Monitoring Results of Alternative Watercourse and Lake Protection Zones in the Etna Creek Watershed in interior, Northern California.

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Abstract

Based on the scientific literature, previously existing stream water, channel and riparian habitat data collected along Etna Creek an alternative WLPZ was proposed for timber harvesting. Stream temperature, air temperature, relative humidity and surface erosion monitoring was supported by California Department of Fish and Game (DFG) and by the North Coast Regional Water Quality Control Board (NCRWQCB). Timber harvesting occurred during the summer of 2007 and the first post harvest water year was 2008. The harvesting of trees from the outer zone of the Class I alternative WLPZ resulted in a reduction of canopy closure from 72% to 53% for the thinning unit and from 67% to 53% for the clearcut unit. Reductions in canopy closure resulted in Class I riparian air temperatures and humidity in the inner zones of the alternative WLPZ's remained relatively unchanged following timber harvest, while the outer zone, along one reach, air temperature increased 1.0C and humidity decreased 9.0%. MWAT water temperature remained relatively unchanged from the Class I alternative WLPZ timber harvest. The harvesting of trees from the Class II alternative WLPZ resulted in a reduction of outer zone canopy closure from 70% to 62%. Class II stream reductions in canopy closure resulted in inner zone air temperatures increased 1.1C and humidity decreased 4.6%. Outer zone air temperatures increased 1.5C and humidity decreased 5.0%. MWAT water temperature remained relatively unchanged from the Class II alternative WLPZ timber harvest. Sediment transported <u>to</u> the WLPZ from roads, skid trails or harvest units was stopped by strategic placement of waterbars and slash over all skids trails and landings, effectively stopping erosion from continuing to route to wetted zones.

1.0 Introduction

The Etna Creek watershed flows directly into the Scott River, a tributary of the Klamath River. Etna Creek is currently known to support anadromous salmonids including chinook and coho salmon at the confluence with the Scott River and steelhead trout are known to occur in reaches of Etna Creek. Currently, based on opportunistic electro-shocking of upper Etna Creek by the DFG, only steelhead trout are known to occupy the upper reaches of the watershed in our study area. Consequently, the monitoring of this alternative WLPZ's occurred in an anadromous watershed.

Direct observation or correlation studies have established relationships between riparian habitat conditions and stream channels and forest management activities. Generalized curves have been developed that describe these relationships and the distances at which riparian habitat provide key functions for stream channel habitats including riparian shade (Spence et al, 1996; FEMAT 1993). In general, observational studies have found that riparian shade could potentially influence streams equal to one site-potential tree height (Beschta et al. 1987). Yet, cause-and-effect studies like the Alsea Watershed Studies in Oregon have found that effective riparian shade buffers from partially harvested riparian habitats occurs between 25 feet to 100 feet from the stream channel (Brown 1971)) and was verified in an additional cause-and-effect study (Brown 1972). Unfortunately, the cause-and-effect relationships between riparian and stream channel habitats, including riparian shade, and current forest management activities in California is relatively poorly understood.

As part of the Etna Creek THP (2-05-098-SIS6), Timber Products Company (Company) summarized regional literature, existing stream water temperature data and watershed level riparian conditions to better understand both historic and existing riparian habitats and stream water temperatures in the Etna Creek watershed. A watershed level assessment of historic and existing riparian habitats found, based on 2001 aerial photography, a total of 49% of the reaches had over 70% canopy closure and another 35% of the reaches had between 40% and 70% canopy closure. Prior to this current THP, the assessment also identified a total of 10,500 feet of Class I riparian habitat and 20,400 feet of Class II riparian habitat that had been previously modified by timber harvest. While significant modifications of riparian habitat had occurred between 1997 and 2002 (Appendix A), MWAT water temperatures downstream of these modifications in Etna Creek remained relatively unchanged (Appendix A).

The three alternative Waltz's for this study were designed to maintain all riparian zone functions including riparian shade, nutrients, filtration of sediments, large wood debris delivery to stream channels and stream bank stabilization. Riparian zone functions specifically monitored as part of the alternative WLPZ's included water temperatures, riparian air and humidity, riparian shade and riparian zone filtration of sediments.

2.0 Study Design – Public Agency Recommendations

During the review of the proposed alternative WLPZ's the NCRWQCB and DFG provided comments, suggestions and recommendations regarding the monitoring of the alternative WLPZ's. In general, both the NCRWQCB and DFG were supportive of the proposed alternative WLPZ's and monitoring and provided specific recommendations to be included into the study design (Appendix B):

(1) Measure pre harvest and post harvest alternative WLPZ canopy closure from the entire alternative WLPZ to document the actual canopy closure reduction from the proposed timber harvest plan units.

(2) Collect summer stream temperatures down stream and upstream of proposed timber harvest plan units.

(3) Conduct a field survey for sediment transported to or through the alternative WLPZ after first winter after operations. Document whether sediment was being transported to the Class I or II stream channel or alternative WLPZ and if so identify the source of the sediment.

(4) If possible, collect baseline (pre harvest) microclimate data (ambient air temperature) to measure response in the alternative WLPZ to the response in stream water temperatures, if any.

3.0 Methods: Summarized Monitoring Plan in the Etna Creek Watershed

Monitoring methods of the alternative WLPZ's in the Etna Creek watershed incorporates the results of timber harvest plan, the watershed level channel and riparian assessment, comments and suggestions provided by the NCRWQCB and DFG (Appendix B). Based on the scientific information and the suggestions and recommendations provided by the cooperators, the most appropriate study design was a before-after design for Class I WLPZ and before-after-control design for the Class II WLPZ's. As the name suggests, the before-after and before-after-control designs are the simple monitoring of the environment before a known disturbance and after a disturbance. These designs also can identify cause-and-effect relationships by measuring which components may adversely impact the environment and estimate the magnitude of the change (Smith 2002). In analysis, any difference found between the before and after results and in comparison to the controls is attributed to the disturbance. However, this design may be limited due to annual variation in environmental conditions like air temperatures, snow melt, stream flows or stochastic events like floods, debris torrents or wildland fires (Smith 2002).

The alternative WLPZ's were designed to maintain all riparian functions, specifically maintaining existing stream water temperatures. Also, within the outer zone an Equipment Limitation Zone was implemented to maintain understory vegetation, down logs, rocks and forest floor litter to potentially filter sediments before being delivered to the stream channel. The alternative WLPZ's included three different protection zones:

Table 1 Proposed alternative WLPZ's

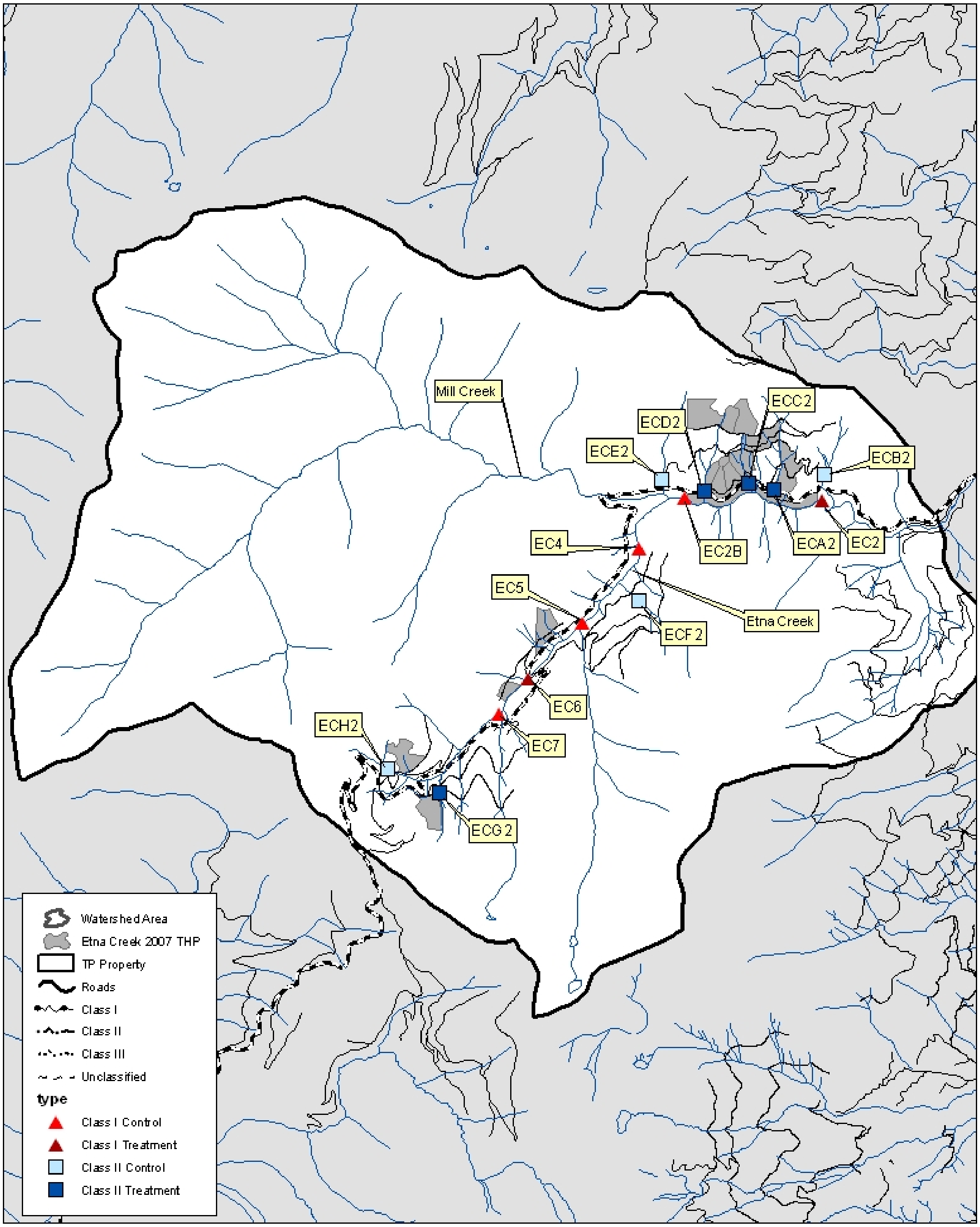
Alternative WLPZ	Adjacent Silviculture	WLPZ width	WLPZ canopy closure
Class I	Selection Unit #8	0 to 50 ft 50 to 150 ft	100% retention of existing canopy closure Maintain 50% canopy closure
Class I	Clearcut Unit #12	0 to 75 ft 75 to 150 ft	100% retention of existing canopy closure Maintain 50% canopy closure
Class II	All Silviculture	0 to 25 ft 25 up to 100 ft	Maintain 70% canopy closure Maintain 50% canopy closure

3.1 Stream Water Temperature and Riparian Air Temperature and Humidity

As described in Appendix B and C, the before-and-after design included two Class I stream reaches and the before-after-control design included four Class II stream reaches with four control reaches. At all these reaches stream water temperature, air temperature and humidity were collected. For the Class I alternative WLPZ, site TEC2 was located immediately down stream and TEC2B was upstream of the selection silviculture Unit #8 (Figure 1). And Site TEC6 was located immediately down stream and TEC7 upstream of the clearcut silviculture Unit #12. For the Class II alternative WLPZ, sites A2, C2, D2 and G2 were treatment sites where the alternative WLPZ was harvested and sites B2, E2, F2 and H2 served as Class II controls (Figure 1).

Water temperatures were measured continuously every one hour interval with electronic recording instruments, which is suitable to detect stream temperature peaks (Lewis et al. 2000). The goal of the field season was to begin on May 15th and end on October 1st. Each instrument was calibrated following calibration protocols (FFFC 1996; USGS 1978). Instruments used in this study were calibrated for accuracy using an EPA certified NIST traceable thermometer, ASTM# 6016. The manufacturer's specifications for accuracy of the instruments, Onset Hobo Temp H8, is stated as +/- 0.2 C at 0C. Additional information collected for each stream water temperature site were those recommended by FFFC (1996) and the USGS (1978). Information collected included date and time of instrument deployment, location name, serial number of instrument, unique location number and personnel. In addition, descriptive information collected for each monitoring site included elevation, tributary basin area, distance to watershed divide and stream summer low flow. And in case of potential equipment malfunction, instantaneous water and air temperatures were recorded on the day of deployment in the field to help identify malfunction.

Figure 1 Alternative WLPZ monitoring sites along Etna Creek 2006 to 2010



3.2 Canopy Closure, Basal area and Trees within alternative WLPZ

Pre harvest and post harvest alternative WLPZ canopy closure, basal area and number of trees were measured to document both the pre and post treatment conditions. At every 100 feet of stream channel a systematic transect perpendicular to each survey plot was measured (Berbach et al. 1999, Zwienicki and Newton 1999). Distances were collected a cloth tape (Caldwell et al. 1991). Canopy closure, basal area and number of trees were measured within the stream channel, at the mid-point of the inner zone and mid-point of the outer zone. Canopy closure refers to the total canopy overhead that was measured by both a densiometer and siting tube (CWHR 1988). Basal area and the number of trees were measured within a 1/50th acre fixed plot centered at the mid-point of the inner zone and mid-point of the outer zone.

3.3 Sediment Transported to or through the alternative WLPZ

In general, filtration of sediment from overland flow can occur by physical barriers that trap sediment such as ground vegetation and down woody debris and can occur at distances equal to one site-potential tree height (FEMAT 1993). However, local watershed or channel conditions including geomorphic characteristics such as slope, soil type and vegetative structure and cover can influence effectiveness of filtration of sediment. This study proposed retaining all vegetation and conifer and hardwoods trees, down logs, rocks and forest floor litter for filtration within 50 or 70 feet of the stream channel, and 50% canopy closure for the remaining zone width and an Equipment Limitation Zone to maintain understory vegetation, down logs, rocks and forest floor litter to also potentially filter sediments.

We conducted a field survey of pre harvest and post harvest of the alternative WLPZ to document sediment transported to or through the alternative WLPZ. Post harvest assessments were conducted following the 1st winter period and 2nd winter as operations were completed. The primary focus of this field survey was to measure sediment transported from overland flow, more concentrated sediment sources like skid trails, road relief culverts, road relief rolling dips, road culvert crossings and small landslides. If any sediment was found to be transported to or through the alternative WLPZ, the key metrics measured were:

Table 2 Sediment Transport field survey information collected

Sediment Erosion Metric	Measurement Method
Date	Pre-harvest, Post-harvest, 1st winter, 2nd winter
Type	Rill, Gully, Channel, Landslide
Size (Volume)	Length x Width x Depth (Cloth tape)
Location	Channel Zone, WLPZ, SOZ, Harvest Unit, Skid Trail, Road
Road Feature Type (if appropriate)	Road related features would be inventoried using our standard quantitative road inventory methods.
Initiation Point	Channel Zone, WLPZ, SOZ, Harvest Unit, Skid Trail, Road
Delivery Point	Wetted Stream Channel, Channel Zone, WLPZ, SOZ, Harvest Unit
Effective Mitigation Measures (if any)	Make qualitative notes regarding waterbars, vegetation, duff layer, coarse soils, topography

4.0 Preliminary Results

4.1 Operations

On May 10, 2006, monitoring of an alternative WLPZ in Etna Creek was proposed by the Company. On June 5, 2006 the NCRWQCB received an application for coverage for the Etna Creek THP under the General Waste Discharge Requirements (WDR). On July 27, 2006 the Etna Creek THP was enrolled and WDID #1A205138SIS was assigned.

Road maintenance operations began on August 8, 2006 and was completed on August 23, 2006. Tractor based timber harvesting operations began on June 1, 2007. Yarder based timber harvesting operations began on June 25, 2007. All timber harvesting operations were completed August 9, 2007. A final timber operations work completion and stocking report was completed and approved by the CDF on June 2, 2008. An application for termination of coverage under the General Waste Discharge Requirements (WDR) for the Etna Creek THP was submitted on July 10, 2009, and a completed Notice of Termination Report was completed by the NCRWQCB staff on March 4, 2010.

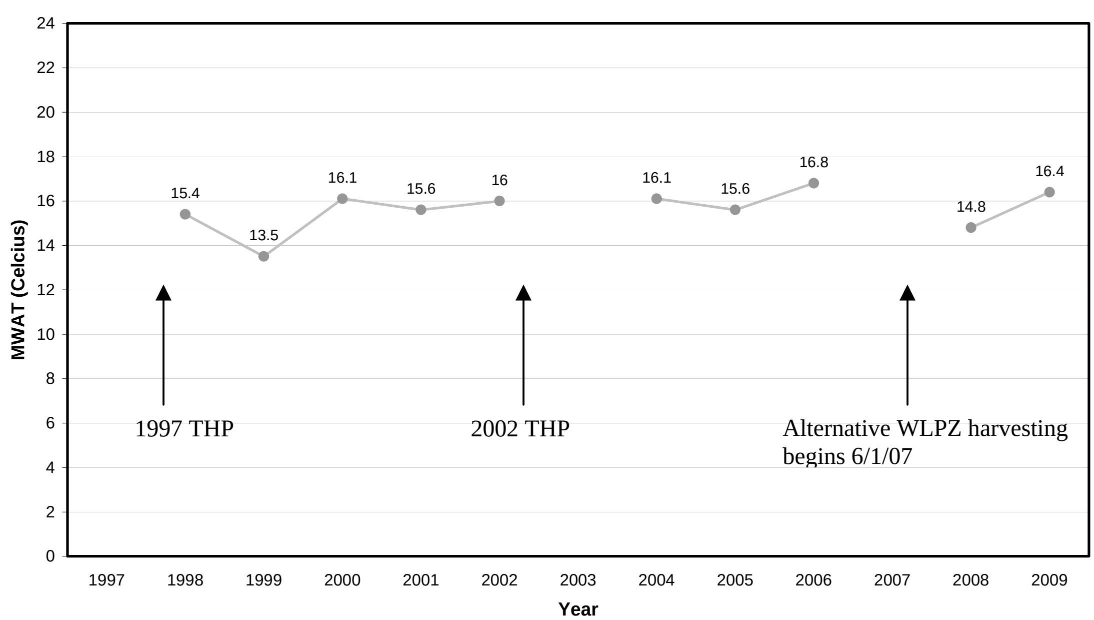
Based on the actual timber harvesting schedule and peak of water temperature in 2007 between July 4th and 10th in lower elevations and July 27th and August 2nd at higher elevations, stream, air and humidity recordings in <u>2006 were considered pre-treatment and 2007, 2008 and 2009 were considered post-treatment.</u>

4.2 Results: Watershed Level Stream Water Temperatures

Stream water temperatures have been collected at one location in the upper Etna Creek watershed since 1998. Since Etna Creek is a very popular for recreational swimming and fishing, over the years equipment has been lost to curious recreationists. While equipment was lost in 1997, 2003 and 2007 at monitoring site TEC2, watershed level monitoring has been completed 10 out of 13 years between 1997 and 2009 (Figure 2 and Appendix D).

During the 13 years of watershed level monitoring three separate THP's have been completed. Following timber harvesting in 1997and 2004 downstream water temperatures remained relatively unchanged. And in this current study pre harvest MWAT temperatures downstream of the alternative WLPZ (Unit #8) was 16.8 C. Following timber harvest MWAT temperatures decreased to 14.8 C and 16.4 in 2008 and 2009, respectively (Figure 2 and Appendix E).

Figure 2 Lower Etna Creek (TEC2) (Downstream of Harvest)



4.3 Results: Reach Level Stream Water Temperatures

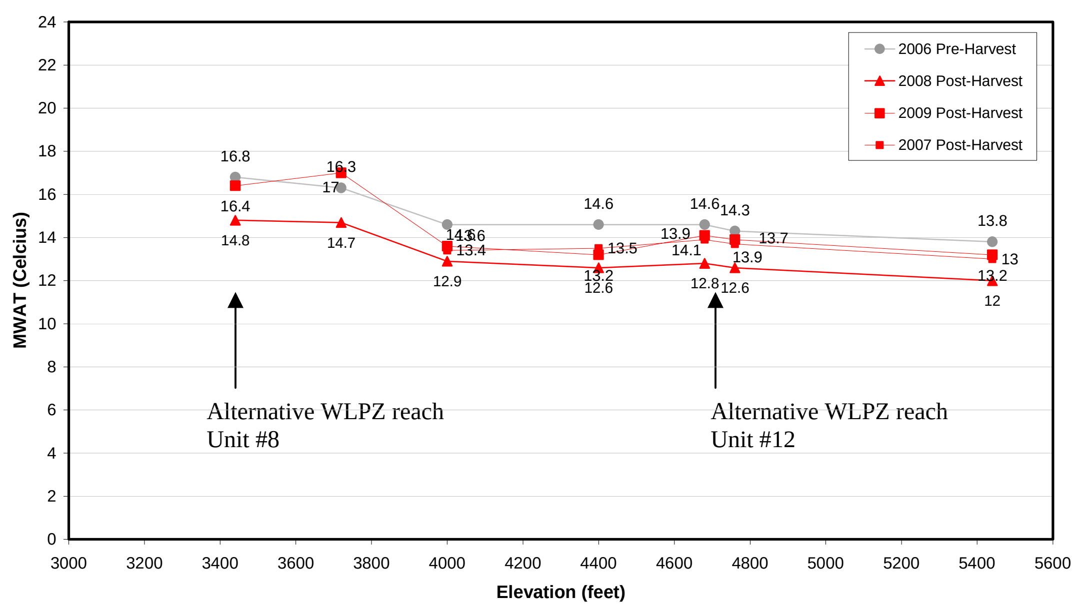
At the reach level, two separate Class I alternative WLPZ reaches, Unit #8 and Unit #12, were measured. Relative to a control upstream of the alternative WLPZ adjacent to the thinning unit (Unit #8), downstream MWAT temperatures were 0.5 C higher pre harvest. MWAT temperatures were 0.1C higher post harvest in 2008 and 0.6 C lower post harvest in 2009 (Figure 3, Table 3 and Appendix E).

At monitoring site TEC6 which was located downstream of the alternative WLPZ adjacent to the clearcut unit (Unit #12), pre harvest MWAT temperature was 14.6 C. MWAT temperatures decreased to 13.9 C, 12.8 C and 14.1 C following harvest in 2007, 2008 and 2009, respectively. Relative to a control upstream of Unit #12, downstream MWAT temperatures was 0.3 C higher pre harvest. MWAT temperatures were 0.2C higher post harvest in 2007, 2008 and 2009 (Table 3, Figure 3 and Appendix E).

Table 3 Etna Creek Class I Streams

Stream Monitoring Location	Monitoring Station Name	Monitoring Year	MWAT (C)	MWAT Relative to Base Year (C)	MWAT Treatment Relative to Control (C)
Downstream of Thinning (Treatment)	TEC2	2006	16.8	- - -	0.5
		2007[A]	- - -	- - -	- - -
		2008	14.8	- 2.0	0.1
		2009	16.4	- 0.4	- 0.6
Upstream of Thinning (Control)	TEC2B	2006	16.3	- - -	- - -
		2007[A]	- - -	- - -	- - -
		2008	14.7	- 1.6	- - -
		2009	17.0	0.7	- - -
Downstream of Clearcut (Treatment)	TEC6	2006	14.6	- - -	0.3
		2007	13.9	- 0.7	0.2
		2008	12.8	- 1.8	0.2
		2009	14.1	- 0.5	0.2
Upstream of Clearcut (Control)	TEC7	2006	14.3	- - -	- - -
		2007	13.7	- 0.6	- - -
		2008	12.6	- 1.7	- - -
		2009	13.9	- 0.4	- - -

Figure 3 Reach Level above and below harvest



At the reach level, for Class II streams, all four of the treatment and control locations were measured 1 year pre harvest and 3 years post harvest (Table 4 and Appendix F). Mean MWAT water temperatures for treatment sites decreased 0.5 C during the study from 13.6 C to 13.1 C. Mean MWAT water temperatures for control sites decreased 0.7 C during the study from 14.0 C to 13.3 C. Relative to controls, mean MWAT water temperatures in Class II streams remained relatively unchanged increasing 0.2 C during the study period.

Table 4 Etna Creek Class II mean temperatures

Stream Monitoring Location	Pre or Post Harvest (years)	MWAT Mean Range (C)	MWAT Mean (C)	MMAT Mean Range (C)	MMAT Mean (C)
Treatment (A2,C2,D2,G2)	Pre (1 year) Post (3 years)	12.7 to 14.2 12.0 to 13.9	13.6 <u>13.1</u> -0.5	13.7 to 16.0 13.2 to 15.3	14.8 <u>14.4</u> -0.4
Control (B2,E2,F2,H2)	Pre (1 year) Post (3 years)	12.9 to 15.8 12.4 to 14.6	14.0 <u>13.3</u> -0.7	13.3 to 17.1 13.2 to 16.5	15.2 <u>14.6</u> -0.6

4.4 Reach Level Air Temperature and Humidity

Air temperature and humidity were collected within both Class I alternative WLPZ's. Adjacent to the thinning, Unit #8, Hobo units functioned well although some data was not retrievable from Hobo units for the outer zone relative humidity (Table 4 and Appendix E). Relative to a control, adjacent to the thinning unit the alternative WLPZ air temperature was relatively unchanged, -0.5 C for the inner zone and 0.3 C for the outer zone. And relative to the control, relative humidity increased 5.3% in the inner zone and decreased 1.4% in the outer zone.

Adjacent to the clearcut, Unit #12, Hobo units functioned well although again some data was not retrievable from Hobo units for the inner zone relative humidity (Table 4 and Appendix E). Relative to a control, adjacent to the clearcut unit the alternative WLPZ air temperature was relatively unchanged, -0.3 C for the inner zone and increased 1.0 C for the outer zone. Relative to the upstream control, relative humidity decreased 9.0% in the outer zone. Since all air temperature and humidity data was not retrievable for all years, creating inconsistencies in sample size and sample years, these results should be viewed with some caution.

Table 4 Etna Creek Class I air temperatures and humidity (See Appendix E)

Stream Monitoring Location	Pre or Post Harvest (years)	Inner Zone Mean Air (C)	Outer Zone Mean Air (C)	Inner Zone Mean RH (%)	Outer Zone Mean RH (%)
Downstream of Thinning (Treatment TEC2)	Pre (1 year)	22.2	22.7	70.7	68.1
	Post (3 years)	21.6	22.5	51.8	51.0
	Change	-0.6	-0.2	-18.9	-17.1
Upstream of Thinning (Control TEC2B)	Pre (1 year)	21.0	22.3	72.7	66.7
	Post (3 years)	20.9	21.8	48.5	51.0
	Change	-0.1	-0.5	-24.2	-15.7
Thinning Treatment relative to Control		**-0.5 C**	**0.3 C**	**5.3 %**	**-1.4 %**
Downstream of Clearcut (Treatment TEC6)	Pre (1 year)	19.2	19.9	80.0	76.2
	Post (3 years)	17.8	19.1	64.9	60.9
	Change	-1.4	-0.8	-15.1	-15.3
Upstream of Thinning (Control TEC7)	Pre (1 year)	18.7	19.6	nd	76.0
	Post (3 years)	17.6	17.8	74.5	69.7
	Change	-1.1	-1.8	nd	-6.3
Clearcut Treatment relative to Control		**-0.3 C**	**1.0 C**	**nd**	**-9.0 %**

Air temperature and humidity were collected within 4 treatment Class II alternative WLPZ's and 4 control WLPZ's. Hobo units functioned very well within all Class II stream WLPZ's with no unit malfunctions. Mean pre harvest air temperature was 1.6 C and 2.4 C greater in the outer zone than the inner zone for the treatment and control sites, respectively. Mean pre harvest humidity was 7.0% and 13.2% lower in the outer zone than the inner zone for treatment and control sites, respectively. During the study the mean treatment alternative WLPZ air temperature decreased -0.7 C for the inner zone and -0.2 C for the outer zone. However, relative to the 4 control sites, air temperature increased 1.1C for the inner zone and 1.5 C for the outer zone.

Mean treatment alternative WLPZ humidity decreased 15.7% in the inner zone and 14.1% in the outer zone. And, relative to the 4 control sites, humidity decreased 4.6% in the inner zone and 5.0% in the outer zone during the study.

Table 5 Etna Creek Class II air temperatures and humidity (See Appendix F)

Stream Monitoring Location	Pre or Post Harvest (years)	Inner Zone Mean Air (n=4)(C)	Outer Zone Mean Air (n=2)(C)	Inner Zone Mean RH (n=4)(%)	Outer Zone Mean RH (n=2)(%)
Treatment (A2,C2,D2,G2)	Pre (1 year)	21.5	23.1	69.8	62.8
	Post (3 years)	20.9	22.9	54.1	48.7
	Change	-0.7	-0.2	-15.7	-14.1
Control (B2,E2,F2,H2)	Pre (1 year)	21.2	23.6	69.6	56.4
	Post (3 years)	19.4	22.0	58.5	47.2
	Change	-1.8	-1.6	-11.2	-9.1
Treatment relative to Control		**1.1 C**	**1.5 C**	**-4.6 %**	**-5.0 %**

4.5 Canopy Closure within alternative WLPZ

Pre and post harvest field surveys were completed for 6,100 feet of Class I stream channel and alternative WLPZ. A total of 61 survey plots (Table 6) along the stream channels were measured. Class I canopy closure measurements with a siting tube consistently measured lower canopy closure than a densiometer. Pre harvest Class I siting tube measurements ranged from 6% to 16% lower, inner zone ranged from 1% to 6% lower and outer zone ranged from 11% to 17% lower (Table 6).

During timber harvest, for the thinning unit the alternative WLPZ siting tube based canopy closure in the outer zone was reduced from 72% to 53% and for the clearcut unit the alternative WLPZ site tube based canopy closure in the outer zone was reduced from 67% to 53%.

Table 6 Pre and Post Harvest Canopy Closure for CLASS I Alternative WLPZ

WLPZ Canopy Closure		Number of Plots (n)	Number of Measure Ments	Pre Harvest Mean (%)	Pre Harvest Range (%)	Post Harvest Mean (%)	Post Harvest Range (%)
Class I (TEC2)							
Stream Channel	(Densiometer)	51	204	74%	40 - 97%	- - -	- - -
Inner Zone	(Densiometer)	51	204	84%	33 - 98%	- - -	- - -
Outer Zone	(Densiometer)	51	204	83%	65 - 95%	73%	34 – 98%
Class I (TEC2)							
Stream Channel	(Siting tube)	51	204	58%	0 – 100%	- - -	- - -
Inner Zone	(Siting tube)	51	204	78%	11 – 100%	- - -	- - -
Outer Zone	(Siting tube)	51	204	**72%**	0 - 100%	**53%**	0 – 100%
Class I (TEC6)							
Stream Channel	(Densiometer)	10	90	67%	35 – 94%	- - -	- - -
Inner Zone	(Densiometer)	10	90	87%	41– 100%	- - -	- - -
Outer Zone	(Densiometer)	10	90	84%	63 - 94%	53%	0 – 100%
Class I (TEC6)							
Stream Channel	(Siting tube)	10	90	61%	44 – 78%	- - -	- - -
Inner Zone	(Siting tube)	10	90	86%	33 – 100%	- - -	- - -
Outer Zone	(Siting tube)	10	90	**67%**	0 - 100%	**53%**	0 – 100%

* TEC2 is the selection unit and TEC6 is the clearcut unit.

Pre and post harvest field surveys were completed for 10,980 feet of Class II stream channel and alternative WLPZ. A total of 124 Class II survey plots (Table 7) along the stream channels were measured. Class II canopy closure measurements with a siting tube consistently measured lower canopy closure than a densiometer. Pre harvest Class II in channel siting tube measurements ranged from 13% to 19% lower, inner zone was 13% lower and outer zone was 13% lower (Table 7).

During timber harvest, as measured with a siting tube, mean alternative WLPZ siting tube based canopy closure in the outer zone was reduced within four treatment reaches from 70% to 62% or an average of 8%.

Table 7 Pre and Post Harvest Canopy Closure for CLASS II Alternative WLPZ

WLPZ Canopy Closure	Number of Plots (n)	Number of Measure Ments	Pre Harvest Mean (%)	Pre Harvest Range (%)	Post Harvest Mean (%)	Post Harvest Range (%)
Class II (Control 3,400ft)						
Stream Channel (Densiometer)	38	152	84%	55 - 98%	- - -	- - -
Inner Zone (Densiometer)	- - -	- - -	- - -	- - -	- - -	- - -
Outer Zone (Densiometer)	- - -	- - -	- - -	- - -	- - -	- - -
Class II (Control)						
Stream Channel (Siting tube)	38	342	65%	22 – 100%	- - -	- - -
Inner Zone (Siting tube)	- - -	- - -	- - -	- - -	- - -	- - -
Outer Zone (Siting tube)	- - -	- - -	- - -	- - -	- - -	- - -
Class II (Treatment 7,580ft)						
Stream Channel (Densiometer)	86	344	87%	47 – 100%	- - -	- - -
Inner Zone (Densiometer)	86	344	88%	55– 100%	81%	0 – 95%
Outer Zone (Densiometer)	86	344	83%	19 – 100%	75%	0 – 89%
Class II (Treatment)						
Stream Channel (Siting tube)	86	774	74%	11 – 100%	- - -	- - -
Inner Zone (Siting tube)	86	774	75%	11 – 100%	74%	0 – 100%
Outer Zone (Siting tube)	86	774	**70%**	0 – 100%	**62%**	0 – 100%

4.6 Sediment Transported to and through the WLPZ

Sediment erosion surveys were conducted, both pre and post harvest, to determine whether sediment was being transported to and through the Class I and II alternative WLPZ's. All existing and historic sediment erosion sources were recorded within the Class I and II stream channel zone, alternative WLPZ, and harvest units immediately adjacent to the alternative WLPZ. Pre harvest sediment erosion surveys started on May 10, 2006. A total of 6,100 lineal feet of Class I and 7,580 feet of Class II stream channel were surveyed (Table 8). Post harvest sediment erosion surveys started on April 15, 2008 following the first winter after operations.

Post harvest sediment erosion surveys found that all 3 erosion sites located along the Class I thinning unit were effectively stopped. The county road ditch was previously gullying through the thinning harvest unit and alternative WLPZ. Strategic placement of waterbars and slash over all skids trails effectively stopped erosion from continuing to route to the wetted zone of Etna Creek. At one of the erosion sites along reach EC2, erosion from the county road ditch and spoils pile was previously gullying through the thinning harvest unit and alternative WLPZ. Again, strategic placement of waterbars and slash over all skids trails effectively stopped erosion from continuing to route to the wetted zone of Etna Creek (Table 8).

Of the five original sediment erosion sites found along Class II treatment streams during pre harvest surveys, two sites had strategic placement of waterbars and slash over all skids trails effectively stopping erosion from continuing to route to the Class II wetted zone. The remaining three sites are in-channel features located within either the channel or wetted zone and no mitigation was proposed for these sites.

Post harvest sediment erosion surveys along the Class II reaches found two new erosion sites (Table 8). One, ECC2 a road surface erosion site where strategic placement of a berm and rolling dip effectively routed erosion away from the WLPZ and over the forest floor. Two, ECA2 a landing failure occurred where less than 0.5 cuyd was routed to the Class III WLPZ. No sediment was routed to the Class II ECA2 reach. Existing ground vegetation, trees and topography limited routing of the landing failure and no further erosion has occurred.

In summary, the alternative WLPZ and adjacent harvest units did not initiate any new large landslides or surface erosion. The alternative WLPZ's effectively stopped pre-existing sources of sediment from road, skid trails and harvest units. Existing roads generated two new relatively small sediment sources. Results indicate that sediment being transported to the alternative WLPZ or initiated within the alternative WLPZ was effectively trapped prior to entering the channel zone or stream wetted zone.

Table 8 Pre harvest erosion survey started on 5/10/06 and post harvest started on 4/15/08

Erosion Survey Reach	Description	Initiation Location	Initiation Source	Delivery Zone	Delivery Distance	Erosion (cuyds)	Post harvest condition
	Pre Harvest Survey						
EC2(t)	County road culvert	HU	R	CZ	395	59.8	No erosion
EC2(t)	County road spoils pile	R	R	WZ	1993	36.6	No erosion
EC2(t)	County road culvert	HU	R	WZ	345	40.8	No erosion
EC6(t)	No erosion found	- - -	- - -	- - -	- - -	- - -	NC
ECA2(t)	No erosion found	- - -	- - -	- - -	- - -	- - -	NC
ECC2(t)	County road ditch line	CZ	R	CZ	30	0.1	NC
ECC2(t)	County road erosion routed	CZ	R	WZ	34	2.5	No erosion
ECD2(t)	Historic in-channel failure	CZ	CZ	WZ	3	7.1	NC
ECG2(t)	Pre-existing gully	WZ	HU	CZ	46	0.6	NC
ECG2(t)	Pre-existing gully	WZ	SK	WZ	112	1.2	No erosion
ECB2(c)	No erosion found	- - -	- - -	- - -	- - -	- - -	NC
ECE2(c)	Historic in-channel failure	WLPZ	WLPZ	WZ	0	303.3	NC
ECH2(c)	Rill and gully	WLPZ	WLPZ	WLPZ	37	0.1	NC
ECF2(c)	Historic in-channel failure	WLPZ	WLPZ	WZ	30	133.3	NC
	Post Harvest Survey	**New Sites**					
ECC2(t)	Road surface erosion	R	R	WLPZ	70	<0.5	Routed away from channel
ECA2(t)	Landing failure	R	R	WLPZ	60	<0.5	No further erosion

CZ = Channel Zone WZ = Wetted Zone WLPZi = WLPZ Inner zone WLPZo = WLPZ Outer zone
WLPZe = WLPZ edge with unit R = Road SK = Skid trail HU = Harvest Unit
(t) = treatment reach (c)=control reach NC=No Change

5.0 Summary of Results

(1) The harvesting of trees from the outer zone of the Class I alternative WLPZ resulted in a reduction of canopy closure from 72% to 53% for the thinning unit and from 67% to 53% for the clearcut unit.

(2) Both watershed level and reach level Class I MWAT water temperatures remained relatively unchanged following alternative WLPZ timber harvest.

(3) Reach level Class II MWAT water temperatures remained relatively unchanged following alternative WLPZ timber harvest.

(4) Class I riparian air temperatures and humidity in the inner zones of the alternative WLPZ's remained relatively unchanged following timber harvest, while the outer zone, along one reach air temperature increased 1.0C and humidity decreased 9.0%.

(5) Following timber harvest Class II riparian inner zone air temperatures increased 1.1C and humidity decreased 4.6%. Outer zone air temperatures increased 1.5C and humidity decreased 5.0%.

(6) Sediment transported <u>to</u> the WLPZ from roads, skid trails or harvest units was stopped by strategic placement of waterbars and slash over all skids trails and landings, effectively stopping erosion from continuing to route to wetted zones.

6.0 Limitations of Results

It should be noted that this investigation has identified some preliminary cause-and-effect relationships between riparian and stream channel habitats and current forest management activities in California. And these results have been measured during, the most acute potential impacts from timber harvesting. However, due to the relatively short study period and limited sample size, one sample reach, generalization of the results should be limited to stream channels with similar geomorphic and ecological conditions and timber harvests with similar silvicultural prescriptions.

7.0 References

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Appendix C: Class I Water Temperature Monitoring Sites (See Water Quality Map)

Monitoring Site #	Elevation (meter) (feet)	Monitoring Type	Monitoring Years	Stream Class	Control or Treatment
TEC2	1024 m (3,410 ft)	Stream Water WLPZ Air < 50ft WLPZ Air < 150ft	1997 to 2009	Class I	Baseline and Treatment
TEC2B	1117 m (3,720 ft)	Stream Water WLPZ Air < 50ft WLPZ Air < 150ft	2006 to 2009	Class I	Control
TEC4	1201 m (4,000 ft)	Stream Water	1997 to 2009	Class I	Control
TEC5	1321 m (4,400 ft)	Stream Water	2006 to 2009	Class I	Control
TEC6	1405 m (4,680 ft)	Stream Water WLPZ Air < 50ft WLPZ Air < 150ft	2006 to 2009	Class I	Treatment
TEC7	1429 m (4,760 ft)	Stream Water WLPZ Air < 50ft WLPZ Air < 150ft	2006 to 2009	Class I	Control
TECA2	1099 m (3,660 ft)	Stream Water WLPZ Air < 25ft WLPZ Air < 100ft	2006 to 2009	Class II	Treatment
TECB2	1093 m (3,640 ft)	Stream Water WLPZ Air < 25ft WLPZ Air < 100ft	2006 to 2009	Class II	Control
TECC2	1087 m (3,620 ft)	Stream Water WLPZ Air < 25ft	2006 to 2009	Class II	Treatment
TECD2	1137 m (3,787 ft)	Stream Water WLPZ Air < 25ft WLPZ Air < 100ft	2006 to 2009	Class II	Treatment
TECE2	1165 m (3,880 ft)	Stream Water WLPZ Air < 25ft WLPZ Air < 100ft	2006 to 2009	Class II	Control
TECF2	1315 m (4,380 ft)	Stream Water WLPZ Air < 25ft	2006 to 2009	Class II	Control
TECG2	1597 m (5,320 ft)	Stream Water WLPZ Air < 25ft	2006 to 2009	Class II	Treatment
TECH2	1634 m (5,440 ft)	Stream Water WLPZ Air < 25ft	2006 to 2009	Class II	Control

Appendix D: Etna Creek (TEC2) (Downstream of Harvest)

Calendar Year	Sampling Period	7-day MWAT Period	Diurnal Fluctuation C	MMAT[1] C° and F°	MWAT[1] C° and F°
1996	No Data				
1997	Dewatered				
1998	5/14 to 11/26	8/9 to 8/15	2.2	16.4 (61.8F)	15.4 (60.0F)
1999	5/21 to 11/18	7/30 to 8/5	3.5	15.2 (59.7F)	13.5 (56.6F)
2000	5/25 to 10/31	8/2 to 8/8	2.7	17.1 (63.1F)	16.1 (61.3F)
2001	7/17 to 10/9	8/3 to 8/9	3.0	16.7 (62.4F)	15.6 (60.4F)
2002	6/19 to 10/9	7/12 to 7/18	3.7	17.8 (64.4F)	16.0 (61.1F)
2003	Hobo Stolen				
2004	6/2 to 9/22	7/23 to 7/29	3.1	17.6 (64.0F)	16.1 (61.3F)
2005	6/9 to 10/29	8/6 to 8/12	2.4	16.8 (62.6F)	15.6 (60.4F)
2006	5/24 to 11/1	7/21 to 7/27	3.4	18.3 (65.3F)	16.8 (62.6F)
2007	Hobo Lost				
2008	5/29 to 10/2	8/12 to 8/18	3.1	16.0 (61.1F)	14.8 (58.9F)
2009	5/29 to 10/12	7/27 to 8/2	2.6	17.5 (63.9F)	16.4 (61.8F)

1 MWAT is the Maximum Weekly Average Temperature, MMAT = Maximum Weekly Maximum Temperature

Appendix E: Etna Creek Class I water temperatures

Calendar Year (Class I Stream)	Sampling Period	7-day MWAT Period	Diurnal Fluctuation	MMAT	MWAT
TEC2					
2006	5/24 to 11/1	7/21 to 7/27	3.4	18.3	16.8
2007[B]					
2008	5/29 to 10/2	8/12 to 8/18	3.1	16.0	14.8
2009	5/29 to 10/12	7/27 to 8/2	2.6	17.5	16.4
TEC2B					
2006	5/24 to 11/1	7/21 to 7/27	3.8	18.3	16.3
2007 [B]					
2008	5/29 to 10/2	8/13 to 8/19	3.1	16.0	14.7
2009	5/29 to 10/12	7/27 to 8/2	3.1	18.7	17.0
TEC4					
2006	5/24 to 11/1	7/21 to 7/27	4.2	16.8	14.6
2007	5/22 to 11/5	7/25 to 7/31	3.4	15.2	13.4
2008	5/29 to 10/21	8/12 to 8/18	3.9	14.9	12.9
2009	5/29 to 10/12	7/26 to 8/1	3.0	15.2	13.6
TEC5					
2006	5/24 to 11/1	7/21 to 7/27	2.3	16.0	14.6
2007	5/22 to 11/5	7/6 to 7/12	2.6	15.2	13.5
2008	5/29 to 10/21	7/9 to 7/15	2.3	13.7	12.6
2009	5/29 to 10/12	7/26 to 8/1	2.9	14.1	13.2
TEC6					
2006	5/24 to 11/1	7/21 to 7/27	2.7	15.6	14.6
2007	5/22 to 11/5	7/25 to 7/31	1.6	14.5	13.9
2008	5/29 to 10/21	8/12 to 8/18	2.7	14.1	12.8
2009	5/29 to 10/12	7/26 to 8/1	3.0	14.9	14.1
TEC7					
2006	5/24 to 11/1	7/21 to 7/27	3.1	16.0	14.3
2007	5/22 to 11/5	7/25 to 7/31	2.6	15.2	13.7
2008	5/29 to 10/21	8/12 to 8/18	3.1	14.1	12.6
2009	5/29 to 10/12	7/27 to 8/2	2.6	15.2	13.9
A = dewatered or partially dewatered	B = Unit lost or stolen				

Appendix E: Etna Creek Class I air temperatures and humidity

Calendar Year (Class I streams)	Sampling Period	Inner Zone Mean Air (C)	Outer Zone Mean Air (C)	Inner Zone Mean RH (%)	Outer Zone Mean RH (%)
(Class I stream)					
TEC2					
2006	5/24 to 11/1	22.2	22.7	70.7	68.1
2007[B]	nd water	21.7	22.3	51.5	50.1
2008	5/29 to 10/2	21.3	21.8	54.5	52.8
2009	5/29 to 10/12	23.7	23.3	49.4	50.0
TEC2B					
2006	5/24 to 11/1	21.0	22.3	72.7	66.7
2007 [B]	nd water	20.8	21.4	48.4	51.0
2008	5/29 to 10/2	20.2	21.0	48.9	nd
2009	5/29 to 10/12	21.7	22.9	48.2	nd
TEC6					
2006	5/24 to 11/1	19.2	19.9	80.0	76.2
2007	5/22 to 11/5	17.9	18.5	63.2	61.2
2008	5/29 to 10/21	17.3	19.0	66.6	58.5
2009	5/29 to 10/12	18.1	19.9	nd	63.1
TEC7					
2006	5/24 to 11/1	18.7	19.6	nd	76.0
2007	5/22 to 11/5	17.0	17.4	nd	69.6
2008	5/29 to 10/21	17.6	17.8	nd	66.0
2009	5/29 to 10/12	18.2	18.3	74.5	73.6
A = dewatered or partially dewatered	B = Water unit lost or stolen	nd=no data			

Appendix F: Etna Creek Class II water temperatures

Calendar Year (Class II Stream)	Sampling Period	7-day MWAT Period	Diurnal Change (C)	MMAT (C)	MWAT (C)
TECA2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	2.3	15.2	14.2
2008	5/22 to 11/5	7/4 to 7/10	3.4	15.2	13.8
2009	5/29 to 10/21	8/11 to 8/17	3.6	15.2	13.6
	5/29 to 10/12	7/26 to 8/1	2.7	15.6	14.3
TECB2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	2.3	14.5	13.5
2008	5/22 to 11/5	7/4 to 7/10	3.1	14.1	12.8
2009	5/29 to 10/21	8/11 to 8/17	2.7	14.1	13.0
	5/29 to 10/12	7/26 to 8/1	2.3	14.8	13.6
TECC2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	1.9	13.7	12.7
2008	5/22 to 11/5	7/27 to 8/2	3.1	14.5	12.9
2009	5/29 to 10/21	8/12 to 8/18	3.5	14.5	12.7
	5/29 to 10/12	7/26 to 8/1	3.1	14.9	13.4
TECD2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	1.9	14.3	13.6
2008	5/22 to 11/5	7/27 to 8/2	1.9	14.5	13.5
2009	5/29 to 10/21	8/12 to 8/18	3.4	15.2	13.4
	5/29 to 10/12	7/26 to 8/1	1.6	14.5	13.8
TECE2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	3.0	17.1	15.8
2008	5/22 to 11/5	7/5 to 7/11	3.5	16.8	15.0
2009	5/29 to 10/21	8/12 to 8/18	3.8	16.4	14.5
	5/29 to 10/12	8/11 to 8/17	5.0	16.4	14.4
TECF2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	1.5	13.3	12.9
2008	5/22 to 11/5	7/27 to 8/2	1.5	12.9	12.3
2009	5/29 to 10/21	8/14 to 8/20	1.9	12.9	11.9
	5/29 to 10/12	7/26 to 8/1	1.9	13.7	13.0
TECG2					
2006[A]					
2007	5/24 to 11/1	7/19 to 7/25	3.4	16.0	13.9
2008	5/22 to 11/5	7/27 to 8/2	3.1	13.3	12.3
2009	5/29 to 10/21	8/12 to 8/18	3.1	12.9	11.6
	5/29 to 10/12	7/26 to 8/1	3.1	13.3	12.0
TECH2					
2006					
2007	5/24 to 11/1	7/21 to 7/27	4.6	16.0	13.8
2008	5/22 to 11/5	7/27 to 8/2	3.8	15.2	13.0
2009	5/29 to 10/21	8/12 to 8/18	3.9	13.7	12.0
	5/29 to 10/12	7/26 to 8/1	3.5	14.9	13.2
A = dewatered or partially dewatered					

Appendix F: Etna Creek Class II air temperatures and humidity

Calendar Year (Class II streams)	Sampling Period	Inner Zone Mean Air (C)	Outer Zone Mean Air (C)	Inner Zone Mean RH (%)	Outer Zone Mean RH (%)
TECA2					
2006	5/24 to 11/1	22.2	23.3	68.6	61.2
2007	5/22 to 11/5	21.8	23.2	64.7	57.0
2008	5/29 to 10/21	21.0	22.3	51.4	46.9
2009	5/29 to 10/12	23.1	24.2	47.3	43.5
TECB2					
2006	5/24 to 11/1	22.9	24.8	62.4	50.1
2007	5/22 to 11/5	20.6	23.7	74.6	51.1
2008	5/29 to 10/21	20.5	23.7	56.9	38.1
2009	5/29 to 10/12	21.5	24.8	58.7	37.2
TECC2					
2006	5/24 to 11/1	21.5	nd	74.3	nd
2007	5/22 to 11/5	17.9	nd	54.9	nd
2008	5/29 to 10/21	20.0	nd	58.1	nd
2009	5/29 to 10/12	22.0	nd	56.2	nd
TECD2					
2006	5/24 to 11/1	21.8	22.8	71.9	64.4
2007	5/22 to 11/5	21.3	22.1	52.8	48.7
2008	5/29 to 10/21	20.6	21.8	54.9	49.2
2009	5/29 to 10/12	22.6	23.6	51.6	47.0
TECE2					
2006	5/24 to 11/1	21.5	22.4	71.8	62.6
2007	5/22 to 11/5	19.9	21.0	73.8	67.4
2008	5/29 to 10/21	18.2	21.4	44.9	45.5
2009	5/29 to 10/12	16.6	17.2	50.0	44.1
TECF2					
2006	5/24 to 11/1	20.3	nd	73.9	nd
2007	5/22 to 11/5	19.1	nd	62.9	nd
2008	5/29 to 10/21	18.2	nd	65.7	nd
2009	5/29 to 10/12	20.6	nd	57.4	nd
TECG2					
2006	5/24 to 11/1	20.5	nd	64.4	nd
2007	5/22 to 11/5	19.2	nd	52.2	nd
2008	5/29 to 10/21	20.1	nd	47.2	nd
2009	5/29 to 10/12	20.6	nd	57.4	nd
TECH2					
2006	5/24 to 11/1	20.0	nd	70.4	nd
2007	5/22 to 11/5	18.2	nd	55.4	nd
2008	5/29 to 10/21	18.9	nd	51.5	nd
2009	5/29 to 10/12	20.6	nd	49.6	nd

nd=no data collected

Appendix A: Etna Creek THP

Appendix B: Etna Creek Monitoring Plan