North River Bacteria and Temperature Verification Study

Data Summary

DEPARTMENT OF ECOLOGY
State of Washington

June 2016
Publication No. 16-03-003

Publication and contact information

This report is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1603003.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search Study ID JKAR0005.

The Activity Tracker Code for this study is 14-058.

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Cover photo: Near the mouth of the North River, facing upstream.
(Photographed by Meghan Rosewood-Thurman)

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Bacteria and Temperature
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Data Summary

by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIA
- 24 - Willapa

HUC number
- 17100106 - Willapa Bay

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Abstract

The North River is located in Pacific and Grays Harbor Counties in rural southwest Washington. The river flows through industrial timberland and empties into the northeast section of Willapa Bay. Certain reaches of the North River and contributing tributaries are included on the Washington State 303(d) list of impaired waterbodies because they did not meet surface water quality criteria for fecal coliform bacteria (FC) and temperature.

This technical study evaluates FC and temperature during the 2014-2015 study and determines whether the existing 303(d) listed stream segments meet Washington State surface water quality criteria. Initial data collection in 1993 and 1996 led to the 303(d) listings for FC and temperature. Since the original listings, actions have been taken to reduce water quality impairments. This data summary verifies current FC and temperature conditions and suggests further recommendations for mitigating the 303(d) listed waterbodies.

The findings of this study reveal exceedance for FC and temperature at the study locations. The two listed FC sites are not meeting *Primary Contact, Marine Water Quality Standards* for FC. This study recommends the listings remain in Category 5 for the next water quality assessment.

The Ecology (2014) and Port Blakely (2010) monitored temperature sites are exceeding their respective *Core Summer Salmonid Habitat* and *Supplemental Spawning Criteria,* with the exception of Upper Martin and Upper Redfield. This study also recommends these listings remain in Category 5.

Acknowledgements

The author of this report thanks the following people for their contributions to this study:

- Blake Murden, Port Blakely Tree Farms
- Faith Taylor-Eldred and Megan McNelly, Pacific County
- Steve Spencer, Shoalwater Bay Tribe
- Hancock Forest Management
- Weyerhaeuser Company
- Washington State Department of Ecology staff:
  - Andrew Kolosseus, Dustin Bilhimer, Craig Graber, and Chad Brown, Water Quality Program
  - Jenny Wolfe, Siana Wong, and Renee Fields for assistance in the field
  - George Onwumere, Nuri Mathieu, and Debby Sargeant for peer review
  - Edlin Limmer, Nancy Rosenbower, Leon Weiks, Dean Momohara, and other Manchester Environmental Laboratory staff
- Former Ecology staff:
  - David Rountry, Robert F. Cusimano, James Kardouni, Meaghan Mounger, and Chelsie Strowbridge

Introduction

Background

Washington State is obligated to meet the federal Clean Water Act requirements of section 303(d). Stream reaches that exceed water quality criteria are placed on the 303(d) list, a list of polluted waters that require a cleanup plan. Certain reaches of the North River and contributing tributaries were listed for violating Washington State's water quality criteria for temperature and bacteria (Table 1). The current water quality assessment may be viewed at the following website: http://www.ecy.wa.gov/programs/wq/303d/currentassessmt.html

Table 1. 303(d) listed stream reaches exceeding water quality criteria.

Water Body	Parameter	Listing ID	NHD Reach Code	Township Range Section
North River	Bacteria	6691	17100106000243	15N - 10W – 23
North River	Bacteria	6686	17100106000240	15N - 10W – 22
North River	Temperature	6909	17100106000257	16N - 9W – 32
North River	Temperature	6913	17100106000268	16N - 8W – 9
North River	Temperature	6907	17100106000266	16N - 8W – 8
North River, East Fork	Temperature	6905	17100106000348	16N - 9W – 29
Joe Creek	Temperature	6906	17100106000434	16N - 8W – 31
Martin Creek	Temperature	35312	17100106000298	15N - 6W – 35
Martin Creek	Temperature	35307	17100106000298	15N - 6W – 28
Raimie Creek	Temperature	35306	17100106000303	15N - 6W – 16
Redfield Creek	Temperature	35316	17100106000300	15N - 6W – 15
Redfield Creek	Temperature	35314	17100106000300	15N - 6W – 22
Salmon Creek, Upper	Temperature	6911	17100106000411	16N - 8W – 9
Sullivan Creek	Temperature	35320	17100106000501	15N - 6W – 10
Unnamed Creek (trib to N. River)	Temperature	6908	17100106000440	16N - 9W – 33

NHD: National Hydrography Data (stream reach code at the 303(d) listed location)

Data collected in 1993 listed two reaches of the North River for fecal coliform bacteria (FC). (Table 1). The Willapa watershed bacterial evaluation and Preliminary Control Strategy, (Seyferlich and Joy, 1993) prompted cleanup actions near the 303(d) listed reaches. These control strategies included restrictions for discharge of septage from Float Houses and the discontinuation of two significant livestock operations near the river's edge. Additional bacteria sampling was conducted by the Shoalwater Bay Tribe from 1999 through 2000 and reportedly met water quality criteria (Rountry, 2013) but that data could not be found and was not included in subsequent water quality assessments. No other recent bacteria data are available.

Temperature data collected in past studies in the 1990s exceeded water quality criteria (Table 1). The temperature listings from the North River, East Fork North River, Joe Creek, Upper Salmon Creek, and the unnamed tributary were collected from time-series data during 1996 and 1997 study period. The temperature listings of Martin, Raimie, Redfield, and Sullivan Creeks represent time-series data collected during 1996 and submitted in 2002.

Since then, efforts to restore and maintain natural thermal conditions have been implemented by the Washington State Department of Natural Resources (DNR) Forest Practice Rules (Title 222 WAC). The Forest Practices Rules establish standards for forest practices such as timber harvest, riparian buffers, pre-commercial thinning, road construction and maintenance, fertilization, and forest chemical application (DNR, 2013). Forest Practice Rules apply throughout the watershed on all industrial timberlands except for parcels managed by Port Blakely Tree Farms (PBTF) under an approved Habitat Conservation Plan.

PBTF has monitored yearly summer temperatures in a network of streams listed under their individually prescribed Habitat Conservation Plan (HCP). The HCP was developed in 1996 between Port Blakely and both the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration (NOAA) Fisheries. The monitoring locations were established to evaluate responses of these streams to their HCP's forest management prescriptions. Port Blakely's temperature monitoring locations coincide with the 303(d) listed reaches for Raimie, Sullivan, Martin, and Redfield Creeks.

The 2014 Quality Assurance (QA) Project Plan for the *North River and Bacteria and Temperature Verification Study* was developed to assess the 303(d) listed stream reaches within the North River watershed (Kardouni, 2014). The study period lasted from February 2014 through June 2015 to verify FC listings at the mouth of the North River and to collect continuous temperature data.

Beneficial Uses and Water Quality Criteria

Fecal Coliform Bacteria

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state (WAC 173-201A, 2011).

The FC criteria have two statistical components: a geometric mean criterion and an upper limit criterion that 10% of the samples cannot exceed. FC samples collected randomly usually follow a log-normal distribution, which will be taken into account in the final data analysis.

Freshwater and marine water bodies are required to meet water quality standards based on beneficial uses. Numeric criteria for specific water quality parameters are intended to protect designated uses. The North River and the nearby brackish estuaries of northern Willapa Bay are classified as *Primary Contact* waters. Potential sources of FC pollution in the study area include

storm runoff from logged hillsides, untreated greywater, Float House septage, and wildlife (the latter is considered part of "natural background levels").

The application of freshwater and marine water quality criteria is based on salinity as described in the WAC 173-201A-260:

"*(e) In brackish waters of estuaries, where different criteria for the same use occurs for fresh and marine waters, the decision to use the fresh water or the marine water criteria must be selected and applied on the basis of vertically averaged daily maximum salinity, referred to below as "salinity."*

(i) The fresh water criteria must be applied at any point where ninety-five percent of the salinity values are less than or equal to one part per thousand, except that the fresh water criteria for bacteria applies when the salinity is less than ten parts per thousand; and

(ii) The marine water criteria must apply at all other locations where the salinity values are greater than one part per thousand, except that the marine criteria for bacteria applies when the salinity is ten parts per thousand or greater".

Freshwater criteria for bacteria apply when 95% of salinity values (in the span of a year) are less than ten parts per thousand (ppt). Marine water criteria apply when salinity is 10 ppt or greater.

For those areas where there is true ambiguity about whether there is marine influence, then the WAC 173-201A-260(c) and -260(d) apply:

"*C. Where multiple criteria for the same water quality parameter are assigned to a water body to protect different uses, the most stringent criterion for each parameter is to be applied.*
D. At the boundary between water bodies protected for different uses, the more stringent criteria apply."

Freshwater Criteria

The upstream bacteria sampling location(s), outside of the 303(d) listed stream sections, are considered indeterminate for marine or freshwater criteria due to tidal and seasonal constraints. To aid in the recommendation for upstream water criteria, the project lead will calculate FC freshwater boundary target values using methods described in the *Lower Skagit River TMDL Water Quality Study* (Pickett, 1997). The boundary target values are weighed by the percentage of fresh and marine water across both the wet and dry seasons.

Marine Water Criteria

In marine (salt) waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, FC are used as indicator bacteria to gauge the risk of exposure to waterborne pathogens.

To protect *Shellfish Harvesting* and *Primary Contact Recreation* (swimming or water play): "*Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL,*

with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100 mL" (WAC 173-201A, 2011).

The *Shellfish Harvesting* and *Primary Contact Recreation* criteria are consistent with National Shellfish Sanitation Program (NSSP) rules. Marine water FC concentrations that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus, the same criteria are used to protect both *Shellfish Harvesting* and *Primary Contact* uses in Washington State standards.

Temperature

Many types of fish species rely on the North River watershed for spawning, rearing, migration, and residence. Anadromous fish in the watershed include; chinook, coho, chum, and trout (Herger, 1997). Therefore, temperature and supplemental spawning criteria have been established in order to protect aquatic life uses across all applicable watersheds. Since temperature affects the physiology and behavior of fish and other aquatic life, it may be the most influential factor for the health and distribution of aquatic species.

Temperature levels fluctuate across the day and night in response to daily fluctuations in ambient air temperatures, direct solar radiation, and hyporheic exchange between surface water bodies and shallow groundwater. Wildlife, such as beavers and other large mammals, can change the structure and function of a stream, creating pools and altering the landscape. Additionally, human activities, including forest management practices, contribute to diurnal fluctuations in stream temperature. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a water body.

In the water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2011 edition].

1. To protect the designated aquatic life uses of "Core Summer Salmonid Habitat" the highest 7-DADMax temperature must not exceed 16°C (60.8°F) more than once every ten years on average.
2. To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only" the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.
3. To adhere to the "Supplemental Spawning and Incubation Criteria" additional spawning temperature criteria of 13°C (as a 7-day average of daily maximum temperatures) from February 1 to July 15 are required to ensure protection for the incubation of salmon, trout, and char (Figure 2).

The salmonid populations requiring the additional supplemental spawning protection are those needing protection for summer reproduction and egg and embryo development in the stream bed in late spring to early fall (Payne 2011).

Washington State uses the criteria described above and in Table 2 to ensure that conditions are maintained when a water body is naturally capable of providing full support for its designated aquatic life uses. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides an allowance for additional warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

Table 2. Beneficial uses and water quality criteria for 303(d) listed reaches.

Parameter	Condition
North River, East Fork North River, and Joe Creek	
Designated Uses: Salmonid Spawning, Rearing, and Migration Habitat - Primary Contact Recreation	
Temperature*	Highest 7-DADMAX (7 day average of the daily maximum temperatures) 17.5º C
Marine Bacteria (North River Near Mouth)	I. Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL. II. No more than 10% of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value > 43 colonies/100 mL.
Salmon Creek (upper) and Sullivan, Raimie, Martin, and Redfield Creeks	
Designated Uses: Core Summer Salmonid Habitat - Extraordinary Primary Contact Recreation	
Temperature*	Highest 7-DADMAX (7 day average of the daily maximum temperatures) 16.0º C

*Supplemental spawning/incubation criteria are 13°C from Feb. 15 to July 1 for the following reaches: Upper and Lower Salmon Creeks, the lower reaches of Raimie, Redfield, Sullivan, Martin, Pioneer Creeks (Figure 2).

Study Area

The North River generally flows east to west for 60.2 river miles (RMs) and empties into the northeastern region of Willapa Bay (Figure 1). Tidal influence has been observed to occur up to RM 7.4 (Phinney and Bucknell, 1975). The watershed area is 252 square miles with a maximum elevation of approximately 1,880 ft. Land use in the watershed predominantly includes industrial timber management/harvest with occasional low-density residential areas in the towns of Artic and Brooklyn as well as the Float Houses in the lower 3 river miles of the North River (Figure 2). Two reaches that exceed water quality criteria and are listed for impairments under Section (303(d)) for FC are located at the mouth of the North River (Table 1 and Figure 1).

The Float Houses on the North River are moored on DNR-owned aquatic state lands. The homeowners entered into a contract with Pacific County in 1993 and signed new leases in 2009 for compliance to mitigate the impacts of sewage and greywater discharge. The regulatory authority remains with Pacific County.

The Float Houses are considered a nonconforming use; no new Float Houses are allowed to be constructed in this area. The lease agreement requires existing and new owners to notify the county when they have installed a functioning composting or incinerating toilet. Existing Float Houses are allowed to maintain the structures under the current lease agreement. (Pacific County, Washington, Facsimile, 2002). The last Pacific County inspection of the Float Houses occurred on July 4, 2001.

The third FC 303(d) listing depicted in Figure 1, is located in Willapa Bay at the mouth of Smith Creek. This FC listing will not be addressed within this study because it is beyond the scope of the project. Furthermore, the Washington State Department of Health's Office of Shellfish and Water Protection currently samples for FC in Willapa Bay near the mouth of North River and Smith Creek as part of the National Shellfish Sanitation Program (NSSP).

Thirteen temperature listings include several mainstem North River locations, the East Fork North River, an unnamed tributary, and Joe, Martin, Sullivan, Raimie, Upper Salmon and Redfield Creeks (Table 1 and Figure 1).

The proposed study area comprises the subbasins (12^{th} HUC) that contain 303(d) listed stream reaches (Figure 1). These subbasins are: (1) Lower North River, (2) Vesta/Little North River, (3) Pioneer Creek, and (4) the Headwaters.

Subbasins of the North River watershed that do not have known water quality impairments are not included in the study area outlined in Figure 1. Subbasins not included in the study area are: (1) Little North River, (2) Vesta Creek, and (3) Fall River.

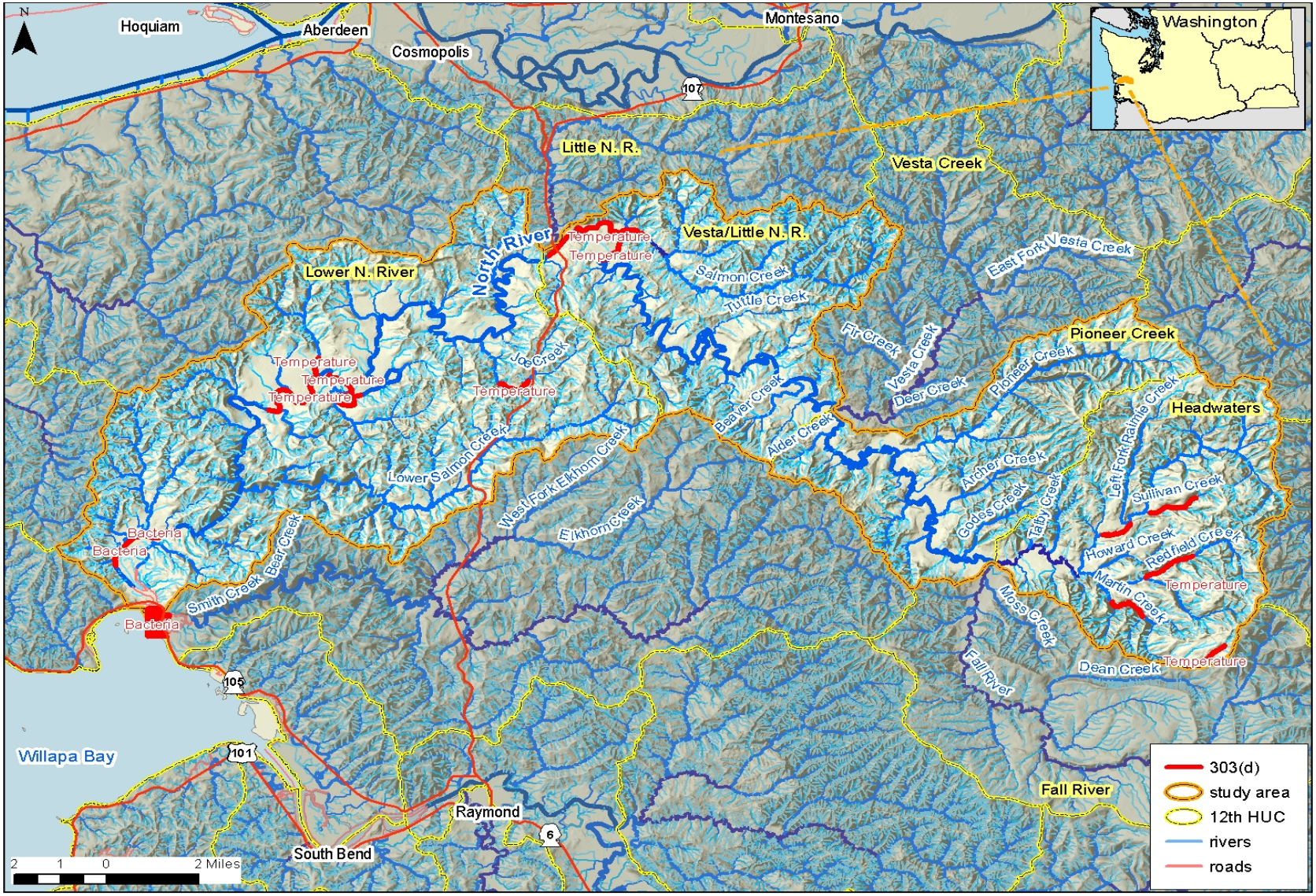


Figure 1. North River study area for 303(d) listed temperature and bacteria.

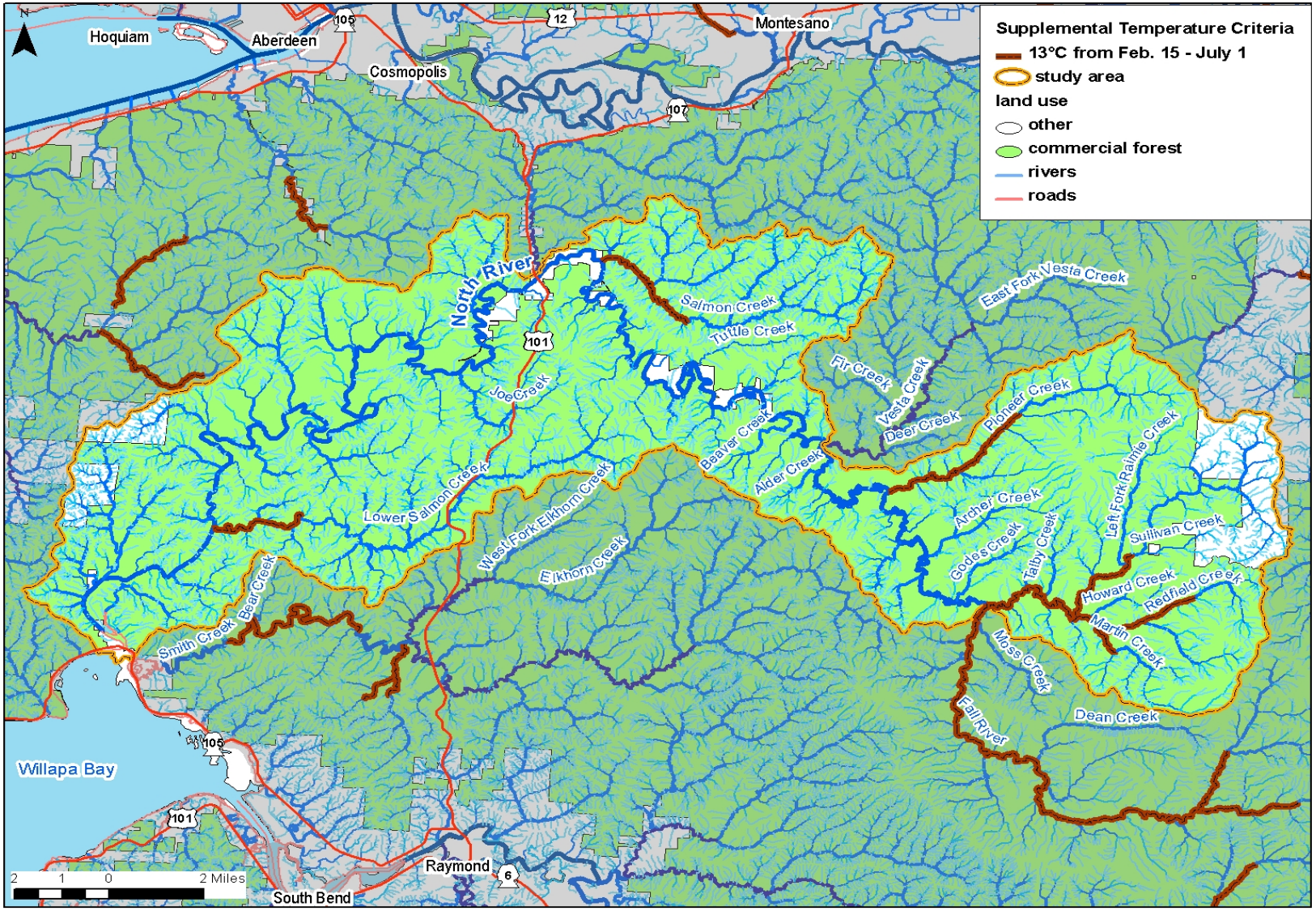


Figure 2. North River supplemental spawning/incubation criteria and land use.

Climate

The North River watershed has a temperate climate with mild wet winters and relatively warmer summers. Western Regional Climate Center data show the basin averages 86.05 inches of precipitation near its mouth in Raymond and 83.09 inches of precipitation slightly downstream of its headwaters in Brooklyn.

Metadata for these discontinued meteorological stations are as follows:

Raymond, WA

- Station Name and ID: WILLAPA HARBOR, WASHINGTON (459291)
- Period of Record: 6/1/1948 to 12/31/1979
- Approximate elevation: 10 ft

Brooklyn, WA

- BROOKLYN, WASHINGTON (450917)
- Period of Record : 12/1/1927 to 3/31/1974
- Approximate elevation: 190 ft

More recent climate information was obtained from the NOAA National Weather Service Forecast office from Raymond 2S, WA:

- RAYMOND WASHINGTON (456914)
- Period of Record : 1980 to present
- Approximate elevation: 30 ft

Most of the precipitation falls from October through April, with the remaining months experiencing relatively less precipitation (Figure 3).

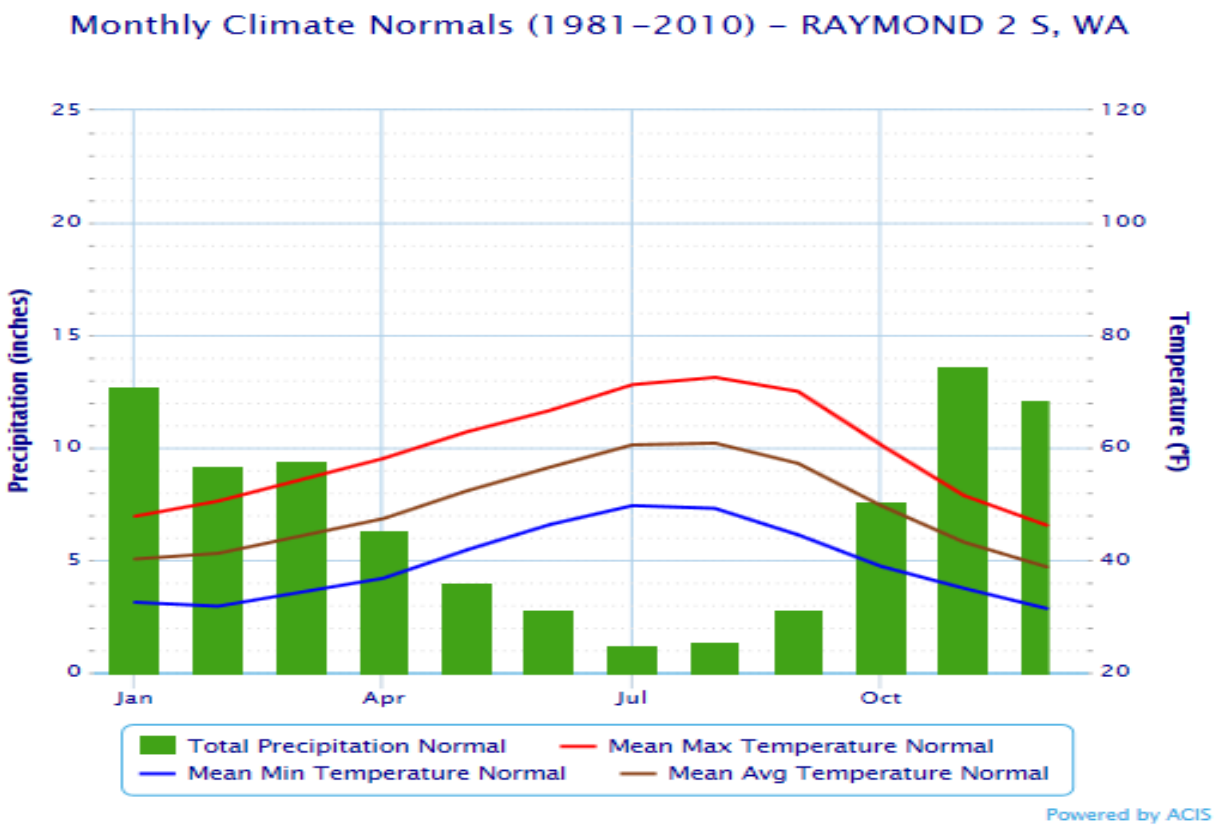


Figure 3. Monthly climate normals (1981-2010) for Raymond 2 S, WA, obtained from NOAA (NOAA, 2014).

Glaciers and snowfields are not present in the basin; therefore, stream discharge is primarily dependent on precipitation and groundwater inputs, with little snowmelt runoff (Smith, 1999). The nearest gage and discharge information is located on the Willapa River, upstream of Raymond, WA (Figure 4).

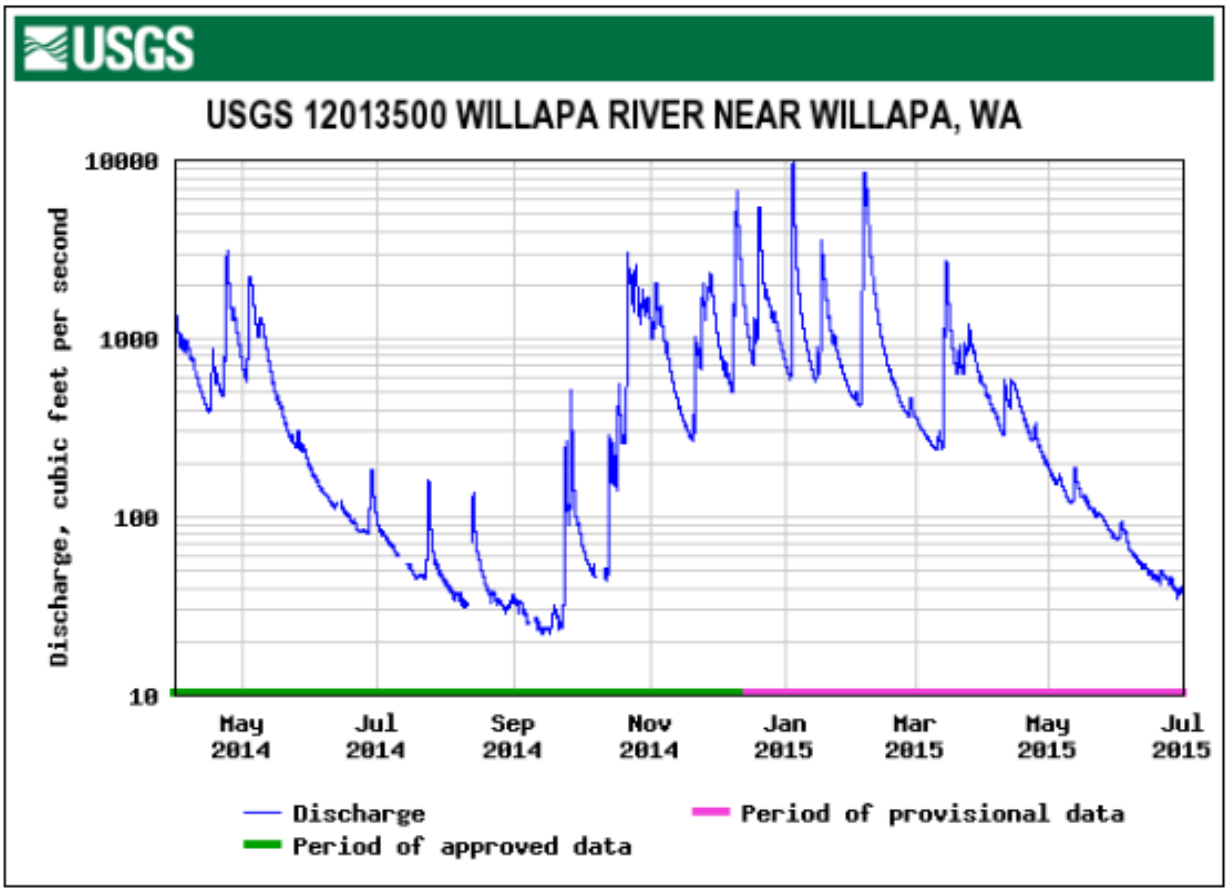


Figure 4. River discharge (cubic feet per second) from April 2014-June 2015 at USGS station # 12013500 on the Willapa River, located near the North River, WA, obtained from USGS (USGS, 2015).

Project Description

Project Goal

The goal of the North River verification study is to determine whether the existing 303(d) listed stream segments meet Washington State surface water quality criteria.

The purpose of the study is to verify temperature and FC conditions since the collection of initial data that led to 303(d) listings. Since initial data collection, actions have been taken to reduce water quality impairments including:

- Discontinuation of two significant livestock operations, and halted discharge of septage from Float Houses near the mouth of North River (Compliance Agreement between Pacific County and Private Owners of North River Float Houses, 2002-2009; Rountry, 2013).
- Implementation of efforts to restore and maintain natural thermal conditions by the DNR Forest Practice Rules (Title 222 WAC). The Forest Practices Rules establish standards for forest practices such as timber harvest, pre-commercial thinning, road construction, fertilization, and forest chemical application (DNR, 2013). This implementation occurs across most of the watershed.

Project Objectives

Project objectives were developed to achieve the project goals. The objectives of this project are as follows:

- Collect FC samples at 303(d) listed segments and compare these data to water quality criteria.
- Collect time-series temperature data at 303(d) listed segments and compare these data to water quality criteria.

To meet the objectives, this project relied on data collected by Ecology staff during the 2014-2015 study period. Data collected by Port Blakely Tree Farms (PBTF) was used at corresponding listed segments across their land. FC and temperature were monitored at the associated 303(d) listed segments (Table 1 and Figure 1) in the North River watershed for each given parameter.

Methods

Quality Objectives

To meet the objectives of this study, all field sampling and lab analysis followed strict protocols outlined in the North River QA Project Plan (Kardouni, 2014). Data credibility and usability is assured in compliance with the Water Quality Data Act (RCW 90.48.570-590) and Water Quality Program-Environmental Assessment Program Policy 1-11, Chapter 2: "Ensuring Credible Data for Water Quality Management" (Ecology, 2012). Data collected in this study attempts to accurately represent water quality for the targeted 303(d) listed stream reaches, both spatially and temporally.

Based on meteorological data collected within the watershed from the Western Regional Climate Center, the wet season spans October through April and the dry season spans May through September. Stream temperatures monitored during warmer months capture the highest potential thermal signal (across the thermal critical period, June through September) and the supplemental spawning period (February 15 through July 1). These seasonal features will be used as guidelines when working with applicable water quality criteria (Table 2).

Experimental Design

FC data collection spanned one year in order to characterize the mouth of the North River and compare seasonal variability. Ecology's Water Quality Program Policy 1-11 (Ecology, 2012) requirements were fulfilled by collecting sufficient data and comparing the results to the water quality criteria. Temperature data were collected by obtaining access permission from private land owners for in-stream deployment. Stream thermistors were placed in situ to capture thermal critical periods, in reference to spawning criteria (Table 2).

The field lead chose sampling locations based on their 303(d) listing location and type (Figures 1 and 2). Table 3 displays parameters that were collected and the locations that were chosen to address the individual listings.

Table 3. Sampling locations with their respective 303(d) listed parameters in the North River watershed.

Site Name	Parameter	Site Description	Latitude	Longitude
E.F. North River	Temperature	East Fork North River upstream of North R	46.83578	-123.81920
Joe Creek	Temperature	Joe Creek at Hwy 101	46.83817	-123.71974
Martin Creek	Temperature	Martin Creek upstream of Redfield Creek	46.76364	-123.44137
	Temperature	Martin Creek near headwaters	46.74449	-123.42050
North River	Bacteria	North River near mouth	46.76375	-123.90670
	Bacteria	North River upstream of mouth	46.77505	-123.88850
	Bacteria	North River (upstream FC sampling)	46.79469	-123.85091
	Temperature	North River at Hwy 101	46.88393	-123.71120
	Temperature	North River upstream of Salmon Creek	46.88437	-123.68262
	Temperature	North River downstream of E.F. North R	46.82821	-123.82106
	Temperature	North River upstream of E.F. North R	46.83593	-123.81311
Raimie Creek	Temperature	Raimie Creek upstream of North R	46.78807	-123.45376
Redfield Creek	Temperature	Redfield Creek upstream of North R	46.77337	-123.43472
	Temperature	Redfield Creek near headwaters	46.78594	-123.40694
Salmon Creek	Temperature	Upper Salmon Creek at mouth	46.89091	-123.68131
Sullivan Creek	Temperature	Sullivan Creek upstream of Raimie Creek	46.79841	-123.42685
Unnamed Tributary	Temperature	Unnamed tributary to North R	46.83029	-123.80352

Latitude and longitude datum: NAD 83 HARN
E.F.: East Fork

Sampling Procedures

Field investigations followed applicable methods described in the Standard Operating Procedures (SOPs) developed by Ecology's Environmental Assessment Program (EAP) including:

- EAP080 Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Ward, 2011)
- EAP030 Standard Operating Procedures for the Collection of Fecal Coliform Bacteria Samples in Surface water (Ward and Mathieu, 2011)
- EAP023 Standard Operating Procedures for the Collection and Analysis of Dissolved Oxygen (Winkler Method) (Ward and Mathieu, 2013)
- EAP033 Hydrolab DataSonde and MiniSonde Multiprobes (Swanson, 2010)

- EAP070 Standard Operating Procedures to Minimize the Spread of Invasive Species (Parsons et al., 2012)
- EAP075 Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters (Mathieu, 2013)

To retrieve the SOP documents listed above, visit the Ecology web site: www.ecy.wa.gov/programs/eap/quality.html.

Fecal Coliform Sampling

FC sampling began in April 2014 and ended in June 2015. Sampling occurred once every two weeks, generating a total of 31 sampling events per site at the two 303(d) listed segments of the North River (Figure 1, 5 and Table 3). An additional upstream location was added during the dry season to assess the existing levels of FC within the system.

Water quality parameters such as dissolved oxygen (DO), temperature, pH, conductivity, and salinity were measured using a Hydrolab Sonde® at the time of FC sampling. To ensure quality assurance, DO Winkler samples were also taken during each sampling event. FC samples were collected from the stream thalweg (center of flow) during each measurement. The North River is too deep to wade at proposed sampling locations; the use of a sample arm was necessary to reach the well-mixed portion of the river. Locations were accessed by boat at or near high tide for safety and to consider marine influence to the river system.

A salinity survey was conducted by Ecology staff following EAP075 *Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters* (Mathieu, 2013). Field staff took additional vertical salinity profiles at each FC sampling event to determine whether freshwater or marine water conditions were present at the time of FC sampling. Tide charts provided by NOAA were also reviewed by the project manager to assess the influence and movement of marine water.

Continuous Temperature

Ecology field staff deployed temperature data-loggers (thermistors) at 8 locations to monitor and verify thermal conditions at the 303(d) listed segments (Figure 1, 5 and Table 3). The thermistors were deployed during May and recovered during late September, with one exception. One supplemental spawning criteria location at Upper Salmon was deployed in early February, 2014. The remaining data from the additional tributaries (Martin, Raimie, Redfield and Sullivan) were supplemented by PBTF.

For Ecology's monitoring locations, each site was implemented with two thermistors; one to measure water and the other for air temperature. The air thermistor serves as a quality assurance (QA) check if the water thermistor becomes dry (out of water). The thermistors measured and recorded temperature at 30-minute intervals; all timepieces and PC clocks were synchronized to the atomic clock using Pacific Daylight Savings Time.

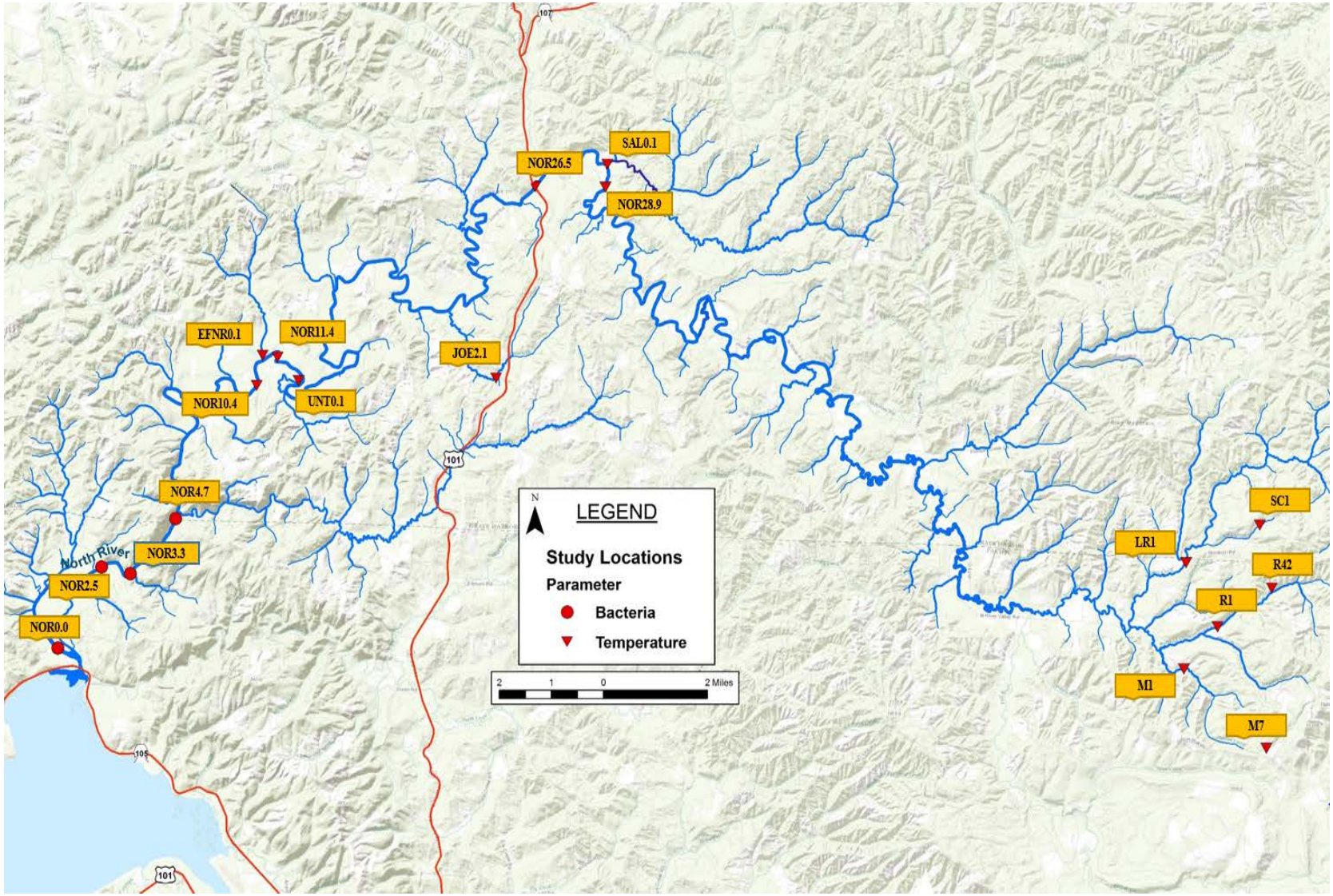


Figure 5. FC sampling and continuous temperature monitoring locations in the North River watershed.

Stream thermistors were deployed in the well-mixed portion (in riffles or glides), and suspended off of the stream bottom. Each of Ecology's thermistors was carefully concealed to reduce the risk of theft or vandalism. Temperature monitoring stations were checked monthly by the project field lead and other staff to conduct field measurements/observations and to clear accumulated debris away from the instruments.

Temperature monitoring targeted the thermal critical period (highest temperatures) the watershed experienced during warmer months of the year and the seasonal supplemental spawning criteria. In the conditions under Policy 1-11 (Ecology, 2012), a Category 1 designation will be satisfied if Washington State water quality criteria meets the following evaluation protocols:

> *Continuous monitoring for temperature during the critical season is required to place a water body segment in Category 1. Sequential data from at least two years must demonstrate consistent compliance with the numeric criteria or established natural conditions. Single sample event (grab sample) data are not used to place a water body segment in Category 1.*

Quality Control Procedures

Ecology characterized total precision from both field sampling and laboratory analysis by collecting and processing replicate (duplicate) samples at 50% of the sites during each survey. The use of replicate samples provides a reliable and repeatable data quality indicator. Additionally, Manchester Environmental Laboratory (MEL) duplicated sample analyses in the laboratory to determine lab precision. Steps are taken at each level to reduce sample field variability, which is the estimated difference between total and laboratory precision.

Laboratory

Chain-of-custody forms and sample tags for FC samples were prepared by field staff before each field study, described in the MEL *Lab User's Manual* (2008). Information printed on the sample tags included: project name, sample identification number, site identification, date, time, and parameter. Date and time were recorded on the sample tags at the time of field collection and the information matched what was copied onto the chain-of-custody form.

Ecology staff collected FC grab samples directly into pre-cleaned containers supplied by the MEL. After collection, FC samples were stored on ice and delivered to MEL within 24 hours of the collection time for laboratory analysis. A chain-of-custody was kept until the samples were received by MEL. The specifications for sample containers, preservations, and holding times are presented in Table 4.

Along with FC collection, DO samples were collected using BOD bottles for field instrument QA/QC (Table 4). The QA/QC grab samples were analyzed for DO concentrations using the Winkler method (Ward and Mathieu, 2013) and titrations were performed at Ecology's wet-lab. The quality of the DO field measurements was assessed by calculating the relative standard difference (RSD) between the Winkler and field-measured DO values.

Table 4. Containers, preservation requirements, and holding times for samples collected.

Parameter	Sample matrix	Container	Preservative	Holding time
Fecal Coliform (FC)	Surface water and runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours
Dissolved Oxygen (DO)	Surface water and runoff	300 mL BOD1 bottle & stopper	2 mL manganous sulfate reagent + 2 mL alkaline-azide reagent	4 days

Continuous Temperature

Ecology's thermistors were checked for accuracy and potential bias as part of the QA/QC process. The Onset Hobo Water Temp Pro v2© instruments received a two-point calibration check both pre- and post-study to document instrument bias and accuracy at representative temperatures. A NIST-certified reference thermometer was used at each calibration check to verify the thermistor was within ±0.21°C of the NIST thermometer. Table 5 lists the manufacturer's specified range, accuracy, and resolution for thermistor equipment used in deployment.

Ecology field staff recorded the depth of the instrument and measured temperature with a field thermometer during deployment, routine site visits, and upon retrieval. Field thermometer checks provide a potential indicator of instrument bias throughout the deployment and can identify issues with instrument drift over time. Depth measurements provide supplemental information to assess the potential for bias (for example if the instrument is too close to the water surface it could be influenced by solar radiation and if it is too close to streambed it could be influenced by groundwater).

PBTF referred to their HCP for specific effectiveness monitoring methods, using the *TFW Ambient Monitoring Program Manual* (Schuett-Hames et al. 1994) and MacDonald et al. (1991).

Post-processing of Ecology water and air temperature data was performed by the project lead to determine that the water instrument was not exposed to the air during deployment. Data were then used to express the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in each individual stream.

Instantaneous Measurements

Prior to each sampling, a Hydrolab Sonde® was calibrated by Ecology staff for dissolved oxygen (DO), pH, and conductivity values that represent the changing conditions across freshwater and marine conditions. After each sampling event, the Hydrolab Sonde® was post-checked to verify that the equipment held its calibration across the sampling day. Data were qualified as an estimate if the sonde failed to hold its calibration. Table 5 presents the specifications of the field instruments that were used for this study.

Table 5. Field instrument specifications.

Analysis	Instrument	Method	Range	Accuracy	Resolution
Continuous temperature	Hobo Water Temperature Pro v2	EAP044	-40°C to 50°C	± 0.21°C	0.01°C
Instantaneous temperature	Hydrolab Sonde®	SM2550B-F	-5°C to 50°C	± 0.10°C	0.01°C
Specific conductivity	Hydrolab Sonde®	EPA120.1M	1 to 100,000 uS/cm	± (0.5% of reading + 1 uS/cm)	0.1 to 1 uS/cm
Dissolved oxygen (DO)	Hydrolab Sonde®	Hach 10360	1 to 60 mg/L	± 0.1 mg/L at ≤ 8 mg/L ± 0.2 mg/L at > 8 mg/L	0.01 mg/L
pH	Hydrolab Sonde®	EPA150.1M	0 to 14 pH units	± 0.2 units	0.01 units

Measurement Quality Objectives

Laboratory measurement/analysis procedures are based on "Standard Methods" (APHA et al., 1999). Measurement quality objectives (MQOs) state the level of acceptable error in the measurement process. Precision is a measure of the variability in the results of replicate measurements due to random error (Lombard and Kirchmer, 2004). This random error includes error inherently associated with field sampling and laboratory analysis. Field and laboratory errors are minimized by adhering to strict protocols for sampling and analysis.

Microbiological and analytical methods, expected precision of sample replicates, method reporting limits and resolution are given in Table 6. The field replicate MQO is expressed as relative standard deviation (RSD) and the laboratory duplicate MQO is expressed as relative percent difference (RPD).

Table 6. Field and laboratory precision measurement quality objectives (MQO) for laboratory samples.

Analysis	Method	Field replicate MQO (RSD)	Lab duplicate MQO (RPD)	Reporting limit
Fecal Coliform (FC) MF	SM 9222D	50% of replicate pairs < 20% RPD 90% of replicate pairs < 50% RPD	40%	1 cfu/100 mL
Dissolved Oxygen (DO)	SM 4500OC	<10% RSD between Winkler DO and Hydrolab Sonde®	NA	0.1 mg/L

MF: membrane filter, RSD: relative standard deviation, RPD: relative percent difference
SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA et al., 1999).

The targets for analytical precision of laboratory analyses are based on historical performance by MEL for environmental samples taken around the state by Ecology's EAP (Mathieu, 2006). The reporting limits of the methods listed in Table 6 are appropriate for the expected range of results and the required level of sensitivity to meet project objectives.

Data Management Procedures

Field measurement data were entered into a notebook of waterproof paper and then carefully entered into EXCEL® spreadsheets. Data were checked to ensure transfer accuracy. The database was then used for preliminary analyses and QA/QC. Statistical methods to verify FC normality and boundary target value calculations for the upstream station are located in Appendix B of this report.

Sample results received from MEL by Ecology's Laboratory Information Management System (LIMS) were loaded into Ecology's Environmental Information Management system (EIM), exported, and added to a cumulative spreadsheet for laboratory results. This spreadsheet was used to informally review and analyze data throughout the course of the project.

All spreadsheet files, photos, paper field notes, and Geographic Information System (GIS) products created as part of the data analysis have been kept with the project data files. Data that did not meet acceptability requirements were separated from data files and not used in analysis.

Data Verification and Validation

MEL followed the procedures outlined in the MEL *Lab User's Manual* (MEL, 2008) through laboratory-generated data reduction, review, and reporting. Lab results were checked for missing and improbable data. Variability in lab duplicates was quantified using the procedures developed by MEL (MEL, 2012). Any estimated results were qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results was sent to the project manager for each set of samples received.

Data validation involved a detailed examination of the data package to determine whether the method quality objectives (MQOs) have been met. The project manager examined the complete data package to determine compliance with procedures outlined in the QA Project Plan and SOPs. The project manager was responsible for data validation by comparing all data to MQOs for precision, bias, and sensitivity to assess data quality. QA field sample replicates were averaged with their equivalent FC field sample. After data verification and data entry tasks were completed, all field and laboratory data were entered into a final file and then loaded into EIM.

Audits and Reports

The project manager was responsible for verifying data completeness before its use in the technical report and entry into EIM. The project manager also wrote and submitted the final technical report to the Water Quality Program watershed lead. This technical report has been peer reviewed by staff with appropriate expertise. The entire data set (100%) was independently reviewed by another EAP employee, due to initial errors in labeling and EIM uploads. The project manager verified full data completeness before its use and entry into the EIM.

This final report includes analyses of results that form the basis of conclusions and recommendations. The results include site-specific information for FC, temperature, multi-probe results, QA results, and seasonal summaries.

Data Quality (Usability) Assessment

The project manager has verified that all measurement and data quality objectives have been met for each monitoring station. Documentation of the data quality and decisions on data usability provide accuracy and transparency of the QA/QC procedures.

Finalized data were uploaded by the project manager into the EIM system after verification and validation. The EIM user study code (JKAR0005) was created for the verification study and all monitoring data are available at: www.ecy.wa.gov/eim/

Results

Salinity

During each FC sampling event, salinity was also measured to determine how freshwater and marine criteria would be applied to the individual 303(d) listed locations. A salinity survey was conducted following EAP075 *Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters* (Mathieu, 2013) at NOR0.0 during a high tide on 10/8/14. The start time for the survey was 13:27, when high tide began. The survey finished at 13:59 with a wetted width of 410 feet and a calculated area weighted salinity of 27.65 square parts per thousand (PPT^2).

A second physical vertical averaged salinity survey was not performed at NOR2.5. However, individual salinity depth measurements were recorded during each visit by measuring the surface water and 4-5 additional increments above the river bottom. Figure 6 plots each salinity cast at NOR2.5 taken by Ecology employees during the time of FC sampling.

Interactions between salinity and temperature at the boundaries of fresh and saltwater parcels can create a halocline−changes in salinity at depth. For example, on 7/22/14, the surface salinity layer was high (19 ppt) and most likely warmer (from solar radiation and increased summer temperatures) than the cooler, less saline wedge (10 ppt) mixing with river water around 2.5 ft (Figure 6). A stable layer of dense saltwater remained below the mixing zone (7-17 ft) at 13 ppt.

Table 7 analyzes the collected salinity cast data over time to calculate vertically averaged salinity for NOR2.5, taking into account High Water Levels (HHWL) at Toke Point, WA. The vertically averaged salinity between Aug 13 and September 24 (a 42-day period) was greater than 10 ppt on the four days measurements were collected (12.87 to 15.35 ppt, Table 7). The tide height during measurements ranged from ~7.7 to 9.8 and was between 91 to 97% of the HHWL for each measurement day, suggesting these values are slightly below the daily max. The HHWL was greater than 7.7 (lowest tide height at measurement) during all 38 days where no measurement was performed in this time period.

Streamflow (freshwater input) was relatively stable in these months, with daily mean flow ranging between 23 and 168 cfs on the nearby Willapa River at USGS Station 12013500 (Figure 4). Thirty-six out of those 42 days were below 50 cfs and the two highest flow days in the period were salinity measurement days (168 cfs on 9/24/14 and 120 cfs on 8/13/14).

For the 38 days during this time period with no salinity measurements, the streamflow was lower and the HHWL was equal or higher to the measured days, therefore it is reasonable to expect that all 42 days had a vertically averaged daily maximum salinity of greater than 10 ppt. A minimum of 19 days above 10 ppt (5% of the year) is needed to make a marine determination for bacteria, thus marine criteria apply at NOR2.5 and all downstream stations.

Table 7. Vertically averaged salinity analysis of NOR2.5

Measurement Date	NOR2.5 Vertically Averaged Salinity	NOR 2.5 Measurement Time	Time offset between Toke Pt and North River	Adjusted Time (Toke Pt lag)	Tide height at Toke Pt during sampling (ft)	HH at Toke Pt (ft)	Daily HH during sampling (%)
8/13/2014	12.87	14:50	0:18	14:32	8.7	9.6	91%
8/26/2014	14.19	14:30	0:18	14:12	7.7	8.3	93%
9/9/2014	15.35	14:20	0:18	14:02	9.2	9.6	96%
9/24/2014	13.35	14:25	0:18	14:07	9.8	10.1	97%

Figure 6 demonstrates how surface sampling and equipment readings may not tell if the parcel is fully freshwater. For example, 5/27/15 has a surface salinity of 1.57 ppt with a maximum salinity of 17.01 ppt, 15 feet below the water surface. Since salinity casts were not performed at the added upstream sampling locations (3.3/4.7) *Marine Criteria* will not be applied. To manage the upstream sampling data, methods were derived from the Skagit River TMDL (Pickett, 1997). Boundary target values for the unverified reaches have been calculated using marine station #73, monitored by DOH (Table 8).

Tidal influence has been observed to occur up to RM 7.4 (Phinney and Bucknell, 1975), and the upstream sampling locations (NOR3.3, NOR4.7) are at the boundary between different uses. Recommended boundary values have been set to meet downstream uses for *Primary Contact Recreation* and *Shellfish Harvesting* (Table 8).

Table 8. Calculation of FC freshwater boundary target values using salinity and FC values from DOH station #73, located in Willapa Bay, near the mouth of the North River.

FC Marine Water Quality Standards (10 ppt Salinity or greater) Geometric Mean = 14 cfu/100 mL 90th Percentile of Data = 43 cfu/100 mL	
Salinity Willapa Bay (Wet Season): 21.19 ppt (Mean) Willapa Bay (Dry Season): 28.33 ppt (Mean) Wet Season % Freshwater at 10 ppt Salinity = 53% Dry Season % Freshwater at 10 ppt Salinity = 66%	**FC Background Levels - Wet Season** DOH Station #73 = 2.6 cfu/100 mL (GeoMean Background) DOH Station #73: 8.0 cfu/100 mL (90th %tile Background) **FC Background Levels - Dry Season** DOH Station #73 = 2.6 cfu/100 mL (GeoMean Background) DOH Station #73: 8.0 cfu/100 mL (90th %tile Background)
Wet Season Equations (2.6 cfu/100 mL*0.47) + (X*0.53)=14 cfu/100 mL (8 cfu/100 mL*0.47) + (X*0.53)=43 cfu/100 mL **Dry Season Equations** (2.6 cfu/100 mL*0.34) + (X*0.66)=14 cfu/100 mL (8 cfu/100 mL*0.34) + (X*0.66)=43 cfu/100 mL	**FC Freshwater Boundary Target Values - Wet Season** Geometric Mean = 24 cfu/100 mL 90th Percentile of Data = 74 cfu/100 mL **FC Freshwater Boundary Target Values - Dry Season** Geometric Mean = 20 cfu/100 mL 90th Percentile of Data = 61 cfu/100 mL

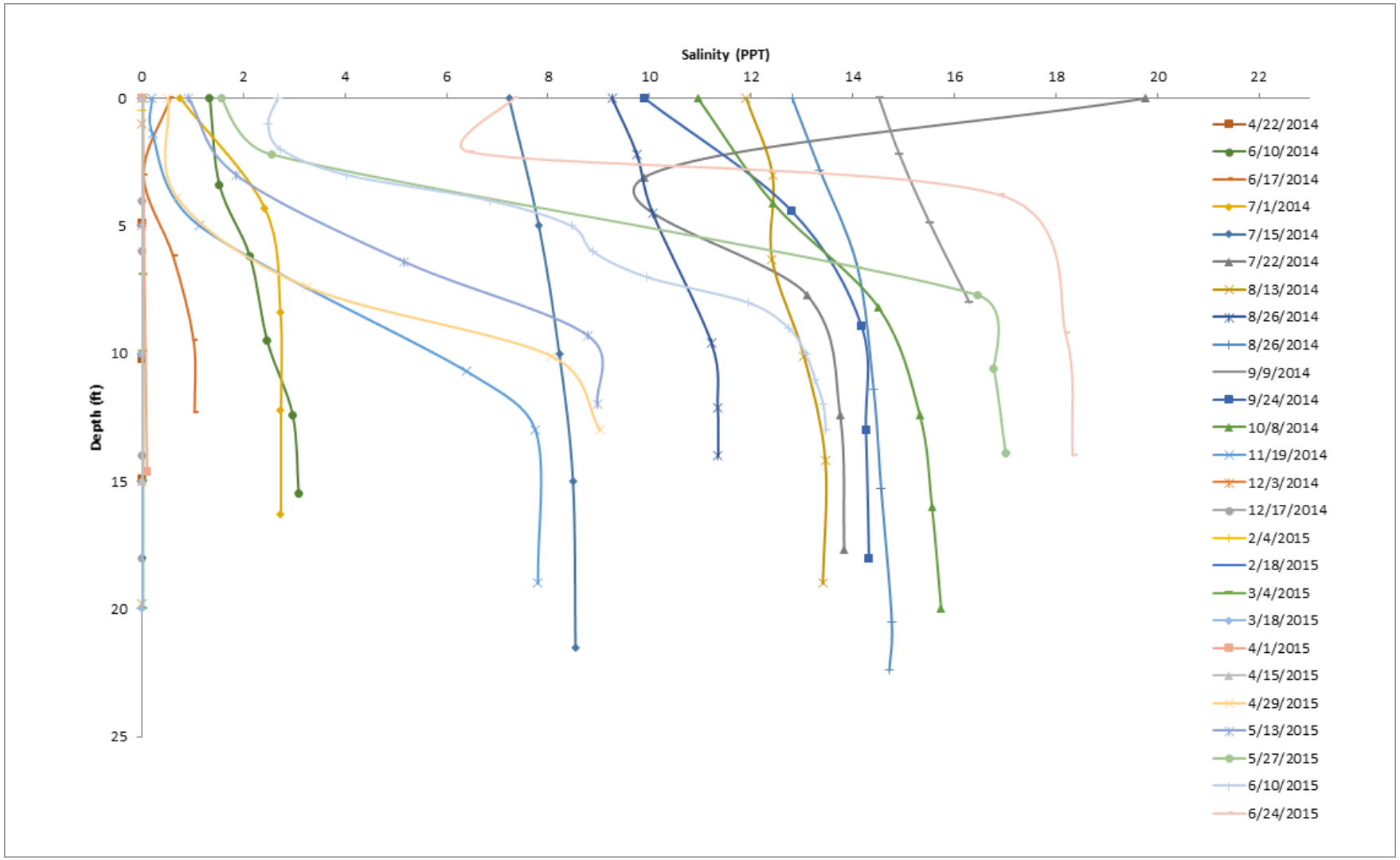


Figure 6. Vertical salinity casts at NOR2.5.

Fecal Coliform

FC sampling began on 4/8/14 and ended on 6/24/15. Sampling occurred once every two weeks, with the exception of a gap between 12/17/14 and 1/21/15. The listed downstream stations NOR0.0 Listing # 6686 and NOR2.5, listing # 6691 were sampled during each occurrence (Table 1, Figure 7). To consider background concentrations of FC, additional sampling stations were investigated on 8/26/14 and 9/9/2014. The final chosen location was moved to NOR4.7 on 9/24/14. On 5/13/15 the upstream sample was not collected at NOR4.7, due to low water conditions that prevented the boat from navigating to the sampling site. Upstream sampling at NOR3.3 resumed from 5/27/15 until the final collections on 6/24/15.

Over the course of the study, the station closest to the confluence of the North River and Willapa Bay (NOR0.0), reported a site maximum FC value on 5/6/14 of 90 cfu (colony forming units/ 100 mL) and the lowest site value on 3/4/15 of 1 cfu (Figure 7, Table 9). Overall, 31 samples were collected at this location with a geometric mean of 13 and a 90th percentile of 54 (Table 9). Based on the reported results, NOR0.0 exceeded part II, upper limit criterion, for marine water quality criteria.

The sampling location at NOR2.5 had the highest FC concentration observed during the study (an estimate reported by the lab of greater than 655 cfu, Figure 7) and the lowest FC concentration occurred on 3/4/15 at 1 cfu. A total of 31 samples were collected at NOR2.5, with a geometric mean of 13 and a 90th percentile of 70 (Table 9). Based on the reported results, NOR2.5 exceeded part II, upper limit criterion, for marine water quality criteria.

The largest FC result sampled at NOR 4.7 on 9/24/15 was 290 cfu. The lowest measured concentration of FC recorded at the NOR 4.7 was 3 cfu on 3/4/15. Sample results collected at NOR4.7 and 3.3 (upstream stations) were combined to calculate summary statistics, for a total of 20 samples, with a geometric mean of 12 and a 90th percentile of 51 (Table 9).

A visual spike in the hydrograph on the Willapa River, shown in Figure 4, occurred during the 9/24/14 sampling event. The increase of river discharge was timed with a documented rain event on 9/23/14, when 1.44 inches of rain was recorded at the Raymond 2S station (NOAA, 2014). This flush of rain in the dry season correlates with increased bacteria concentrations at NOR2.5 and NOR4.7 (Figure 7). NOR0.0 FC collection data on the same day (9/24/14) also exceeded the upper limit for marine criteria, at 59 cfu.

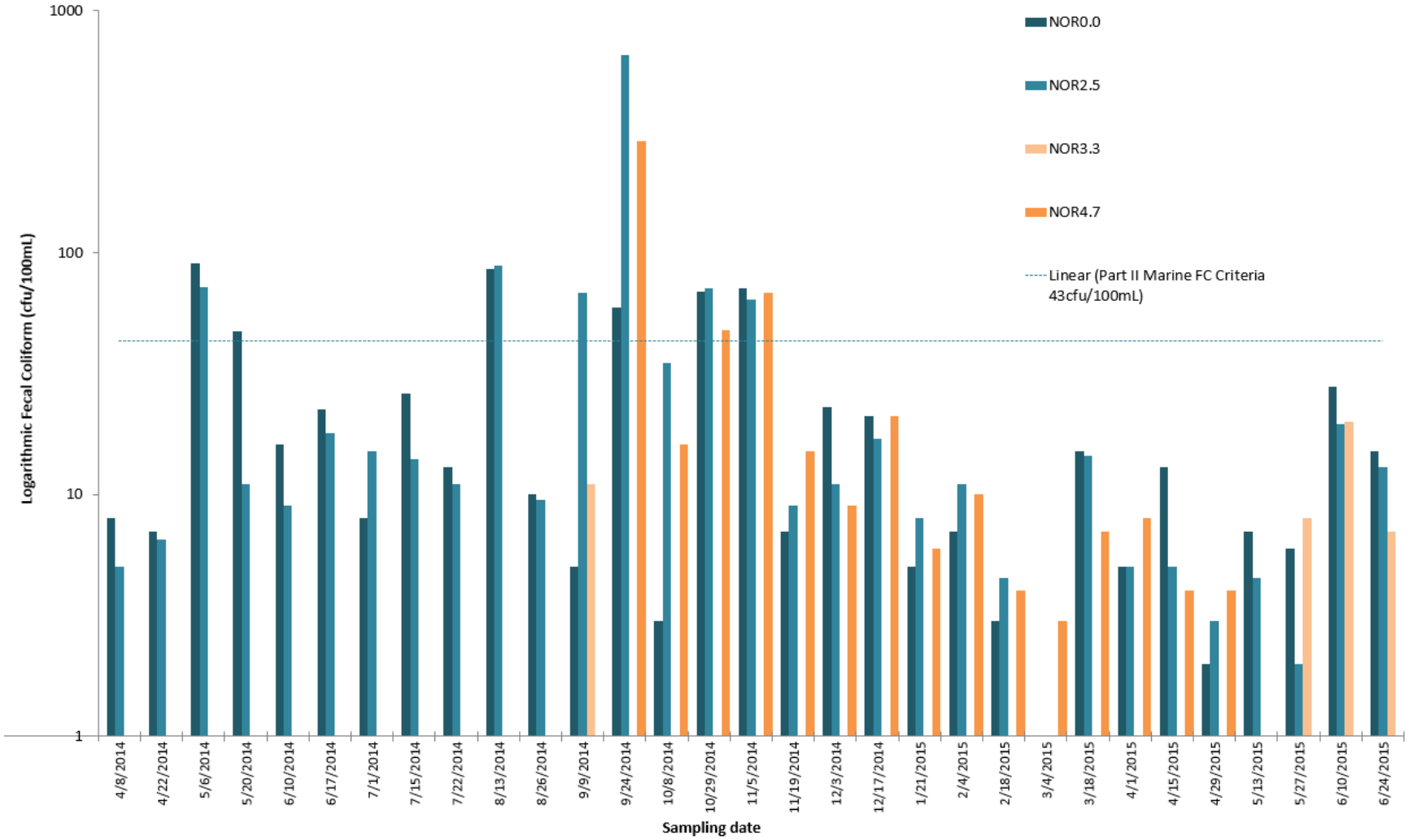


Figure 7. FC concentrations (cfu) from sampling locations on the North River.

Table 9. Concentrations of FC samples (cfu/100 mL), surface salinity measurements (ppt), and the corresponding tide data (NOAA online, 2013) from the North River.

Station ID	NOR0.0		NOR2.5		NOR3.3/4.7		Tide Stage
	FC (cfu/100 mL)	Salinity (ppt)	FC (cfu/100 mL)	Salinity (ppt)	FC (cfu/100 mL)	Salinity (ppt)	Toke Point 9440910
4/8/2014	8	0.65	5	0.01	-		-
4/22/2014	7	1.9	7	0.01	-		Low/ Out
5/6/2014	**90**	0.01	**72**	0.01	-		High/ Out
5/20/2014	**47**	0.04	11	0.01	-		High/ Out
6/10/2014	16	12.24	9	1.34	-		High
6/17/2014	23	3.24	18	0.56	-		Incoming
7/1/2014	8	9.18	15	0.76	-		Incoming
7/15/2014	26	17.67	14	7.23	-		High/ In
7/22/2014	13	19.76	11	6.89	-		High
8/13/2014	**85**	22.56	**89**	11.9	-		Incoming
8/26/2014	10	18.91	10	9.26	11		Incoming
9/9/2014	5	28.43	**68**	14.52	18	0.35	High/ In
9/24/2014	**59**	24.42	**655** [1]	9.9	**290**	0.05	High
10/8/2014	3	27.51	35	10.95	16	0.11	High/ Out
10/29/2014	**69**	0.03	**71**	0.01	**48**	0.01	Low/ In
11/5/2014	**71**	0.03	**64**	0.01	**68**	-	High/ In
11/19/2014	7	3.56	9	0.2	15	0.01	High/ Out
12/3/2015	23	1.16	11	0.01	9	0.01	Outgoing
12/17/2015	21	1.76	17	0.01	22	0.01	Outgoing
1/21/2015	5	0.02	8	0.01	6	0	Incoming
2/4/2015	7	3.3	11	0.01	10	0.01	Incoming
2/18/2015	3	7.68	5	0.01	4	0.01	Incoming
3/4/2015	1	7.26	1	0.02	3	0.01	Incoming
3/18/2015	15	0.14	15	0.01	7	0.01	High/ Out
4/1/2015	5	0.38	5	0.01	8	0.01	Incoming
4/15/2015	13	0.57	5	0.01	4	0.01	High/ Out
4/29/2015	2	3.75	3	0.52	4	0.01	Outgoing
5/13/2015	7	6.35	5	0.92	-	-	Outgoing
5/27/2015	6	6.54	2	1.57	8	0.12	Outgoing
6/10/2015	28	13.73	20	2.67	20	0.43	Outgoing
6/24/2015	15 [2]	11.39	13 [2]	7.33	7 [2]	1.61	Outgoing
Number of samples (n)	31	31	31	31	20	18	
max	90	28	655 [1]	15	290	2	
min	1	0	1	0	3	0	
geometric mean	13		13		12		
90th percentile	54		70		51		
# of Samples Exceeding (43 cfu/100 mL)	6		6				
% of Samples Exceeding Part II of WQ Criterion	19		19				

Gray shaded cells exceed 43 cfu/100 mL for marine criteria 100 cfu/100 mL and yellow shaded cells exceed the WQ criteria.

[1] *The organism was positively identified and the numerical result is greater than estimate.*

[2] *Samples were processed 65 min outside their 24-hr holding time.*

Temperature

Temperature data-loggers (thermistors) were deployed at 8 locations by Ecology to monitor and verify thermal conditions at the 303(d) listed segments (Table 3, Figure 5, 8). The thermistors were deployed on May 21 and 22, 2014 and recovered during late September 8 and 9, 2014. Separate from the other deployments, a supplemental spawning criteria station, located at Upper Salmon Creek, was deployed on February 13, 2014.

Temperatures at Ecology's continuous temperature monitoring locations all exceeded their respective criteria (Figures A-7 to A-14, Table 10). NOR11.4 had the highest percentage of monitoring days exceeding criteria (Figure 8), although NOR28.9 had the highest recorded 7-DAD-Max of 21.67°C. The lowest recorded 7-DADMin (11.22°C) occurred at JOE2.1 (Table 10).

The East Fork of the North River (EFNR0.1) was the closest of the Ecology-monitored streams to meeting water quality standards. EFNR0.1 exceeded the criteria eight 7-DADMax days, and had a maximum peak of 0.38°C above the 17.5°C criteria on July 10 (Figure A-7, Table 10).

Table 10. Ecology 2014 monitoring station criteria and exceedance by month.

Site ID	EFNR 0.1	JOE 2.1	NOR 10.4	NOR 11.4	NOR 26.5	NOR 28.9	SAL 0.1	UNT 0.1
Maximum 7-DADMax Temp (C°)	17.88	18.13	21.26	21.57	21.44	21.67	18.49	18.14
Date of 7-DADMax	07/10/14	07/09/14	08/02/15	08/02/14	08/02/14	08/03/14	07/01/14	07/09/14
Minimum 7-DADMin Temp (C°)	11.5	11.22	12.91	12.94	12.43	12.45	6.74	11.06
Criteria (C°)	17.5	17.5	17.5	17.5	17.5	17.5	13.0/16.0	17.5
February	-	-	-	-	-	-	0	-
March	-	-	-	-	-	-	0	-
April	-	-	-	-	-	-	0	-
May	-	-	-	-	-	-	3	-
June	0	0	9	11	**	4	31	0
July	4	6	31	31	6**	31	30	10
August	4	3	31	31	31	31	31	9
September	0	0	3*	4*	5*	4*	2	0
Days of Exceedance During Total Deployment Days	8/105	9/105	70/98	77/102	41/69**	70/103	97/157	19/104
Percent Exceedance	7.62%	8.57%	71.43%	75.49%	59.42%	67.96%	61.78%	18.27%

*Thermistor was pulled at the beginning of the month; values may not reflect total days of criteria exceedance

**Water level dropped below the thermistor; a portion of data has been removed from the corresponding thermograph

The remaining data for the North River headwaters (Martin, Raimie, Redfield and Sullivan Creeks) were supplemented by Port Blakely Tree Farms (PBTF). As per the conditions outlined in Port Blakely's HCP, their monitoring period spans from June through September each year. The most recent published 2010 data set was used (Murden and Reynolds, 2011) to verify temperature conditions in the 303(d) listed waters in the North River. Stream temperature data are not collected by PBTF during the *Supplemental spawning criteria* period from February through May. However, data collection during the *Supplemental spawning criteria* time period does occur for the month of June for Martin, Raimie, Redfield, and Sullivan Creeks, as well as for July, August, and September. Therefore, different criteria applies to the beginning of the monitoring data (13°C 7-DADMax) until July when it resumes the Core Summer criteria (16°C 7-DADMax) (Table 11.).

Most all of the PBTF thermographs exceeded their designated criteria, with the exception of Upper Martin Creek (M7) and Upper Redfield Creek (R42) (Figures A-2 and A-5, Tables 10 and 11). From the PBTF 2010 data, the two highest thermal maximums for the core summer salmonid habitat criteria (16.0°C 7-DADMax) occurred during July 7-13 and August 8-20.

Additionally, during *supplemental spawning criteria*, a thermal peak occurred for Lower Martin (M1), Raimie Creek (LR1) and Redfield Creek (R1) between June 22 and 30 (Figures A-1, A-3 and A-4, Table 11). Although unlikely, it is possible the peak 7-DADMax occurred before the month of June, during the period when temperature data were not being recorded. Sullivan Creek (Figure A-6) is also subject to supplemental spawning criteria. Its 7-DADMax did not peak above 13°C in June, however, as the other locations did.

Table 11. PBTF 2010 monitoring station criteria and exceedance by month.

Site ID	M1	M7	LR1	R1	R42	SC1
Maximum DADMax Temp (°C)	16.83	16.83	17.88	16.97	14.33	16.09
Date of 7-DADMax	08/16/10	08/16/10	08/15/10	08/15/10	08/16/10	08/14/10
Minimum DADMin Temp (°C)	9.19	9.19	9.65	9.25	9.33	9.03
Criteria (°C)	13.0/16.0	17.5	13.0/16.0	13.0/16.0	17.5	13.0/16.0
February	n/d	-	n/d	n/d	-	n/d
March	n/d	-	n/d	n/d	-	n/d
April	n/d	-	n/d	n/d	-	n/d
May	n/d	-	n/d	n/d	-	n/d
June	4	0	9	5	0	0
July	0	0	13	0	0	0
August	6	0	9	6	0	3
September	0	0	0	0	0	0
Days of Exceedance During Total Deployment Days	10/99	0/96	31/99	11/99	0/96	3/96
Percent Exceedance	10.10%	0.00%	31.31%	11.11%	0.00%	3.13%

n/d: No data available to measure supplemental spawning criteria (13°C from February 15- July 1) during these months.

Overall, Raimie Creek (LR1) had the greatest number of days exceeding criteria, during both the supplemental spawning and the core summer salmonid criteria (Table 11). Sullivan Creek (SC1) had the lowest proportion of days exceeding criteria (Figure 9). The temperature at SC1 peaked only 0.09 over the 7-DADMax of 16.0°C between August 14 and 15 (Figure A-6). In the headwaters, Upper Martin (M7) and Upper Redfield (R42) both have less stringent water quality criteria (17.5°C) and both reported below the beneficial maximum (Figures A-2 and A-5, Table 11, Figure 9).

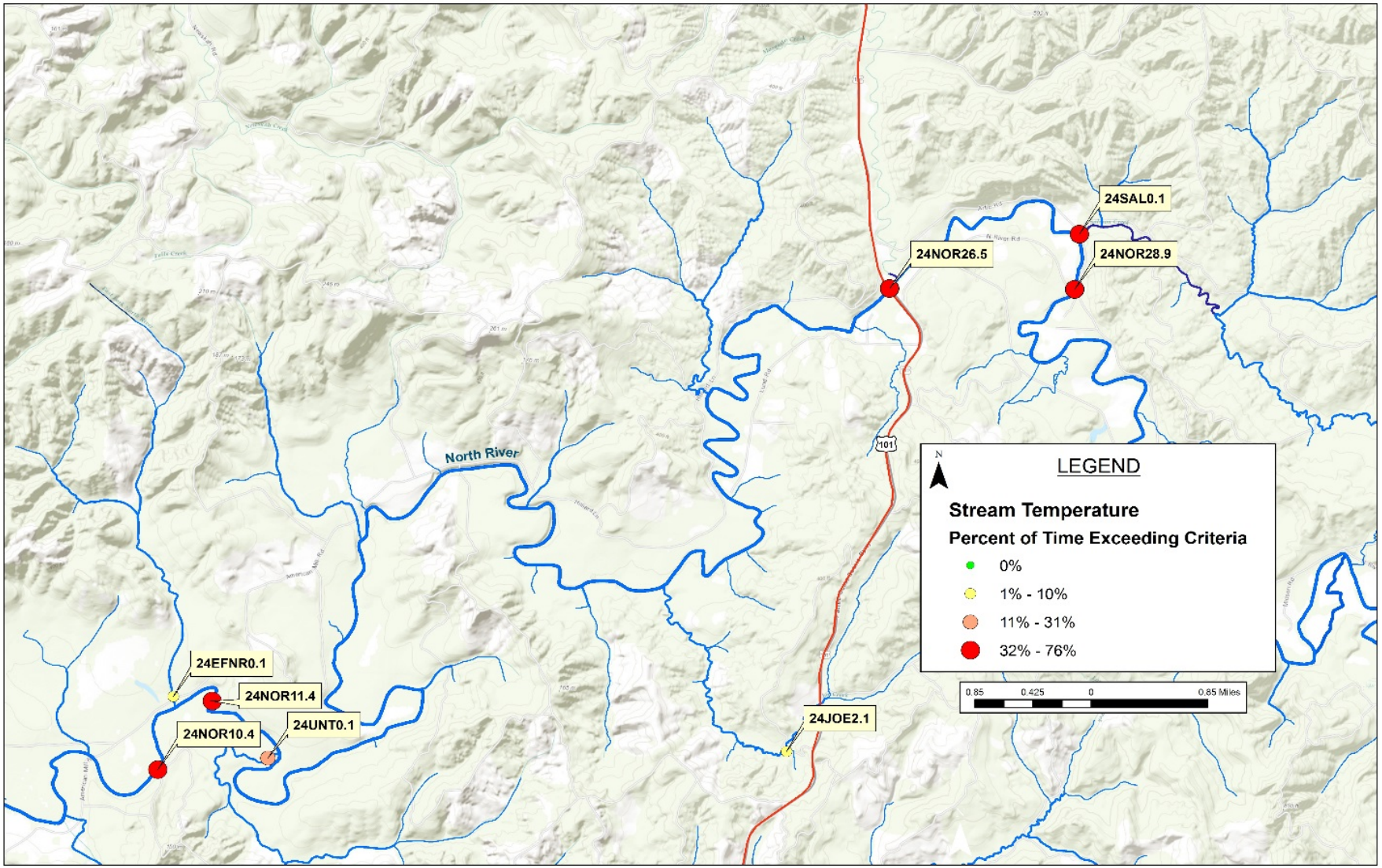


Figure 8. Ecology-monitored locations: Proportions of 7-DADMax exceedance during the thermal critical period (June-Sept 2014, with the exception of SAL0.1 which additionally captures the Supplemental Spawning Criteria (Feb 15-July 1)).

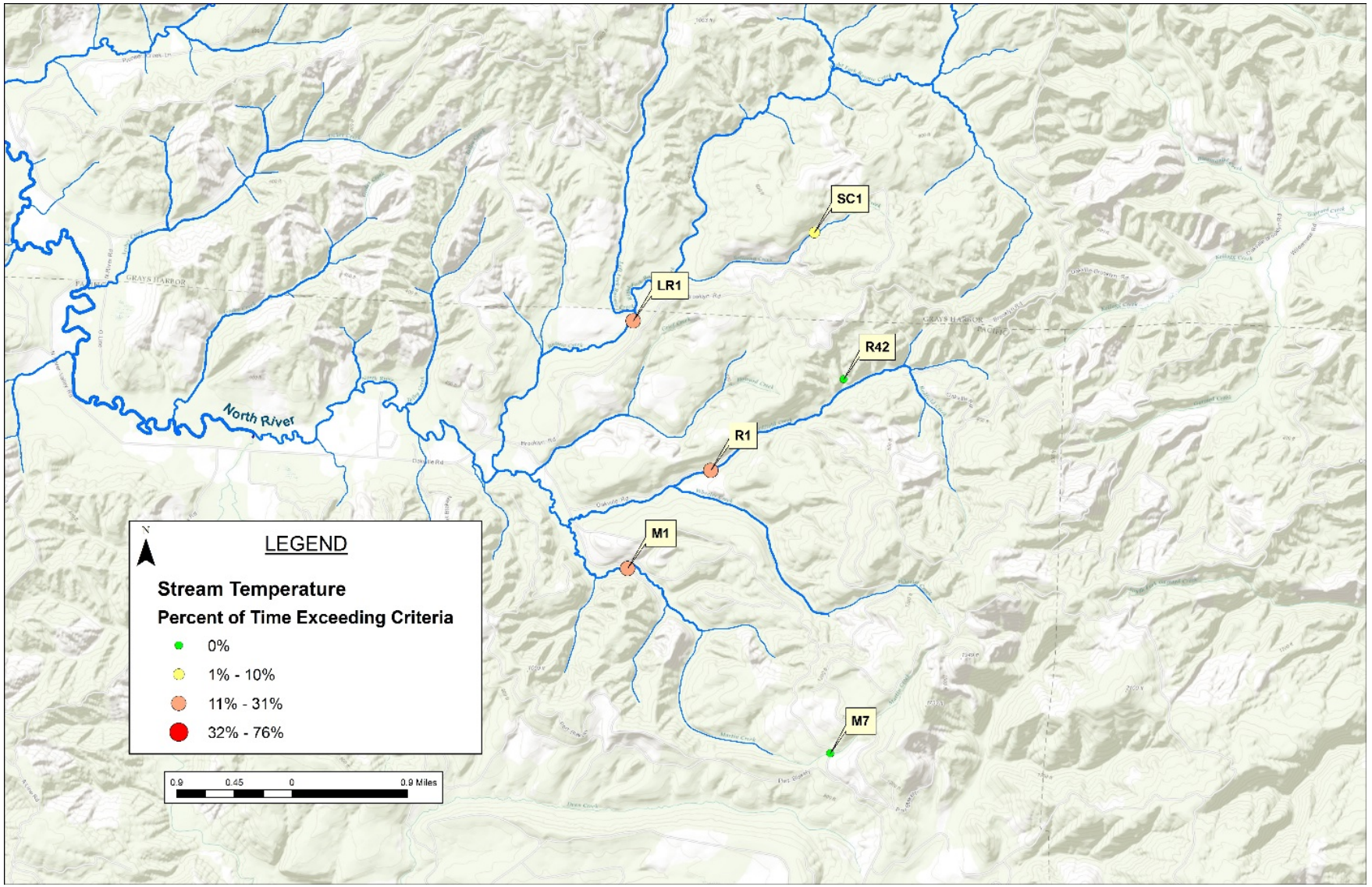


Figure 9. PBTF-monitored locations: Proportions of 7-DADMax exceedance during the thermal critical period (June-Sept 2010).

Quality Assurance Results

Fecal Coliform Laboratory Data

Field replicate and lab duplicate data are required to meet Measurement Quality Objectives outlined in Table 6. For the field replicates, 51.6% of replicate pairs were less than 20% RSD, and 93.5% of the replicate pairs were less than 50% of the RSD. The field replicates met the project objectives for sample precision. For the lab duplicate data, 68% of the duplicate pairs were less than 40% RPD, leaving 32% of the replicate pairs greater than the target 40% RPD. Based on these MQOs all collected data were included as valid collection values and used within the analyses. Field replicate values (QA) were averaged for the summary statistics analyses with their respective sampling location data to better represent variation across concurrent sampling.

The set of FC samples collected on 6/24/15 were received after their designated holding times. All samples on this date were processed within 65 minutes over the holding time (Table 5). A comparison study was conducted to assess the effect of holding times on bacteria samples (Mathieu, 2005). The study demonstrated that the 24-hour holding time has little effect on fecal coliform bacteria (FC) results processed by MEL. Samples with longer holding times did not show a significant tendency towards higher or lower FC counts compared to the samples analyzed within 6-8 hours. Therefore the over-hold on the 6/24/15 samples is not likely to have much influence on the final results; these values were considered useful in the data analysis and were not discarded.

Temperature Data

Thermistor data were downloaded by Ecology staff during several equipment checks over the summer. Two thermistors were found to be out of water; both NOR26.5 and SAL0.1 were relocated to deeper portions to recapture accurate water temperature data. The air and water thermistor data for these sites were compared to determine unrepresentative data (Figures A-11 and A-13); this portion of the data record was removed from the thermographs. Post study, all thermistors were collected and post-calibrated to confirm that the margin of error between the NIST-certified reference thermometer and thermistors was within ±0.21°C. All thermistors used by Ecology met the specified accuracy target, therefore data were deemed acceptable for project objectives and used without qualification.

PBTF installed and retrieved the temperature thermistors used in their Effectiveness Monitoring study, downloaded data, and performed quality control and quality assurance checks (Murden and Reynolds, 2011).

Discussion

Application of Water Quality Criteria

Fecal Coliform Bacteria

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state (WAC 173-201A, 2011).

Based on the results of the study, Ecology's listed bacteria stations, NOR0.0 and NOR2.5 are failing to meet Part II of the water quality criteria for FC. To further discern trends, a single year's worth of data (May 2014-April 2015) was used to calculate the annual/ seasonal boxplot and geometric data (Figures 10, 11).

When evaluating differences across wet and dry seasons, data collected on either side of the dry and wet season were omitted, to restrict the influence of a several season analysis. Dry season analysis spanned from 5/6/14 to 9/24/14 and wet season analysis spanned from 10/8/14 to 4/29/15.

The recommended boundary target values for the upstream stations (NOR3.3/4.7) are listed below:

- Wet Season - FC *Freshwater Boundary Target Values*
    - Geometric Mean = 24 cfu/100 mL
    - 90th Percentile of Data = 74 cfu/100 mL

- Dry Season - FC *Freshwater Boundary Target Values*
    - Geometric Mean = 20 cfu/100 mL
    - 90th Percentile of Data = 61 cfu/100 mL

The measured wet season geometric mean at station 3.3/4.7 was 10 cfu/100 mL with a 90^{th} percentile of 33 cfu/100 mL. This indicates that the wet season FC samples are meeting the *Target Freshwater Boundary Values*. The dry season geometric mean at station 3.3/4.7 was 20 cfu/100 mL with a 90^{th} percentile of 117 cfu/100 mL. The geometric mean is meeting the *Freshwater Boundary Target Values*, however the 90^{th} percentile is far above the target value.

NOR4.7/3.3 had just 6 dry season samples collected at the upstream station over the course of the study. The small number of dry season FC samples is due to adding the station later in the season and site access limitations in the summer of 2015. The Ecology sampling team was unable to navigate to the upper sampling location, NOR4.7, after the end of April and therefore returned to sampling at NOR3.3.

The low number of samples with a high FC count on 9/24/14 of 290 cfu/100 mL may have a strong impact on the 90th percentile exceedance. It is recommended to continue water quality monitoring at these locations to obtain adequate data that represent the system.

Dry season geometric means for NOR0.0 and NOR2.5 are exceeding parts I and II of water quality standards, whereas wet seasons are below or at the cusp of meeting both criteria (Figure 10). Figure 11 further demonstrates that dry season geometric means are negatively impacting water quality.

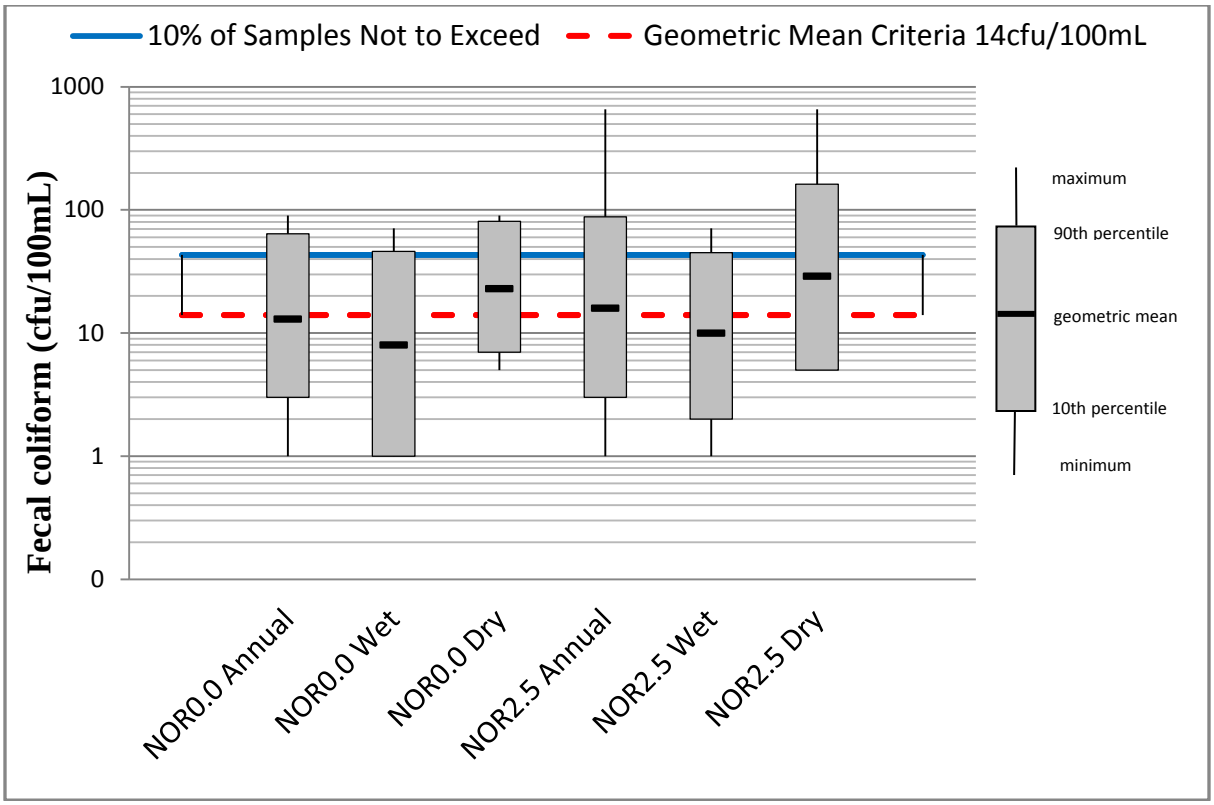


Figure 10. Boxplots for annual, wet, and dry FC concentrations at NOR0.0, NOR2.5, and NOR4.7/3.3 using marine criteria.

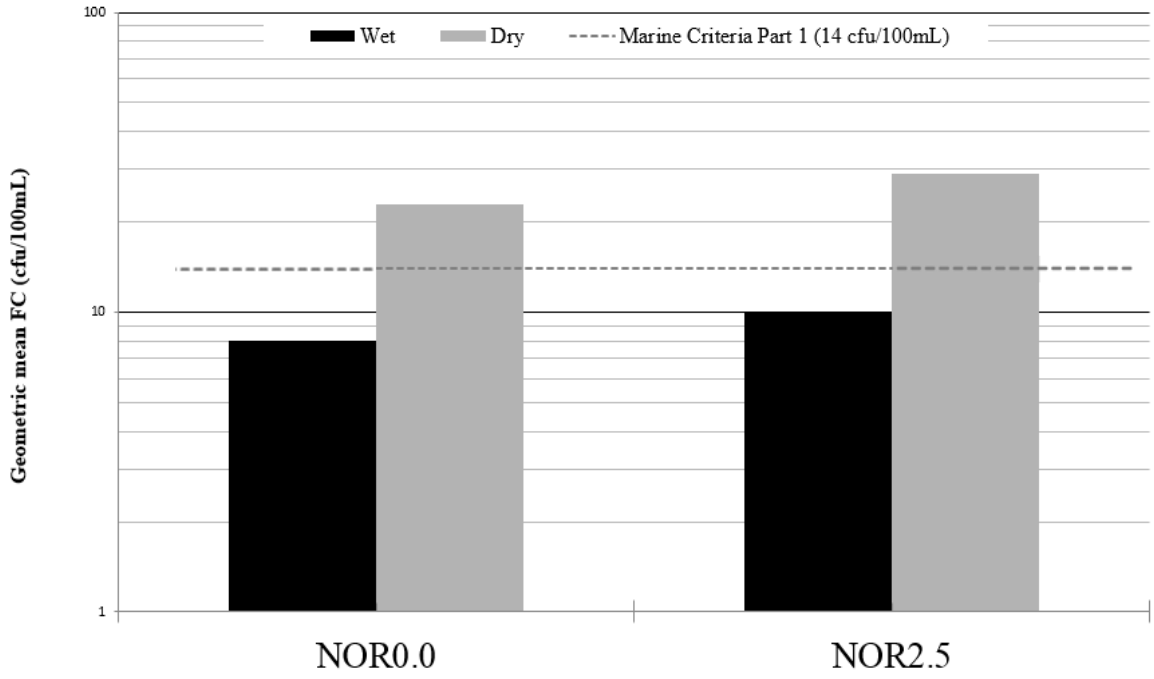


Figure 11. Differences across FC wet and dry season geometric means for marine criteria sampling locations.

To investigate the effects of salinity on FC, measured salinity (ppt) and FC (cfu/100 mL) lab result data from wet and dry seasons at each sampling location were plotted together. The data generally follow that the higher the salinity, the lower the FC (Figure 12). There are several instances where the data points do not follow this trend. For example, the rain event on 9/24/14 that produced the highest FC concentrations (Table 9, Figure 7) also created outliers in the data (Figure 12).

At NOR4.7, the highest measured dry season FC concentration (290) on 9/24/14 is influenced by a surge of freshwater (0.05 ppt). The water parcel increases in salinity as it moves downstream (9.9 at NOR2.5, 24.42 at NOR0.0). However, the 9/24/14 outlier continues to carry across the top of each dry season graph. Higher salinity at NOR0.0 may also correlate with lower hits (59 cfu) as opposed to the largest FC hit at NOR2.5 (greater than 655).

The rain event (1.44") within this dry period sampling event (9/24/14) stands out, and is one data set that may be contributing to the high dry season geometric means (Figure 11). Additional sampling events during the dry season with documented rain events include: 0.87" total from 8/12-8/13/14 and a total of 1.83" that fell during 5/3-5/5/14 (NOAA 2014). A repetitive outlier during the wet season was seen on 10/8/14, where higher salinities at the upper stations were a dominating factor.

Other potential sources of FC pollution in the study area include storm runoff from logged hillsides, untreated greywater, Float House septage, and wildlife. In 1993, the Willapa Watershed Bacterial Evaluation and Preliminary Control Strategy study was conducted to

identify problem areas (Seyferlich and Joy, 1993). This study identified the Float Houses as a health hazard to the shellfish growing area because of their inadequate waste disposal systems. Improvements were made, requiring that owners of the Float Houses obtain composting toilets and prevent septage from entering the river. However, there is still a possibility of persistent inputs from non-compliance or untreated greywater inputs.

Increased colonies of FC during the dry season are occurring in the river and the Float Houses appear to have greater occupancy in the summer seasons. More people are accessing the river for fishing and other recreational activities, thus increasing the possibility of anthropogenic inputs. Alternatively, less fresh water is entering the system and more tidal water fills into the brackish area. Movements of tides expose tidal flats where more sediment and bacteria colonies can be re-suspended up into the water column. In addition to tidal flux, heavy rain events can cause soil to enter the system from logged hillsides near the river's edge.

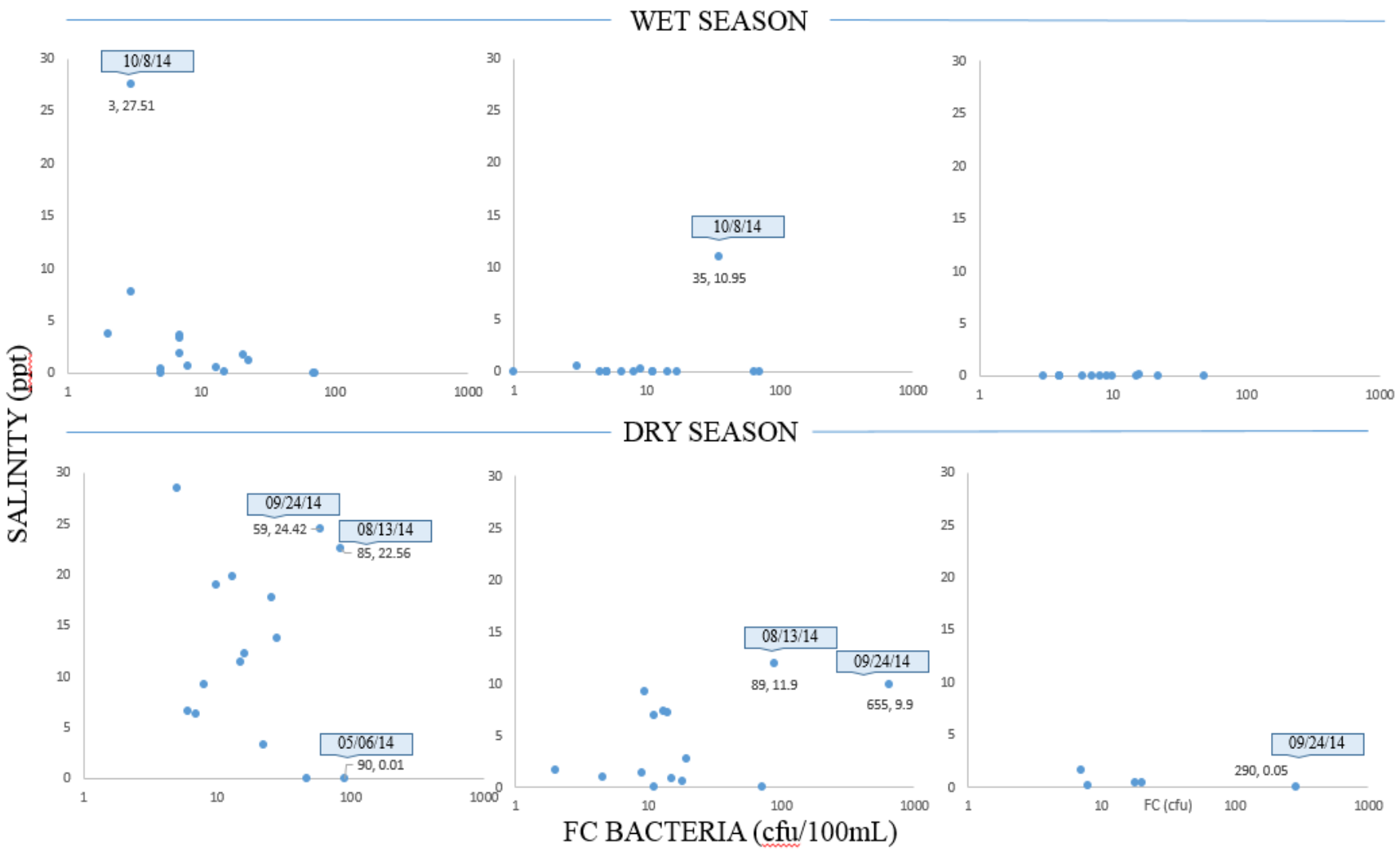


Figure 12. Comparisons of wet and dry season salinity to FC values for NOR0.0, NOR2.5 and NOR4.7/3.3.

Temperature

Historical land uses that have contributed to exceedances in stream and river temperatures include past disturbances from logging practices and splash damming. Creating temporary dams to impound lumber and then removing the dams to move a lot of water and the lumber down river have changed the original structure and function of the watershed (Sedell and Luchessa, 1992). This practice is no longer used and some industrial forest landowners are required to follow Forest Practice Rules or an approved HCP, as is the case with Port Blakely Tree Farm (PBTF).

The water quality standards recognize that not all waters are naturally capable of staying below protective temperature criteria. Additional allowance for warming, due to human activities, may not increase 0.3°C (0.54°F) above the natural high temperature conditions. Defining natural conditions is outside the scope of this study; therefore, the continuous temperature results are just compared to the numeric criteria and not a modeled natural condition.

River and stream recovery from historical disturbances is a slow and difficult process. Ongoing compliance with an HCP prescriptions and forest practice rules will assist in achieving system potential temperature conditions.

2010 Temperature Data

Two record maximum air temperatures were set in 2010, on 7/7/10 (93°F) and the other on 8/14/10 (95°F) (Figure 13, Figure A-2). The thermal peaks, visible across all of the data provided in Appendix A (Figures A-1 through A-7) display a delayed stream temperature increase approximately two days after the record high air temperatures. These record air temperature maximum values contributed to Raimie, Martin, Sullivan, and Redfield Creeks exceedances of their respective water quality standards for their designated uses.

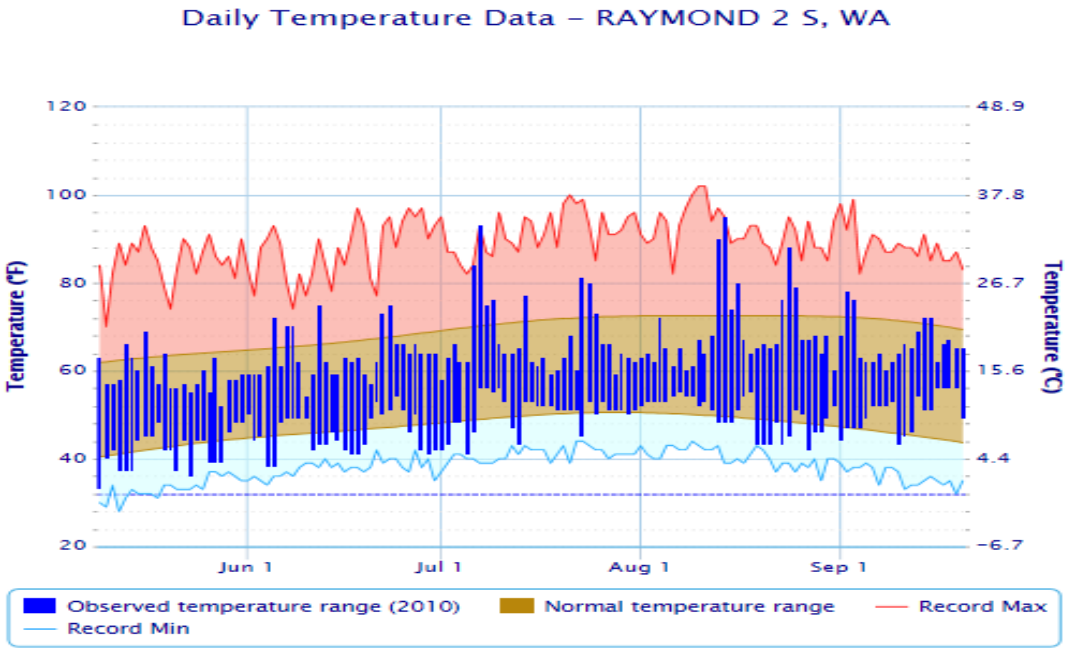
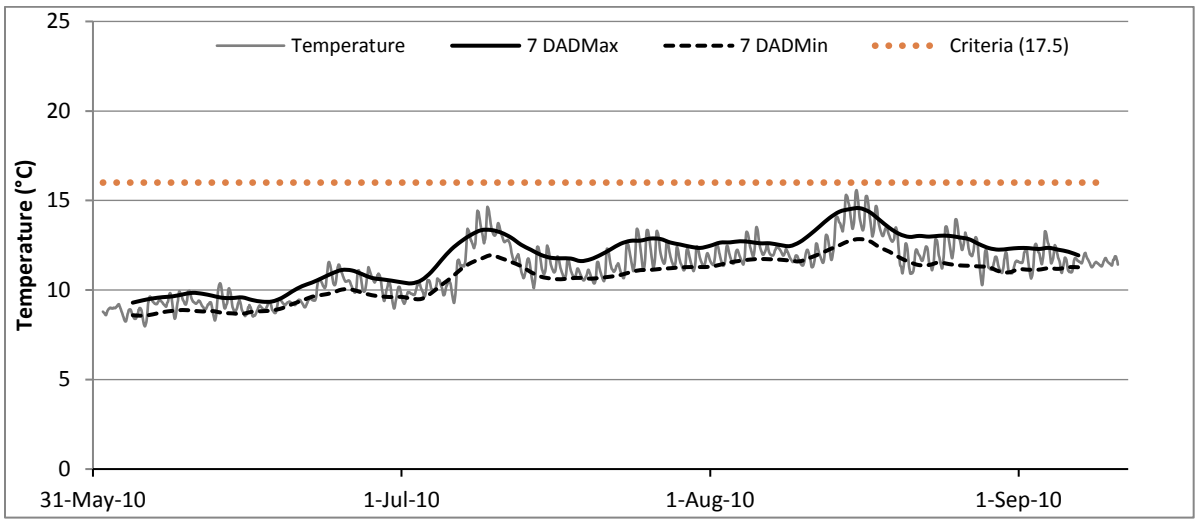


Figure 13. Summer daily air temperature data for 2010, obtained from NOAA (NOAA, 2014).

In addition to ambient air temperatures, increased water temperature data at PBTF have been identified near beaver impoundments and low gradient stream segments. These natural constituents can create temperature variation across the landscape.

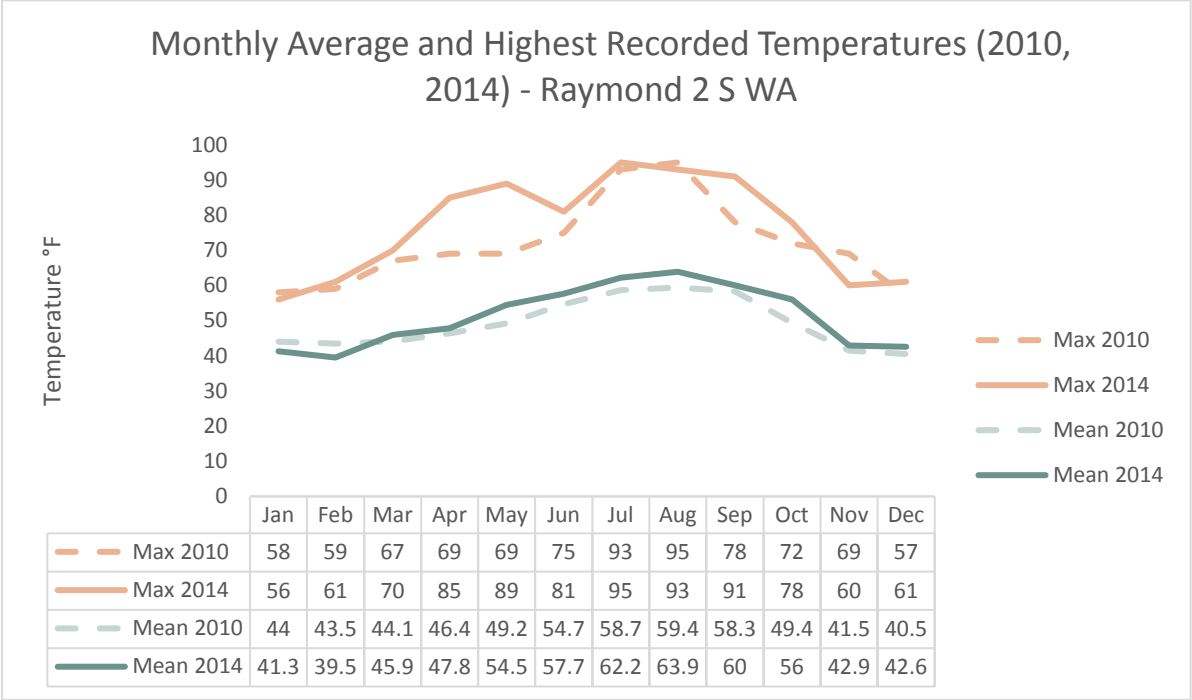
Upper Martin Creek (M7) and upper Redfield (R42) are the only two stations meeting criteria across the entire study. They fall outside the supplemental spawning criteria areas and have less stringent water quality criteria. M7 and R42 are also located at higher elevations and steeper gradients than their lower counterparts, lower Martin (M1) and lower Redfield (R1). M7 and R42 have received riparian boundary prescriptions and have had a decreased number of pools over time (Murden and Reynolds, 2011).

The 2010 data from Upper Martin (M7) demonstrates the cool creek's response to record high summer temperatures. The thermal peaks are evident; Martin Creek reacted to the high temperatures on 7/7/10 (93°F) and 8/14/10 (95°F) (Figure A-2).



(Figure A-2). 7-DADMin/Max of **Upper Martin Creek (M7)**, listing #35312 on the 303(d) list.

Figure 14 displays the average monthly air temperatures and the maximum air temperatures across both study years (2010, 2014). The mean air temperatures are relatively stable, whereas the maximum air temperatures are extremely variable from year to year. Therefore, long-term data sets with continuous records are recommended in evaluating variations in seasonal warming or rain duration/intensity.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max 2010	58	59	67	69	69	75	93	95	78	72	69	57
Max 2014	56	61	70	85	89	81	95	93	91	78	60	61
Mean 2010	44	43.5	44.1	46.4	49.2	54.7	58.7	59.4	58.3	49.4	41.5	40.5
Mean 2014	41.3	39.5	45.9	47.8	54.5	57.7	62.2	63.9	60	56	42.9	42.6

Figure 14. Monthly average and highest air temperatures for 2010 and 2014.

2014 Temperature Data

In 2014, several record air temperatures were reached in the North River watershed: 95°F on 7/1, 91°F on 9/6, and 90°F on 9/7. Stream thermographs from the Ecology study display 3 waves of thermal peaks, at the beginning of July, August and September (Figures A-7 through A-14). These stream temperature peaks appear to coincide with series of days that are above the normal temperature range for the time of year (Figure 15, Figure A-9).

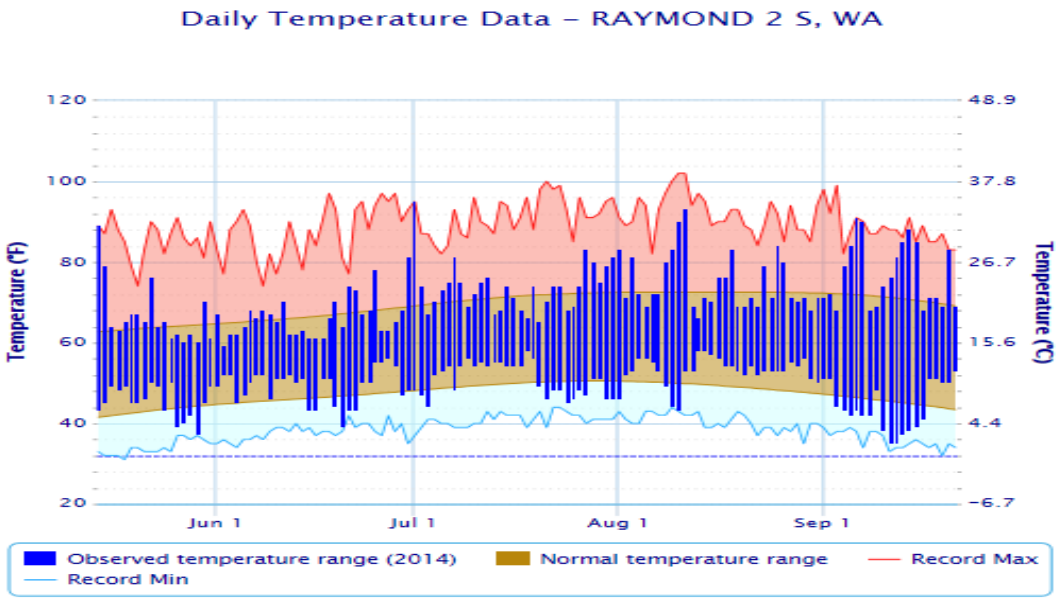
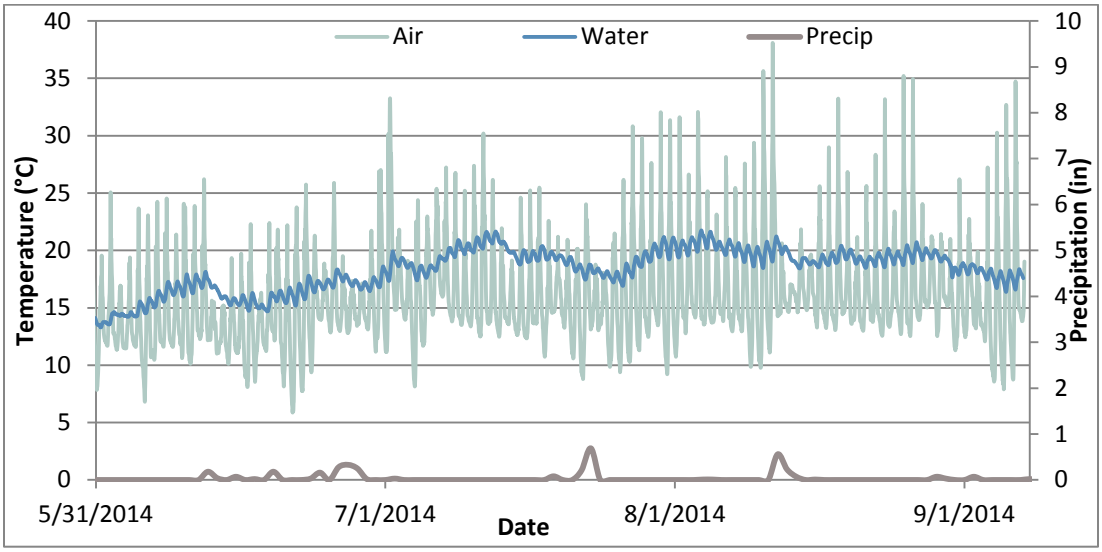


Figure 15. Summer daily air temperature data for 2014, obtained from NOAA (NOAA, 2014).



(Figure A-9). **North River Mainstem (NOR10.4)** 2014. Thermograph of air and water temperatures with precipitation. Listing # 6909 on the 303(d) list.

Several of the streams are close to meeting temperature criteria: Joe Creek and the East Fork of the North River, as well as Lower Martin and Sullivan Creeks. However, they all exceed the 0.3°C incremental allowance for their respective designated criteria.

Ecology's temperature monitoring equipment passed all accuracy checks. However, the range of instrument error, along with the incremental allowance for warming due to human activities may be greater than stream temperature exceedances of numeric criteria. Continued monitoring of these locations will be necessary to understand long-term patterns and trends in the North River and its tributaries.

Conclusions

The North River verification study has determined whether the existing 303(d) listed stream segments meet Washington State surface water quality criteria. To meet the objectives, this project relied on data collected by Ecology staff during the 2014-2015 study period and the 2010 data collected by Port Blakely Tree Farms (PBTF). Fecal coliform bacteria (FC) and temperature were monitored at the associated 303(d) listed segments (Table 12) in the North River watershed for each given parameter. Recommended actions are shown in Table 12 and detailed in Recommendations section of this report.

Table 12. Recommendations for North River Verification Study listings.

Water Body	Parameter	Listing ID	Associated Sampling Location	Issues/ Concerns	Recommended Action
North River	Bacteria	n/a	NOR4.7/3.3	Selected as upstream sampling location(s) for bacteria portion of the study	Not meeting *Freshwater Boundary Target Values;* Re-sample across dry season; measure vertically averaged salinity
North River	Bacteria	6691	NOR2.5	Not meeting Primary Contact Marine Water Quality Standards	Category 5 listing stands
North River	Bacteria	6686	NOR 0.0	Not meeting Primary Contact Marine Water Quality Standards	Category 5 listing stands
North River	Temperature	6909	NOR10.4	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
North River	Temperature	6913	NOR28.9	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
North River	Temperature	6907	NOR26.5	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
North River, East Fork	Temperature	6905	EFNR0.1	Exceeding criteria by a maximum of 0.38°C	Re-instrument Tributary for verification
Joe Creek	Temperature	6906	JOE2.1	Exceeding criteria by a maximum of 0.63°C	Re-instrument Tributary for verification
Martin Creek	Temperature	35312	M7	Meeting criteria	--
Martin Creek	Temperature	35307	M1	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
Raimie Creek	Temperature	35306	LR1	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
Redfield Creek	Temperature	35316	R42	Meeting criteria	--
Redfield Creek	Temperature	35314	R1	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
Salmon Creek, Upper	Temperature	6911	SAL0.1	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands
Sullivan Creek	Temperature	35320	SC1	Exceeded Criteria by a maximum of 0.09°C	Category 5 listing stands
Unnamed Creek (trib to N. River)	Temperature	6908	UNT0.1	Not Meeting Primary Contact Recreation Criteria	Category 5 listing stands

Recommendations

Fecal Coliform Bacteria

- At NOR3.3/4.7, re-sample FC during dry season to further assess exceedance; measure vertically averaged salinity using methods from EAP075 *Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters* (Mathieu, 2013).

- Examine influence of incoming tides on FC in the North River, using DOH shellfish sampling data near the mouth of North River and Smith Creek, and look for trends.

- Coordinate efforts between Ecology, DNR, and Pacific County to ensure that owners of Float Houses are in compliance with their lease agreements and following applicable county ordinances to remove their sewage from the river and properly manage and dispose of that waste.

Temperature

- Several of the instrumented temperature listings were close to meeting criteria. It is recommended that the following reaches have continued monitoring to evaluate long-term trends and inter-annual variability: East Fork North River, Joe and Sullivan Creeks.

- Several of the PBTF creeks fall under critical spawning criteria from Feb 15 to July 1. To investigate whether these listed reaches meet the criteria, Ecology staff should re-instrument the following tributaries to capture the supplemental spawning period: Raimie, Lower Redfield, Lower Martin, and Sullivan Creeks.

- Continue forest management practices in accordance with Forest Practice Rules where applicable; continued forest management and monitoring by PBTF under their HCP at existing stations.

- Further analyze and interpret Port Blakely Tree Farms' upcoming publication (2011-2015 data set) to observe inter-annual variability and data trends.

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Appendices

Appendix A. Thermographs

Port Blakely Thermographs

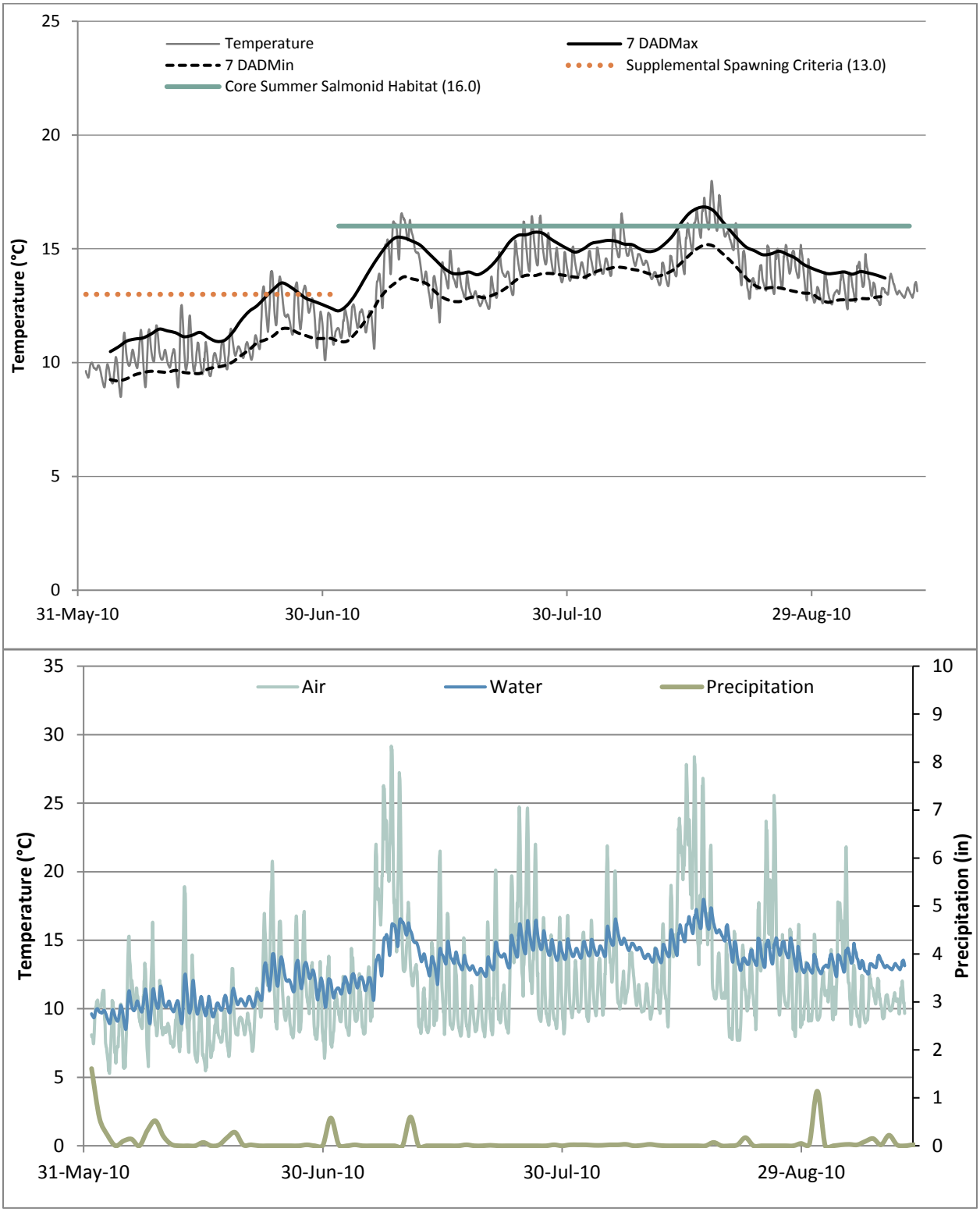

Figure A-1. Upper: 7-DADMin/Max of **Lower Martin Creek (M1)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing #35307 on the 303(d) list.

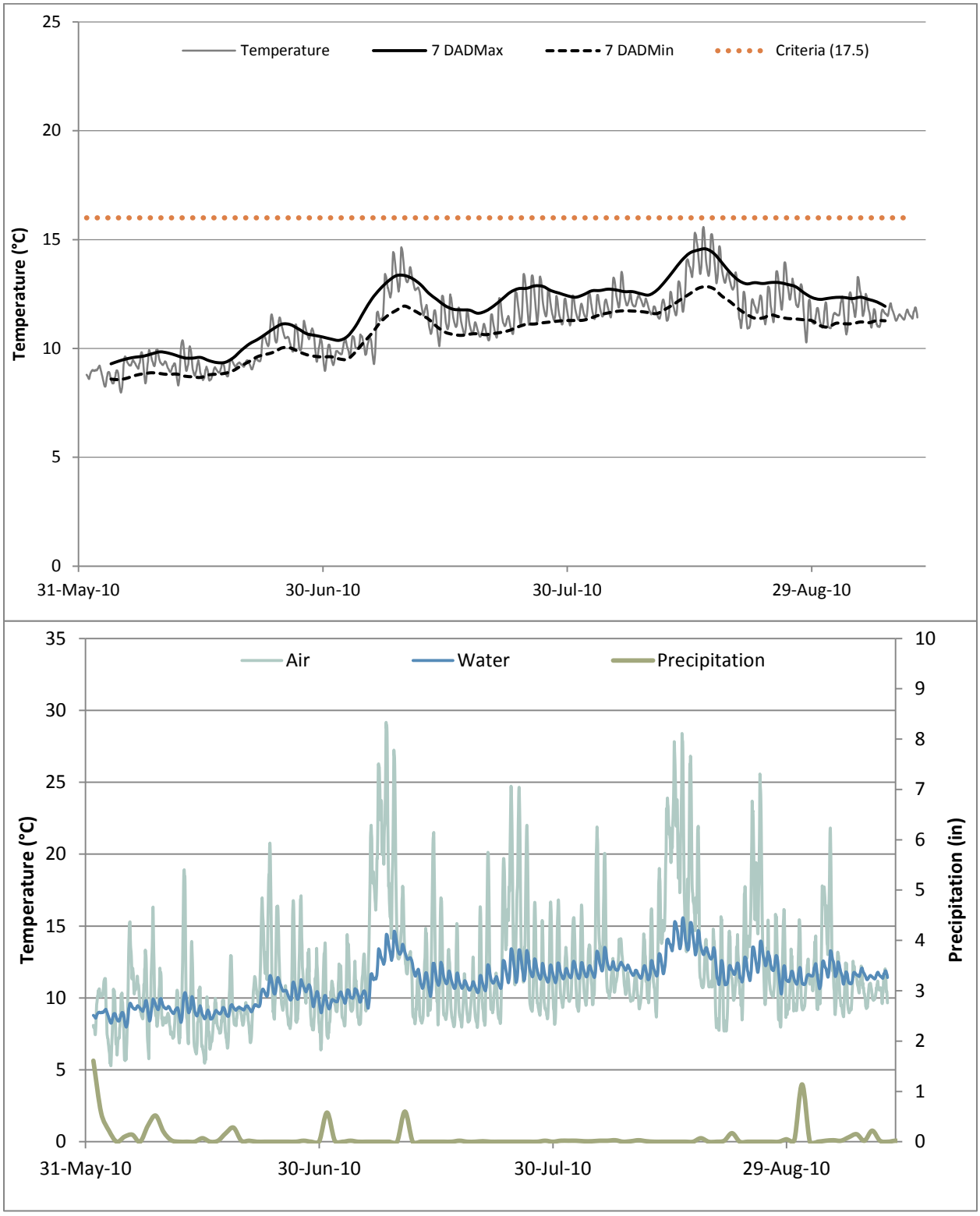

Figure A-2. Upper: 7-DADMin/Max of **Upper Martin Creek (M7)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing #35312 on the 303(d) list.

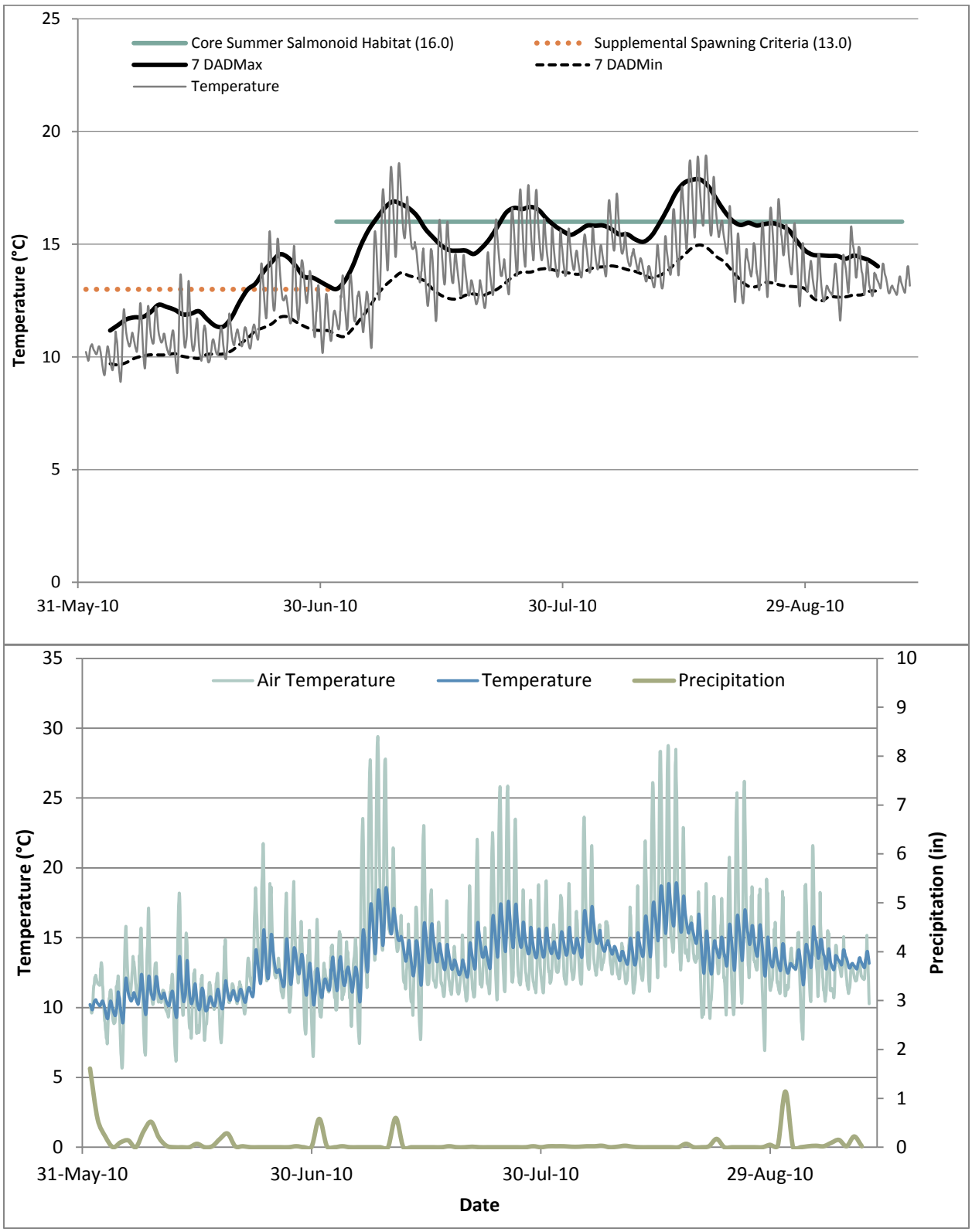

Figure A-3. Upper: 7-DADMin/Max of **Raimie Creek (LR1)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing #35306 on the 303(d) list.

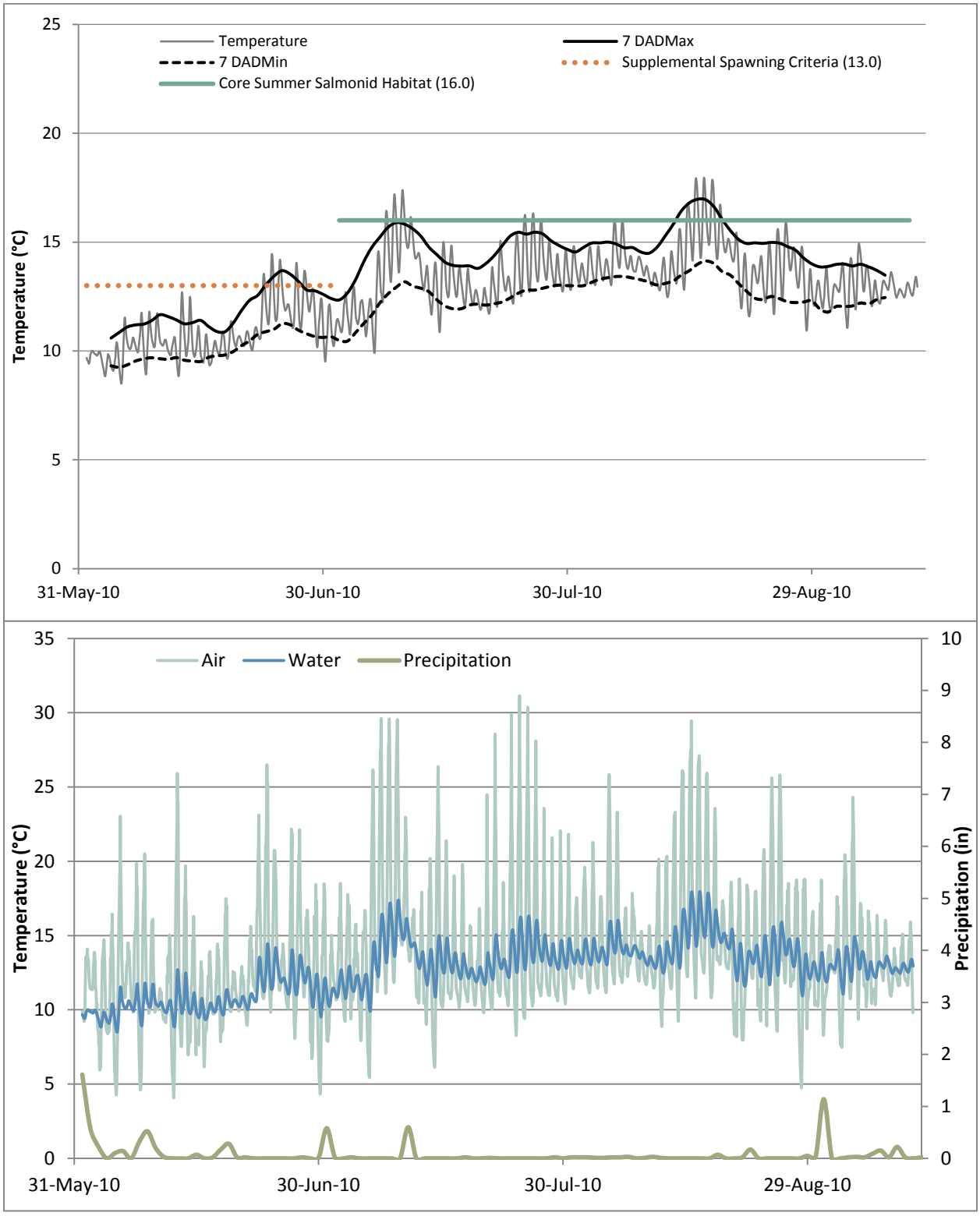

Figure A-4. Upper: 7-DADMin/Max of **Redfield Creek (R1)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing #35314 on the 303(d) list.

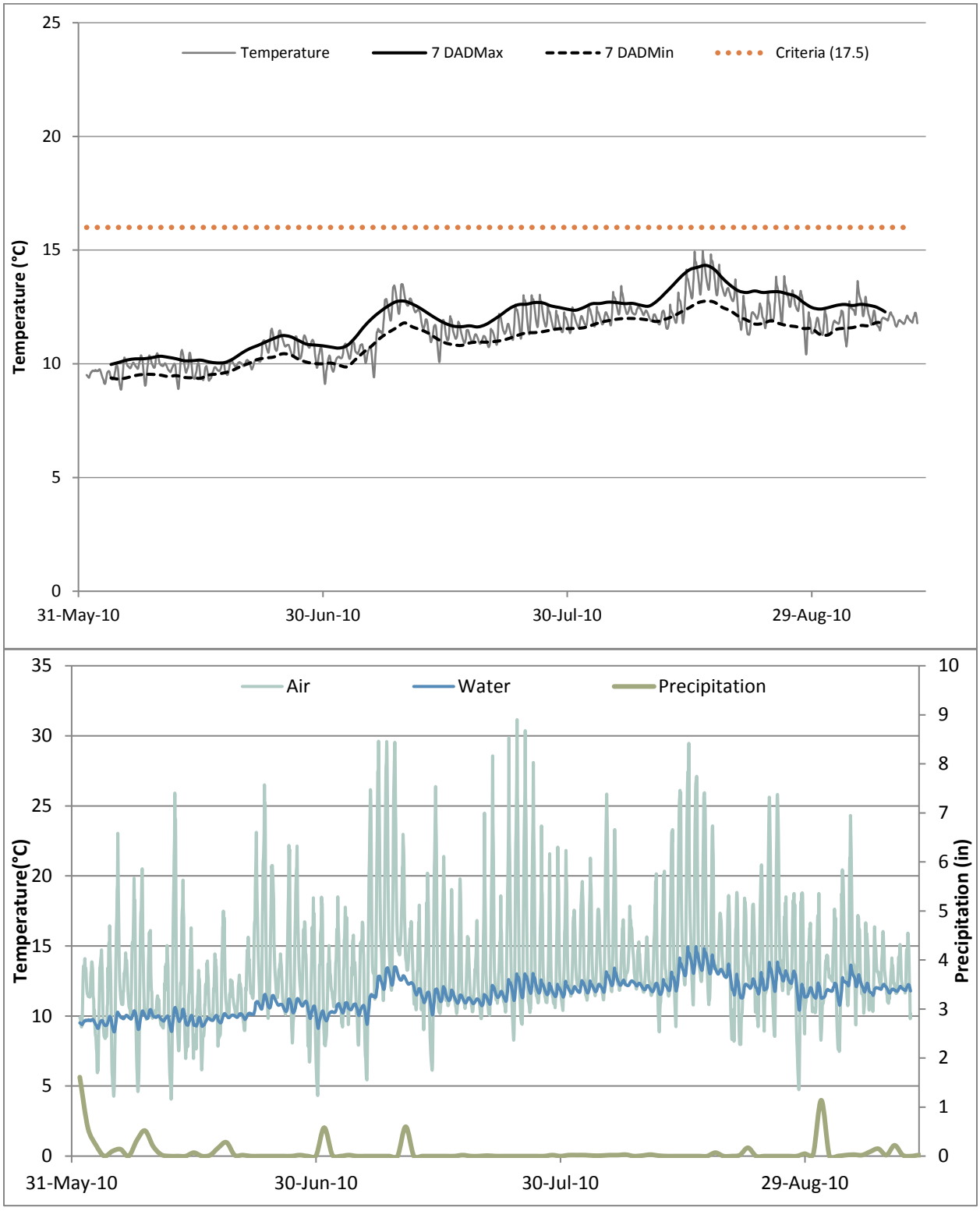

Figure A-5. Upper: 7-DADMin/Max of **Redfield Creek (R42)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing #35316 on the 303(d) list.

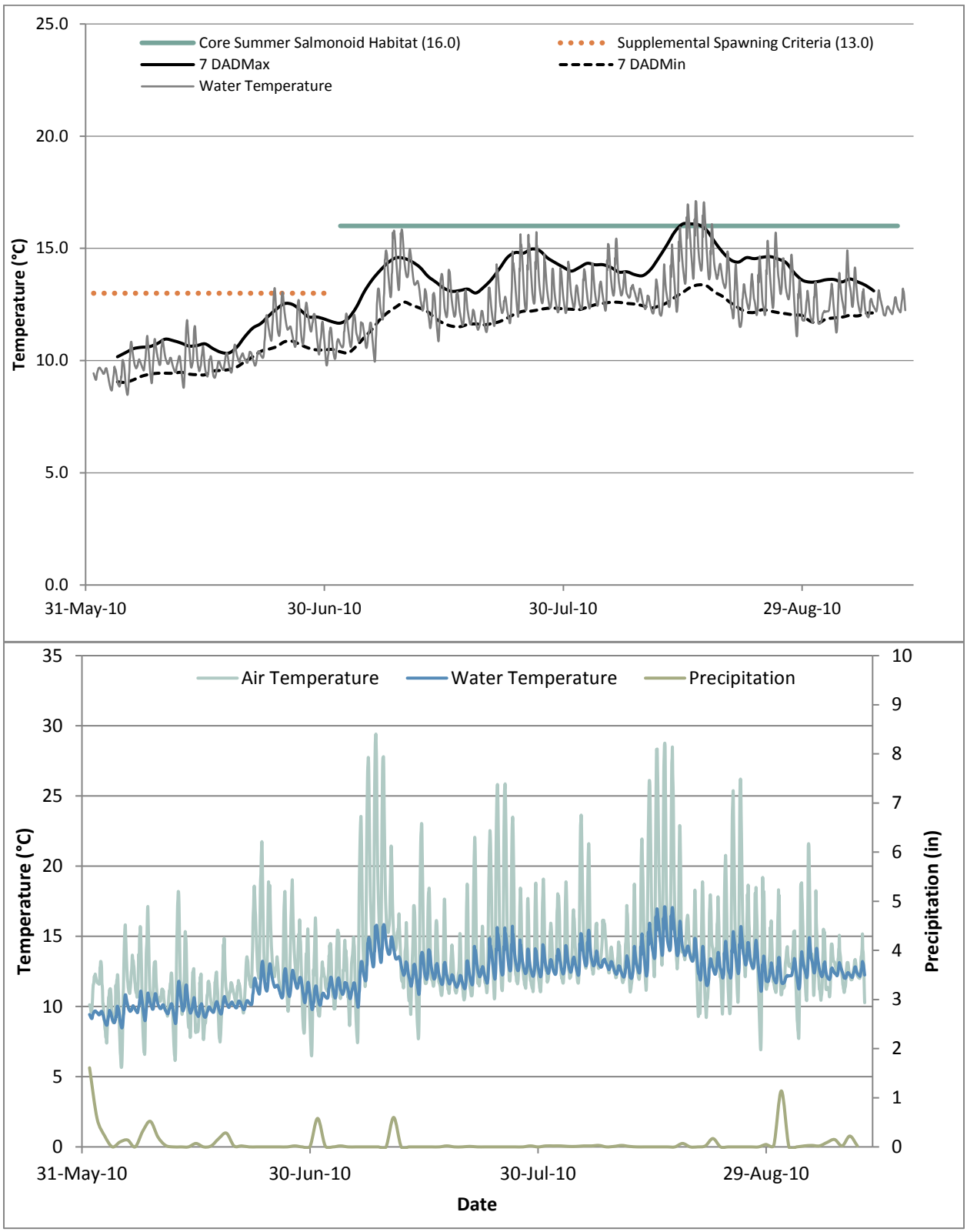

Figure A-6. Upper: 7-DADMin/Max of **Sullivan Creek (SC1)**, 2010; Lower: Thermograph of air and water temperatures with precipitation. Listing # 35320 on the 303(d) list.

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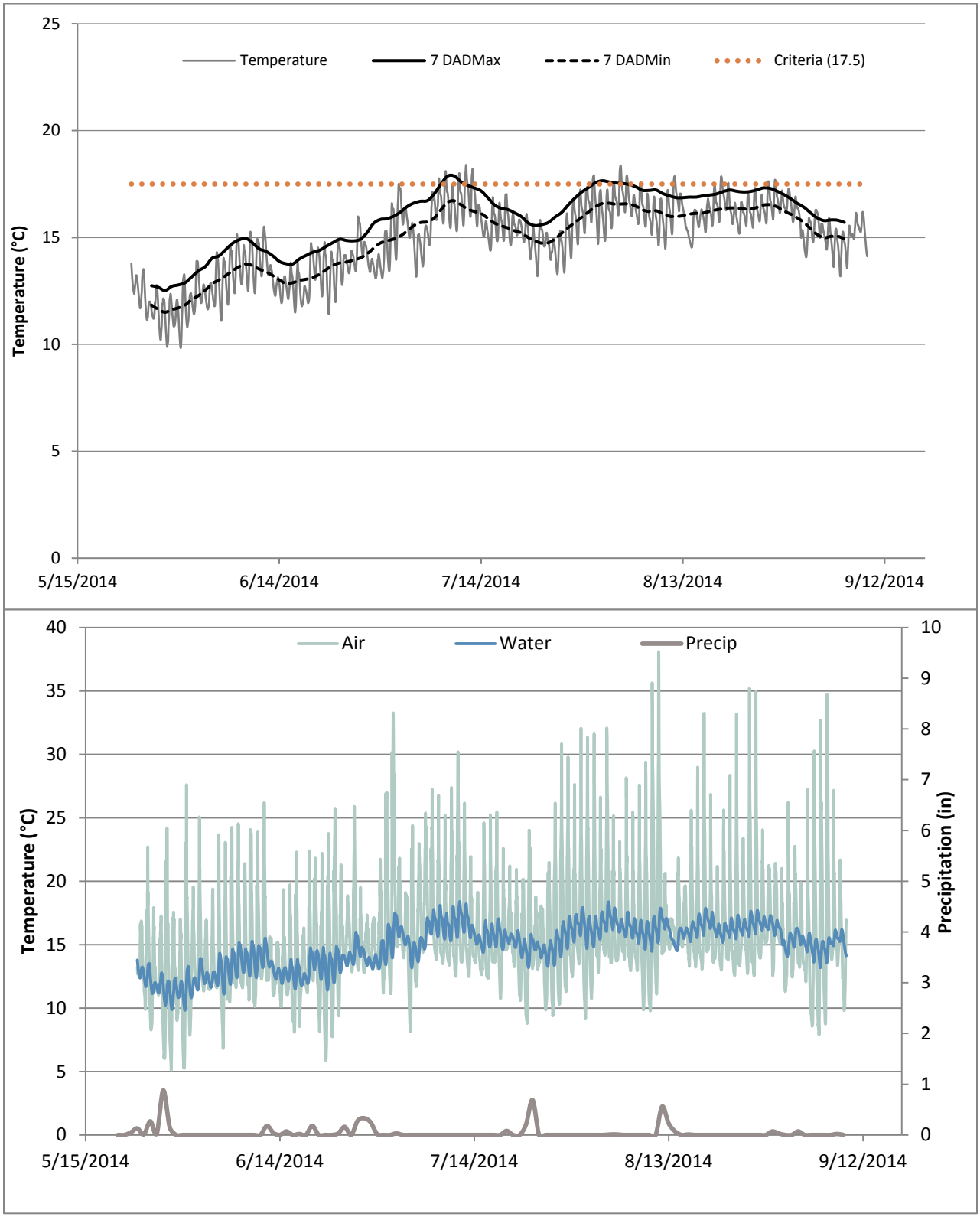

Figure A-7. 7-DADMin/Max of East Fork **North River (EFNR0.1)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6905 on the 303(d) list.

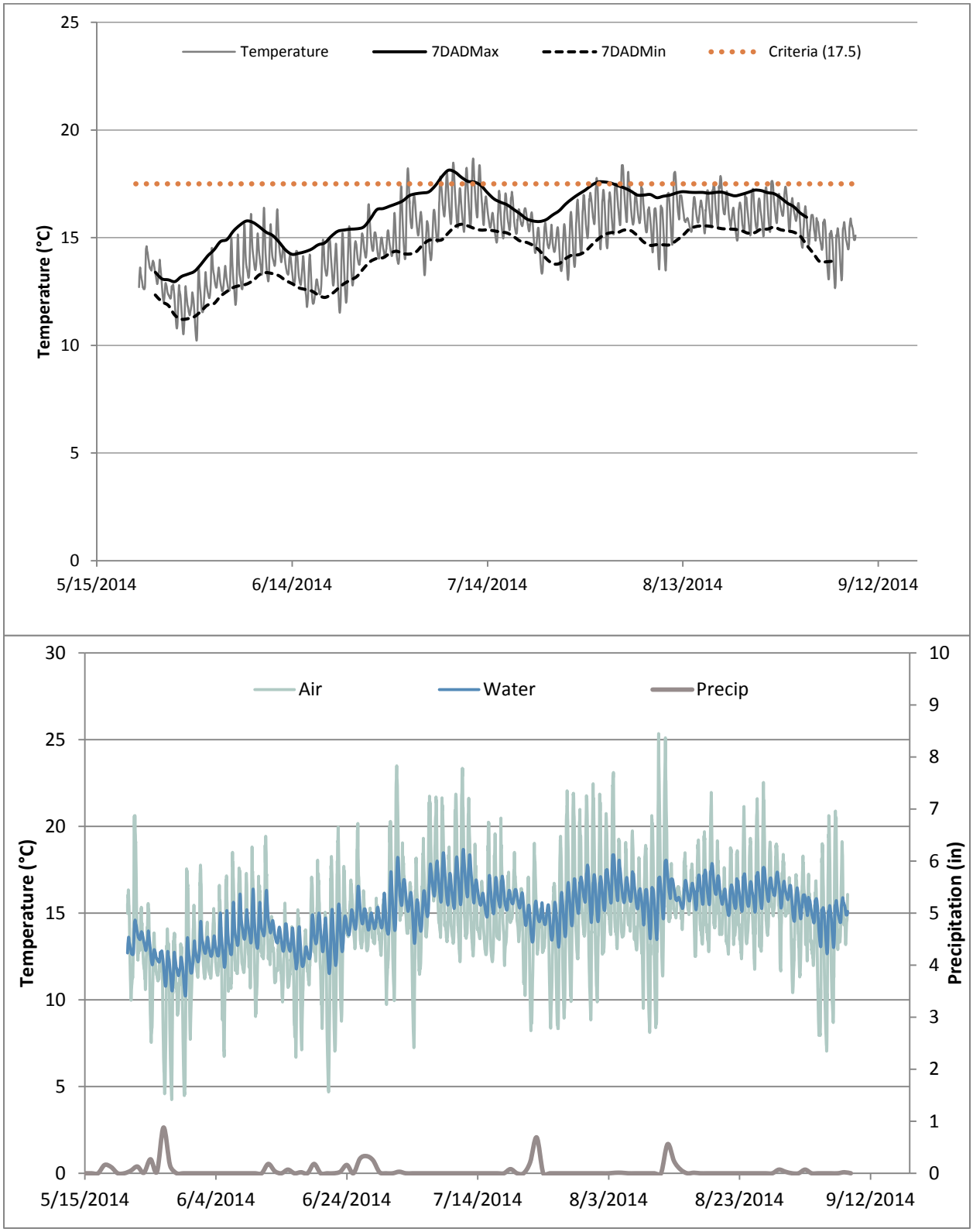

Figure A-8. 7-DADMin/Max of **Joe Creek (JOE2.1)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6906 on the 303(d) list.

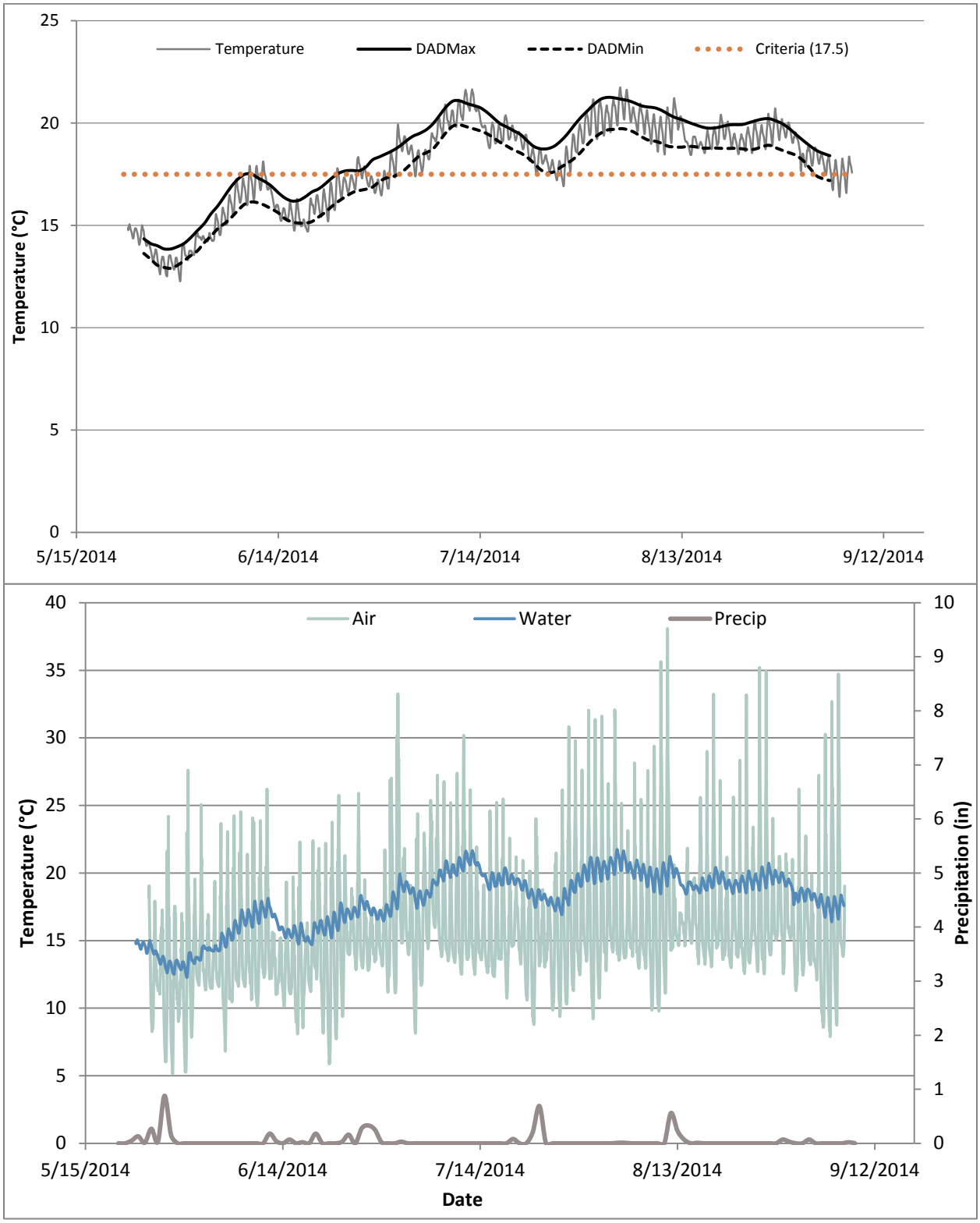

Figure A-9. 7-DADMin/Max of **North River Mainstem (NOR10.4)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6909 on the 303(d) list.

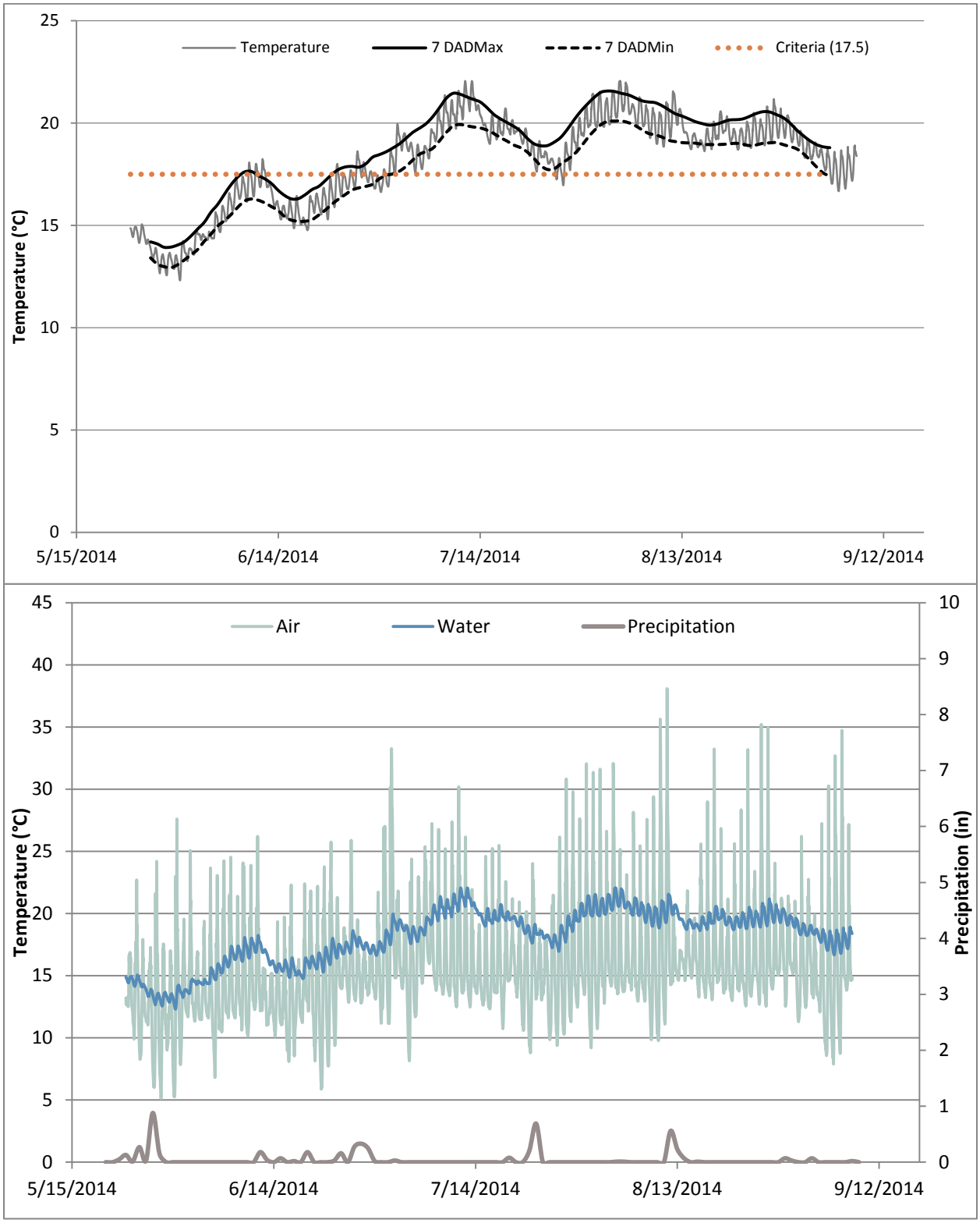

Figure A-10. 7-DADMin/Max of **North River Mainstem (NOR11.4)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6908 on the 303(d) list.

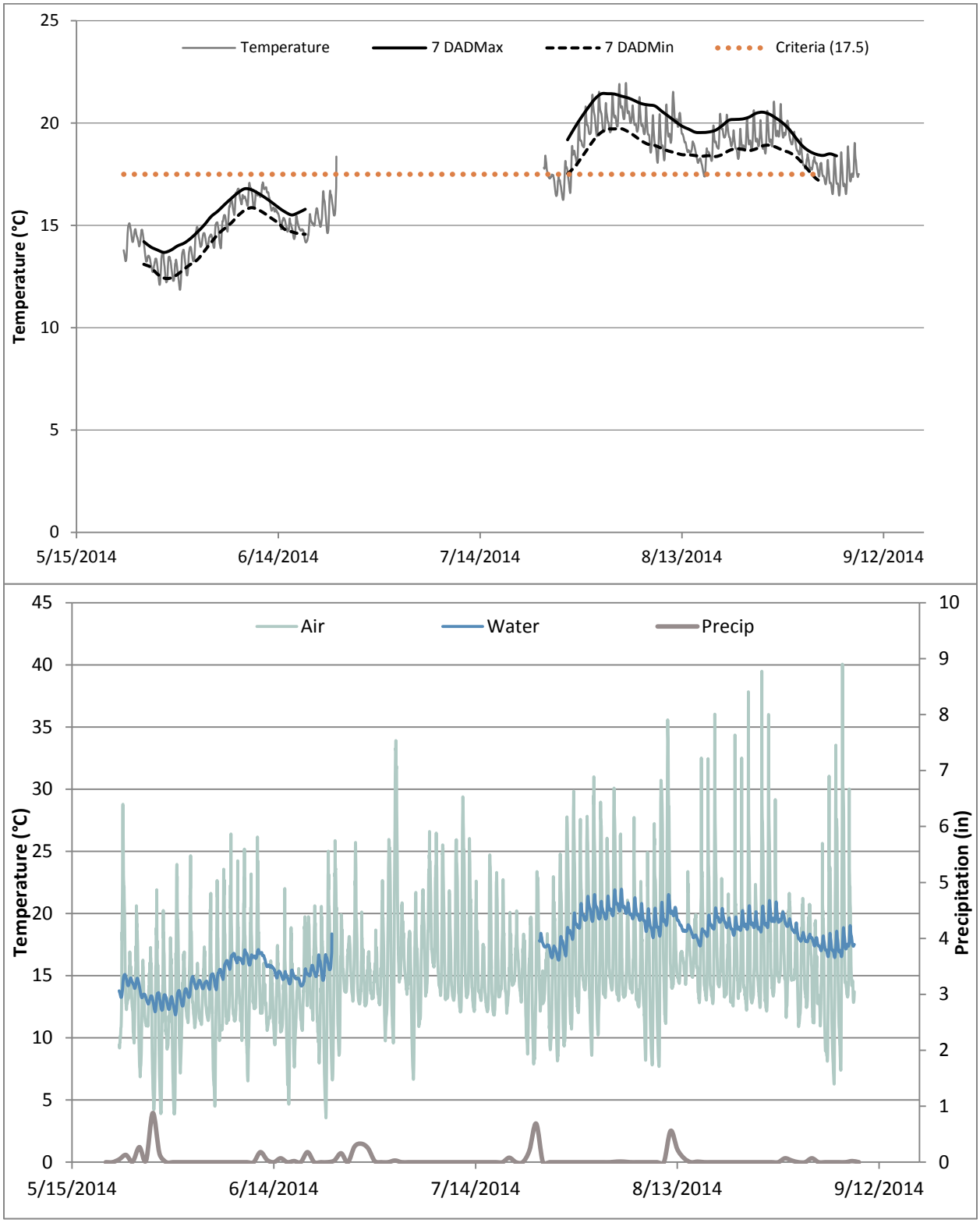

Figure A-11. 7-DADMin/Max of **North River Mainstem (NOR26.5)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6907 on the 303(d) list.

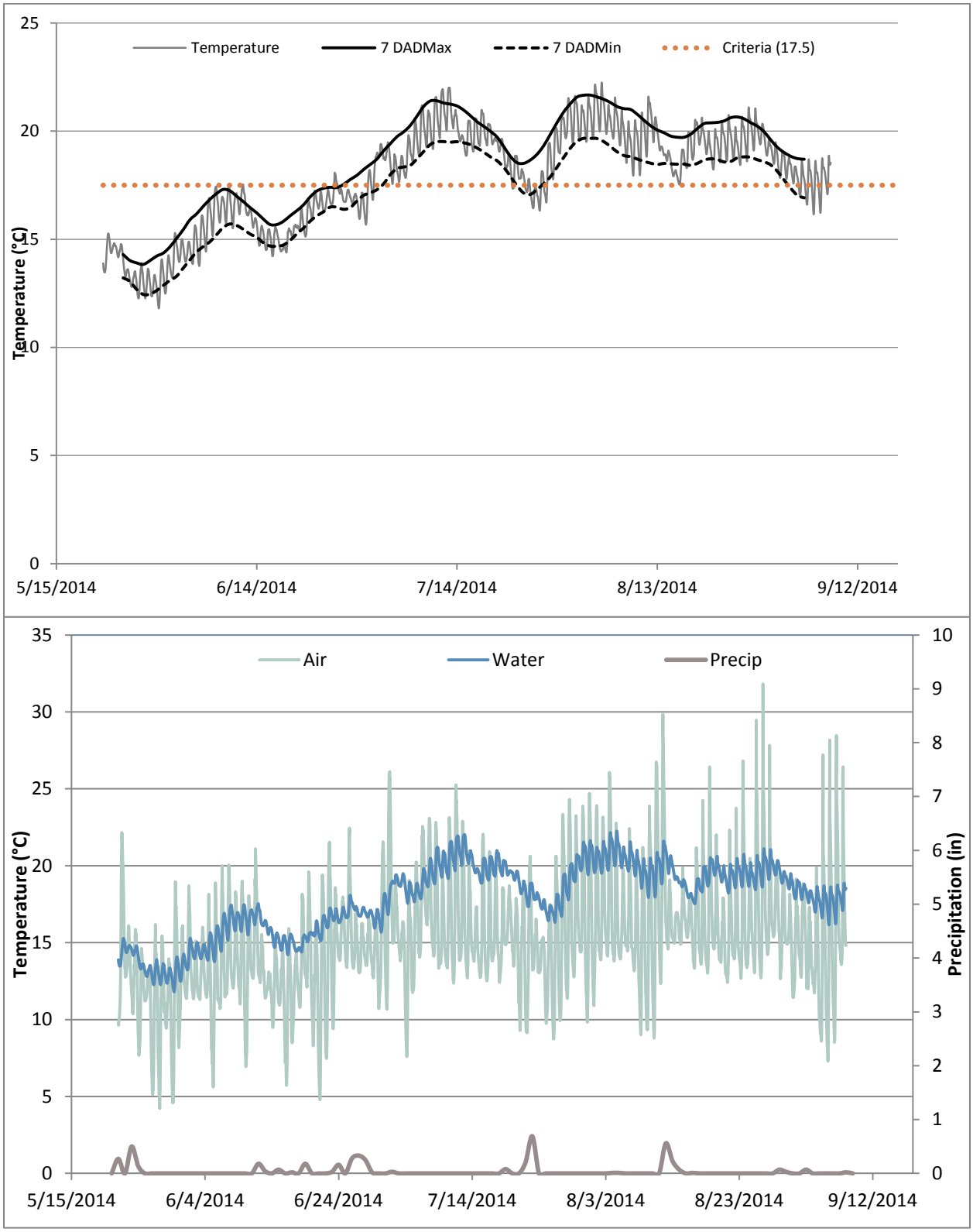

Figure A-12. 7-DADMin/Max of **North River Mainstem (NOR28.9)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6913 on the 303(d) list.

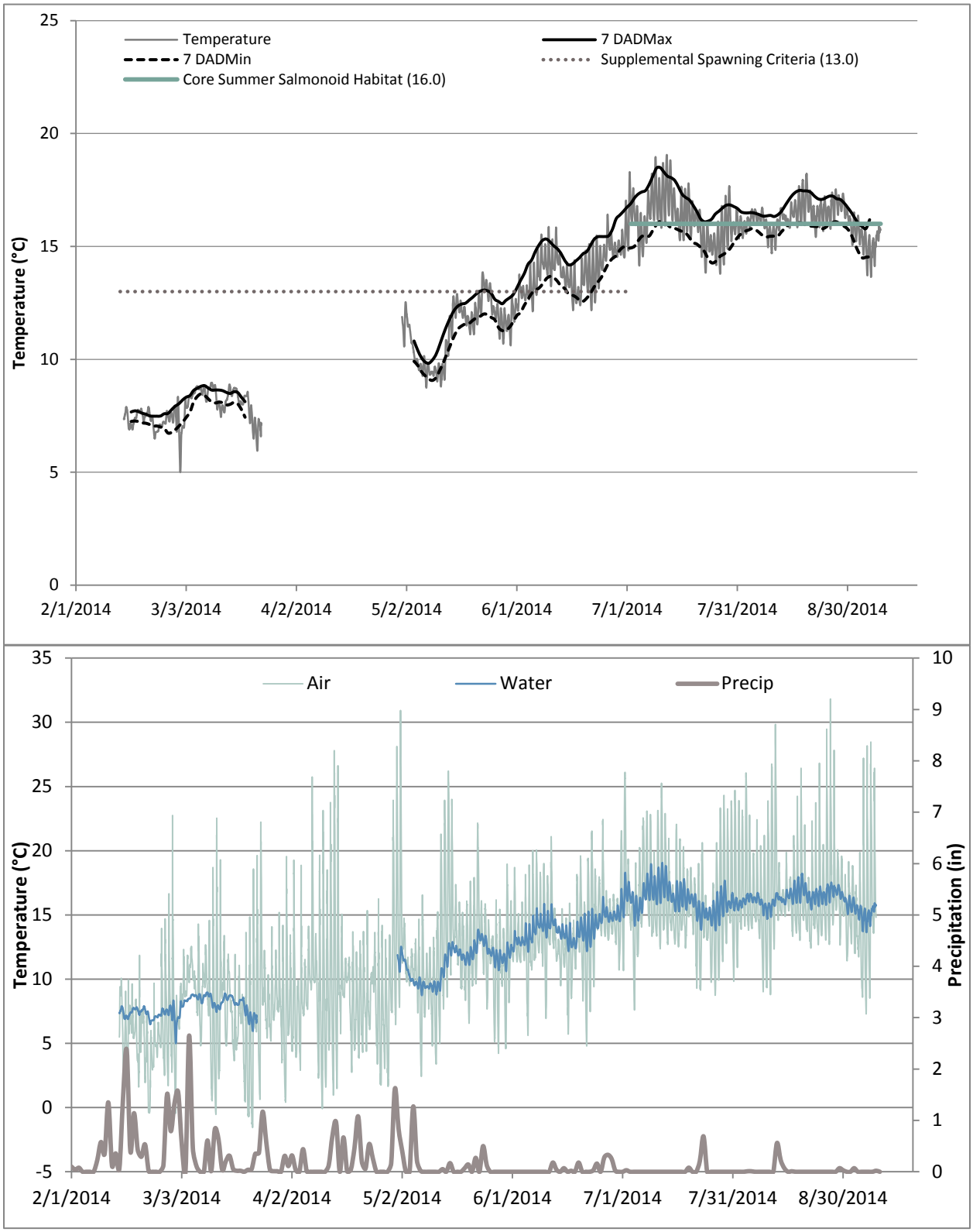

Figure A-13. 7-DADMin/Max of upper **Salmon Creek (SAL0.1)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6911 on the 303(d) list.

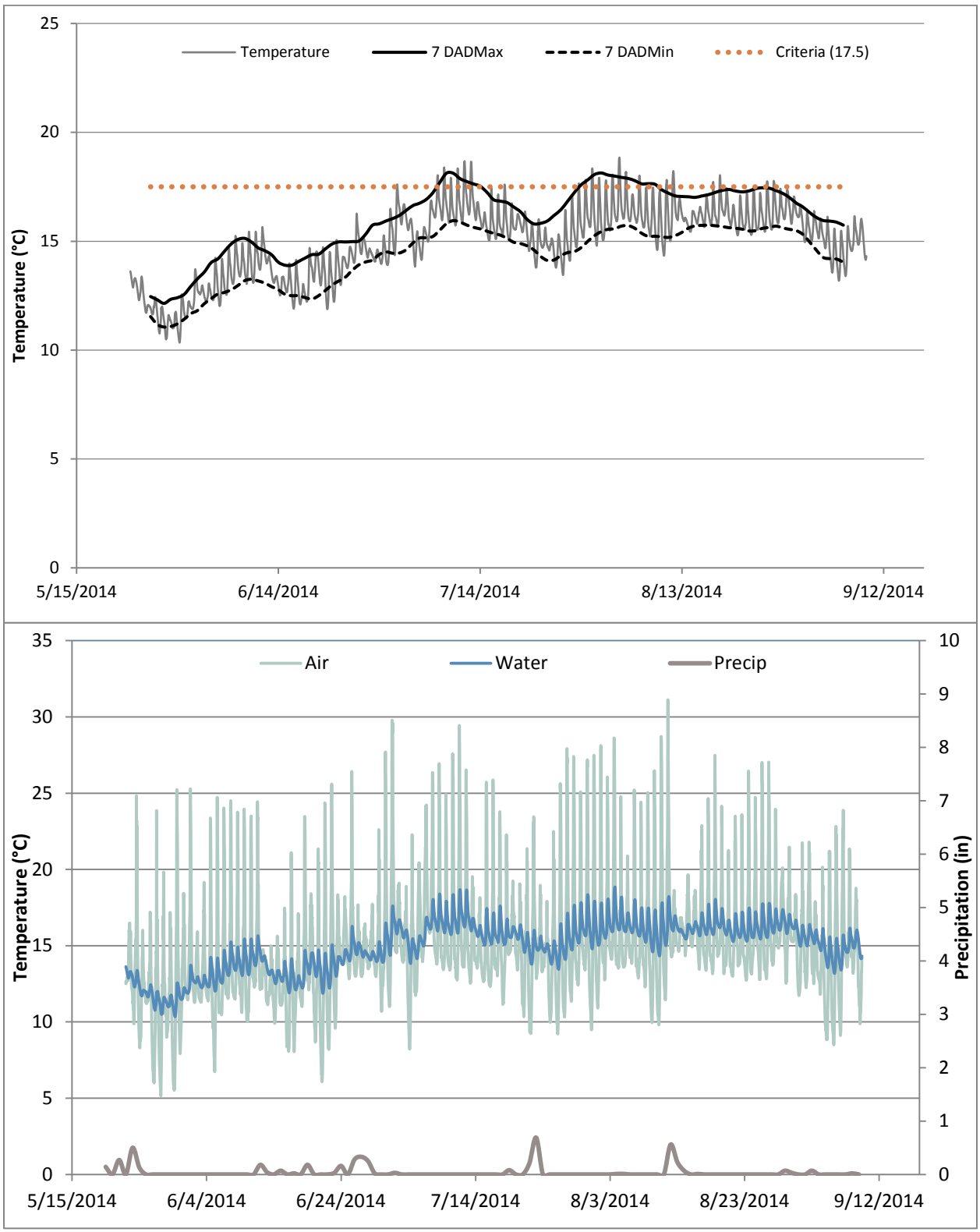

Figure A-14. 7-DADMin/Max of **Unnamed Tributary (UNT0.1)** 2014; Lower: Thermograph of air and water temperatures with precipitation. Listing # 6908 on the 303(d) list.

Appendix B. Statistical Procedures

- A check was made to ensure the FC data fit a log-normal distribution at each sampling location. Excel® (Microsoft, 2007) was used to test the FC data for log-normal distribution fit.
- An Excel® spreadsheet was used to calculate the geometric mean of the data by calculating the average of the logarithms of the results and then using exponentiation to return the average to the original scale.
- The 90th percentile of the data was estimated by using the following statistical equation (the 90th percentile value of samples was used in this TMDL evaluation as an estimate for the "no more than 10% samples exceeding …." criterion in the FC standard (WAC 173-201A)).

$$90^{th}\text{ percentile} = 10^{(\mu_{\log} + 1.2817 * \sigma_{\log})}$$

Where: $\mu_{\log}$ = mean of the log transformed data

$\sigma_{\log}$ = standard deviation of the log transformed data

- The recommended boundary target for upstream station to meet Parts I and II of the *Marine Criteria* was set as the highest of the following two resulting values:

$$\text{Boundary Target Geometric Mean} = \left[\frac{observed\ geometric\ mean - 14\ cfu/100mL}{observed\ geometric\ mean}\right] x100$$

$$\text{Boundary Target } 90^{th}\text{ Percentile} = \left[\frac{observed\ 90th\ percentile - 43\ cfu/100mL}{observed\ 90th\ percentile}\right] x100$$

Appendix C. Glossary, Acronyms, and Abbreviations

Glossary

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Fecal coliform (FC): That portion of the coliform group of bacteria that is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10- to 10,000-fold over a given period. The calculation is performed by either (1) taking the nth root of a product of n factors or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Salmonid: Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standard and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

DNR	Washington State Department of Natural Resources
DO	Dissolved oxygen
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	Fecal coliform bacteria
GIS	Geographic Information System software
HCP	Habitat Conservation Plan
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NOAA	National Oceanic and Atmospheric Association
NSSP	National Shellfish Sanitation Program
PBTF	Port Blakely Tree Farms
QA	Quality assurance
QC	Quality Control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units per 100 mL
ft	feet
mL	milliliters
ppt	parts per thousand
uS/cm	microsiemens per centimeter, a unit of conductivity