	13.7	19.8	14.5	2	5	5	10
440	22000	24.8	16.2	10.5	10	10	10	10
444	22200	10.8	22.2	16.5	5	10	10	10
448	22400	27.5	41.6	36.8	10	10	10	10
452	22600	17.7	32.4	15.1	10	10	10	10
456	22800	15.6	22.7	14.5	10	10	5	10
460	23000	17.6	29.5	18.8	5	10	5	10
464	23200	11.5	21		5	5		8
468	23400	16.9	20.5		5	5		8
472	23600	8.2	5.9		5	5		8
476	23800	18.9	7.5		2	5		8
480	24000	9.6	4.5		5	5		8
484	24200	12.3	13.9		5	10		8
488	24400	10.4	8.8		2	2		8
492	24600	9.3	9.5		2	5		8
496	24800	11.9	7.9		2	2		8
500	25000	8.0	13.5		2	5		8
504	25200	7.3	8		2	5		8
508	25400	9.0	8.5		5	5		8
512	25600	13.4	10.4		5	5		8
516	25800	8.5	17.5		5	5		8
520	26000	14.4	11.8		5	2		8
524	26200	13.5	6.8		2	2		8
528	26400	8.7	8.4		2	2		8
532	26600	15.0	6.5		5	5		8
536	26800	18.0	6.8		5	5		8
540	27000	11.3	8.7		5	10		8
544	27200	12.4	20.3		5	2		8
548	27400	12.3	17.3		5	5		8
552	27600	20.5	31.9		10	10		8
556	27800	17.5	22.2		10	10		8

Note: Blank values indicate no photo records were available.

Table 3-3
Estimated Hyporheic Flow Exchange Over Time (South Fork).

Point ID	Dist. From Mouth (m)	Bankfull Width (Range in Feet)	Hyporheic Flow % (Natural Conds.)
0-7	350	12.1 - 9.7	8
8-32	1600	16.1 - 14.6	12
33-53	2650	13.4 - 13.6	10
54-61	3050	20.4 - 14.0	8
62-124	6200	12.3 - 17.3	10
125-146	7300	15.6 - 17.8	8
147-174	8700	17.1 - 12.6	8
175-192	9600	8.3 - 15.5	10
193-222	11100	18.4 - 17.2	8
223-248	12400	15.2 - 17.5	8
249-276	13800	15.3 - 18.2	10
277-312	15600	8.8 - 13.7	8
313-351	17550	18.5 - 18.1	8
352-380	19000	16.9 - 10.6	10
381-418	20900	11.5 - 27.5	10
419-427	21350	14.9 - 8.6	8

Note: The range in bankfull widths correspond to the point IDs in column 1 (beginning and ending of each segment).

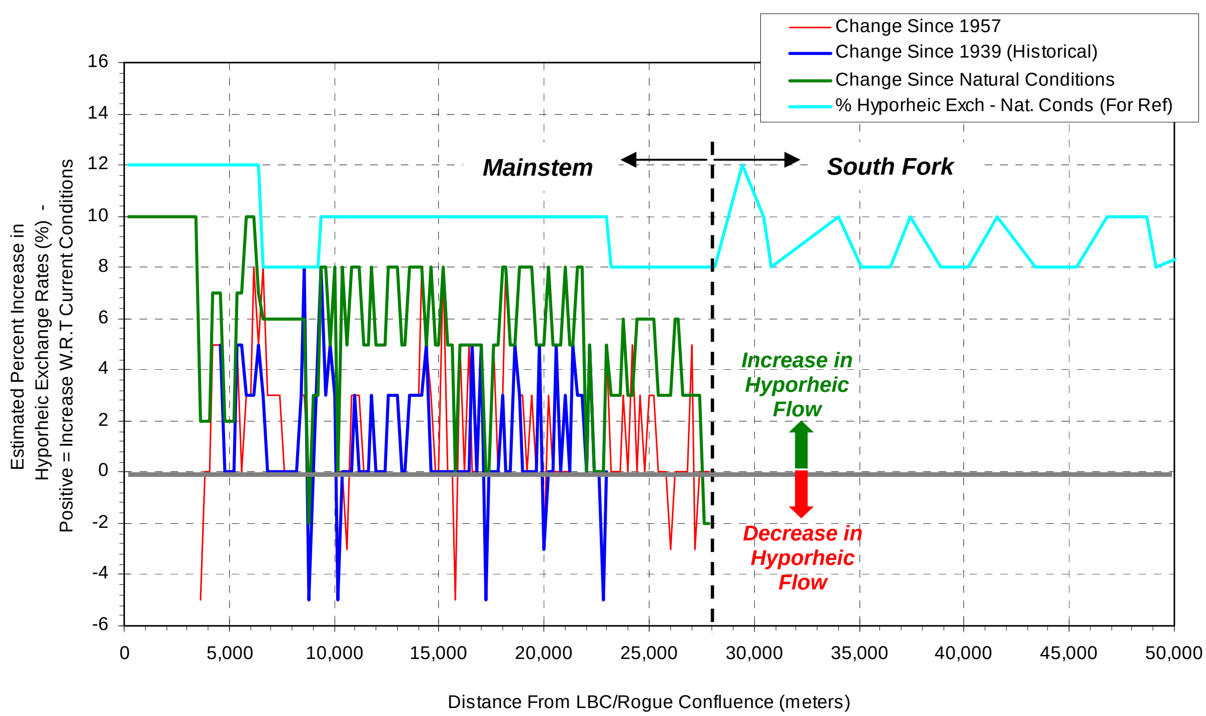

Figure 3-1
Estimated Percent Changes in Hyporheic Flow Exchange in Little Butte Creek (Mainstem and South Fork).

Table 3-4
Summary Statistics – Changes in Hyporheic Flow Over Time Relative to 2005.

Parameter	1957	1939 (Historic Conds.)	Natural Conds.
Average Change (%)	1.8	1.4	5.7
Std. Dev. Of Change (%)	2.7	2.6	2.9
Min Change (%)	-5	-5	-2
Max Change (%)	8	8	10

Hyporheic flow exchange is difficult to characterize even with a detailed monitoring program. Actual hyporheic flow exchanges vary spatially and temporally based on flow regime and variations in stream bank and substrate conditions, among other factors. Typically field measurements of flow, water temperature, dye tracers, or other parameters are used to calculate or verify hyporheic flow estimates from aerial photographs or similar analyses. Thus the estimates made from this study, although useful, should be regarded as preliminary. Estimates were not verified in a field study, so the range of uncertainty in the measurements could be on the order of 5 to 10% or higher. At the same time, because the methods and data used in this approach were consistent, the results should at a minimum reflect relative differences in hyporheic flow exchange over the study extents.

In addition and as part of ***Step 5*** of the approach described in Section 3.1.1, hyporheic estimates were evaluated in the ODEQ temperature model and found to have reasonable and expected impacts on stream temperatures. Impacts to stream temperatures are shown in Figure 3-2. The plot shows stream temperatures as a function of river kilometer, beginning at kilometer zero at the confluence with the Rogue River. The scenarios of interest are the current conditions, “CCC,” shown in red, and the hyporheic scenario, “Hypo,” shown in lavender. The hyporheic scenario is based on the current conditions and also includes the hyporheic flow estimates representing the natural conditions (light blue line in Figure 3-1). Differences between these lines indicate the impacts of incorporating hyporheic flow into the model. On average the difference in stream temperatures is 1.0 degrees Celsius, and the maximum difference is approximately 3.5 degrees Celsius. These impacts on stream temperatures are well within the ranges cited in literature (see Section 2.4).

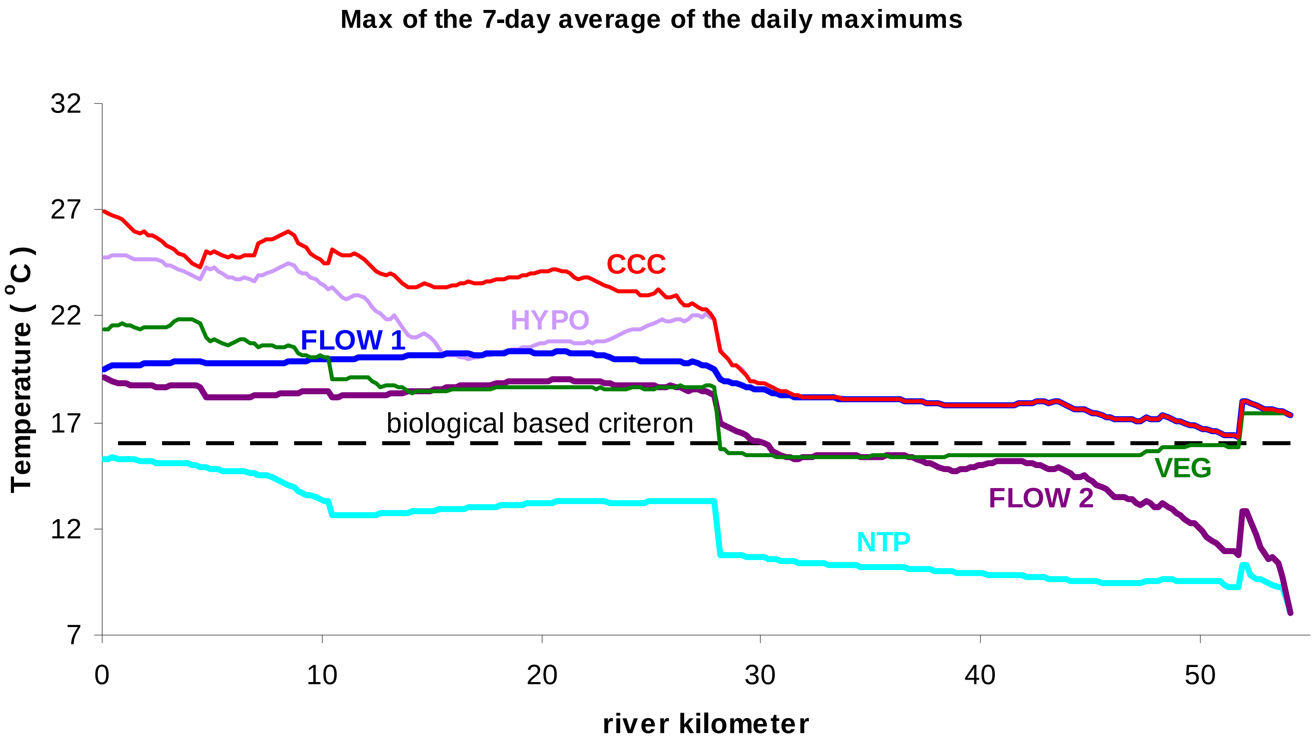

Figure 3-2
Comparison of Results for Various Temperature Scenario Simulations; Note Comparison of the Current Conditions ("CCC") Shown as a Red Line Versus the Hyporheic Conditions ("Hypo") Shown in Lavender. Other ODEQ Modeling Scenarios are Shown for Reference Only and Do Not Pertain Directly to the Hyporheic Flow Scenario.

4. Fish Lake Dam and Reservoir

4.1 Background & History

Fish Lake Dam and reservoir was constructed by the Fish Lake Water Company in 1908. It is currently owned and operated by the Medford Irrigation District (MID) (USBR, 2008). The dam and reservoir was intended primarily to supply irrigation water to farmers and ranchers in the valleys below the reservoir. The earth-fill dam and reservoir is located high in the watershed along the North Fork at the headwaters of the drainage near the Cascade Divide. The reservoir is bounded by the slopes of Mt. McLaughlin to the north and Brown Mountain located to the southeast.

The crest elevation of the reservoir is approximately 4,832 feet National Geodetic Vertical Datum (NGVD29), and the full pool capacity is approximately 7,836 acre-feet. The structural height of the dam is 49 feet, while the hydraulic height (depth of reservoir outlet below the top of the storage pool) is 28 feet (USBR, 2008). The lake surface area averages approximately 480 acres and an average depth of 18 feet.

The reservoir has a relatively small tributary area with no major natural surface tributaries entering the lake. Other than local rainfall-runoff, snow melt, and spring inflows which are not well quantified, the main inflow to the reservoir is the Cascade Canal that conveys water from Four-Mile Reservoir which is located outside of the watershed boundary, northeast of Fish Lake (just off the map in Figure 1-1) . The canal terminates underground before it reaches Fish Lake and discharges directly into the fractured, volcanic rock substrate. Through tracking reservoir elevations and outflows, it has been determined that the Cascade Canal inflows reach Fish Lake relatively quickly, at an estimated lag time of approximately four days (Busch, 2008).

Before the reservoir was constructed in 1908, this region of North Fork was by best accounts a groundwater-supplied high alpine marsh that likely remained wet year-round (Bradford, 2008; Busch, 2008; USFS, 1906a; USFS, 1906b). Although groundwater conductivity through the fractured hard-rock soils in this part of the watershed is relatively high, the total groundwater storage pool is believed to be substantial enough to span water years. Because of this, the high alpine marsh likely received spring inflows through the summer except after multiple, successive dry years.

The main objective of analyzing Fish Lake is to characterize the potential impacts of the reservoir on water temperatures in the North Fork relative to natural conditions (pre-dam). In practical terms, this means providing justification for or against the temperature boundary conditions being used in the Little Butte Creek Temperature model.

4.2 Review of Archives

Detailed historical information and data, specifically regarding Fish Lake and Marsh water temperatures, are not readily available and may not exist. Several sources of historical documents and maps were queried including the Southern Oregon Historical Society (Enright, 2008), the Jackson County GIS Map Archive (Jackson, 2008), and the Southern Oregon Digital Archives at Southern Oregon University (SODA, 2008). Some pertinent information was found, but the majority of related documents are only peripherally relevant (USFS, 1952).

Two collections of documents found within the Southern Oregon Digital Archives included survey plans and characterizations of the existing creek (and lake) by the Fish Lake Water Company and US Forest Service dated 1904 (USFS, 1906a; USFS, 1906b). The survey plan blueprint for the reservoir is shown in Figure 4-1, and a map describing land cover acreages is shown in Figure 4-2. This blueprint details the level survey route around what appears to be the current reservoir footprint, along with a section through the dam. The proposed reservoir section shows a maximum reservoir depth of 30 feet. The plan also shows the alignment and other details of the North Fork channel and marsh before the dam was built.

Figure 4-1 shows that the historic creek drains a natural, flat, and elongated basin. The creek appears wide and shallow, and was lined on either side by a marsh fringe. An excerpt from one collection of records describes the general site conditions, topology, and soils before the dam was constructed:

> *The topography of the proposed reservoir site as well as the surrounding country for a short distance, is comparatively level with the exception of an occasional Butte, and Mt. Pitt which is about five miles to the North, from the summit of the Cascade Range to Fish Lake a distance of about 2 ½ miles is a gentle slope to the west, there is also a gentle slope from the North and South to the Lake.*
>
> *The source of the Lake is from large springs which come out of the lava at the east end, from the east of the Lake which forms the widest part, the lake as well as the valley gradually narrows to the outlet. The surface of the reservoir site is practically smooth, with the exception of some lava on the east end, and a ridge of lava rock which forms the left bank of the outlet from the dam site easterly probably ½ mile, this ridge of lava then leaves the reservoir site and extends to the summit of the mountains to the east, but bearing around the reservoir are to the south then extending east.*
>
> *The soil is a deep rich alluvial composition from the margin of the lake to the timbercovering the Marsh and the Lodge Pole pine (timberstrip) on the south side, this land is of first quality, from this Marsh land extending back the exterior boundary line of the reservoir site, the land is of second and third quality being more or less rock and is heavily timbered…* (USFS, 1906b).

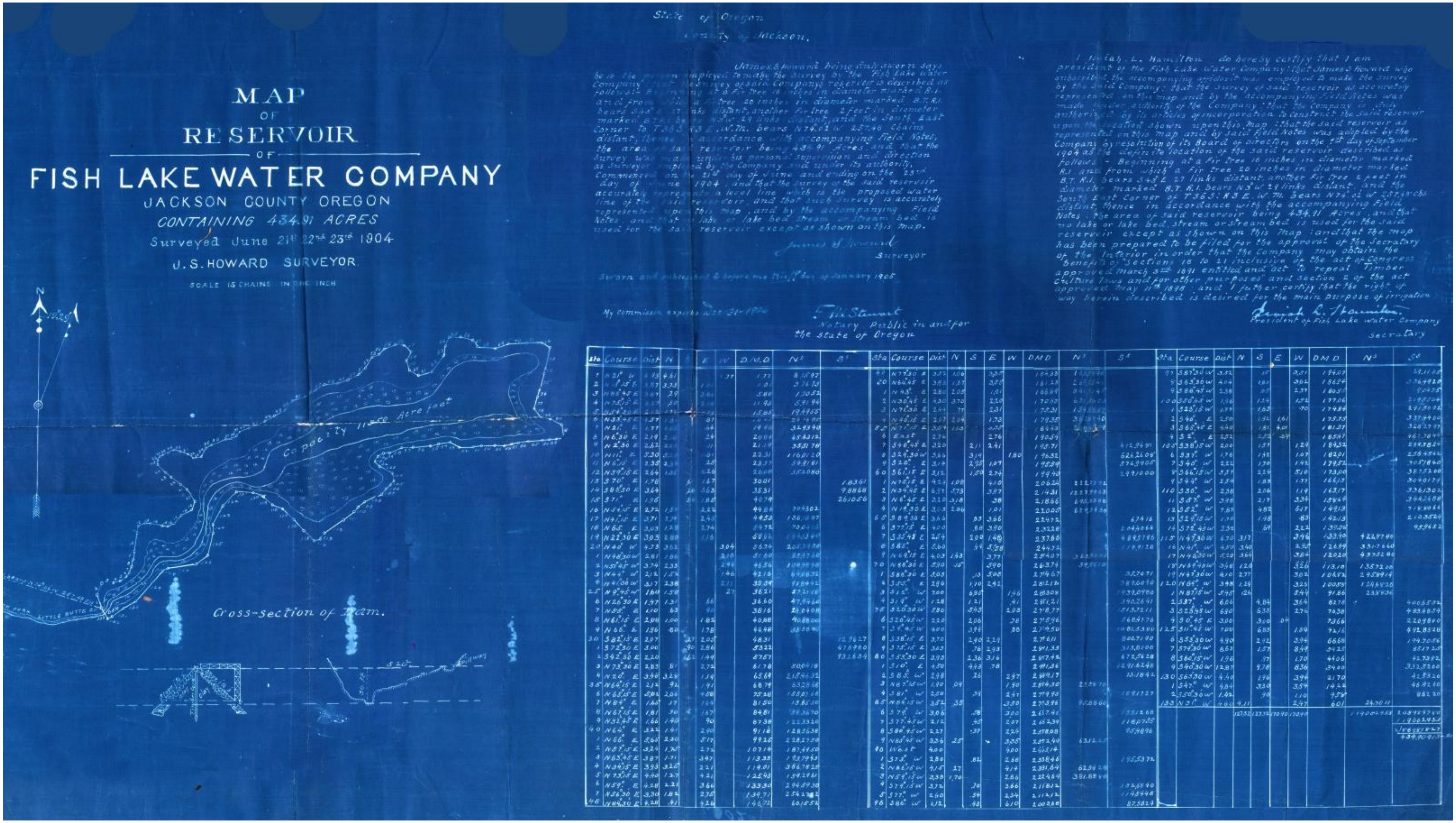

Figure 4-1
Survey Plans of the North Fork Little Butte Creek for Proposed Fish Lake Reservoir in 1904 (USFS, 1906a).

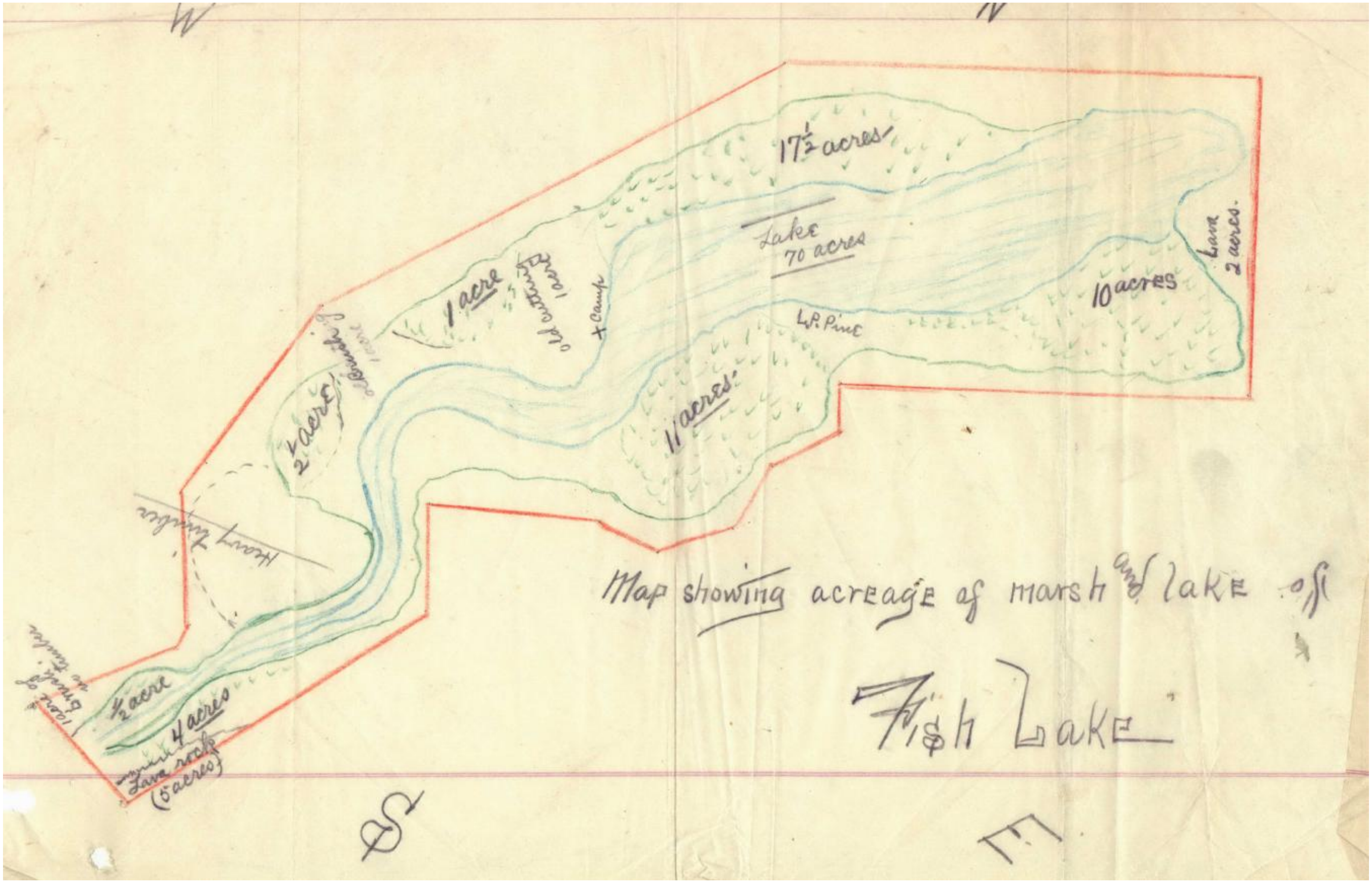

Figure 4-2
Schematic Showing Acreages of Fish Lake Marsh and Lake Regions circa 1904 (USFS 1906b).

4.3 Analysis

It is not possible to characterize specific details of the hydrology and temperature regime of the natural conditions of Fish Lake and Marsh pre-dam. Instead a reference location was used as a surrogate for the natural pre-dam conditions. Using a reference location is commonly done when little or no data exists for a site. Reference locations are typically similar in appearance, function, or other quality to the actual location.

In this case, the most appropriate reference location for the North Fork is likely the South Fork. It is believed that South Fork is primarily spring-fed during summer months, and the current conditions in this reach may be comparable to the historic conditions in the North Fork (Busch, 2008). Moreover, there is a gage in the South Fork at Gilkey, where the creek is believed to receive significant spring inflows. The Gilkey station (USBR Hydromet GILO) is located approximately 9 to 10 rivermiles from the South Fork – North Fork confluence (see Figure 4-3).

Temperature data on the South Fork at Gilkey were compared to temperatures of releases from Fish Lake (USBR station FSH). This comparison may indicate differences in natural spring-fed temperatures versus those representative of current conditions. South Fork and Fish Lake release temperatures were compared during August to capture dry season extreme temperatures for all available years, 2003 to 2007 – 5 years total.

Plots of average daily maximum, average and minimum water temperatures are shown in Figure 4-4, Figure 4-5, and Figure 4-6, respectively. Flow rates for these locations are shown in Figure 4-7. Statistical comparisons of these parameters are shown in Table 4-1. This table compiles the average and standard deviation of only the August water temperatures and flow records in common so that summer trends can be isolated. Thus these values represent the average August daily minimum, average, and maximum temperatures.

The most striking result of the comparison of temperatures is that the South Fork exhibits a larger diurnal variation than that of the North Fork. The average daily minimum and maximum temperatures of the South Fork are 56.6 and 68.8 degrees Fahrenheit (F.) – a range of 12.2 degrees F. as shown in Table 4-1. Corresponding temperatures of the North Fork are 62.0 and 64.7 degrees F. (range of only 2.7 degrees F.). This is likely due to the fact that the Fish Lake reservoir discharge outlet is near the bottom, and thus withdrawals are made from the coldest pool of water through the summer. Although the extent of thermal stratification in Fish Lake is not known, the outlet temperatures to North Fork are likely thermally buffered by the epilimnion (upper layers of water) of the reservoir, as is typical in reservoirs that become stratified during the summer in warm, semi-arid climates.

Another contributing factor to the larger diurnal fluctuation in the South Fork could be its relatively small flow. During August the average flow in the South Fork is approximately 22 cfs versus approximately 70 cfs in the North Fork. The spring-fed inflows in the South Fork likely experience some degree of atmospheric heat exchange by the time they reach Gilkey.

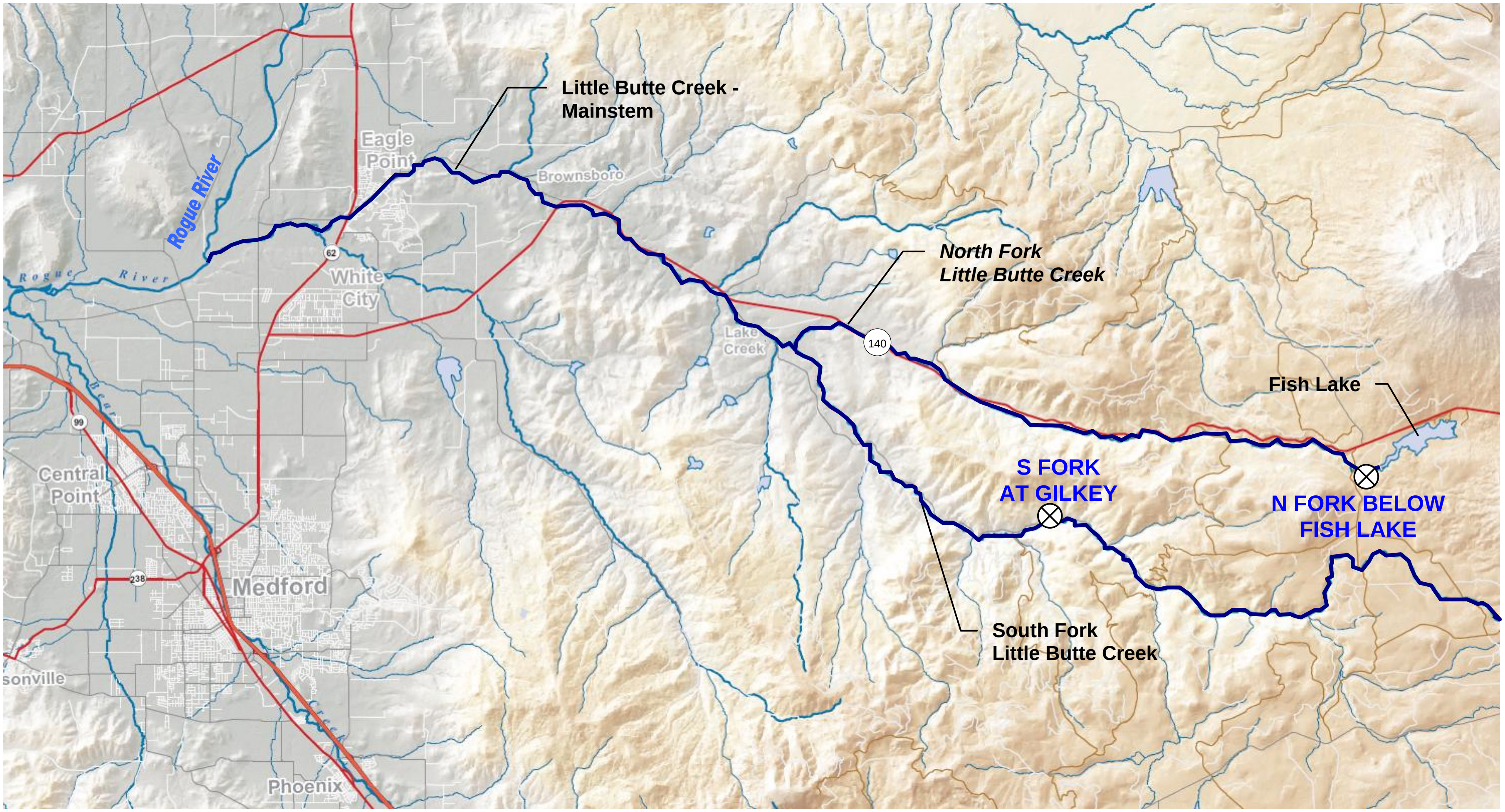

Figure 4-3
Observed Data Station Located at (1) Below Fish Lake and (2) the South Fork Little Butte Creek at Gilkey.

Though the South Fork experiences a greater daily variation, its average August temperature is not significantly different than that of the North Fork. The South Fork average is 61.6 degrees F., versus 63.2 degrees F. of the North Fork—a difference of 1.6 degrees F. If recent South Fork temperature data are representative of historical or natural spring water inflow temperatures (in the North Fork), on average Fish Lake does not have either a significant warming (or cooling) influence on temperatures in the North Fork during summer extreme temperature season. The summer time average difference of 1.6 degrees F. is within the range of uncertainty and assumptions made in this reference temperature condition comparison.

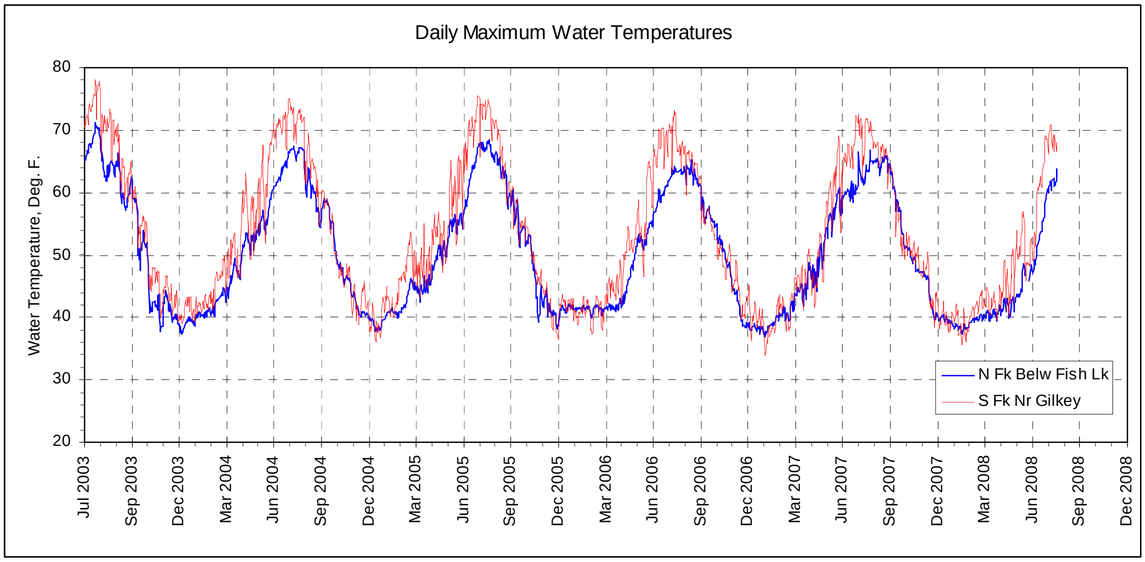

Figure 4-4
North Fork and South Fork Daily Maximum Water Temperatures.

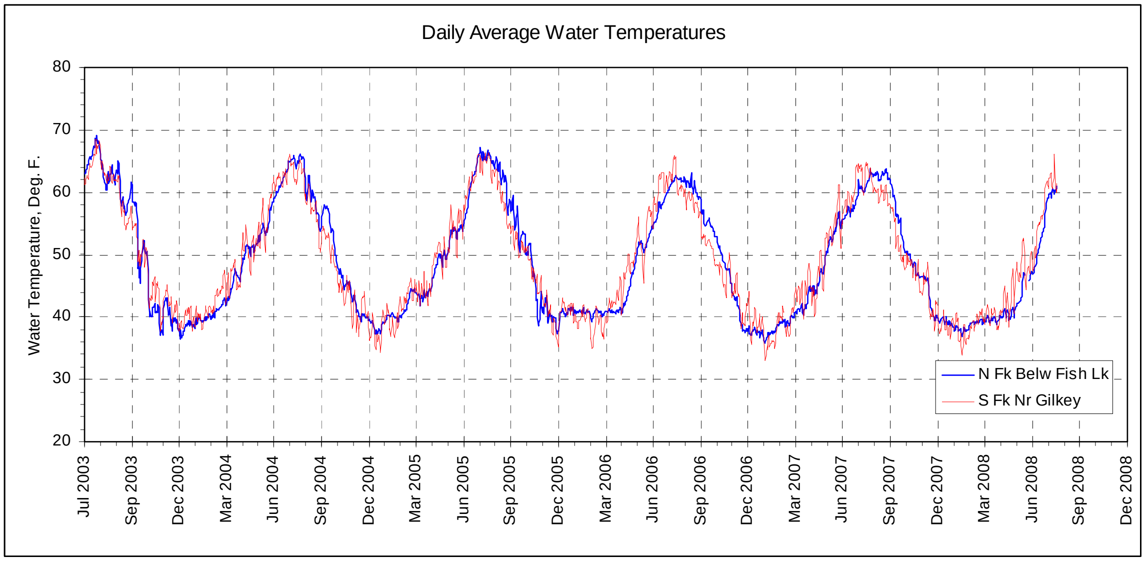

Figure 4-5
North Fork and South Fork Daily Average Water Temperatures.

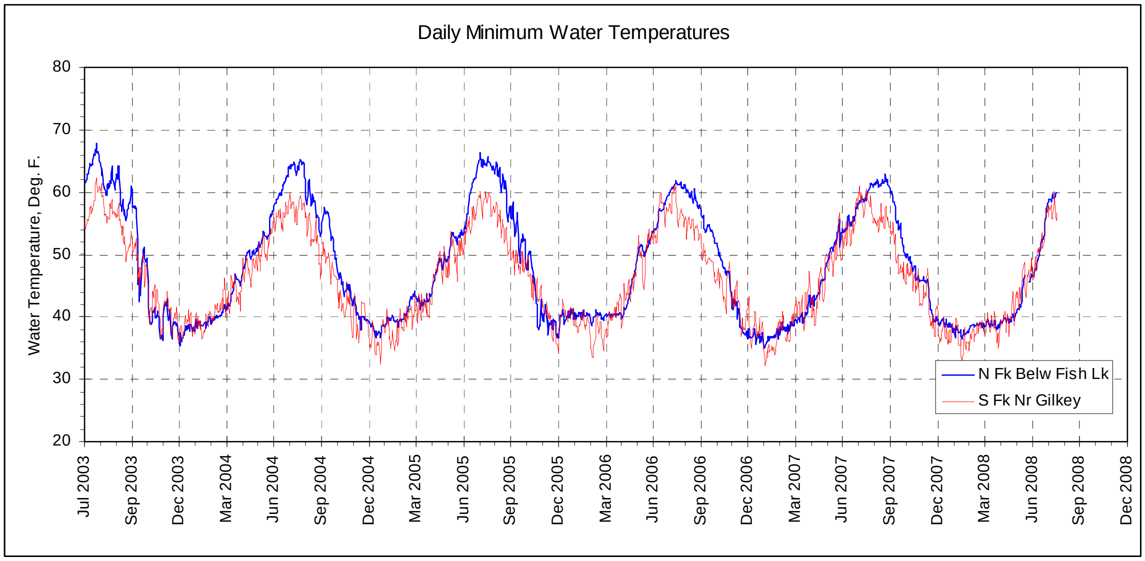

Figure 4-6
North Fork and South Fork Daily Minimum Water Temperatures.

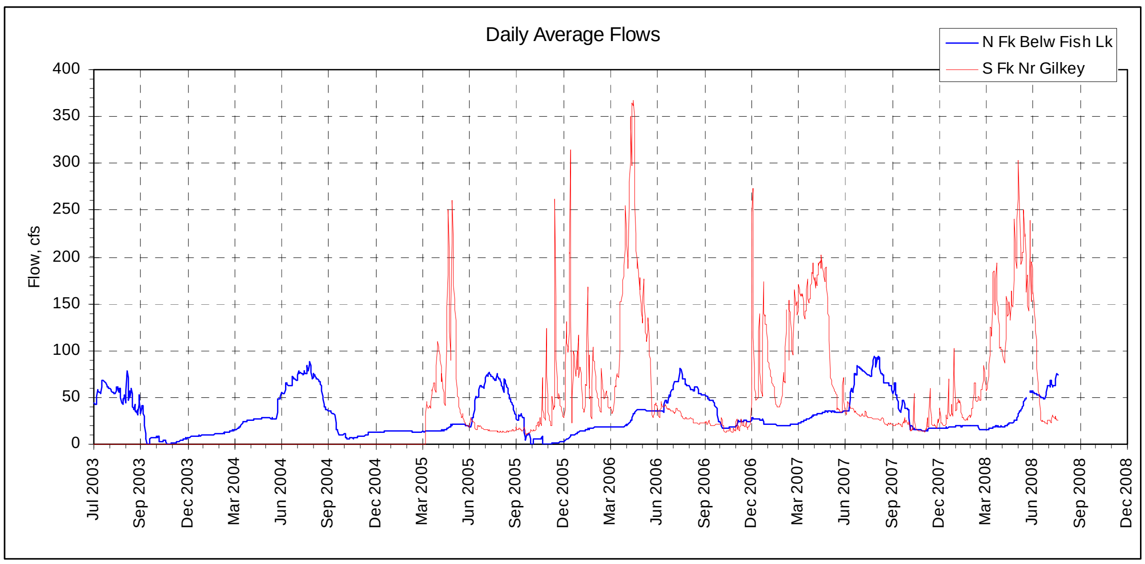

Figure 4-7
North Fork and South Fork Daily Flows.

Table 4-1
Statistical Comparison of North Fork and South Fork Flow and Temperature Data.

	North Fork				South Fork			
August Statistics:	**Flow, cfs**	**Min. Daily Temp., Deg. F.**	**Ave. Daily Temp., Deg. F.**	**Max. Daily Temp., Deg. F.**	**Flow, cfs**	**Min. Daily Temp., Deg. F.**	**Ave. Daily Temp., Deg. F.**	**Max. Daily Temp., Deg. F.**
Average	69.9	62.0	63.2	64.7	21.7	56.5	61.6	68.8
Std. Dev.	10.3	1.8	1.7	1.7	6.2	1.7	2.1	3.1
Count	93	155	155	155	93	155	155	155
Period of Record	*2003-2007	2003-2007	2003-2007	2003-2007	2005-2007	2003-2007	2003-2007	2003-2007

* Only 2005 to 2007 August flow data for the North Fork were analyzed so that comparisons could be made to the South Fork records.

5. Recommended Restoration Actions

This section identifies and discusses potentially beneficial stream and watershed restoration actions that could be implemented within the Little Butte Creek Watershed. These actions could have benefits that extend beyond the creek system and into the greater Rogue River system. These actions are targeted towards water quality impairments as well as species of concern to generally protect and restore the riverine ecosystem.

5.1 Conservation and Protection

Protection of existing river systems is possible where historic land use practices have preserved, through accident or plan, watershed and riparian features that reflect natural conditions and contain functioning habitats. Conservation of such areas may occur through conservation easements, strategic purchases by government agencies or non-government organizations, or by encouraging retention of large private landholdings in an undeveloped state. This approach may have merit, although much of the Little Butte Creek system even in the upper reaches has already been impacted by roadways and other types of existing development.

5.2 Watershed and Land Use Management

Although much of the land in the watershed within proximity to the creek is allocated among existing uses, these lands can still be managed to prevent further degradation of the ecosystem. Detailed watershed management practices are beyond the scope of this study, but areas restored according to the general recommendations described in this section would be further enhanced if upstream land use practices were altered to reduce the strain on downstream habitat areas. Examples of land use and management approaches that would enhance downstream conditions include:

- ⇒ Floodplain, channel migration and critical area zoning and restrictions. This is most applicable within existing areas of development in Eagle Point as well as those targeted for future development.
- ⇒ Land use planning and management of resource industries such as mining, forestry and agriculture to provide buffers along waterways and wetlands. One type of commonly implemented and effect best practice within agricultural regions is livestock exclusion from the streams. This may be applicable throughout the mainstem downstream of Eagle Point and near the confluence of the South and North Forks.
- ⇒ Stormwater management and planning of urbanized and developing areas. Typical types of projects would include regional stormwater facilities or Low Impact Development to limit increases in stormwater and pollutant runoff.

5.3 Process Based Restoration

Process based river restoration focuses on restoring physical, biological and chemical processes and the connective linkages that may have been lost due to anthropogenic impacts (Kondolf, 2006). The underlying approach is based on restoring natural riverine hydrologic and biologic processes and not simply fixing specific symptoms, like an eroding bank. The following are a few examples of process based restoration:

- ⇒ Riparian plantings along river banks and floodplains to restore natural recruitment of wood to the system.
- ⇒ Removal of dams and other smaller barriers to fish passage that have changed watershed hydrology but are no longer efficiently providing their intended purposes, or cause significant environmental degradation that cannot be mitigated. Specific barriers such as culverts below roadways or diversion dams have not been identified; however, it is believed that there may be numerous good candidates for removal or modification simply because of the particularly high number of small diversion and water intake structures throughout the creek system.
- ⇒ Consolidation and improvement of water intake structures. Locations of withdrawals can often be consolidated and screened, for example, to minimize the overall impacts on fish and other aquatic species. Consolidating numerous small diversions into one or more structures with modern designs allows fish barriers or dams to be removed with affecting overall water use.
- ⇒ Re-operation of Fish Lake Dam water release schedules to account for and simulate natural flows. This can include the quantity of flow, timing, and water quality (i.e. temperature) of flow releases.
- ⇒ Levee notching, removal or setback to restore floodplain connections and allow habitats to form naturally, particularly in the lower portion of the watershed, below and possibly above Eagle Point, where the creek is less confined by its natural valley shape.
- ⇒ Gravel and wood augmentation in the North Fork to offset trapping of these natural materials behind Fish Lake Dam. In order to be a functional restoration measure, the scale of wood and gravel loading needs to be similar to the amount of trapping occurring behind the dam(s).
- ⇒ Revetment removal to allow natural channel migration processes.

5.4 Engineered and Constructed Restoration

Engineered and constructed restoration involves physical manipulation of the river and floodplain to promote, enhance or augment river processes related to fish habitat conditions. Typically, restoration features of this scale and type involve some type of installation of a hydraulic structure or channel manipulation to a desired condition. Engineering analysis and design is needed to support construction. Typically, an engineered and constructed restoration plan can attain results in the short term very efficiently. However there is a higher risk of not being sustainable over the long term, unless the project is designed to accommodate on-going natural processes. The following are a few examples of engineered restoration:

- ⇒ Design and construction of rock or large wood structures to provide in-channel scour, gravel deposition, and cover.
- ⇒ Reconnection or reconfiguration of floodplain side channels, backwaters, and wetlands using excavation.
- ⇒ Bioengineering bank enhancement to reduce impacts from past or future bank stabilization activities.

5.5 Restoration Feature Types

Using process-based and engineered and constructed restoration methods, specific restoration project types were developed that would be suitable within the Little Butte Creek system. In general, all proposed projects fall into one or more of the categories described below.

⇒ ***Floodplain Restoration and Enhancement***
This type of project would involve enhancing or reconnecting existing floodplain areas that may include side channels, backwaters, or wetlands, and that have been disconnected in some manner. Floodplain enhancement can also include placement of large wood (LWD) in the floodplain to provide habitat and cover during high flow events, and planting of riparian vegetation. Floodplain restoration may be particularly applicable to areas of the creek that have been channelized to maximize agricultural production.

⇒ ***Riparian Restoration and Non-native Vegetation Removal***
These projects are for river bank, side channel, tributary, floodplain, and bar areas that either lack riparian vegetation or have significant non-native vegetation populations. In many cases, riparian plantings and non-native vegetation removal will be part of other project feature types. However, there are instances when it is the only proposed treatment, and will be identified in this manner. Riparian restoration typically involves planting native tree and shrub species within the maximum potential floodplain/riparian zone area available at that site. In some locations, banks may need to be sloped back to provide a suitable area for planting or revetments may need to be modified through rock removal and replacement with bioengineered materials and riparian plantings. In some locations, removal of rip rap or fill could create a riparian bench at the appropriate elevation along the river to allow for natural recruitment of wood and other processes. Riparian restoration generally improves instream water temperatures and acts to reduce siltation from eroding banks.

⇒ ***Side Channel Creation, Restoration and Enhancement***
This type of project would involve creating, restoring and/or reconnecting side channel or slough features, or enhancing an existing side channel. Side channel enhancement may be part of other project types. The scale and restoration approach may also vary from project to project. The simplest type of project would involve minor excavation to remove deposited materials to reconnect the side channel. More extensive project types include excavation of new side channels in areas where there is a paucity of off-channel habitat, or where significant levees or berms have been placed between the historic side channel and the main channel to which it was once connected. Restoration can involve measures such as restoring historic overflow connections that are currently blocked and enhancement may involve general features such as placement of LWD, riparian plantings, or species-specific enhancements such as placement of rock and wood clusters for pond turtles. Other types of side channel enhancement include placement of LWD at the entrances or within side channels to improve habitat complexity and cover or to provide scour to keep the entrance open.

6. Summary and Recommendations

To address the water temperature impairment of the Rogue River, ODEQ along with US EPA has supported and sponsored this assessment of changes in geomorphology and groundwater connectivity in Little Butte Creek. The assessment addresses these changes in terms of their location, type, timing, magnitude, and possible cause(s). Little Butte Creek was selected as a candidate for study both because of its level of development related to roads, water diversions and structures, etc., and because of the potential for restoration and enhancement of the creek.

Based on the analysis presented in this assessment, the following summary of findings and recommendations for future work are made:

⇒ ***Geomorphology and groundwater connectivity*:**
The magnitude of changes in geomorphology and groundwater connectivity in Little Butte Creek from present conditions to natural conditions is estimated to be generally moderate. The overall average change in hyporheic flow exchange is approximately 6%. Changes in geomorphology showed variations in both time and through different reaches of the Mainstem and South Fork. The estimates of the geomorphic parameter values and corresponding hyporheic flow exchange percentages appear reasonable. They are in line with comparable literature values from various studies of stream systems both within the state of Oregon and from similar stream types in other locations. In addition, the impacts of estimated changes in hyporheic flows on creek water temperatures are not outside typical ranges cited in literatures and appear reasonable and as expected.

The estimates of geomorphic parameters and changes in hyporheic flows should be considered preliminary and should be verified with field-collected data. Field corrections and verification can lead to significant improvements in the estimates. A basic field reconnaissance program to ground truth these estimates could be completed in approximately two to three days of work in the field.

⇒ ***Hyporheic flow*:**
One indicator of surface water-groundwater connectivity is hyporheic flow. Hyporheic flow is comprised of surface water flow that seeps into the porous substrate along the channel margins and later re-emerges, often with a temperature (or other quality) that is different and/or out of phase with the surface water. Hyporheic flow was estimated based on common geomorphic parameters, and in this study is considered a surrogate measure of groundwater connectivity, primarily because of the lack of available groundwater data.

To assess actual groundwater movement and connection within and around the floodplain and banks of the Little Butte Creek, a groundwater well (piezometer) monitoring program is necessary. This information cannot readily be assessed from common groundwater well data or other general information. To more accurately estimate the level of groundwater-surface water disconnection, it is recommended that a groundwater well/piezometer network be installed and monitored through a range of hydrologic conditions, ideally spanning several years. A monitoring program of this type would require an experienced hydrogeologist, and could cost on the order of approximately $50,000 or more depending on the number of piezometers installed and the duration of monitoring.

⇒ ***Fish Lake*:**
Before Fish Lake was constructed in 1908, this region of the North Fork was referred to as Fish Lake and Marsh because it was a broad and flat reach bordered with marsh vegetation. The natural temperature conditions of the Fish Lake and Marsh may have exhibited larger diurnal fluctuations than present temperatures in the North Fork. However, there may not have been a significant difference in average summer time water temperatures between natural conditions and those of the present. This could be due to the fact that the reservoir currently releases from an outlet in the dam that draws cold water from the hypolimnion throughout much of the summer, in much the same way that cold groundwater spring inflows historically fed Fish Lake and Marsh and ultimately the North Fork.

⇒ ***Impairment Sources*:**
There have been several land-use based causes of changes over time in the geomorphology and groundwater connectivity in Little Butte Creek. These include agricultural development, other types of development such as roadways and residential development, water diversions and their associated physical structures and channel modifications, and water supply reservoirs. Based on review of previous studies, observations within the watershed, and analysis of current and historical aerial photographs, the most prominent causes of change are believed to be (1) channel modifications associated with roadways adjacent to the stream and (2) channel and flow modifications related to water diversions and their structures.

The relative magnitude of these two impairments relative to others in the watershed cannot be specified with certainty without additional analysis. A study to determine the specific impacts of these impairments might involve comparing the temperature regimes in the vicinity of selected impairments to those in non-impacted reaches during the summer months over various water year types.

⇒ ***Recommended Restoration Actions*:**
There are many restoration actions that could provide significant benefits to the water quality of and priority aquatic species in Little Butte Creek as well as the Rogue River. These actions include conservation and land use management approaches that either protect existing creek reaches that have not yet been negatively impacted or prevent further degradation with reaches that have been impacted. Several key process-based restoration measures include: (1) riparian plantings along regions of agricultural or residential properties, (2) removal of dams and other small barriers to allow fish passage and open spawning habitat, (3) consolidation of and improvement to water diversions, (4) gravel and wood augmentation particularly in the North Fork where it may be limited by Fish Lake Dam, (5) levee notching or setback to restore floodplain functions in agricultural regions and downstream of Eagle Point, and (6) re-operation of Fish Lake Dam to mimic natural hydrologic variations, restore transport and channel forming

processes and potentially improve instream water temperatures.

These potential restoration measures are general in nature. It is recommended as a future work item that these optional measures be studied further, refined, and prioritized. Creek restoration is one way that watershed stakeholders realize load allocation requirements of the TMDL study.

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8. Appendix A
Current and Historical Aerial Photograph Plates

Aerial Photograph Analysis

Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem

Layout I

Photograph Date 2005

1939 Channel Center Line

1957 Channel Center Line

PLATE I - 2005

Tetra Tech
July 2008

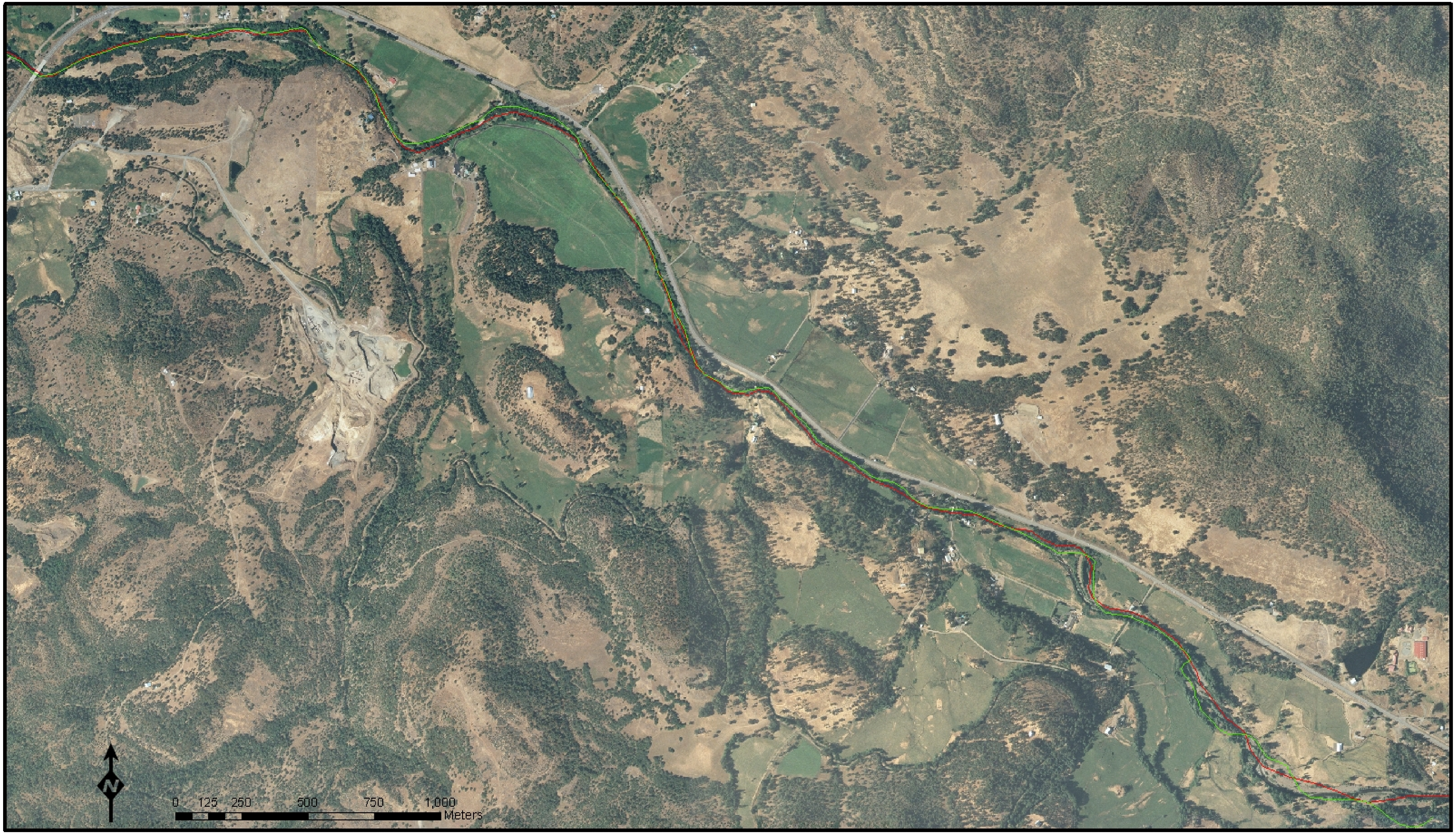
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 2005

1939 Channel Center Line
1957 Channel Center Line

PLATE II - 2005

Tetra Tech
July 2008



Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 2005

1939 Channel Center Line
1957 Channel Center Line

PLATE III - 2005

Tetra Tech
July 2008

Aerial Photograph Analysis

Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem

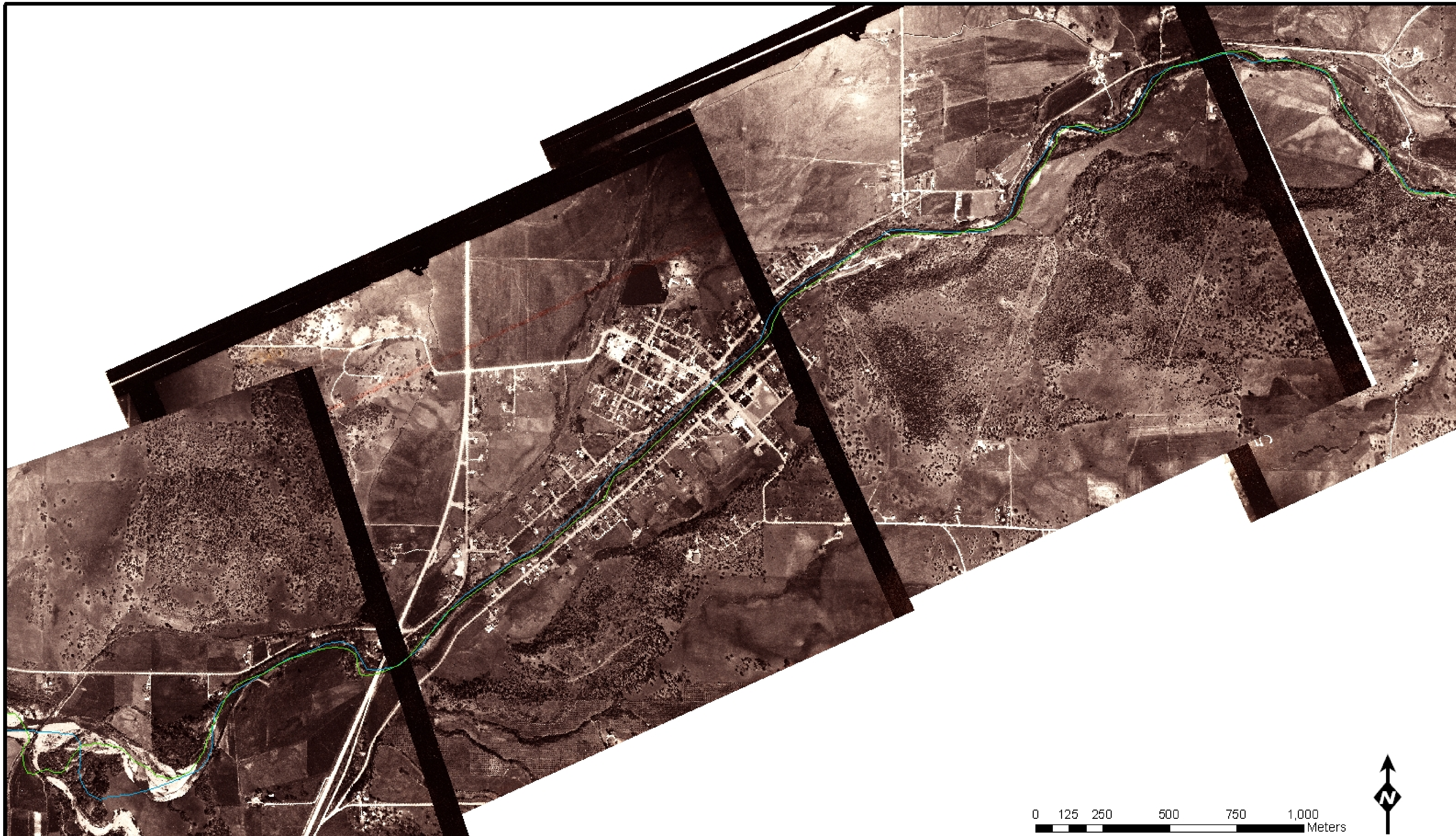
Layout I
Photograph Date 2005

1939 Channel Center Line

1957 Channel Center Line

PLATE IV - 2005

Tetra Tech
July 2008



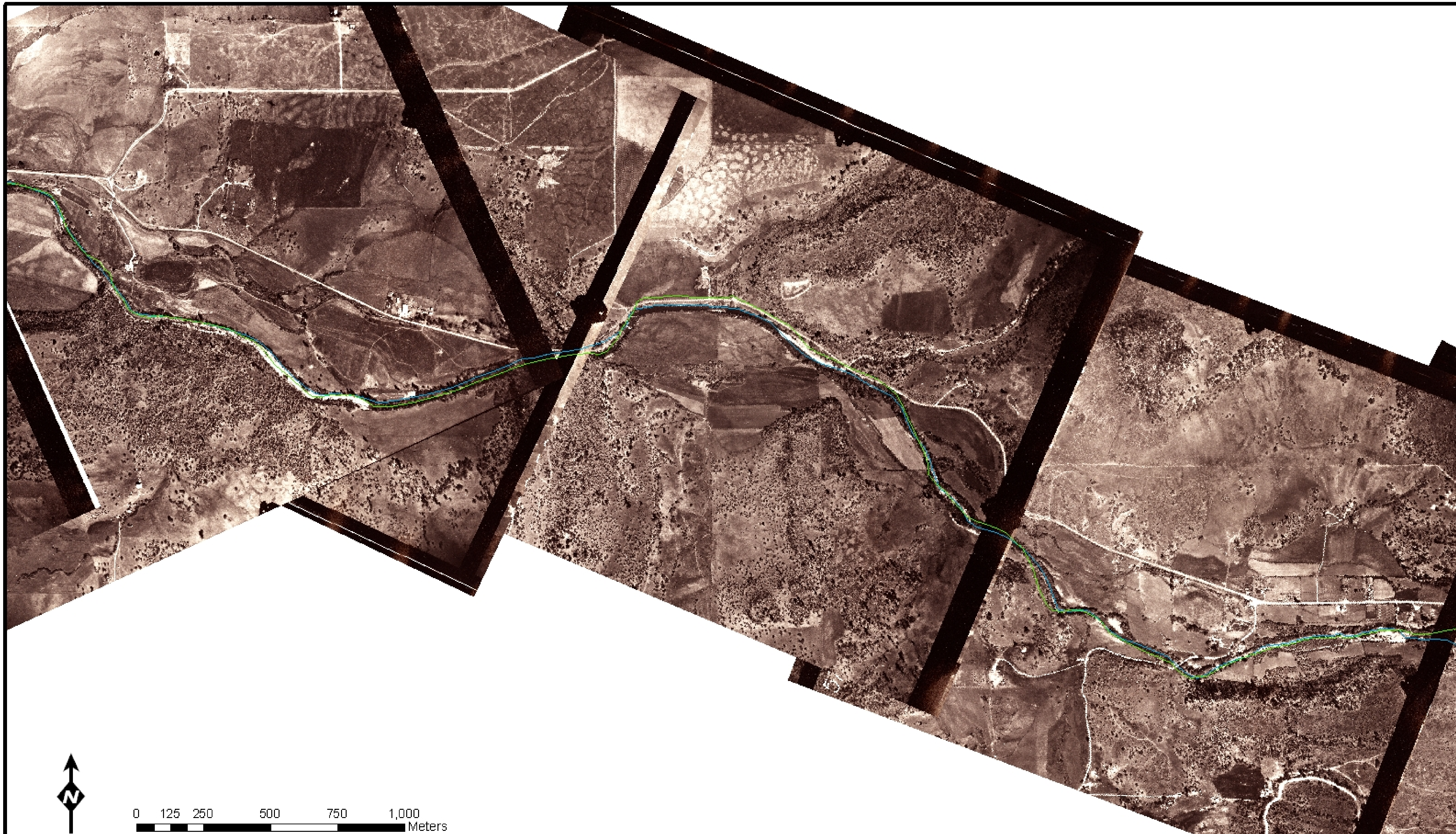
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1957

1939 Channel Center Line
2005 Channel Center Line

PLATE I - 1957

Tetra Tech
July 2008



Aerial Photograph Analysis

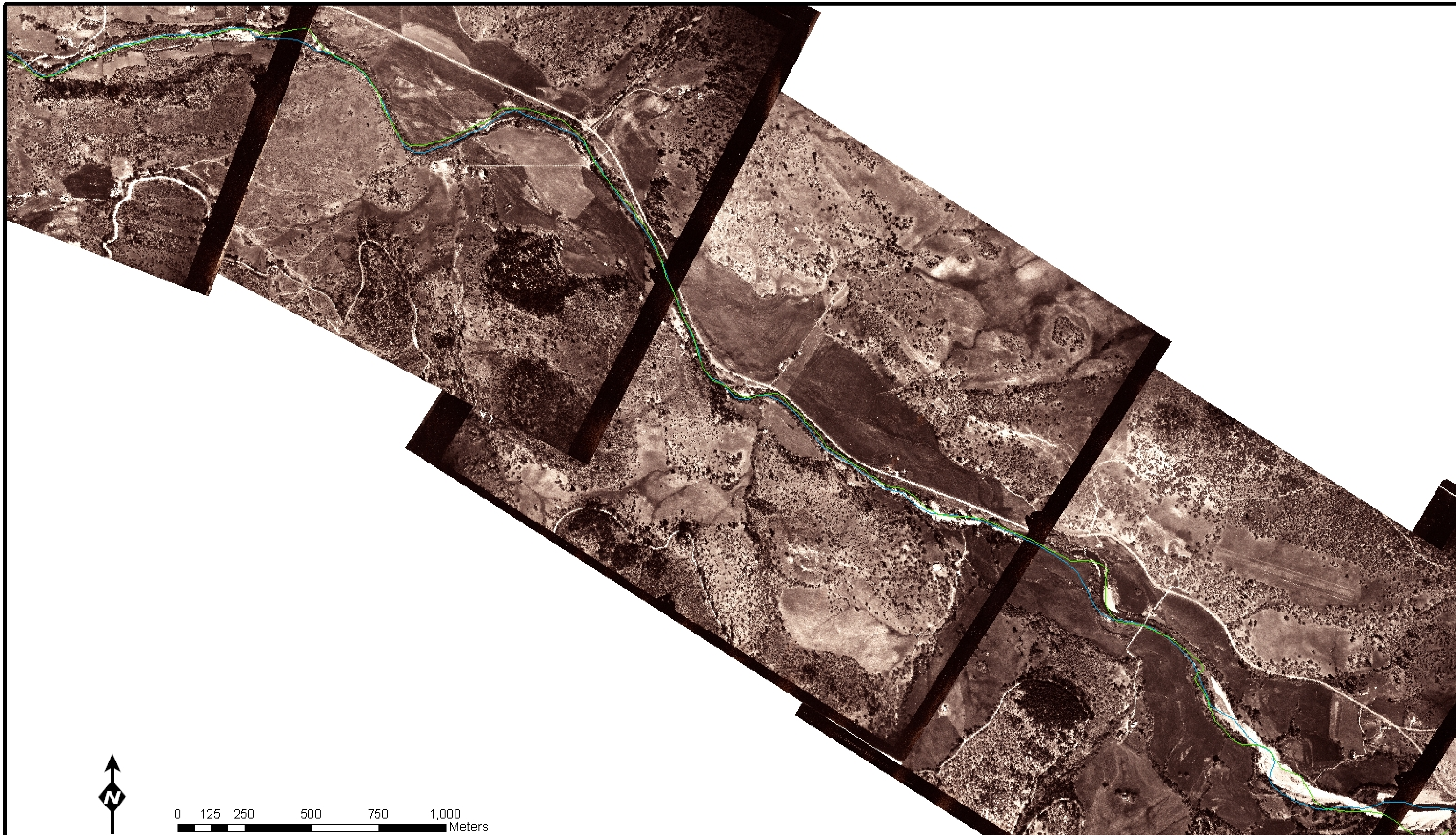
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1957

1939 Channel Center Line
2005 Channel Center Line

PLATE II - 1957

Tetra Tech
July 2008



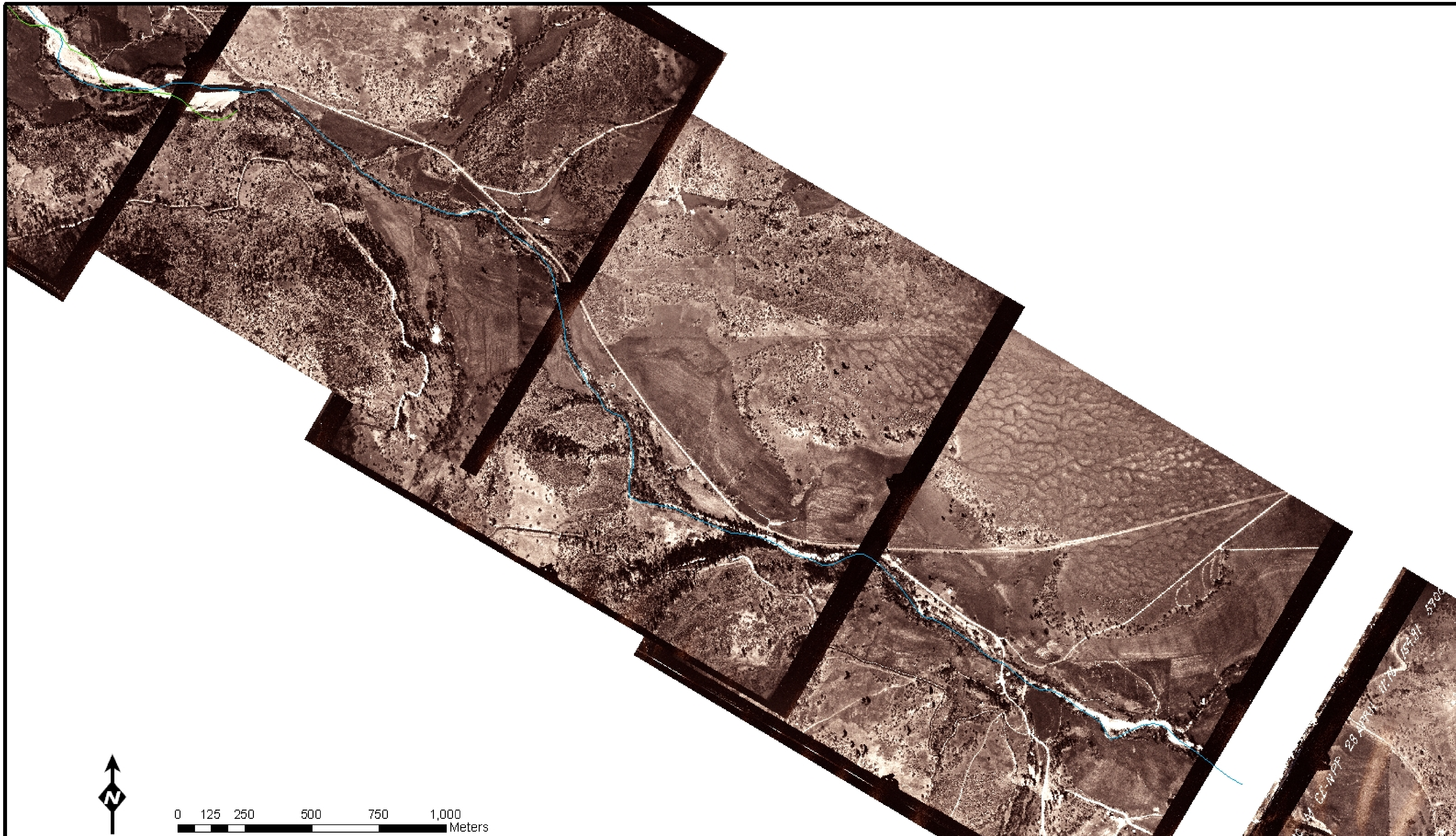
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1957

1939 Channel Center Line
2005 Channel Center Line

PLATE III - 1957

Tetra Tech
July 2008



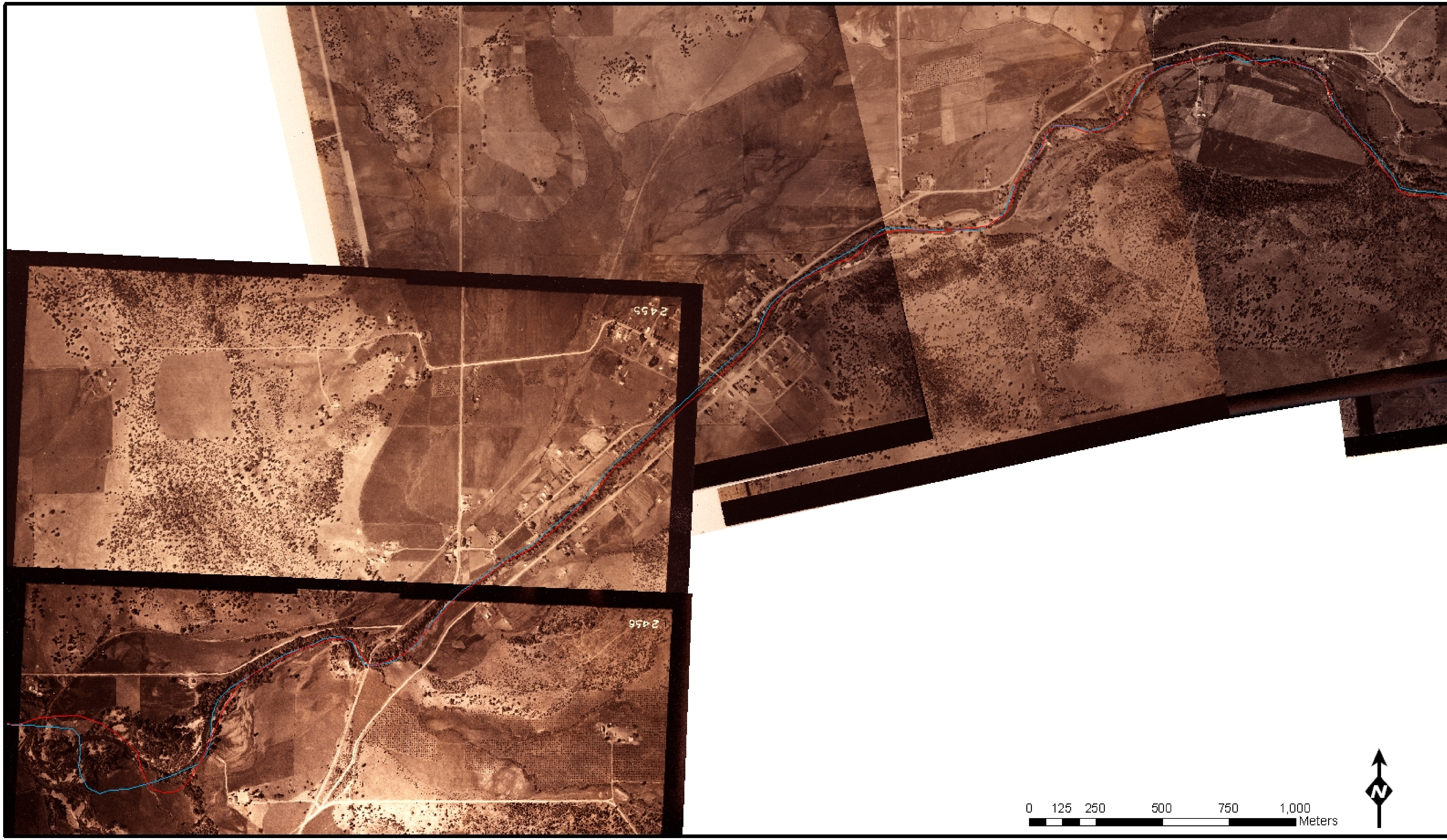
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1957

1939 Channel Center Line
2005 Channel Center Line

PLATE IV - 1957

Tetra Tech
July 2008



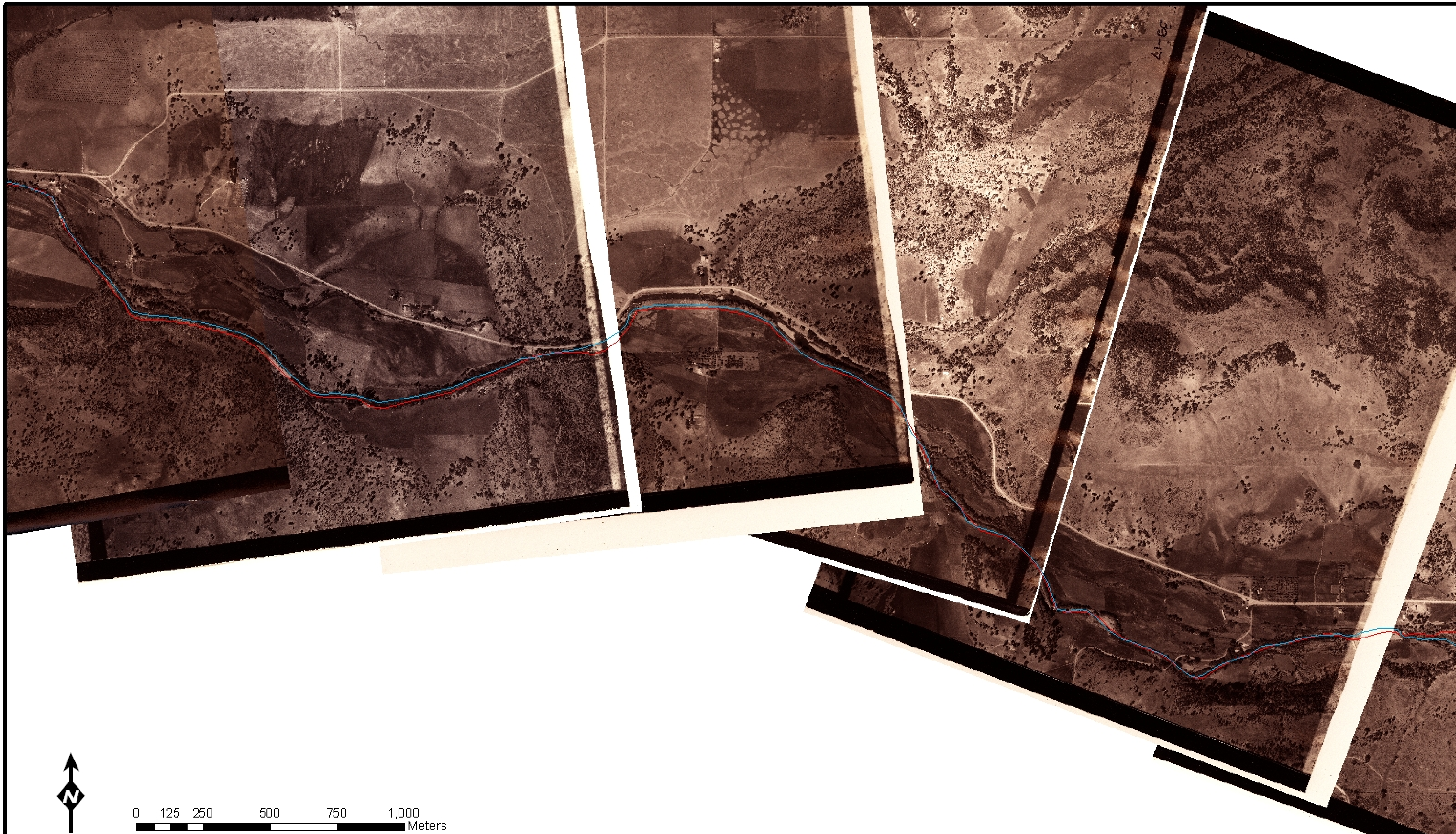
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1939

1957 Channel Center Line
2005 Channel Center Line

PLATE I - 1939

Tetra Tech
July 2008



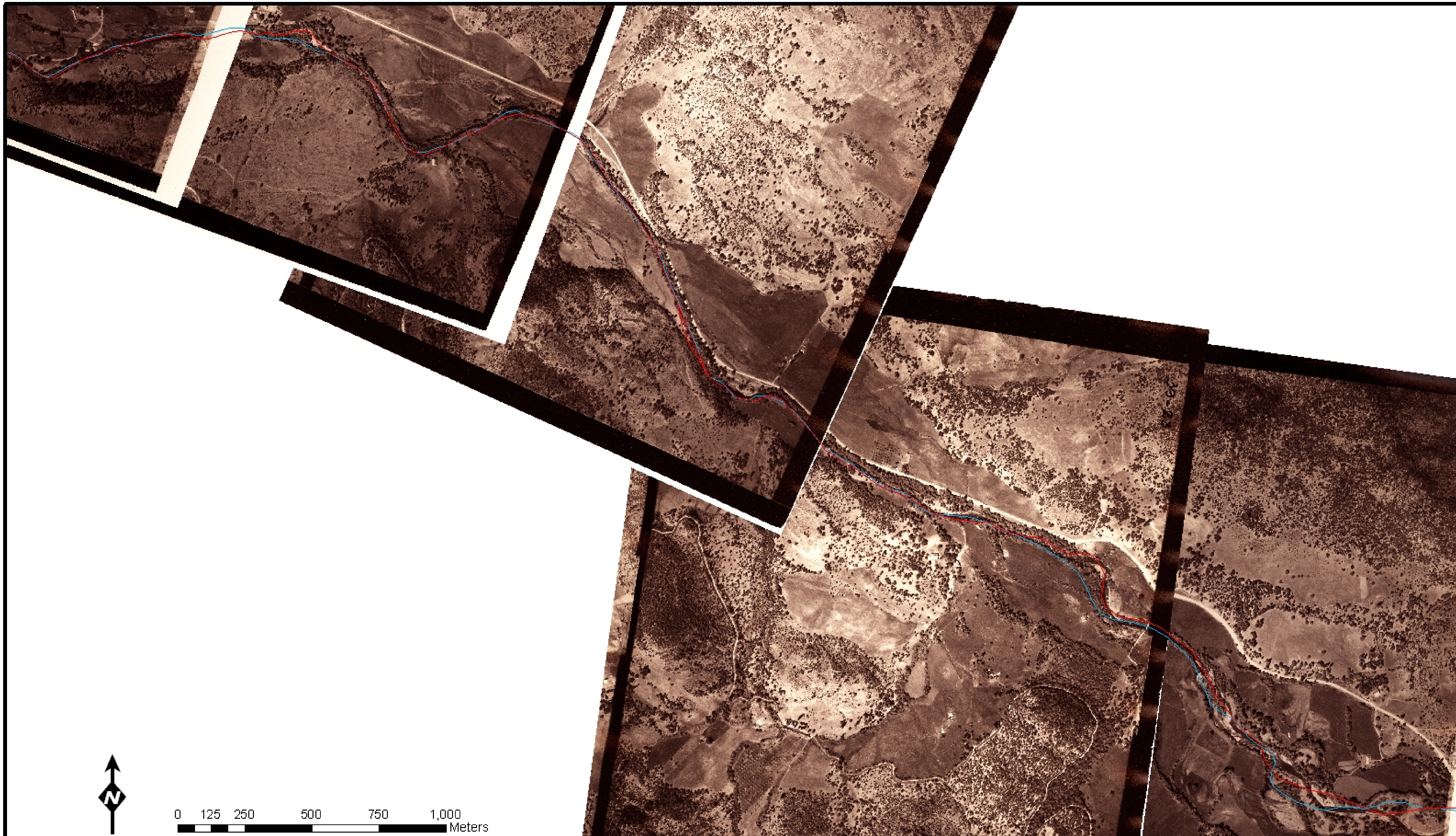
Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1939

1957 Channel Center Line
2005 Channel Center Line

PLATE II - 1939

Tetra Tech
July 2008



Aerial Photograph Analysis
Rogue Tributary - Little Butte Creek
Geomorphic and Groundwater Connectivity Assessment

Little Butte Creek - Mainstem
Layout I
Photograph Date 1939

1957 Channel Center Line
2005 Channel Center Line

PLATE III - 1939

Tetra Tech
July 2008

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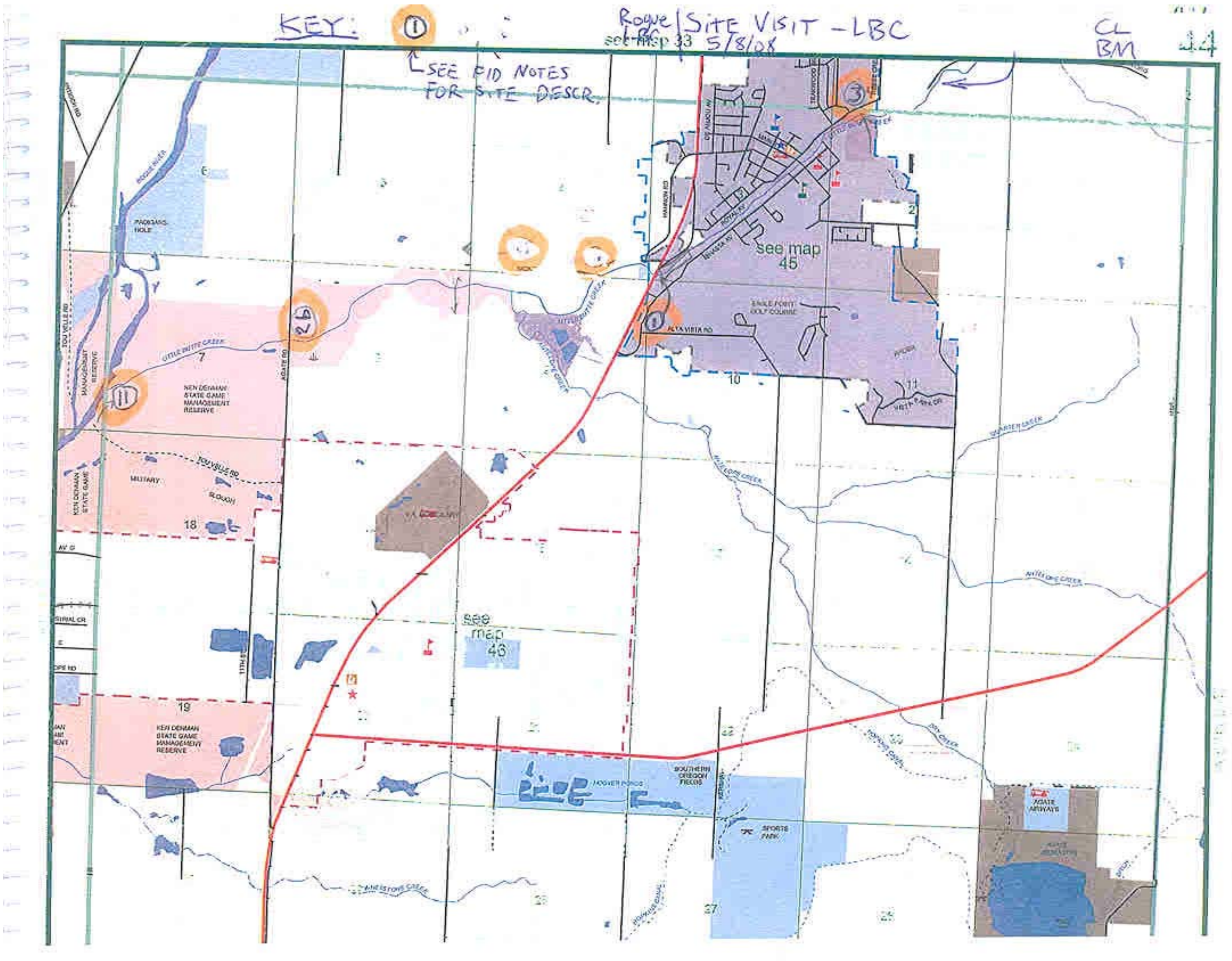
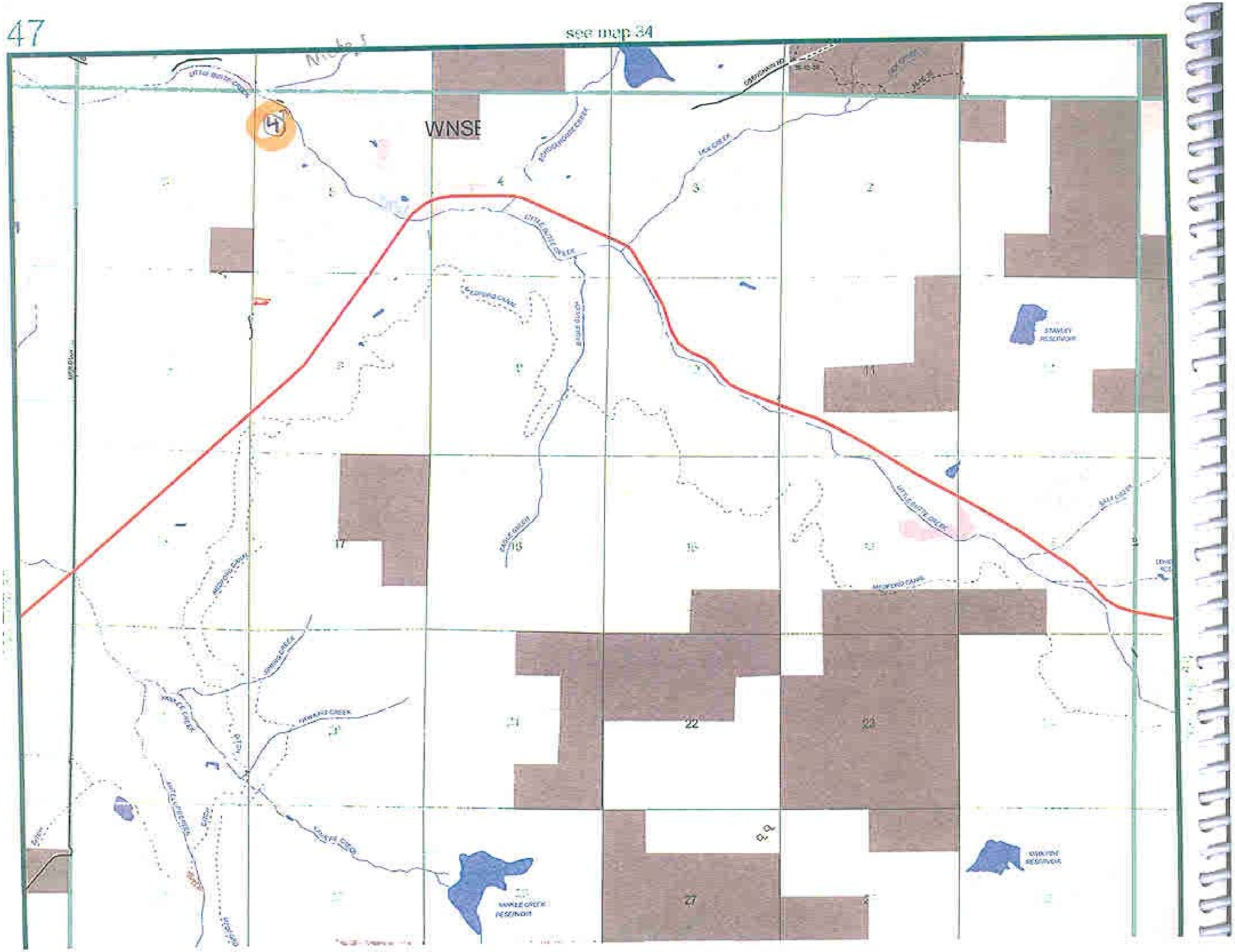
9. Appendix B: Watershed Tour May 2008 – Field Maps, Notes & Selected Photographs


KEY:
SEE FID NOTES FOR SITE DESCR.
Rogue Site Visit – LBC
5/8/08
CL
BM
see map 45
see map 46
KEN DENMAN STATE GAME MANAGEMENT RESERVE
MILITARY
SLOUGH
ALTA VISTA RD
EAGLE POINT GOLF COURSE
HOOVER PONDS
SOUTHERN OREGON FIELDS
SPORTS PARK
AGATE AIRWAYS


47
see map 34
WNSE
22
23
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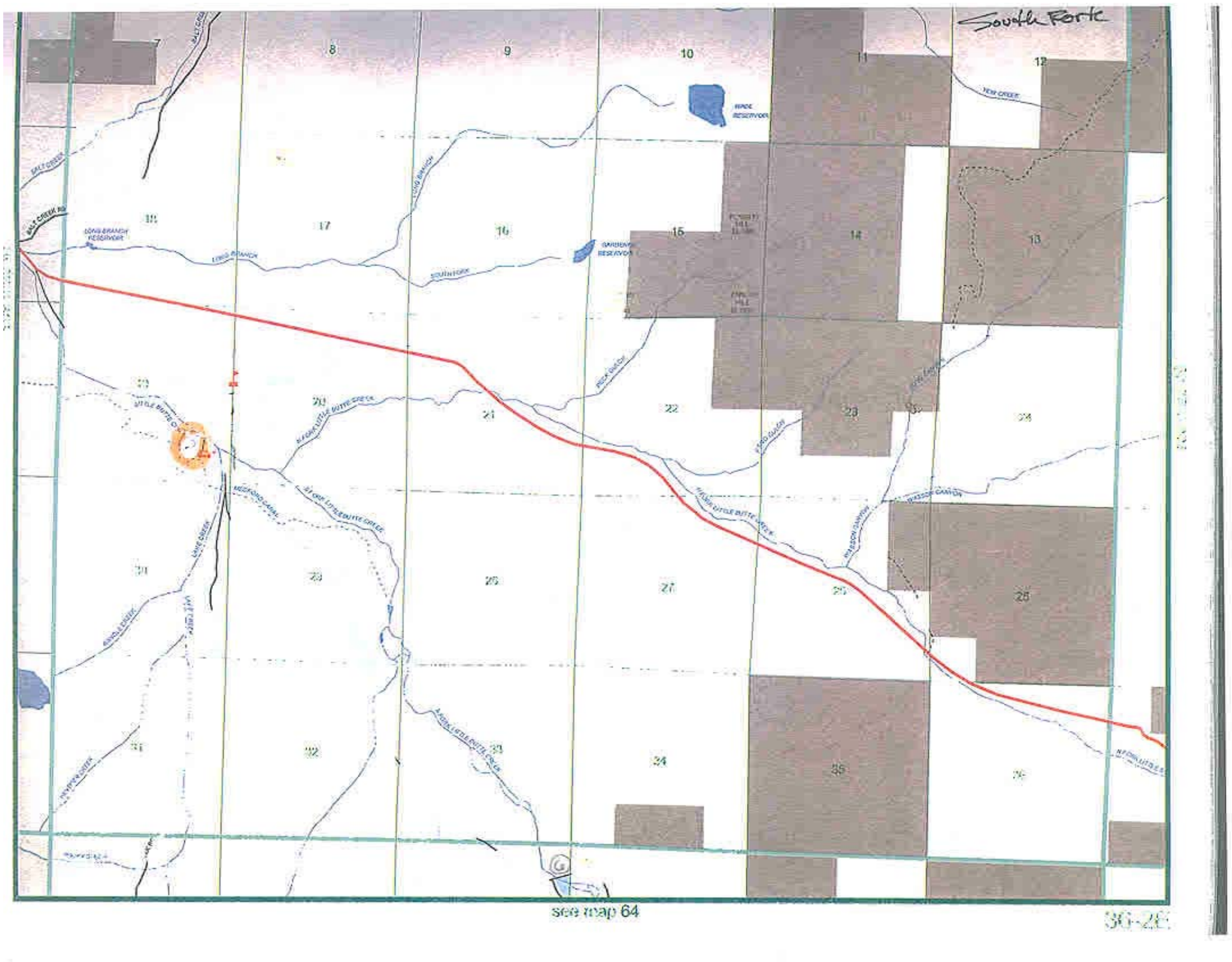
South Fork
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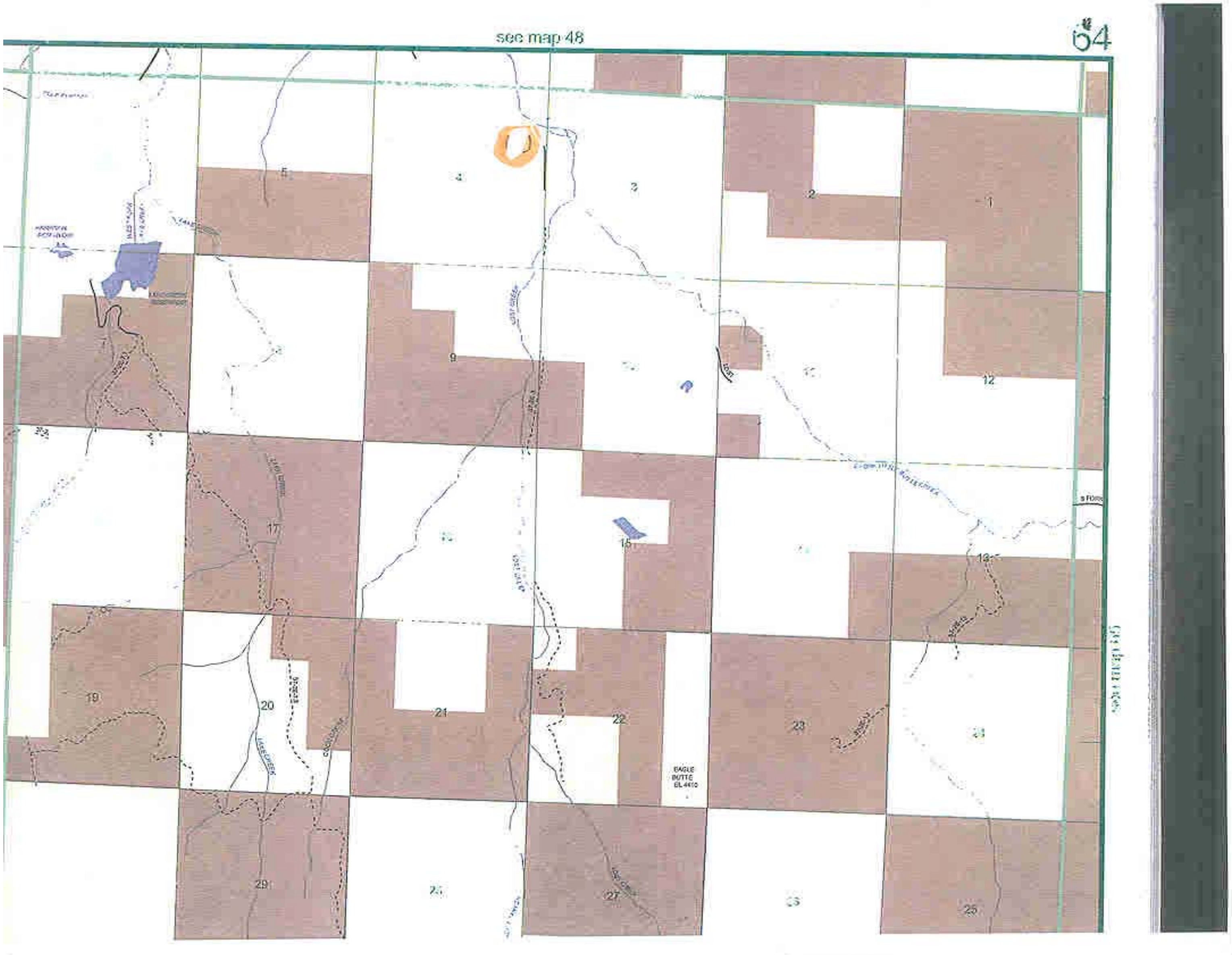
35
see map 64


see map 48
64
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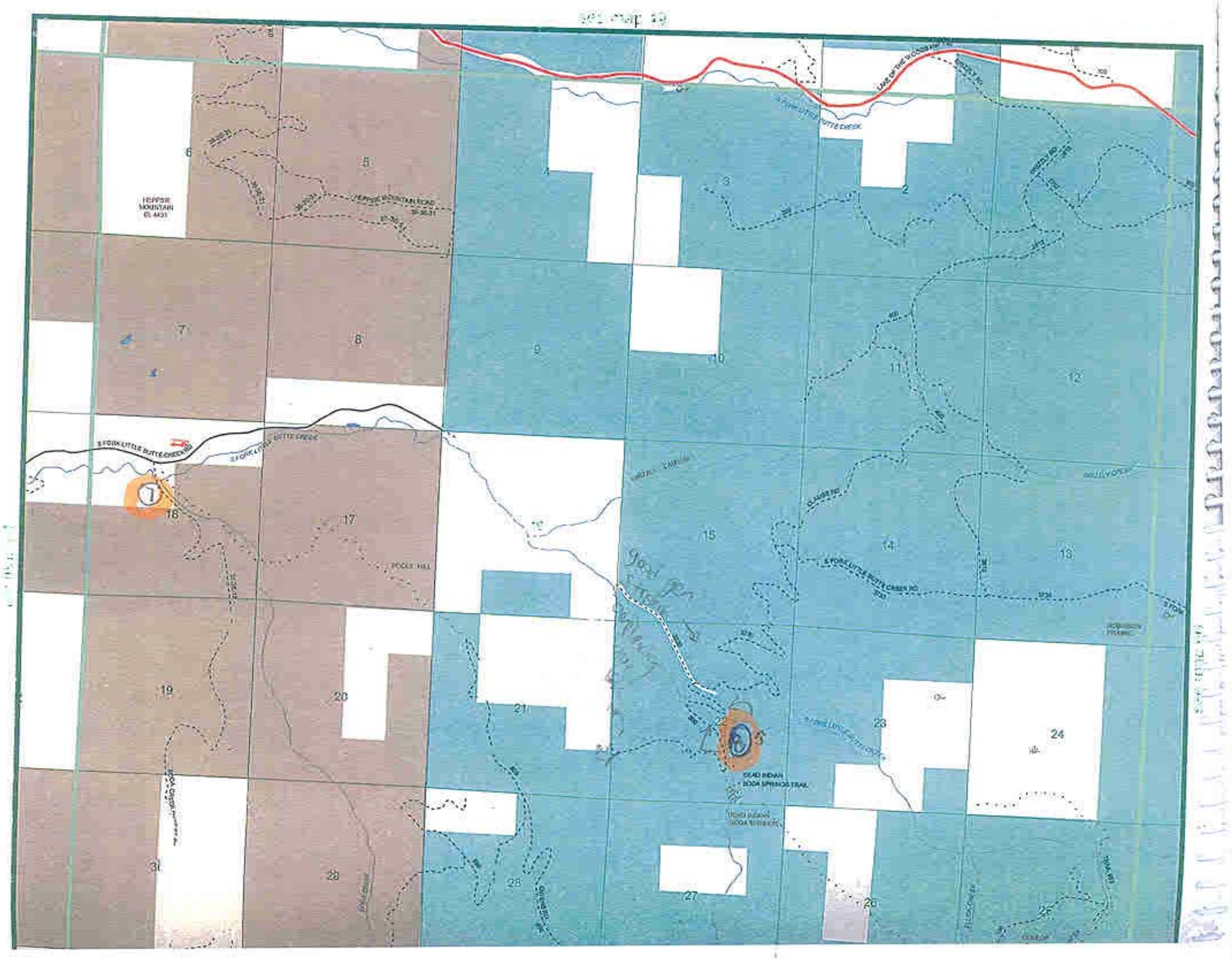
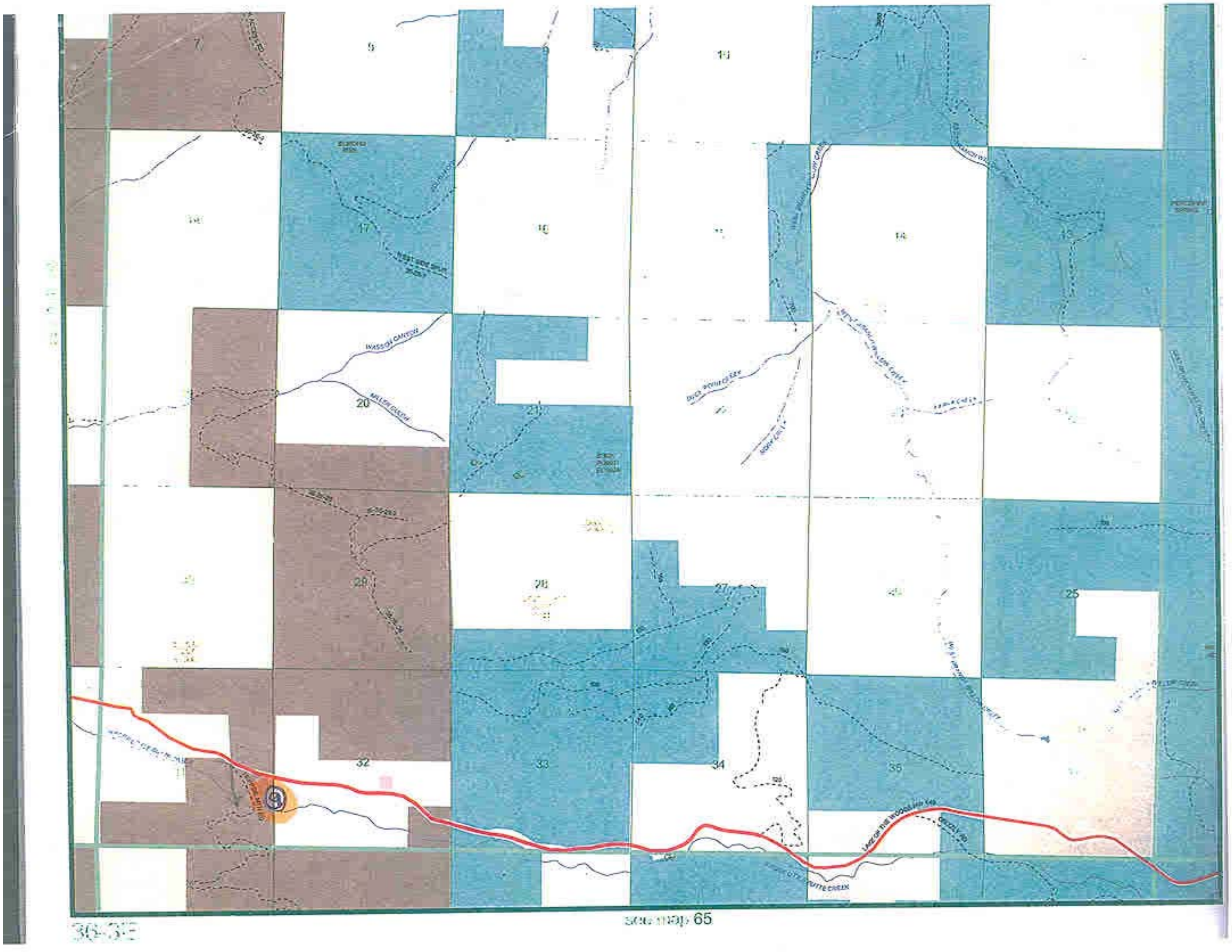




LBC Tour – BM, CL 5/8/08 p. 1

Site	Descr.	Photo
(1) Harnish Wayside @ 62 Hwy	Flow nr bankful check gaged flow (@ br. USGS Hwy 62 gage) estim bnkful width ~60' (20 yds), flow depth in channel ~4' max depth	1~6 8:45 am

Tim mtg:

– County Jackson website } historical
– Historical Society } aerials

(2) Nick Young Rd Confined channel, narrow riparian strip, rd close to creek on N side, pasture on S side (no pic)

(2b) Agate Rd Br – (d/s of Agate Cr) ~4 pics
– small mid chan island on u/s side – appreciably higher than @ (1) Harnish
– flows high – up to rip. corridor
– floodplain confined or not visible due to high Q 10:30 am

p.1

5am

~o pic)

~4 pics

Harnish
@ (1)

10:30 am

p.2

(3) Diversion (on Brownsboro / Eagle Pt Rd) ~3-4 pics
~4' overflow conc div. dam
w/ side conc. div. weir w/
turn gates (2)
- Cr ~ 25 yds wide @ structure
(slightly narrower than u/s & d/s
- Mostly confined channel next
to Eagle Pt Rd ~ 30 yd away

(4) Restoration Site - ~4 photo.
- Vehicle br - mid chan bar, sloped
bank on South side channel
- rd close by on N side
- sheep grazing

(5) Lake Cr Br - (gaging station) * ~5 pics
- 25 yd wide flow width
- high velocity
- narrow riparian
- still mainstem below SF/NF
Confluence

(6) Meander Site - 4 mi marker from 11:30am
Hwy turn off 10 pics
- @ Lost Cr Rd
- Channel at bridge ~ 30-40 yds wide
- floodplain d/s ~ 60 yds wide
- cut bank / meander u/s of br
- bankfull evidence on N bank - see photo

p. 2

(7) Soda Cr / SF junction — p. 3
- Soda Cr - clear
- SF silty — 12pm
- high Q — (pics)
- good habitat, veg cover good

~3-4 pics

(8) Camp Latgawa - SF — 12:30
- bridge over SF — (pics)
- very high flows
- Soda springs foot bridge
- flows @ approx bankful
- SF width ~ 10 yds

~4 photo

Soda:
- 2 pics @ soda springs / SF confluence
- slight diff sed load (soda more clear)
- Soda flow width ~ 8-10 yds perhaps slightly lower, but not much ✓
- very steep canyon walls, both sides
- likely topo shade affects
- good veg / riparian cover w/ moderate to ok effect shading

5 pics

1:30am
10 pics

p. 3

2pm
pics)

2:30
ics)

oar)

p. 4

(9) NF Heppsie Rd 1:20pm
- very diff ~3 pics
- stable flow, no apparent flooding
- moss on rocks, clear water,
- no main bank vs floodplain,
- hardened substrate & banks presumably due to Fish Lk

Fish Lk - 'Oregon Lakes Atlas' for info: bathym, etc.

(10) FISH LK

(11) Confluence LBC / Rogue 4pm
- Rogue ~ at bankful b/c some ~10 pics
veg submerged
- very visible sed. pulse in Rogue
- large broad floodplain w/ gravels, cobbles, sands at south side of LBC mouth
- cottonwoods & oaks @ perimeter of chanel, not an edge indicating possibl. hist bounds of meander belt

p.4
2 0pm
~3 pics

p.5

LBC - mouth
- did small 1/4 to 1/2 mile
loop

4 pm
~10 pics

+

Site Visit - Harnish Wayside Park, Eagle Point
(05/08/08 Approx 9am)

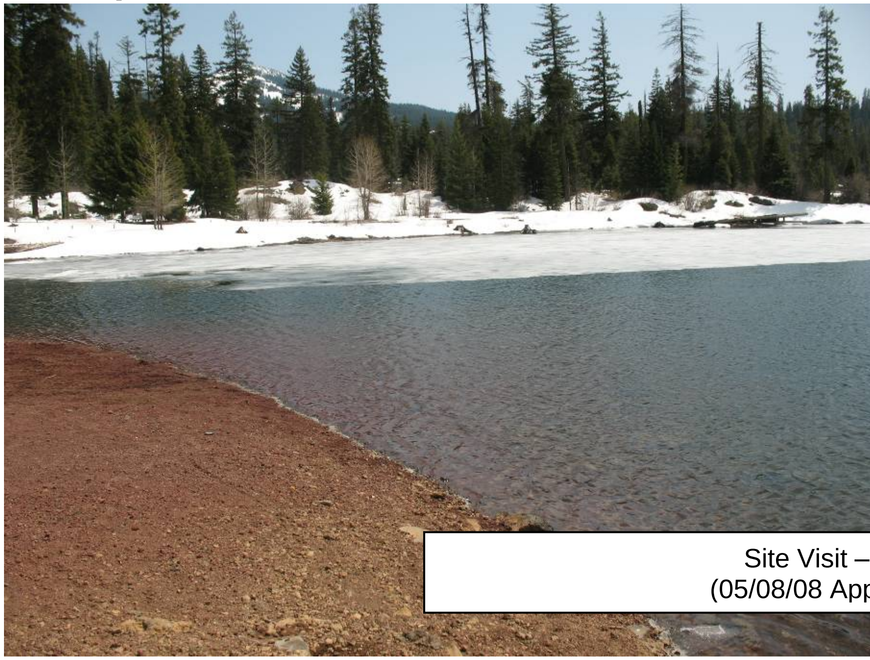
Site Visit – Agate Road Bridge
(05/08/08 Approx 10:30 am)

Site Visit – Diversion (near Brownsboro/Eagle Pt Rd)
(05/08/08 Approx 10:45 am)

Site Visit – Restoration Site U/S of Brownsboro
(05/08/08 Approx 10:55 am)

Site Visit – Meander Site near SF LBC Rd at Lost Cr Rd
(05/08/08 Approx 11:30 am)

Site Visit – South Fork LBC (turbid) / Soda Creek (clear) Confluence
(05/08/08 Approx 12:00 pm)



Site Visit – Fish Lake
(05/08/08 Approx 2:00 pm)

Site Visit – Little Butte Creek Near Mouth/Rogue River Confluence
(05/08/08 Approx 4:00 pm)