TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 6

Water Quality Monitoring and Continuous Temperature Monitoring Study

Revised Final Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

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EXECUTIVE SUMMARY

This revised final study report presents the results of a comprehensive water quality study conducted in 2015 in support of Federal Energy Regulatory Commission (FERC) relicensing efforts by TransCanada Hydro Northeast Inc. (TransCanada) for the Wilder Hydroelectric Project (FERC No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855), and Vernon Hydroelectric Project (FERC No. 1904) (projects), located on the Connecticut River in Vermont and New Hampshire. Project licenses will expire in April 2019 and TransCanada is using the Integrated Licensing Process (ILP) for relicensing of these projects. The water quality study presented herein was designed and revised with stakeholder feedback to satisfy state water quality certification criteria and is presented as fully supporting study for the FERC relicensing efforts. The study supplements and expands upon a water quality study performed in 2012 (Normandeau, 2013) by including an extended study period (April to November), stations upstream of each impoundment, an intensive study during high temperature low-flow summer conditions, and tributary temperature measurements.

This revised final study report includes additional analysis and discussion, and responds to stakeholder comments on the final study report filed August 1, 2016.

The primary goals of the study were to: (1) characterize and describe the water quality throughout the study area; (2) determine potential effects of the projects on water quality parameters of water temperature, dissolved oxygen (DO), conductivity, turbidity, pH, nutrients, and chlorophyll-*a*; and (3) determine whether the Connecticut River within the project-affected areas is in compliance with state surface water quality standards.

Water quality parameters were monitored on a continuous and discrete basis. From April through November 15, 2015 water temperature was continuously monitored throughout the study area. From June through September, water temperature, DO, pH, specific conductivity, and turbidity were continuously monitored at the project forebays, tailraces, and within the Bellows Falls bypassed reach. Also from June through September, water quality vertical profiles were collected for these parameters at all mainstem stations, except the Bellows Falls bypassed reach. Within the project forebays, nutrient and chlorophyll-*a* data were collected from June through September. Over a 10-day high temperature low-flow period from August 30 through September 8, specific conductivity, DO, pH, and turbidity were continuously monitored at all mainstem stations, as well as water temperature along transects at various depths. The study period included a wide range of weather and flow conditions.

Water temperatures generally warmed slightly through the project impoundments, and were similar between the project forebays and tailraces. Overall, the impoundments did not stratify, although there was mild surface warming during a few individual sampling events in the summer; however, this did not result in depleted DO levels within the hypolimnion or bottom waters. Dissolved oxygen levels throughout the study area were above state standards at all times and at all stations. Nutrient and chlorophyll-*a* concentrations indicated oligotrophic to mesotrophic conditions in the impoundments.

All applicable Vermont and New Hampshire surface water quality standards were met, with the exception of the upper limit for pH (VT and NH) and temperature (VT only). However, the data suggest project operations were not the major cause of the exceedances; instead, exceedances appear to be caused primarily by natural conditions (low flow, high air temperature) or potential nutrient loading from sources outside the projects. Specifically for pH, pH values rose occasionally above VT and NH state surface water quality standards in late summer, particularly during the high temperature low-flow monitoring period; however, well-defined diel fluctuations and simultaneously elevated chlorophyll-*a* concentrations suggest that elevated pH levels were related to photosynthesis. For water temperature, as water flows from the upstream areas and through the project impoundments and tailraces the temperature data suggest an overall gradually warming pattern over the approximate 120 river mile (RM) study area. The warming of water temperatures in the mainstem Connecticut River partially occurs naturally due a change in latitude, as suggested by the average water temperatures in the tributaries, which also exhibited a north to south warming trend. Further, the continuous mainstem temperature data show that upstream riverine stations respond more quickly to changes in air temperature than lower impoundment and tailrace stations. This results in water temperatures at upstream river stations and upper impoundment stations that are warmer or cooler than downstream impoundment and tailrace stations. In addition, when air temperatures tend to be consistent for a longer period of time (e.g., 5 to 6 days) or gradually warm or cool, mainstem water temperatures typically converge and become similar.

Results of the 2012 and 2015 water quality studies were generally similar, except that in 2012 DO and pH levels were observed to fall below state surface water quality standards on occasion. In addition, and similar to the 2012 baseline study, high generation discharges at the projects resulted in decreased DO levels within the tailraces when flows increased; DO levels increased again when project discharges decreased and returned to minimum flows. This is likely because of slightly lower DO within the hypolimnion drawn in during generation and a relatively higher rate of re-oxygenation during minimum flow in the project turbines. Temperature and pH also were observed in both studies to slightly increase and decrease during high generation and minimum flows, respectively, but were largely indistinguishable from normal diurnal fluctuations.

Overall, the data from both the 2012 and 2015 studies suggest that, irrespective of the effects of project operations, water quality for the parameters which were sampled in project-affected waters met applicable Class B VT and NH surface water quality standards for the vast majority of the study period throughout the entire study area.

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

7Q10	seven day low flow that occurs every 10 years on average
°C	degrees Celsius
°F	degrees Fahrenheit
cfs	cubic feet per second
CRWC	Connecticut River Watershed Council
dd	decimal degrees
DO	Dissolved oxygen
EAI	Eastern Analytical, Inc.
ELAP	Environmental Laboratory Accreditation Program
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
ft	foot (feet)
FWS	U.S. Department of the Interior – Fish and Wildlife Service
GIS	Geographic Information System
ILP	Integrated Licensing Process
m	meter(s)
mg/m^3	milligram(s) per cubic meter
mL	milliliter(s)
µm	micrometer(s)
µS/cm	micro-siemens per centimeter
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Unit(s)
NH	New Hampshire
QA/QC	Quality assurance/quality control
PSI	pounds per square inch
RM	river mile
RSP	Revised Study Plan
S&A	sampling and analysis
sq. mi.	square mile(s)
SSR	Site Selection Report
s.u.	standard units

TKN	total Kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TransCanada	TransCanada Hydro Northeast Inc.
USGS	U.S. Geological Survey
USR	Updated Study Report
VANR	Vermont Agency of Natural Resources
VT	Vermont
VTDEC	Vermont Department of Environmental Conservation
VY	Vermont Yankee Nuclear Power Plant
WSE or WSEL	water surface elevation

1.0 INTRODUCTION

TransCanada conducted this Water Quality Study (ILP Study 6) in 2015 to determine potential effects of the Wilder, Bellows Falls, and Vernon projects (projects) on water quality parameters including dissolved oxygen (DO), water temperature, pH, turbidity, conductivity, nutrients, and chlorophyll-*a*. In their study requests, U.S. Fish and Wildlife Service (FWS), New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Vermont Agency of Natural Resources (VANR), and the Connecticut River Watershed Council (CRWC) requested that TransCanada monitor water quality throughout the project-affected reaches of the Connecticut River and in a subset of tributaries to the projects to determine the operational effects of the projects on water quality.

Revised Study Plan (RSP) 6, as supported by stakeholders in 2013 and approved by FERC in its February 21, 2014 Study Plan Determination, specified that a subset of the project-affected area would be studied. On December, 31, 2013, TransCanada filed with FERC proposed revisions to the study, which included removing the additional continuous temperature monitoring transect at the Vernon forebay from April 1 through November 15 because of the closure of the Vermont Yankee Nuclear Power Plant (VY) in 2014. Continuous transect monitoring during a 10-day, low-flow period at this location was maintained as part of the study.

An initial site selection report was posted on TransCanada’s relicensing website on February 6, 2015 and comments were received during an aquatics working group conference call on February 10, 2015. The Site Selection Report (SSR) included a Sampling & Analysis (S&A) Plan as requested by NHDES and Vermont Department of Environmental Conservation (VTDEC). NHDES provided written comments on the plan on March 23, 2015 as well as information on 7Q10 flows via email on March 24, 2015 and VTDEC indicated that staff had no comments on the plan. The plan was subsequently revised (Louis Berger and Normandeau, 2015) and provided to agencies on April 29, 2015, and was filed as Volume II.A of the Updated Study Report (USR) on September 14, 2015 with site locations included as a GIS layer in Volume II.I of the USR.

This revised final report provides results from data collected at the selected study locations during the 2015 monitoring season and has been revised in response to stakeholder comments on the final study report filed August 1, 2016.

2.0 STUDY GOALS AND OBJECTIVES

The overall goal of the study was to determine potential effects of Wilder, Bellows Falls, and Vernon operations on water quality parameters of water temperature, dissolved oxygen (DO), conductivity, turbidity, pH, nutrients, and chlorophyll-*a*.

The specific goals and objectives of the study were to:

- Characterize water temperature upstream of the impoundments, and within the impoundments, tailraces, Bellows Falls bypass reach, and selected tributaries;
- Characterize water temperature, DO, specific conductivity, turbidity, and pH of the forebays, tailraces, and Bellows Falls bypass reach;
- Characterize water temperature, DO, specific conductivity, turbidity, and pH of the impoundments and upstream areas during a period with 10-day low-flow (less than 3 times 7Q10 flow) and high temperature (preferably over 23°C);
- Describe water temperature, DO, specific conductivity, turbidity, and pH stratification of the impoundments, upstream areas, forebays, tailraces, and Bellows Falls bypassed reach;
- Characterize nitrate/nitrite, total nitrogen, total phosphorus, total Kjeldahl nitrogen, and chlorophyll-*a* of the forebays;
- Determine potential impacts of project operations on water quality and temperature;
- Document whether the Connecticut River in the vicinity of the projects is in compliance with VT and NH surface water quality standards.

The water quality data collected in this study was also compared to the 2012 baseline water quality study conducted in the same study area (Normandeau, 2013).

3.0 STUDY AREA

The study area has a drainage area of 4,056 square miles and is characterized by northern hardwood and spruce-fir forests with mixed land uses. The study area is populated with interspersed small towns and villages with larger towns and cities present around the project dams. The predominant land use within the river floodplain is agriculture (TransCanada, 2012a; 2012b; 2012c).

The study area included the Wilder, Bellows Falls, and Vernon impoundments and tailraces, Bellows Falls bypassed reach, key tributaries, and riverine locations upstream of the upper limit of each impoundment. The study included 16 mainstem and 10 tributary sampling stations, which span the distance from the riverine station upstream of the upper limit of the Wilder impoundment (at approximately river mile [RM] 265) to the Vernon tailrace (RM 142). Thirteen of the 16 mainstem stations were the same stations sampled in the 2012 baseline water quality monitoring study; the 2015 study added three upstream riverine and 10 tributary stations. Study sites were selected in accordance with the process described in the Revised SSR and with concurrence from the aquatics working group. Station locations are described in Tables 3.0-1, 3.0-2, and 3.0-3, and are shown in Figure 3.0-1. Field conditions at stations 06-W-04 and 06-V-04 precluded the installation of moorings and monitoring equipment at the pre-defined locations due to very shallow depths (see Section 4.4). Field conditions at two tributary stations were also moved from their pre-determined locations as described in the

SSR to facilitate representative water temperature data collection (see Section 4.4). All other mainstem Connecticut River and tributary stations were installed at their pre-determined locations listed in the Revised SSR. Supporting geodata with final monitoring site locations was filed separately as Appendix N to the final report on August 1, 2016 in kmz and ARC (zipfile) formats, and is not being refiled with this revised final report.

Table 3.0-1. Mainstem study site locations.

Station ID	**Latitude** (dd)	**Longitude** (dd)	**Mean Depth**[a]	**Description**
Wilder				
06-W-04	44.12492	-72.04302	0.7	Above the Wilder impoundment at about River Mile (RM) 262.8
06-W-03	44.08398	-72.03933	1.9	Wilder upper impoundment at 257.7
06-W-02	43.88191	-72.17243	6.5	Wilder mid-impoundment at RM 224.9
06-W-01	43.66865	-72.30215	10.0	Wilder forebay at RM 217.3
06-W-TR	43.66597	-72.30510	1.5	Wilder tailrace, below dam and powerhouse at RM 217.1
Bellows Falls				
06-BF-04	43.48855	-72.37969	1.9	Above the Bellows Falls impoundment, 0.5 miles upstream of the Cornish Boat Landing at RM 202.1
06-BF-03	43.39374	-72.40287	2.8	Bellow Falls upper impoundment at RM 194.7
06-BF-02	43.27538	-72.41202	3.2	Bellows Falls mid-impoundment at RM 184.8
06-BF-01	43.13809	-72.44863	10.8	Bellows Falls forebay at RM 174.4
06-BF-BR	43.13617	-72.44041	1.1	Bellows Falls bypass reach, approximately 30 m upstream of railroad bridge at RM 173.9
06-BF-TR	43.13148	-72.44181	4.1	Bellow Falls tailrace, below dam and powerhouse at RM 173.6
Vernon				
06-V-04	43.09888	-72.44144	1.6	Above Vernon impoundment at about RM 171.0
06-V-03	43.06154	-72.45566	3.3	Vernon upper impoundment at 167.9
06-V-02	42.92468	-72.52500	5.7	Vernon mid-impoundment at RM 154.4
06-V-01	42.77288	-72.51204	16.3	Vernon forebay at RM 142.1
06-V-TR	42.76928	-72.51394	3.1	Vernon tailrace, below dam and powerhouse at RM 141.8

a. Mean depth was determined by averaging the individual depths measured using a HONDEX® SM-5 portable depth sounder at each station during each visit.

Table 3.0-2. Tributary water temperature sampling stations.

Station ID	**Tributary**	**State**	**Latitude** (dd)	**Longitude** (dd)	**Mean Depth** (m)[a]
Wilder					
06-W-T02	Waits River	VT	43.99209	-72.12692	0.5
06-W-T01	Ompompanoosuc River	VT	43.77015	-72.24579	0.4
Bellows Falls					
06-BF-T05	White River	VT	43.65763	-72.33616	0.5
06-BF-T04	Mascoma River	NH	43.63501	-72.31761	0.3
06-BF-T03	Sugar River	NH	43.39205	-72.38599	0.2
06-BF-T02	Black River	VT	43.27127	-72.45636	0.3
06-BF-T01	Williams River	VT	43.19229	-72.48660	0.4
Vernon					
06-V-T03	Saxtons River	VT	43.12303	-72.44227	0.3
06-V-T02	Cold River	NH	43.12295	-72.42489	0.2
06-V-T01	West River	VT	42.88341	-72.58680	0.4

a. Mean depth was determined by averaging individual depths measured using a HONDEX® SM-5 portable depth sounder or visually estimated when the depth was too shallow for the portable depth sounder during each station visit.

Table 3.0-3. Ten-day high temperature low-flow monitoring period station locations.

Station ID	**Station Location**[a]									**Multiparameter Sonde Deployment Location**
	River Left			**Mid-Channel**			**River Right**			
	Latitude (dd)	**Longitude** (dd)	**Mean Depth** (m)[b]	**Latitude** (dd)	**Longitude** (dd)	**Mean Depth** (m)[b]	**Latitude** (dd)	**Longitude** (dd)	**Mean Depth** (m)[b]	
Wilder										
06-W-04	44.12431	-72.04252	0.2	44.12450	-72.04263	0.4	44.12488	-72.04300	0.7	River Right
06-W-03	44.08441	-72.03904	1.4	44.08393	-72.03940	1.4	44.08369	-72.03960	2.6	Mid Channel
06-W-02	43.88195	-72.17210	3.9	43.88201	-72.17257	6.2	43.88210	-72.17313	5.7	Mid-Channel
06-W-01	43.66848	-72.30164	6.7	43.66863	-72.30223	9.9	43.66890	-72.30282	13.0	Mid-Channel
Bellows Falls										
06-BF-04	43.48856	-72.37905	0.8	43.48863	-72.37967	1.5	43.48875	-72.38037	0.4	Mid-Channel
06-BF-03	43.39364	-72.40134	1.8	43.39377	-72.40231	0.8	43.39377	-72.40329	3.0	River Right
06-BF-02	43.27454	-72.41038	3.0	43.27502	-72.41145	3.2	43.27546	-72.41265	3.8	Mid-Channel
06-BF-01	43.13857	-72.44815	4.2	43.13812	-72.44864	10.3	43.13769	-72.44900	7.9	Mid-channel
Vernon										
06-V-04	43.09916	-72.44088	0.6	43.09878	-72.44122	1.8	43.09841	-72.44184	3.8	Mid-Channel
06-V-03	43.06141	-72.45444	3.5	43.06179	-72.45507	2.9	43.06220	-72.45555	2.2	Mid-Channel
06-V-02	42.92479	-72.52399	4.8	42.92466	-72.52497	5.6	42.92459	-72.52570	6.5	Mid-Channel
06-V-01	42.77196	-72.51033	6.8	42.77259	-72.51104	5.4	42.77296	-72.51207	17.1	River Right

a. River left (looking downstream) refers to the NH side, river right to the VT side.
b. Mean depth was determined by averaging the individual depths measured using a HONDEX® SM-5 portable depth sounder at each station during each visit.

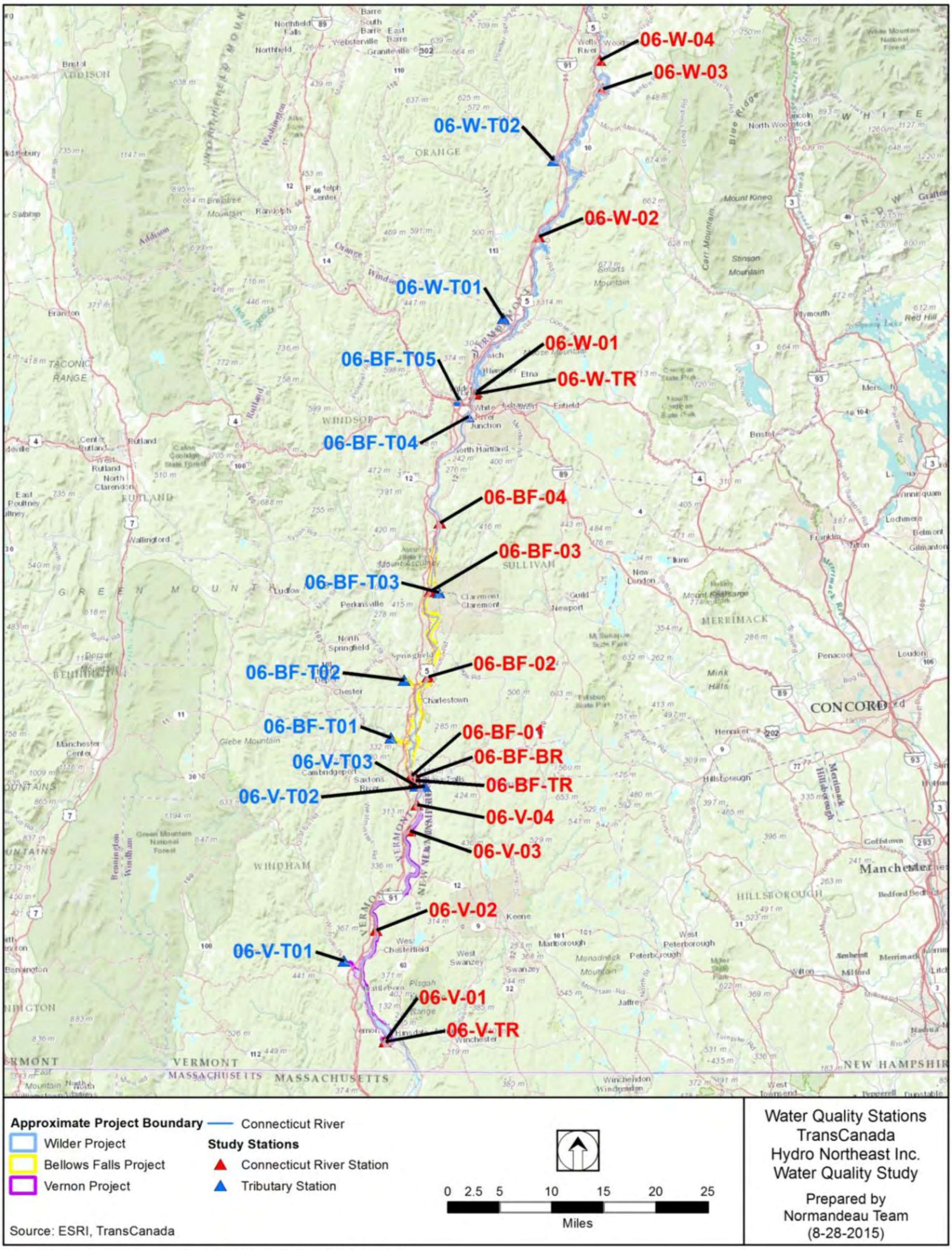

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Figure 3.0-1. Overview of study area and water quality stations.

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4.0 METHODS

To achieve the study goals and objectives, continuous temperature monitoring, continuous water quality monitoring, vertical profile measurements, and impoundment water column sampling were performed throughout the study. The schedule of field sampling activities described in the Revised SSR is depicted in Table 4.0-1. The equipment, calibration procedures, and field sampling specifics are discussed briefly below and in detail in the Revised SSR.

4.1 Data Collection

4.1.1 Continuous Temperature Monitoring

Water temperature (°C) was continuously monitored *in-situ* at all 16 mainstem and 10 tributary stations at 15-minute intervals with HOBO® Water Temp Pro v2 (Model U22-001, Onset Computer Corporation) loggers. Temperature loggers deployed at the mainstem stations were suspended at 25 percent depth from a mooring, except at station 06-W-04 where the logger was anchored to the riverbed with a cinderblock due to shallow depths (<1m). Depth was determined using a portable depth sounder (HONDEX® SM-5) or visually estimated if depth was too shallow for use of the depth sounder in the tributaries (<0.6 m). Temperature loggers deployed at the tributary stations were secured to cinderblocks and anchored to the streambed in representative flow. Most of the mainstem temperature loggers were installed in late April through early May due to ice cover in April and unsafe high flows and spilling conditions at the project dams. All mainstem stations were installed by May 21, 2015. All tributary stations were installed by early April except station 06-V-T01 (West River), which was installed on April 23, 2015 due to significant shelf ice along the river margins. All tributary stations were installed upstream of backwatering effects from the Connecticut River; stations were identified prior to the field study using maps and field reconnaissance to assure that stations were well upstream of the maximum extent of the impoundment. As confirmation, during the study, the Connecticut River was never observed to backwater up to the tributary monitoring stations, as would be indicated by ponded water with little current. The dates of when continuous temperature monitoring at each station commenced are listed in Table 4.0-1. Continuous water temperature was monitored at each station through November 15, 2015 or until a logger was replaced with a water quality multiparameter sonde from June through September as discussed below and in the Revised SSR. Each station was visited on a near weekly (mainstem) or biweekly basis (tributary) for inspection, data download, and collection of replicate discrete measurements with a National Institute of Standards and Technology (NIST) traceable high-accuracy platinum thermometer (Fisher Scientific, Model 15-081-108).

In addition, continuous water temperature monitoring also occurred along transects at each mainstem station within the impoundments and upstream areas during a 10-day, high temperature low-flow monitoring period. Each transect consisted of a station at river left (looking downstream e.g., the New Hampshire side), mid-channel, and river right (looking downstream e.g., the Vermont side) (Table 3.0-3). The number of loggers deployed at each station was dependent on water depth, whereby one logger was deployed mid-depth when the depth at the time of deployment was less than 3 m; two loggers were deployed at 1 m below the surface and 1 m above the river bottom when depths at the time of deployment were between 3 and 4 m; and three loggers were deployed at 1 m below the surface, mid-depth, and 1 m above the river bottom when depths at the time of deployment were greater than 4 m (see Section 4.4). Conditions for the 10-day, high temperature low-flow monitoring were met between August 30, 2015 through September 8, 2015 when mean daily water temperatures generally equaled or exceeded 23°C and provisional average daily flows at USGS streamflow gages at West Lebanon, NH (01144500) and North Walpole, NH (01154500) were near or below 3 x 7Q10 flows. Pre- and post-deployment accuracy checks were performed using certified NIST traceable high-accuracy platinum thermometers (Fisher Scientific, Model 15-081-108) on all temperature loggers deployed during the intensive continuous water temperature monitoring period. Details about the temperature logger deployment, configurations, and specifications are described in the SSR.

4.1.2 Continuous Monitoring with Multiparameter Datasondes

Temperature (°C), DO (percent saturation and mg/L), specific conductivity (µS/cm), pH (standard units, s.u.), and turbidity (NTU) were collected continuously at 15-minute intervals from June through September at the projects' tailraces (stations 06-W-TR, 06-BF-TR, 06-V-TR), forebays (stations 06-W-01, 06-BF-01, 06-V-01), and the Bellows Falls bypassed reach (station 06-BF-BR) with YSI 6920 V2 multiparameter datasondes. These sondes replaced the continuous temperature data loggers at the above stations at the beginning of the first week of June; however, high flows through much of June prevented the installation of a sonde in the Wilder tailrace (station 06-W-TR) and Bellows Falls bypassed reach (station 06-BF-BR) until June 19 and June 18, 2015, respectively. Prior to deployment each sonde was calibrated following the manufacturer's recommended procedure using NIST traceable calibration solutions. At each station, except for station 06-BF-BR, a water quality vertical profile was taken (discussed below in Section 4.1.3) to determine whether the water column was stratified. If the water column was determined to be stratified the sonde was suspended so that the sensors of the sonde were just above the metalimnion. Stratification was determined if the temperature difference in the stratum of greatest thermal discontinuity (metalimnion) exceeded 1°C per meter (Wetzel, 2001). If the water column was not stratified the sonde was suspended so that the sensors were at 25 percent depth from the water surface. The sonde deployed at the Bellows Falls bypassed reach (06-BF-BR) was encased in a PVC pipe for protection. The case was perforated with many ¾-inch holes to allow for sufficient water flow over the sensors, and anchored in place with cinderblocks so that the sensors were above the riverbed. Near-weekly visits were conducted to inspect the sonde for fouling, data download, sensor cleaning, calibration, and to obtain replicate measurements. Details for sonde deployment, calibration, maintenance, and specifications are described in the Revised SSR.

Multiparameter sondes were also deployed at all impoundment and upstream stations during the 10-day high temperature low-flow monitoring period to collect continuous temperature, DO, specific conductivity, pH, and turbidity at 15-minute intervals. These sondes we deployed from one of the three moorings (river left, mid-channel, river right), at whichever location was most representative of the river cross-section, following the procedure above and as described in the Revised SSR. Each sonde was in place for the entire 10-day high temperature low-flow monitoring period.

4.1.3 Instantaneous Monitoring with Multiparameter Datasondes

Instantaneous vertical profiles of temperature (°C), DO (percent saturation and mg/L), specific conductivity (µS/cm), pH (s.u), and turbidity (NTU) were collected using YSI 6920 V2 multiparameter datasondes with a 30-m data cable. Vertical profiles were collected on a near-weekly basis from June 4 through October 2, 2015, at all mainstem stations, except at the Bellows Fall bypassed reach as described further in Section 4.4. Prior to collecting vertical profiles, the sonde was calibrated using NIST-traceable calibration solutions following the manufacturer's calibration procedure. Vertical profiles were collected at each station by allowing the boat to drift as the multiparameter sonde was slowly lowered through the water column. Each profile began at the water surface at the time of measurement. Measurements were collected at 1-m intervals after allowing the readings to stabilize until the instrument was 0.5 m above the river bottom. At least one replicate measurement was collected per profile at an *a priori* randomly selected depth interval. Each profile was subsequently reviewed for thermal and chemical stratification. Stratification was determined if the temperature difference in the stratum of greatest thermal discontinuity exceeded 1°C per meter (Wetzel, 2001). If surface waters were warm compared to bottom water temperatures but did not fit the technical definition of stratification above, this was considered to be mild surface warming. Details for collecting vertical profiles and the instrument specifications are described in the Revised SSR.

4.1.4 Impoundment Water Column Sample and Laboratory Analyses

Impoundment water column samples of nitrate/nitrite (mg/L), total nitrogen (TN, mg/L), total phosphorus (TP, mg/L), total Kjeldahl nitrogen (TKN, mg/L) and chlorophyll-*a* (mg/m^3) for laboratory analysis were collected at each of the three forebay stations (06-W-01, 06-BF-01, 06-V-01) using long, weighted flexible PVC tubing with an inside diameter of 7/8 inches and marked in 1-m increments. The long, weighted tubing was lowered slowly and evenly into the water column until the bottom end was at 1 m above the river bottom. The vented end of the tubing was then capped and the weighted end was slowly raised to the surface. The sample was then transferred from the tubing to a pre-rinsed 5-gallon bucket, mixed, and decanted into labelled, sterile acid-washed 500-mL sample bottles provided by the contracted laboratory (Eastern Analytical, Inc., Concord, NH), placed on ice, and then refrigerated before being transferred to the laboratory under a chain of custody. Chlorophyll-*a* samples were filtered within 24 hours of collection using 0.45-µm cellulose filters, 1000-mL vacuum flask, and hand pump to create a vacuum of 5 PSI or less. Filtered samples were placed in sterile sample vials, wrapped in aluminum, and frozen prior to analysis. In addition, six duplicate samples (two from each impoundment) were collected at *a priori* randomly selected sampling events for quality control purposes. All samples analyzed by the laboratory were analyzed within the required holding time of 28 days for each analyte. On average, impoundment water column sampling for nutrients and chlorophyll-*a* occurred every eight days (range: 4 to 13 days). Additional details about holding times, reporting limits, and analysis methods are described in the Revised SSR.

4.2 Quality Assurance/Quality Control

4.2.1 Data Quality Objectives

Data quality objectives for this study were as follows: actual measurements obtained pre- and post-deployment shall have a relative percent difference of ≤10 percent to that of the field replicate collected with the certified NIST-traceable thermometers or recently calibrated multiparameter sonde; and 80 percent of all measurements collected shall pass the QA/QC process. The relative percent difference between the deployed continuous temperature loggers and the certified NIST-traceable thermometers were less than 10 percent, and nearly all temperature measurements passed the QA/QC process for the loggers deployed in the mainstem of the Connecticut River (99 percent) and tributaries (96 percent), respectively. The relative percent difference between the deployed sonde and recently calibrated sonde was less than 10 percent for temperature, pH, and DO. In four instances the relative percent difference exceeded 10 percent for specific conductivity post-deployment comparison because of significant fouling (e.g., sediment and debris clogging the sensor) and a voltage spike. Data affected by significant fouling could be corrected; however, the data affected by a voltage spike could not be corrected and were omitted from all analyses. The comparisons between the deployed and a recently calibrated sonde often resulted in a relative percent difference for turbidity greater than 10 percent, even though the absolute difference between the deployed sonde and recently calibrated sonde was within the instruments accuracy rating of ±0.3 NTU. Between 95 and 97 percent of the readings for temperature, DO, specific conductivity, pH and turbidity passed the QA/QC process. Laboratory analyses were performed by Eastern Analytical, Inc. (EAI, Concord, NH), an U.S. Environmental Protection Agency (EPA) certified laboratory. EAI is also certified in NH (ELAP # 1012) and VT (Certification # VT-101204); therefore, data quality objectives for the laboratory analyses adhere to EPA, NH, and VT requirements.

4.2.2 Instrument Testing, Inspection and Maintenance

All temperature loggers and multiparameter sondes were tested and inspected prior to deployment. Prior to initial deployment, each temperature logger was tested in a water bath or deployed in the river or tributary then removed to examine the data and compare those data against spot measurements collected with the certified NIST-traceable thermometers. Following subsequent station visits, the temperature loggers were cleaned, inspected for damage, and their data offloaded. Replicate side-by-side measurements were collected using certified NIST-traceable thermometers on a monthly basis and at the end of deployment. Multiparameter sondes deployed for continuous monitoring were inspected for damage, fouling, and cleaned during each station visit following the manufacturer’s recommended cleaning procedures. Data from the multiparameter sondes for continuous monitoring were offloaded and examined for aberrant measurements. Upon retrieval and prior to redeployment, each multiparameter sonde for continuous monitoring was tested alongside a recently calibrated multiparameter sonde. The multiparameter sondes used for vertical profiles were inspected and tested before and after each field day during calibration and while performing side by-side comparison with the continuous multiparameter sondes.

4.2.3 Instrument Calibration and Frequency

The continuous temperature loggers were factory calibrated and required no additional calibration during deployment. Each continuous monitoring multiparameter sonde was calibrated following the manufacturer's recommended procedure using NIST-traceable calibration solutions and as described in the Revised SSR. Calibration was performed prior to each deployment and during subsequent station visits on a near-weekly basis concurrent with each data download. Table 4.2-1 provides each multiparameter sonde sensor calibration method and frequency. Initial testing of the multiparameter sondes resulted in negative turbidity readings. Negative turbidity readings result from the sonde being deployed in very clear water along with potential contamination of the 0.0 NTU calibration standard. According to the manufacturer, 0 NTU standards, on average, are contaminated easily between the levels of 0.2 and 0.8 NTU. In very clear waters and when contamination of the 0.0 NTU standard is suspected a 0.5 NTU single point calibration offset was applied after a two-point calibration was performed, as recommended by the manufacturer (YSI, 2010).

4.2.4 Laboratory Analysis Controls

Six duplicate samples (two from each impoundment) were collected at *a priori* randomly selected sampling events for quality control purposes. The duplicate samples were blind to the laboratory and were aliquots of the same water column sample as their paired, known sample.

4.2.5 Data Synthesis

All data from the continuous water temperature data loggers and continuous multiparameter datasondes were downloaded to a HOBO® Waterproof Shuttle (U-DTW-1) or YSI 650 MDS handheld display computer during each station visit, then backed-up to a rugged field laptop and transferred to a spreadsheet database. Data collected during the instantaneous, vertical profile measurements were also recorded on the YSI 650 MDS handheld display computer, offloaded to the field laptop then subsequently to a spreadsheet database. Flow and project operations data including hourly generation, impoundment elevation at each dam, and discharge were provided by TransCanada. Flow data were obtained from USGS Streamflow gages at Wells River, VT (Station No. 01138500), West Lebanon, NH (Station No. 01144500), and North Walpole, NH (Station No. 01154500). Flow in the Bellows Falls bypassed reach during spill was provided by TransCanada. Flow in the bypassed reach during periods without spill were assumed to be minimum leakage flows, which was determined by TransCanada to be approximately 125 cfs[1] although the actual leakage flow can change depending upon conditions at the dam. Weather data were obtained from area National Oceanic and Atmospheric

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[1] Estimated by TransCanada at the fish barrier dam.

Administration (NOAA) weather stations at Lancaster, NH (Station USC00274556), Union Village Dam, VT (Station USC00438556), North Springfield Lake, VT (Station USC00435982), and Keene, NH (Station USC00274399). Data and field notes were transferred or manually transcribed from field notebooks and datasheets to a spreadsheet database for further review, QA/QC, and analysis.

4.2.6 Data Censorship and Correction

The continuous temperature datasets were initially reviewed and analyzed for outliers, aberrant measurements, and missing data to ensure the collected data represented a complete record. Corresponding certified NIST-traceable thermometer readings were then used to determine if data correction was required for a specific time interval. Temperature logger data were accepted if the temperature recordings of the logger were within ±0.5°C of the corresponding NIST thermometer reading (MassDEP, 2009). All temperature logger to certified NIST thermometer reading comparisons were within ±0.5°C; therefore, no corrections of the temperature time-series were necessary. The temperature time-series for each station were then reviewed on a weekly time step. Aberrant measurements, such as out-of-water readings, were flagged and removed from subsequent analyses. Flow and temperature data from nearby stations were also used to determine the quality of the temperature time-series (Sowder and Steel, 2012).

For the continuous water quality dataset obtained from the deployed YSI 6920 V2 multiparameter datasondes, some deployment intervals required correction to adjust for calibration drift and biofouling effects on sensor readings. The decision to apply a correction was based on criteria described in USGS (2006), summarized in Table 4.2-1, professional judgment, described in the Revised SSR. Certain deployment intervals for specific conductivity, dissolved oxygen (mg/L), pH, and turbidity required correction. Appendix A provides a summary of the corrected parameters, corrected intervals, calculated correction criteria, and correction factors used to correct each parameter for each deployment interval requiring correction. Appendix A also provides univariate regression illustrating the relationship between uncorrected and corrected data collected by the continuous multiparameter sondes.

4.3 Data Analysis

Data in the final water quality dataset were summarized (maximum, minimum, mean, and median) and plotted through time to illustrate spatial and temporal variations and trends in water quality and temperature. Collectively, all data were then examined to determine compliance with Vermont and New Hampshire surface water quality standards. Applicable standards are presented in Table 4.3-1 and Table 4.3-2. The final dataset was also compared to project operations data and prevailing air temperature and daily precipitation to assess how water quality and temperature were affected by project operations and weather. Historical (previous 10 years) and mean monthly air temperature from area NOAA weather stations and precipitation data from TransCanada were used to determine if the weather observed throughout the study period (April 1 to November 15, 2015) was representative of the historical conditions. Furthermore, mean daily historical flows (1972-2014) and mean daily flows observed throughout the study period at the West Lebanon, NH, and North Walpole, NH, USGS gages for the study period were used to develop flow duration curves. The flow duration curves were used to determine if flows throughout the study period were representative of historical flows. In addition, mean daily flows during the high temperature low-flow monitoring period were compared to estimated 7Q10 flows at each Project dam. Vertical profile data were analyzed to assess limnological conditions and trends at each station over the study period. The water quality results from the 2012 baseline water quality study (Normandeau, 2013) were compared to results of the 2015 study.

4.4 Variances from the Study Plan

The purpose of the RSP and the Revised SSR developed in consultation with the aquatics working group was to ensure the goals and objectives of the study were met by adhering to sampling protocols and procedures, laboratory analyses, data management, QA/QC, data analysis, and reporting criteria. Field conditions, equipment malfunctions, and vandalism resulted in some variances from the RSP and/or Revised SSR, which are described below:

- Continuous temperature monitoring was to occur at all mainstem and tributary stations from April 1 through November 15. Ice cover and high-flow conditions observed through much of April prevented the safe installation of the continuous temperature monitoring equipment. Most of the mainstem temperature loggers were installed between late April and early May due to ice cover in April, unsafe high flows, and spill conditions at the project dams. All mainstem stations were installed by May 21, 2015 and all tributary stations were installed by early April, except station 06-V-T01 (West River), which was installed on April 23, 2015 due to significant shelf ice along the river margins. The dates of when continuous temperature monitoring at each station commenced are listed in Table 4.0-1.
- Continuous multiparameter water quality sondes scheduled to be deployed in the Wilder tailrace (06-W-TR), Bellows Falls bypassed reach (06-BF-BR) and Bellows Falls tailrace (06-BF-TR) in the first week of June, were not deployed until June 19, June 18, and June 10, respectively, because of continued high flows and spill conditions in June.
- Vertical profiles in the Bellows Falls bypassed reach were to be collected on a weekly basis from June 1 through September 30. The monitoring station in the Bellows Falls bypassed reach (06-BF-BR) was located 13 m upstream of the fish barrier dam (see maps in Appendix A of the SSR). Because of the unsafe distance from the monitoring station to the fish barrier dam, no protective boat barrier in the Bellows Falls bypassed reach, and very shallow riffles upstream of the monitoring station, no vertical profiles were collected at the 06-BF-BR station.
- Field conditions and shallow water depths required some of the predetermined monitoring stations to be moved. Shallow depths precluded the installation of moorings and monitoring equipment at the pre-defined locations at stations 06-W-04 and 06-V-04. Station 06-W-04 was moved from mid-channel to river right where the thalweg and majority of the flow passed. Similarly, station 06-V-04 was moved approximately 150 m

upstream from the pre-determined location to avoid stranding on a large gravel bar during low-flow conditions. Locations of the moved stations are presented in Table 3.0-1.

- Station 06-W-T02 (Waits River) was moved downstream 1,500 m from its original location to 100 m below the tailrace of the hydroelectric project at the Bradford Dam, Bradford, VT (FERC No. P-2488), in order to collect representative water temperature data of those waters flowing into the Connecticut River unaffected by any other hydroelectric project. This area of the Waits River did not appear to experience backwater effects from the Connecticut during the study period. During initial deployment station 06-BF-T04 (Mascoma River) was moved 130 m upstream to avoid Connecticut River backwatering effects during periods of high flow. Moving station 06-BF-T04 upstream placed the station 175 m downstream of the tailrace of the Glen Road Hydro project (FERC No. P-8405) on the Mascoma River, Lebanon, NH. Locations of the moved stations are presented in Table 3.0-2.
- High flows through the Bellows Falls bypassed reach at the end of June and in early July displaced the continuous monitoring sonde onto shore from June 27 through June 28, and from July 4 through July 6. This resulted in the loss of approximately three days of continuous temperature, pH, DO, specific conductivity, and turbidity data.
- Vandalism of the continuous monitoring sonde deployed in the Bellows Falls bypassed reach resulted in the sonde being out of water for 12 days from August 28 through September 9, 2015. These data were omitted from subsequent analyses.
- During a high-flow event the pH sensor on the continuous sonde deployed at the Bellows Falls tailrace station (06-BF-TR) broke and resulted in erratic pH readings from June 14 through June 27. These data were omitted from subsequent analyses.
- The Saxtons River (station 06-V-T03) continuous temperature logger was discovered missing, which resulted in the loss of 11 days of continuous temperature data from July 10 through July 21, 2015. The continuous temperature monitoring station was subsequently moved approximately 100 m upstream.
- Other minor variances from the Revised SSR included the loss of data from several continuous temperature loggers deployed at the tributary monitoring stations due to the loggers being out-of-water during low-flow conditions for short and infrequent durations. In addition, the continuous temperature logger at station 06-BF-04 was found removed from the river and placed on the bank. Review of the data indicates the logger was removed from the river from August 16 until August 20, 2015 when it was discovered. Review of continuous temperature logger data deployed at station 06-V-04 suggested the logger was periodically out of water from July 12 to July 16 due to deployment on a shallow gravel bar, which became dewatered during low-flow conditions. This logger was redeployed approximately 150 m upstream in a deeper area of the river not observed to become dewatered.

Table 4.0-1. Water quality monitoring field activities summary.

Station ID	Wilder	Bellow Falls	Vernon	Location	2015 Study Period							
					Apr 01 - May 31		Jun 01 - Sep 30					Oct 01-Nov 15
					Continuous		Continuous			Discrete		Continuous
					Temp. Logger	Date Deployed	Temp. Logger	Temp Transect[a]	Sonde[b]	Vertical profile[c]	Water Column Sample	Temp. Logger
Mainstem												
06-W-04	🟥			upstream	●	1-May	●	7Q10	7Q10	●		●
06-W-03	🟥			upper impoundment	●	1-May	●			●		●
06-W-02	🟥			mid-impoundment	●	1-May	●			●		●
06-W-01	🟥			lower impoundment	●	7-May			●	●	●	●
06-W-TR	🟥			tailrace	●	7-May			●	●		●
06-BF-04		🟦		upstream	●	29-Apr	●	7Q10	7Q10	●		●
06-BF-03		🟦		upper impoundment	●	29-Apr	●			●		●
06-BF-02		🟦		mid-impoundment	●	29-Apr	●			●		●
06-BF-01		🟦		lower impoundment	●	8-May			●	●	●	●
06-BF-BR		🟦		bypassed reach	●	13-May			●			●
06-BF-TR		🟦		tailrace	●	21-May			●	●		●
06-V-04			🟩	upstream	●	30-Apr	●	7Q10	7Q10	●		●
06-V-03			🟩	upper impoundment	●	30-Apr	●			●		●
06-V-02			🟩	mid-impoundment	●	30-Apr	●			●		●
06-V-01			🟩	lower impoundment	●	13-May			●	●	●	●
06-V-TR			🟩	tailrace	●	6-May			●	●		●
Tributaries												
06-W-T02	●			Waits River	●	25-Mar	●					●
06-W-T01	●			Ompompanoosuc R.	●	7-Apr	●					●
06-BF-T05		●		White River	●	7-Apr	●					●
06-BF-T04		●		Mascoma River	●	25-Mar	●					●
06-BF-T03		●		Sugar River	●	7-Apr	●					●
06-BF-T02		●		Black River	●	25-Mar	●					●
06-BF-T01		●		Williams River	●	26-Mar	●					●
06-V-T03			●	Saxtons River	●	24-Mar	●					●
06-V-T02			●	Cold River	●	24-Mar	●					●
06-V-T01			●	West River	●	23-Apr	●					●

a. Three stations per transect with up to 3 loggers each (1 m below surface, mid-depth, 1 m above river bottom; less if station is shallow) at 10-day high temperature low-flow conditions only.
b. Multiparameter sonde used at these stations only during 10-day high temperature low-flow period for temp., DO, conductivity, turbidity, and pH. At other times only temperature was recorded with a logger.
c. Instantaneous measurement with multiparameter sonde, at 1-m increments (surface to bottom). Monitored parameters were temperature, DO, conductivity, turbidity, and pH.

Table 4.2-1. Continuous water quality monitor calibration and correction criteria for YSI 6920 V2 Multiparameter Sondes.

Parameter	**Correction Criteria**[a]
Temperature	± 0.2 °C
Specific Conductance	± 5 µS/cm or ±3 percent of the measured value, whichever is greater
Dissolved Oxygen	± 0.3 mg/L
pH	± 0.2 pH s.u
Turbidity	± 0.5 turbidity unit or ± 5 percent of the measured value, whichever is greater

a. The correction is applied when the absolute value of the fouling error plus the absolute value of the calibration drift error exceeds the value listed. Fouling error and calibration drift error are calculated following USGS (2006).

Table 4.2-2. YSI 6920 V2 multiparameter sonde calibration method, solutions and frequency.

Sensor	**Calibration Method**	**Calibration Solutions**	**Calibration Frequency**
Continuous Monitoring Sondes			
Temperature	Default factory	Not applicable	Not applicable
Dissolved Oxygen	Saturated air[a]	Not applicable	Initial deployment Weekly at time of data download
Specific Conductivity	One point[b]	1000 µS/cm	
pH	Two point[c]	pH of 4, 7, and 10	
Turbidity	Two point[d]	0 NTU and 126 NTU	
Instantaneous Monitoring Sondes			
Temperature	Default factory	Not applicable	Not applicable
Dissolved Oxygen	Saturated air[a]	Not applicable	At start of sampling day At end of sampling day
Specific Conductivity	One point[b]	1000 µS/cm	
pH	Two point[c]	pH of 4, 7, and 10 s.u.	
Turbidity	Two point[d]	0 NTU and 126 NTU	

a. For the optical type dissolved oxygen sensors used in the multiparameter sondes, YSI does not recommend using 2-point calibration with zero dissolved oxygen solution unless the sensor does not meet the accuracy requirements at low DO values and, under operating conditions, it can be certain that a medium of zero dissolved oxygen can be generated.

b. The YSI conductivity system is very linear over its range of 0-100 mS/cm. YSI recommends using calibrations of 1 mS/cm (1,000 µS/cm) for freshwater environmental applications.

c. YSI recommends a two-point calibration between a pH of 7 and 10 because the majority of all water types in the environment have a pH between 7 and 10. A pH standard of 4 may be used in calibration if a pH of less than 7 is regularly observed.

d. YSI recommends a two-point calibration with 0 NTU and 126 NTU standard solutions for most applications.

Table 4.3-1. Applicable Vermont and New Hampshire surface water quality standards for the mainstem Connecticut River.[a]

Class	Designated Uses	Parameter	Standard
Vermont[b]			
B	Fully supports aquatic biota, wildlife and aquatic habitat; Good to excellent aesthetics; Suitable public water supply with filtration and disinfection, irrigation of crops, primary contact recreation, boat, fishing, other recreation	Temperature	Change or rate of change in temperature, either upward or downward, shall not exceed 1°F (0.56°C) from ambient temperatures due to all discharges and activities and be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses.
		Dissolved Oxygen	Not less than 6 mg/l and 70 percent saturation.
		Specific Conductivity	None.
		pH	Between 6.5 and 8.5 standard units.
		Turbidity	None in such amounts or concentrations that would prevent the full support of uses, and not to exceed 10 NTU as an annual average under dry weather base-flow conditions.
		Nutrients	Nitrates not to exceed 5.0 mg/L as NO_3-N at flows exceeding low median monthly. Phosphorus is to be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses.
New Hampshire[c]			
B	Waters that are considered acceptable for fishing, swimming and other recreational purposes, and, after adequate treatment, for use as water supplies. See Table 4.3-2 for specific designated uses.	Temperature	Any increase shall not be such as to appreciably interfere with the uses assigned to this class.
		Dissolved Oxygen	Daily average at least 75 percent saturation; instantaneous minimum of 5.0 mg/L.
		Specific Conductivity	None.
		pH	6.5 to 8.0, unless due to natural causes.
		Turbidity	Not exceed naturally occurring conditions by more than 10 NTU.[d]
		Nutrients	Nitrogen none in such concentrations that would impair any existing or designated uses, unless naturally occurring. Phosphorus none in such concentrations that would impair any existing or designated uses, unless naturally occurring.

a. Temperature standards also apply to tributaries.

b. Source: VANR, 2014

c. Source: NHCAR, 2008.

d. If a discharge causes or contributes to an increase equal to or more than 10 NTU of receiving water upstream of the discharge or otherwise outside of the visible discharge, a violation of the turbidity standard shall be deemed to have occurred (NH Code of Administration Rules, Env-Wq 1703.11. Note definitions of 'discharge' in Env-Wq 1702.18 and of 'pollutant' in 40 CFR 122.2.

Table 4.3-2: Designated Uses for Applicable to Class B New Hampshire Surface Waters.[a]

Designated Use	**NHDES Definition**
Aquatic Life	Waters that provide suitable chemical and physical conditions for supporting a balanced, integrated and adaptive community of aquatic organisms.
Fish Consumption	Waters that support fish free from contamination at levels that pose a human health risk to consumers.
Shellfish Consumption	Waters that support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers
Drinking Water Supply after Adequate Treatment	Waters that with adequate treatment will be suitable for human intake and meet state/federal drinking water regulations.
Primary Contact Recreation	Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water
Secondary Contact Recreation	Waters that support recreational uses that involve minor contact with the water.
Wildlife	Waters that provide suitable physical and chemical conditions in the water and the riparian corridor to support wildlife as well as aquatic life.

a. Source: NHDES, 2015.

5.0 RESULTS AND DISCUSSION

5.1 Weather, Flow, and Operations

Water quality monitoring and field sampling occurred over a variety of weather conditions. Mean monthly air temperatures and total monthly precipitation for the 2015 study period are presented in Tables 5.1-1 and 5.1-2, respectively. In addition, Table 5.1-3 presents the change in daily mean air temperatures for each month and over the entire study period which was determined by calculating the difference between mean daily air temperatures between stations noted in the table, then calculating each statistic for each month and the study period.

Mean monthly air temperatures during the study period were warmer than the previous ten years for May, August, September and November whereas air temperatures in April, June, July, and October were cooler than the previous 10-year mean. July and August were the warmest months during the study, and April and November the coolest. The change in daily mean air temperatures indicates daily mean air temperatures generally increased from north to south, with the greatest overall increase occurring through the Wilder study area (1.22°C) followed by the Vernon (0.36°C) and Bellows Falls study areas (0.36°C) (Table 5.1-3). Appendix B presents mean daily air temperatures and total daily precipitation for the Wilder, Bellows Falls, and Vernon study areas and the upper watershed for the entire study period.

Monthly precipitation data are collected by TransCanada at the projects (Table 5.1-2). Overall, the study season had less precipitation than the 10-year average. The month of June was wetter than the 10-year average at Wilder and Bellows Falls and drier than average at Vernon; rain events resulted in periods of spill throughout June at all three projects. Rain events at the beginning and in mid-July resulted in spill at the three project dams, but July was overall drier than the average. August was slightly wetter at Bellows Falls than average, but slightly drier than average at Wilder and Vernon. September was wetter than the 10-year average at all three projects. A single rain event resulted in spill at all three projects from September 30 continuing into the first few days of October. Bellows Falls also spilled briefly on September 15.

Monitoring and sampling also occurred over a wide range of flows and project operations. Figure 5.1-1 shows mean daily flow at several points in the Connecticut River as flows enter and travel through the study area. As a result of snowmelt runoff and precipitation in April, flows peaked in April with mean daily flows ranging from approximately 35,000 to 65,000 cfs at the project dams. Through May, flows generally decreased, but in June several large rain events increased flows, which resulted in spill conditions at each dam (Figures 5.1-2 through 5.1-5). A single, moderate rain event in July caused flows to increase and result in spill conditions at the projects, but flows decreased rapidly and remained at their lowest level through August and September. At the end of September a large rain event caused mean daily flows to peak between approximately 20,000 to 30,000 cfs, resulting in spill conditions at each dam at the beginning of October. During periods of non-spill generation for the three projects ranged between minimum flow and maximum generating capacity. Maximum generating capacity occurred more frequently at Wilder than at either Bellows Falls or Vernon (Figures 5.1-2 through 5.1-5).

Flow durations curves of mean daily flow observed at USGS streamflow gages at West Lebanon, NH (01144500) indicate that mean daily flows during the study were generally representative of historical mean daily flows (Figure 5.1-6). For the North Walpole, NH (01154500) gaging station, the frequency of occurrences of mean daily flows lower than 20,000 cfs over the study period were also representative of historical flows; however, the frequency of mean daily flows higher than 20,000 cfs during the study period was slightly lower than historical occurrences (Figure 5.1-6). Flow conditions that triggered the start of the high temperature low-flow monitoring occurred from August 30 through September 8, 2015. Mean daily flows during the intensive 10-day monitoring at Wilder were below the 3 x 7Q10 threshold of 2,598 cfs. At Bellows Falls, only one day exceeded the mean daily flow 3 X 7Q10 threshold of 2,979 cfs. Table 5.1-4 presents mean daily flows during the 10-day high temperature low-flow monitoring period.

Over the entire study period (April 1 through November 15, 2015), water surface elevations (WSEs) ranged between 381.8 to 384.6 ft (NAVD88; Figure 5.1-7) at Wilder dam, 90 percent of the time, 288.6 to 291.1 ft (NAVD88; Figure 5.1-8), 100 percent of the time at Bellows Falls dam, and 217.9 to 219.6 ft (NAVD88; Figure 5.1-9) 100 percent of the time at Vernon dam. Prior to and during high flow events the WSE at the dam was lowered according to established high water operating procedures. The most significant range occurs within the Wilder impoundment at the dam. The median daily fluctuation (as measured by the difference between the maximum and minimum WSEs for a given day) at the Wilder dam, Bellows Falls dam, and Vernon dam was 1.2 ft (maximum range: 0.1 to 3.2 ft NAVD88), 0.8 ft (range: 0.1 to 1.7 ft NAVD88), and 0.7 ft (range: 0.1 to 1.3 ft NAVD88), respectively, over the study period. On a daily basis, water levels exhibited either a single maximum or minimum level, multiple maxima or minima, or relatively no change over the study period (Appendix O).

Monitoring within the tributaries also occurred over a wide range of flows. Appendix C presents the hydrographs for each tributary where water temperature was monitored. In general, the highest flows were observed throughout April as a result of snowmelt runoff and precipitation, and ranged from 1,450 cfs (Ompompanoosuc River) to 12,000 cfs (White River). Tributary flows were generally lowest in late-August and early-September. Table 5.1-5 presents mean monthly flow contributions of each tributary of the Wilder, Bellows Falls, and Vernon study areas. The Waits River and Ompompanoosuc River, tributaries to the Wilder contributed approximately 3 to 5 percent of the mean monthly discharge at the Wilder Project. The White River, the largest tributary below Wilder dam and above the Bellows Falls Project, contributed approximately 11 to 18 percent of mean monthly Bellows Falls discharges, whereas other Bellows Falls tributaries contributed approximately 1 to 6 percent of the mean monthly Bellows Falls discharges. Similarly, the largest tributary below Bellows Falls dam into the Vernon project (West River) contributed approximately 3 to 11 percent of mean monthly Vernon discharges, and the Cold and Saxtons River contributed 0.3 to 2.1 percent of the mean monthly Vernon discharges.

Table 5.1-1. 2015 and previous 10-year mean monthly air temperatures (°C) for the Wilder, Bellows Falls, and Vernon study areas.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Wilder[a]								
2015 Mean	4.9	15.6	16.5	20.4	20.6	17.8	7.6	4.4
10-Year Mean[b]	6.2	13.1	18.0	21.0	19.5	15.3	8.8	2.3
Difference[e]	-1.3	2.5	-1.5	-0.5	1.1	2.5	-1.2	2.1
Bellows Falls[c]								
2015 Mean	5.1	15.8	16.8	21.3	20.5	17.6	7.9	5.1
10-Year Mean[b]	7.1	13.4	17.9	21.3	19.6	15.8	9.1	2.4
Difference[e]	-2.0	2.4	-1.1	0.0	0.9	1.8	-1.2	2.8
Vernon[d]								
2015 Mean	6.0	16.2	17.1	20.6	21.0	18.3	8.6	5.2
10-Year Mean[b]	7.5	13.4	18.7	21.7	20.2	16.4	9.8	3.2
Difference[e]	-1.5	2.7	-1.6	-1.1	0.8	1.9	-1.2	2.0

a. NOAA NOWData for Station USC00438556, Union Village Dam, VT (NRCC, 2015a).

b. Calculated based on monthly average air temperatures for years 2005 through 2014.

c. NOAA NOWData for Station USC00435982, North Springfield Lake, VT (NRCC, 2015b).

d. NOAA NOWData for Station USC00274399, Keene, NH (NRCC, 2015c).

e. Negative values indicates mean temperatures in 2015 were cooler whereas positive values indicate 2015 temperatures were warmer.

Table 5.1-2. 2015 and previous 10-year monthly total precipitation (inches) for Wilder, Bellows Falls, and Vernon study areas.

Precipitation (inches)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Wilder[a]								
2015 Total	1.8	2.7	8.1	2.5	3.5	6.7	2.2	1.4
10-Year Mean	2.9	3.3	4.0	5.0	3.6	3.7	4.9	3.2
Difference[b]	-1.1	-0.6	4.1	-2.5	-0.2	3.0	-2.6	-1.8
Bellows Falls[a]								
2015 Total	2.0	1.9	6.0	2.2	3.7	6.7	1.8	1.4
10-Year Mean	2.4	3.2	4.4	4.5	3.4	3.3	4.8	2.6
Difference[b]	-0.4	-1.3	1.6	-2.3	0.3	3.4	-3.0	-1.1
Vernon[a]								
2015 Total	2.2	1.0	3.9	1.9	3.9	6.6	2.2	1.4
10-Year Mean	3.2	3.7	5.5	4.2	4.2	3.6	6.0	3.3
Difference[b]	-1.0	-2.6	-1.6	-2.3	-0.3	3.0	-3.8	-1.9

a. Precipitation data collected at each of the three project dams by TransCanada.

b. Negative values indicates 2015 was dryer whereas positive values indicate 2015 was wetter.

Table 5.1-3. Change in 2015 daily mean air temperatures throughout the study area.

Statistic	**Daily Mean Air Temperature Change (°C)[a]**								
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov[b]**	**Overall**
Lancaster, NH[c] to Wilder[d]									
Min	-1.11	-0.28	-1.94	0.00	-0.56	-1.39	-0.83	-0.83	-1.94
Max	4.44	5.00	2.50	4.44	2.78	2.50	3.61	2.78	5.00
Median	1.39	1.11	1.39	1.39	1.11	0.83	1.11	1.39	1.11
Mean	1.40	1.34	1.09	1.33	1.14	0.94	1.28	1.33	1.22
No. Days < 0°C	6	3	4	0	2	3	2	1	21
No. Days > 0°C	22	28	26	29	28	26	25	14	198
Wilder[d] to Bellows Falls[e]									
Min	-1.94	-4.17	-2.50	-1.39	-2.22	-1.94	-4.44	-1.67	-4.44
Max	3.33	3.06	3.61	2.50	0.83	1.11	4.44	6.39	6.39
Median	0.42	0.28	0.00	0.83	0.00	0.00	0.56	0.56	0.28
Mean	0.40	0.17	0.25	0.82	-0.11	-0.18	0.35	1.04	0.30
No. Days < 0°C	11	10	12	7	15	14	9	2	80
No. Days > 0°C	18	19	14	22	10	14	22	12	131
Bellows Falls[e] to Vernon[f]									
Min	-1.39	-1.94	-1.94	-3.61	-1.11	-0.56	-5.00	-6.94	-6.94
Max	3.33	2.50	3.61	2.22	2.50	3.61	7.50	3.33	7.50
Median	0.83	0.28	0.56	-0.83	0.56	0.56	0.28	0.28	0.28
Mean	0.85	0.41	0.35	-0.65	0.46	0.76	0.66	-0.20	0.36
No. Days < 0°C	7	7	8	18	8	1	8	5	62
No. Days > 0°C	20	18	19	11	18	21	16	9	132

a. Determined by calculating the difference between mean daily air temperatures between stations noted, then calculating each statistic for each month and the study period.

b. Through November 15, 2015.

c. NOAA NOWData for Station USC00274556, Lancaster, NH (NRCC, 2016).

d. NOAA NOWData for Station USC00438556, Union Village Dam, VT (NRCC, 2015a).

e. NOAA NOWData for Station USC00435982, North Springfield Lake, VT (NRCC, 2015b).

f. NOAA NOWData for Station USC00274399, Keene, NH (NRCC, 2015c).

Table 5.1-4. Mean daily flow (cfs) during the high temperature low-flow monitoring period at Wilder, Bellows Falls, and Vernon.

Date	Wilder[a]	Bellows Falls[a]	Vernon[a]
08/30/2015	1,596	3,584	4,170
08/31/2015	2,501	2,548	3,077
09/01/2015	2,543	2,702	2,997
09/02/2015	1,555	1,863	2,162
09/03/2015	1,627	1,563	2,050
09/04/2015	1,928	2,167	2,412
09/05/2015	1,181	1,282	2,001
09/06/2015	1,507	1,272	1,959
09/07/2015	1,703	1,766	2,098
09/08/2015	1,692	1,994	2,597
Max	2,543	3,584	4,157
Min	1,181	1,272	1,956
3 x 7Q10 Threshold[b]	2,598	2,979	–

a. Determined from TransCanada operations data.

b. There was no 3 x 7Q10 threshold defined for the Vernon Project.

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Table 5.1-5. Mean monthly flow and percent of mean monthly flow of main tributaries within the study area that contribute to mainstem Connecticut River flows of the Wilder, Bellows Falls, and Vernon Projects.[a]

Tributary	River Mile	Watershed Area (sq mi)	Discharge (cfs) and Percent (%)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov[b]
Wilder[c]											
Waits River[d]	247.0	155	Discharge (cfs)	623	207	374	261	105	93	179	138
			Percent (%)	5.1	3.3	3.5	4.9	3.8	4.5	4.5	4.5
Ompompanoosuc River[e]	224.9	137	Discharge (cfs)	550	183	331	231	93	82	158	122
			Percent (%)	4.5	2.9	3.1	4.3	3.3	4.0	4.0	4.0
Wilder[f]	217.2	3,375	Discharge	12,170	6,264	10,704	5,318	2,784	2,062	3,968	3,069
Bellows Falls											
White River[g]	215.8	712	Discharge (cfs)	4,216	1,231	2,282	1,101	411	303	647	691
			Percent (%)	18.2	13.3	14.2	14.0	11.9	11.8	10.6	15.6
Mascoma River[h]	214.5	195	Discharge (cfs)	895	185	397	193	70	91	311	243
			Percent (%)	3.9	2.0	2.5	2.4	2.0	3.5	5.1	5.5
Sugar River[i]	195.3	276	Discharge (cfs)	1,150	208	246	240	63	127	376	165
			Percent (%)	5.0	2.2	1.5	3.0	1.8	4.9	6.1	3.7
Black River[j]	183.3	204	Discharge (cfs)	1,212	222	361	194	76	99	217	192
			Percent (%)	5.2	2.4	2.2	2.5	2.2	3.9	3.5	4.3
Williams River[k]	177	117	Discharge (cfs)	710	96	137	78	30	70	92	83
			Percent (%)	3.1	1.0	0.8	1.0	0.9	2.7	1.5	1.9
Bellows Falls[f]	173.6	5,414	Discharge (cfs)	23,193	9,249	16,121	7,888	3,452	2,562	6,127	4,426
Vernon											
Saxtons River[l]	173.1	78	Discharge (cfs)	437	63	70	48	19	43	54	56
			Percent (%)	1.5	0.7	0.4	0.5	0.5	1.3	0.8	1.0
Cold River[m]	172.6	102	Discharge (cfs)	580	62	53	50	18	71	104	109
			Percent (%)	1.9	0.6	0.3	0.6	0.4	2.1	1.5	2.0
West River[n]	149.7	420	Discharge (cfs)	3,269	355	620	338	99	195	559	390
			Percent (%)	10.8	3.7	3.7	3.8	2.5	5.9	7.9	7.1
Vernon[f]	141.8	6,266	Discharge (cfs)	30,147	9,641	16,940	8,786	3,959	3,297	7,102	5,518

a. Percent of flow contributing to mainstem Connecticut River flows are based on mean monthly project discharges. All data were calculated from 15-minute discharge data; tributary flows were prorated to drainage area.

b. Mean flow through November 15, 2015.

c. Major tributaries to the mainstem Connecticut River upstream of the Wilder study area include the Wells River and Ammonoosuc River, located 2.4 and 2.7 RM upstream of the upstream station 06-W-04, respectively (i.e., 4.9 and 5.2 RM upstream of the upper end of the Wilder impoundment, respectively).

d. Source: Prorated based on Ompompanoosuc River flows

e. Source: U.S. Army Corp of Engineers, Union Village Dam, Thetford, VT

f. Source: TransCanada

g. Source: USGS Gage No. 01144000, White River at West Hartford, VT

h. Source: NHDES, Mascoma Lake Dam, Lebanon, NH

i. Source: USGS Gage No. 01152500, Sugar River at West Claremont, NH

j. Source: U.S. Army Corp of Engineers, North Springfield Dam, Springfield, VT

k. Source: USGS Gage No. 01153550, Williams River near Rockingham, VT

l. Source: USGS Gage No. 01154000, Saxtons River at Saxtons River, VT

m. Source: USGS Gage No. 01154950, Cold River at High Street, Alstead, NH

n. Source: USGS Gage No. 01155910, West River below Townshend Dam, Townshend, VT

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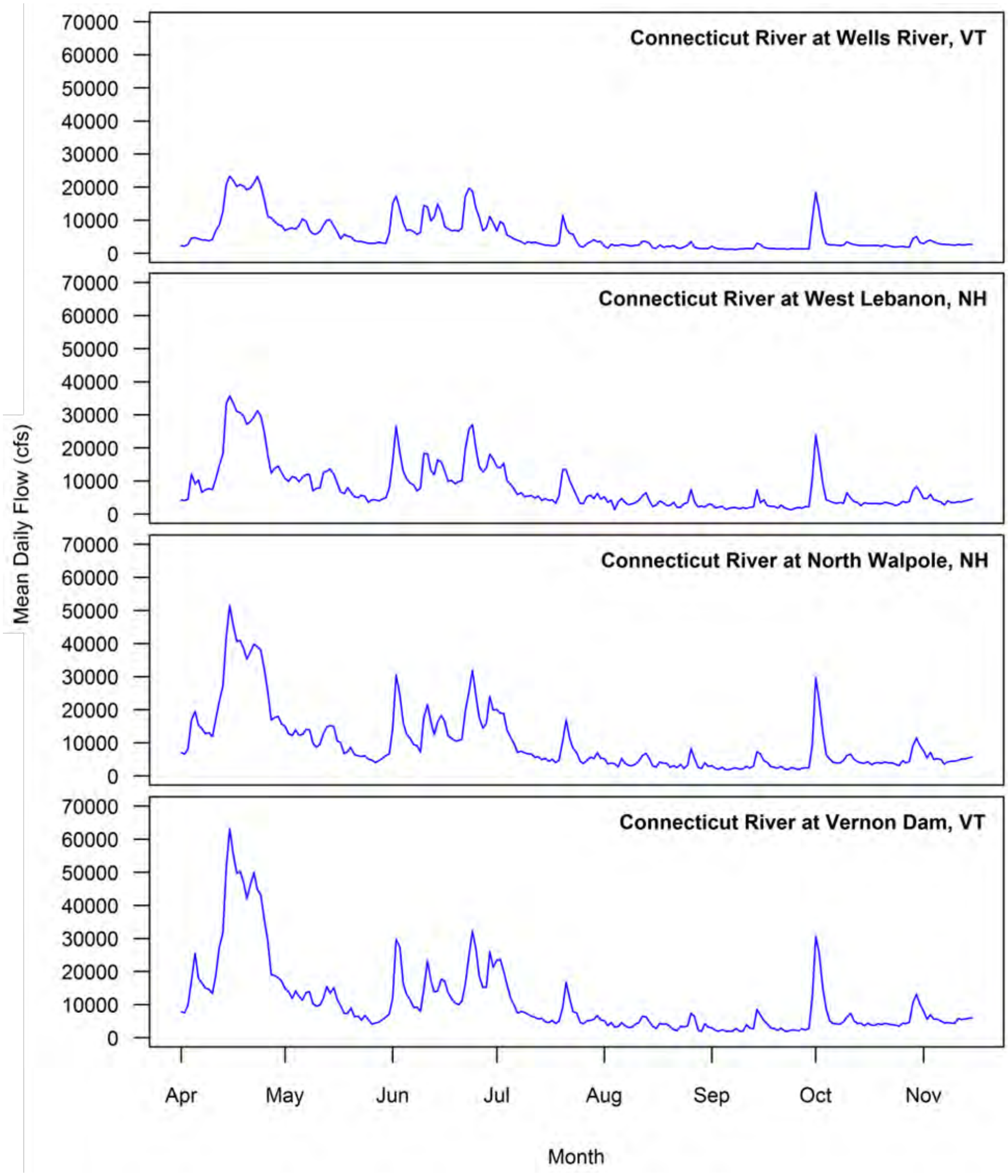

Figure 5.1-1. Connecticut River mean daily flow from April 1 through November 15, 2015. Discharge data from the Connecticut River at Wells River, VT, Connecticut River at West Lebanon, NH, and Connecticut River at North Walpole were obtained from USGS stream flow gages 01138500, 01144500, and 01154500, respectively. Flow of the Connecticut River at Vernon, VT, were obtained from TransCanada.

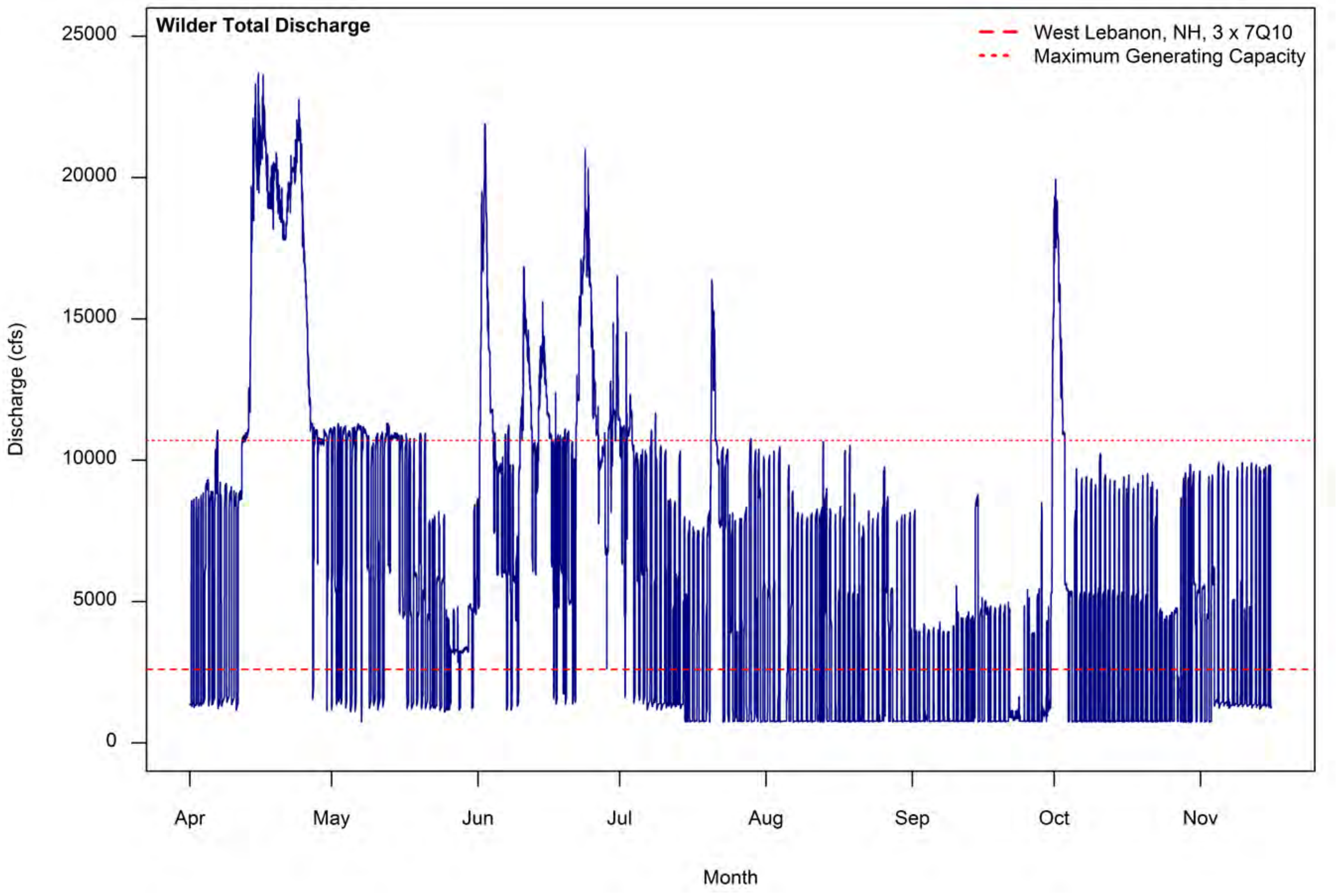

Figure 5.1-2. Wilder discharge during the study period.

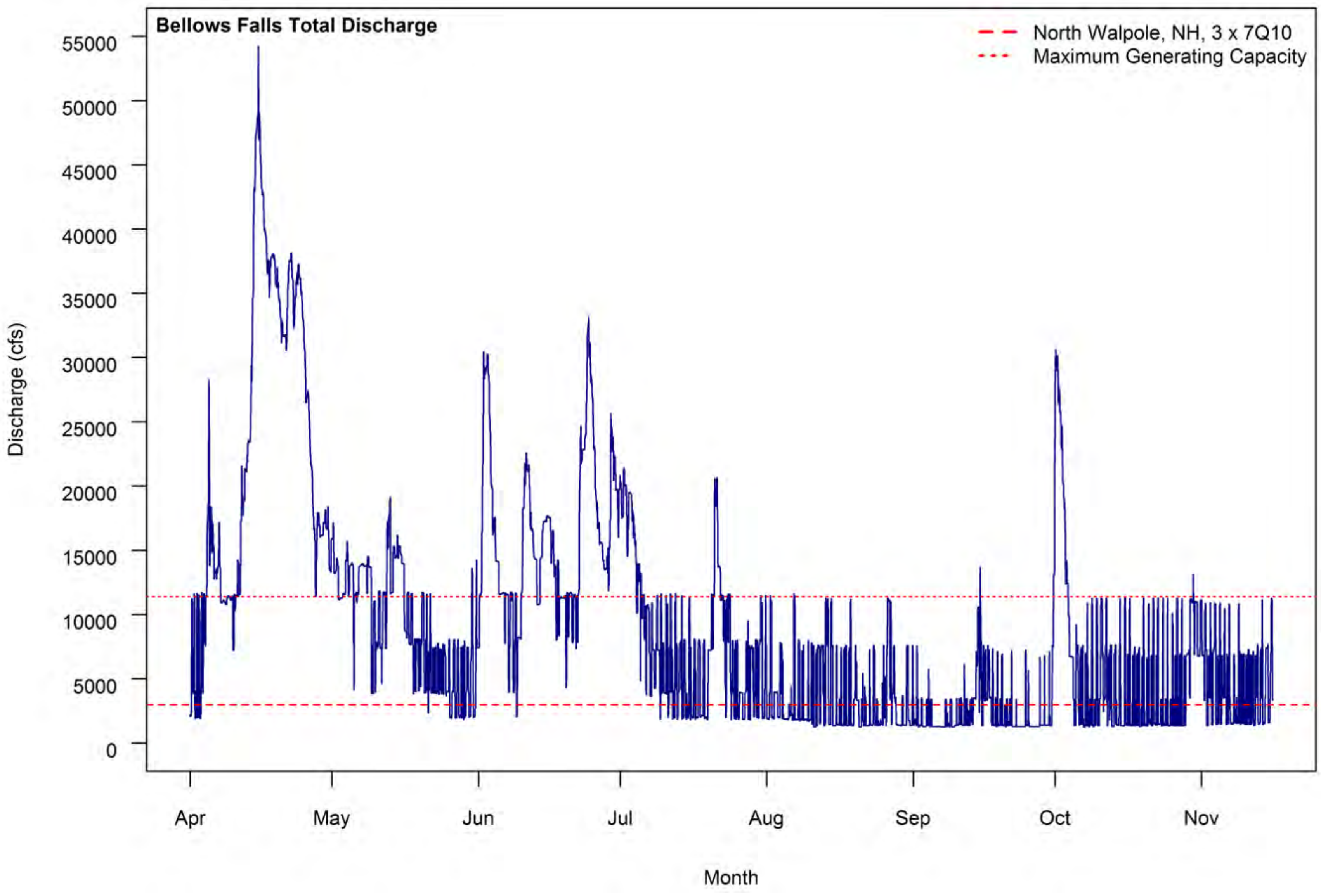

Figure 5.1-3. Bellows Falls discharge during the study period.

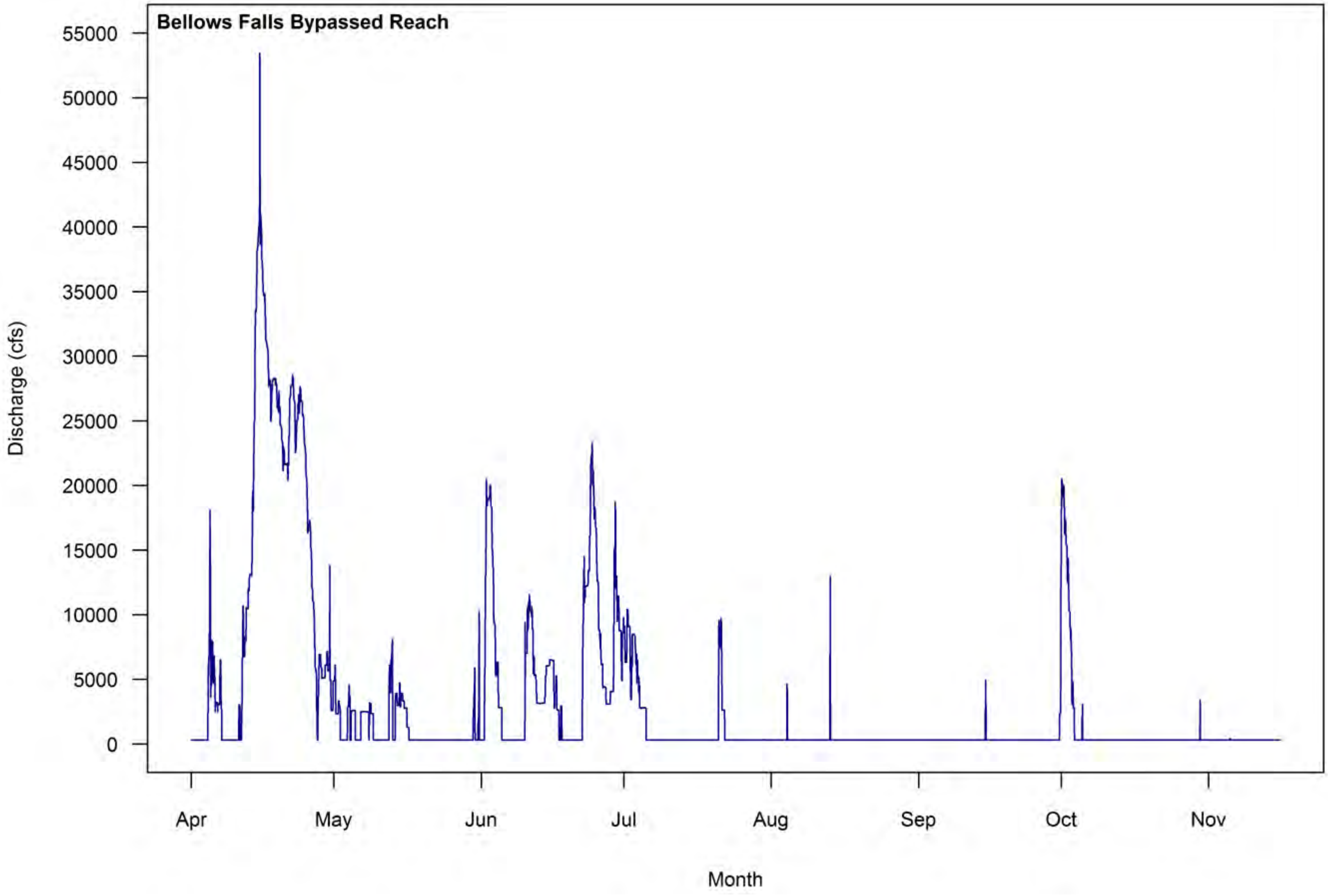

Figure 5.1-4. Bellows Falls dam discharge during the study period.

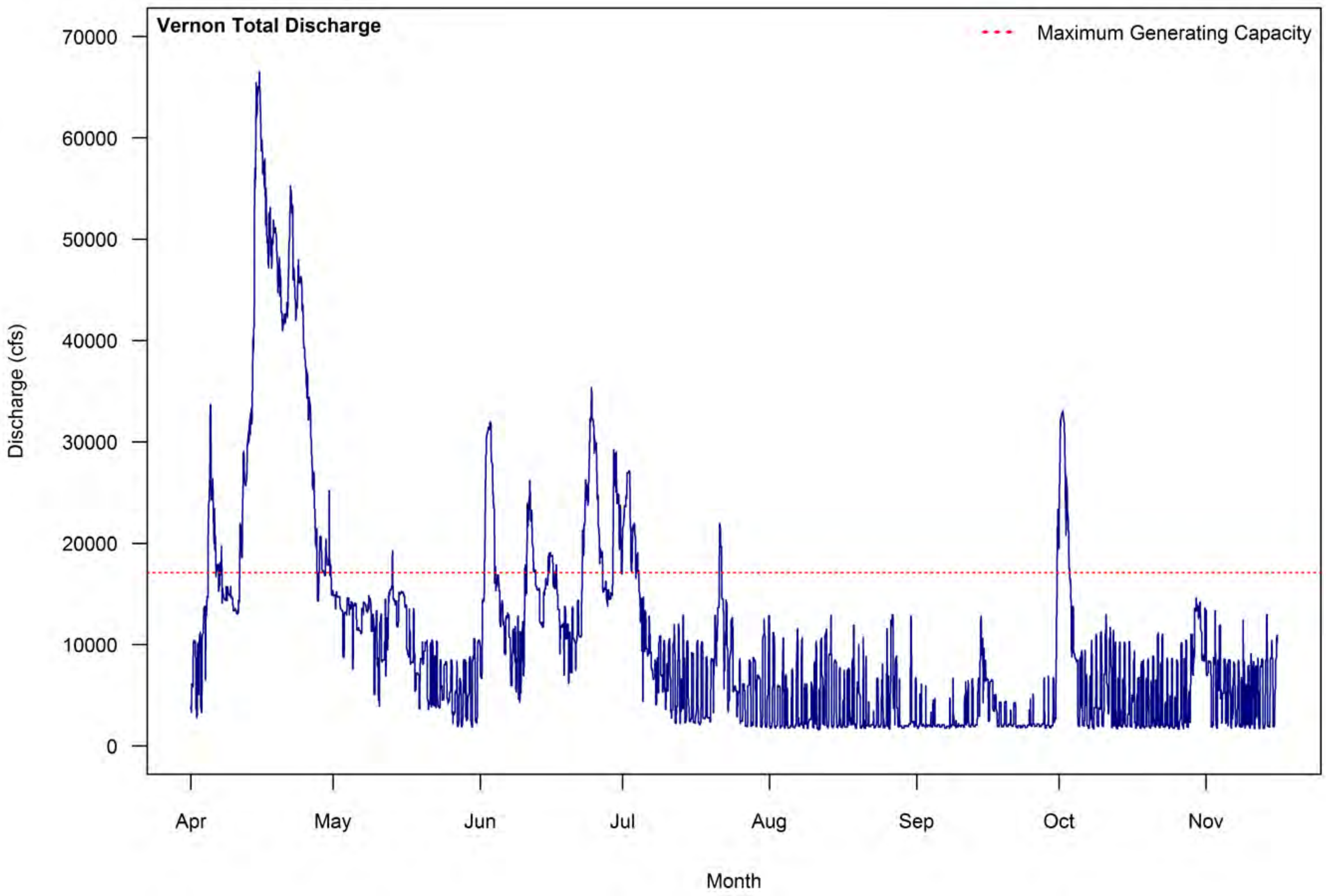

Figure 5.1-5. Vernon discharge during the study period.

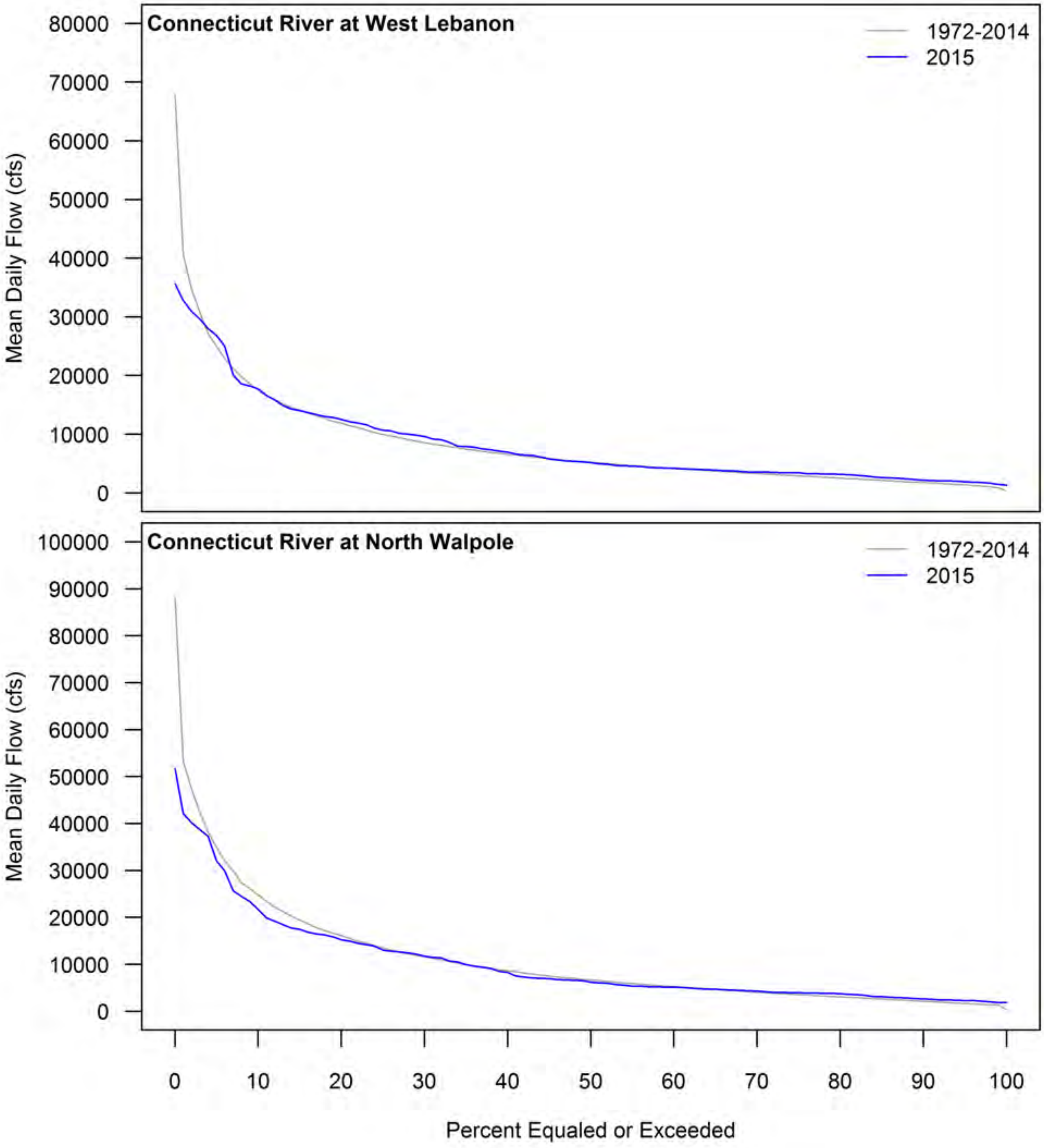

Figure 5.1-6. Flow duration curves for the Connecticut River at West Lebanon, NH, and North Walpole, NH, USGS stations from April 1 to November 15 for 1972 to 2014, and for 2015.

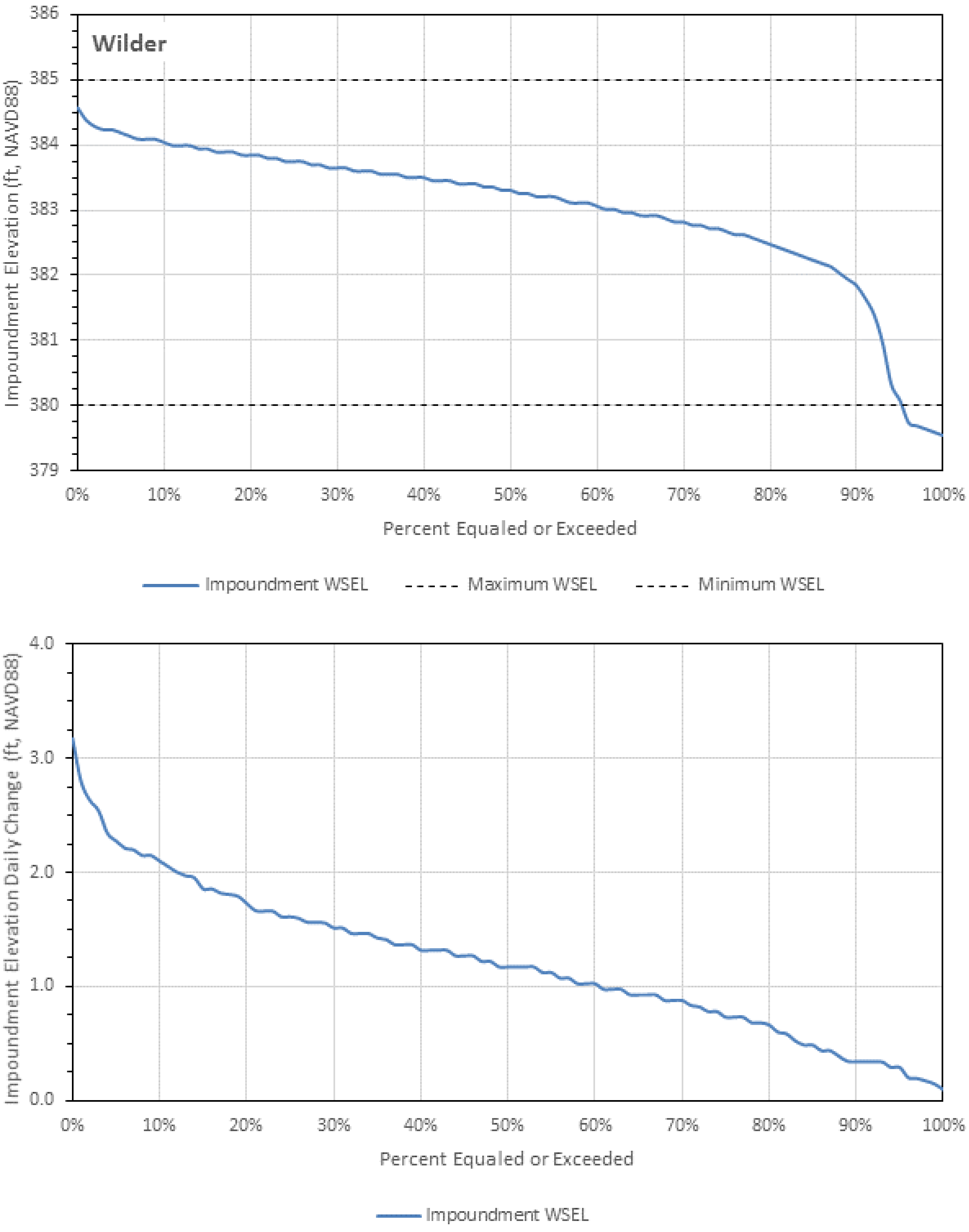

Figure 5.1-7. Wilder impoundment WSE duration curve (top panel) and daily WSE change duration curve (bottom panel) over the study period (April 1 through November 15, 2015) including periods when spill occurred.

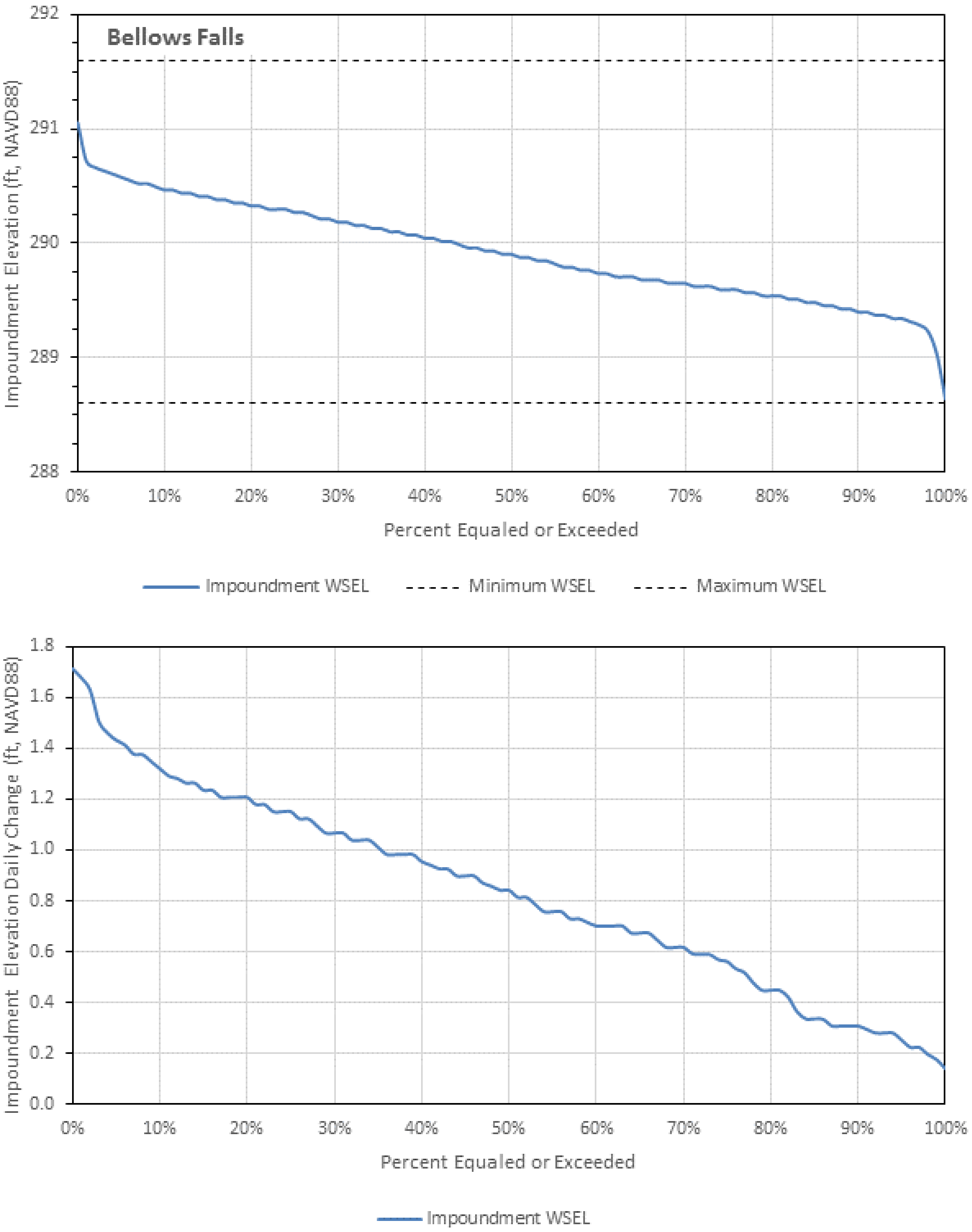

Figure 5.1-8. Bellows Falls impoundment WSE duration curve (top panel) and daily WSE change duration curve (bottom panel) over the study period (April 1 through November 15, 2015) including periods when spill occurred.

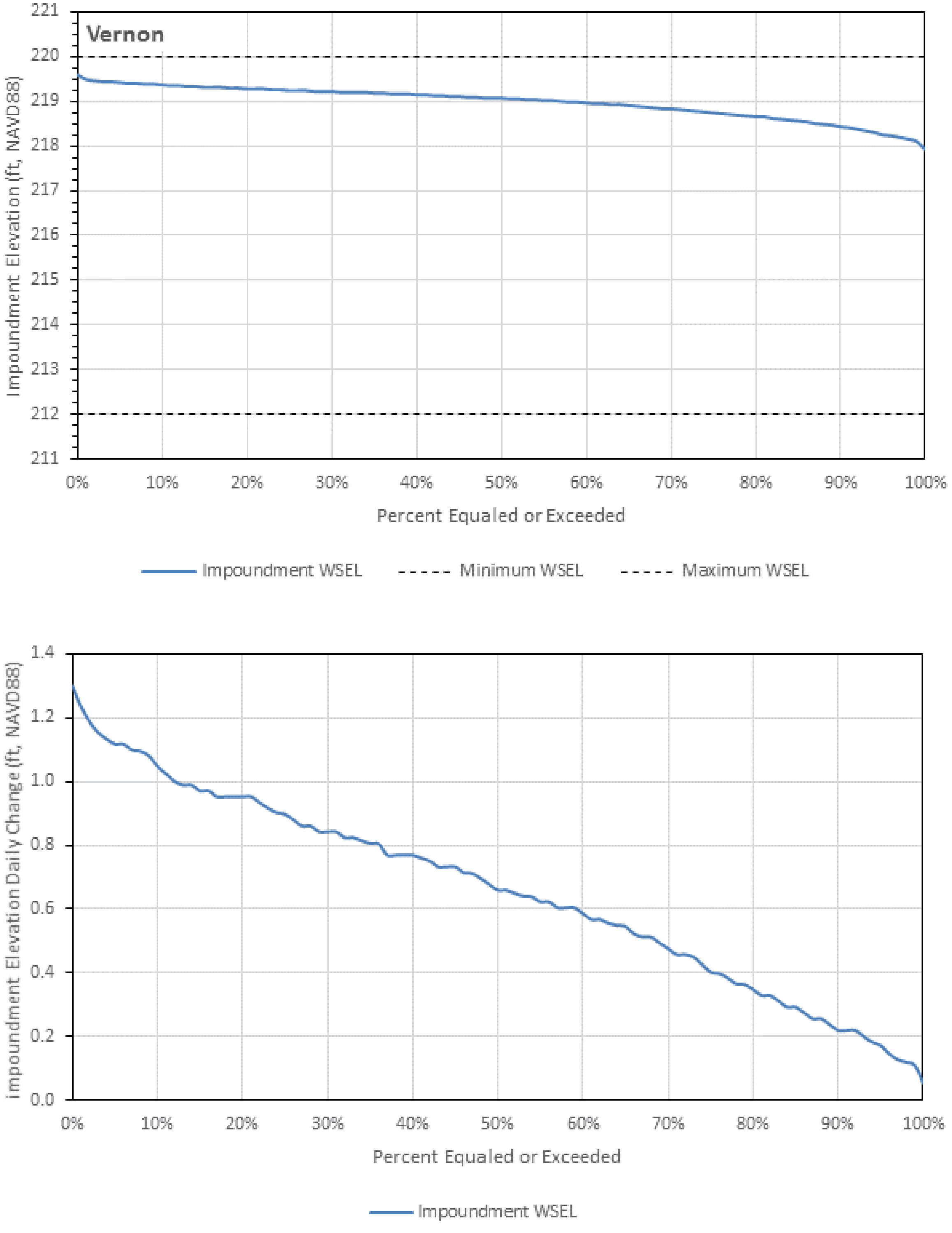

Figure 5.1-9. Vernon impoundment WSE duration curve (top panel) and daily WSE change duration curve (bottom panel) over the study period (April 1 through November 15, 2015) including periods when spill occurred.

5.2 Monitoring Results

5.2.1 Tributaries

The distribution of water temperatures were generally similar among the 10 tributaries, with slightly cooler temperatures observed in northern tributaries and warmer temperatures observed in southern tributaries (Figure 5.2.1-1). The two coldest tributaries on average, the Waits and Ompompanoosuc Rivers, had an overall mean temperature of 13.5 and 14.4°C, respectively (Table 5.2.1-1). The most southern tributary, the West River, had on overall mean temperature of 18.2°C (Table 5.2.1-1). Tributaries with similar temperature distributions tended to be spatially near each other such as the White and Mascoma Rivers, Sugar and Black Rivers, and Williams, Saxtons, and Cold Rivers (Figure 5.2.1-1).

Tributaries that are geographically close typically exhibited similar temporal patterns in their thermal regimes. Appendix D presents the temperature regimes for each tributary over the entire study period and Table 5.2.1-1 presents monthly water temperature summary statistics for each tributary. Water temperatures generally increased rapidly from April into May and gradually increased until peak temperatures were reached in August. Mean August temperatures for those tributaries ranged between 20.0°C (Waits River) and 24.2°C (West River), whereas August monthly maximum temperatures ranged from 25.7°C (Waits River) to 30.1°C (West River) (Table 5.2.1-1). Figure 5.2.1-1 also shows that tributary water temperatures generally encompass mainstem water temperatures, and that cooler tributary water temperatures would result in mainstem cooling and warmer tributary temperatures would result in mainstem warming.

Appendix E presents tributary water temperatures with discharges on a monthly basis through the study period. Greater diel fluctuations were observed during the warmer summer months when temperatures were more likely influenced by lower flows and a greater difference between daily maximum and minimum air temperatures than those during cooler spring and fall periods when flows were generally higher (Sinokrot and Gulliver, 2000). Water temperatures began to cool through September, and continued to cool until the end of the study period.

The coolest temperatures were consistently recorded in the Waits and Ompompanoosuc Rivers, and warmest temperatures were recorded in the West River. Tributary water temperatures are influenced by multiple factors such as latitude, climate, season, time of day, weather, flow, channel depth and shape, riparian vegetation cover, substrate, and channel gradient (Chapman and Kimstach, 1996; Wetzel, 2003). The similar temperature trends over the study period and the general trend of cooler tributaries in the north and warmer tributaries in the south suggest that the thermal regime is primarily influenced by climate and season. Therefore, the temperature of the water in each tributary that contributes to its respective project appears to be influenced by location within the watershed, flow, and prevailing weather with cooler contributions in the northern areas and warmer contributions in the southern areas.

Table 5.2.1-1. Maximum, minimum, mean, and median monthly water temperatures at tributary monitoring stations.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
06-W-T02 Waits River									
Max	11.88	22.73	21.34	24.97	25.72	24.87	13.79	11.180	25.72
Min	0.02	5.44	9.71	12.82	15.41	11.56	2.34	2.66	0.02
Median	3.09	14.46	15.37	18.53	19.94	18.03	8.84	6.55	14.86
Mean	3.21	14.57	15.44	18.55	20.00	17.77	8.55	6.50	13.50
06-W-T01 Ompompanoosuc River									
Max	9.73	23.16	21.72	25.77	26.43	24.63	14.74	11.37	26.43
Min	0.61	7.57	10.96	14.10	15.89	10.32	2.98	3.12	0.61
Median	4.82	14.24	16.27	19.34	20.39	17.80	9.49	7.12	15.51
Mean	4.77	14.30	16.13	19.37	20.45	17.79	9.11	6.96	14.36
06-BF-T05 White River									
Max	10.17	27.43	22.56	28.59	29.22	29.44	15.37	11.15	29.44
Min	1.18	8.69	10.78	15.18	19.41	14.46	5.05	4.38	1.18
Median	5.44	15.34	17.20	21.72	23.52	21.21	10.56	7.70	16.91
Mean	5.30	15.50	16.94	21.37	23.51	21.18	10.35	7.78	16.08
06-BF-T04 Mascoma River									
Max	9.34	25.28	24.00	28.64	28.32	27.31	17.80	12.12	28.64
Min	0.22	6.91	14.27	18.46	19.72	13.47	7.19	6.03	0.22
Median	3.83	15.03	19.20	22.63	23.35	20.96	12.22	8.94	17.63
Mean	3.81	15.00	19.22	22.65	23.40	20.42	12.31	8.99	16.14
06-BF-T03 Sugar River									
Max	11.27	24.75	24.41	29.06	27.95	28.00	16.03	11.86	29.06
Min	0.47	8.99	12.63	16.87	20.65	14.29	4.95	4.35	0.47
Median	5.75	16.94	20.30	23.04	23.69	20.08	11.30	8.17	18.03
Mean	5.47	17.33	19.60	22.91	23.83	20.24	10.65	8.05	16.91
06-BF-T02 Black River									
Max	10.42	25.04	24.03	28.37	27.50	25.60	15.75	11.25	28.37
Min	0.30	8.74	13.26	16.68	19.70	13.57	6.33	2.85	0.30
Median	5.08	16.92	19.44	23.06	23.06	23.35	20.22	11.03	17.72
Mean	4.68	17.11	19.32	22.76	23.40	20.03	10.63	7.87	16.20

Table 5.2.1-1. Continued.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
06-BF-T01 Williams River									
Max	11.61	25.04	23.50	28.77	27.75	26.16	14.91	12.32	27.77
Min	0.19	7.47	11.15	14.58	17.44	11.71	4.69	3.75	0.19
Median	4.74	16.03	18.05	21.25	21.87	18.70	10.34	7.77	16.44
Mean	4.71	16.03	17.87	21.13	21.93	18.68	9.78	7.63	15.19
06-V-T03 Saxtons River									
Max	12.51	24.90	25.33	26.92	26.30	25.23	15.08	13.21	26.92
Min	0.08	7.49	11.27	14.86	17.13	11.59	3.62	3.09	0.08
Median	5.04	16.15	18.46	21.22	21.70	18.79	10.15	7.77	16.34
Mean	4.89	16.15	18.31	20.94	21.68	18.64	9.77	7.67	15.03
06-V-T02 Cold River									
Max	11.13	24.90	25.04	28.00	27.43	25.77	15.68	13.11	28.00
Min	-0.14	6.69	11.00	15.06	16.34	10.81	4.64	2.98	-0.14
Median	4.43	15.51	17.82	20.77	21.22	18.25	10.17	7.59	16.63
Mean	4.28	15.44	17.92	20.79	21.30	18.36	10.05	7.55	15.04
06-V-T01 West River									
Max	11.98	27.26	27.38	31.41	30.14	29.56	16.87	12.92	31.41
Min	3.54	8.57	11.93	15.89	19.01	13.45	4.71	3.38	3.38
Median	7.19	18.13	19.98	23.59	24.20	20.58	10.81	8.12	19.41
Mean	7.59	17.96	19.81	23.34	24.24	21.00	10.65	8.00	18.17

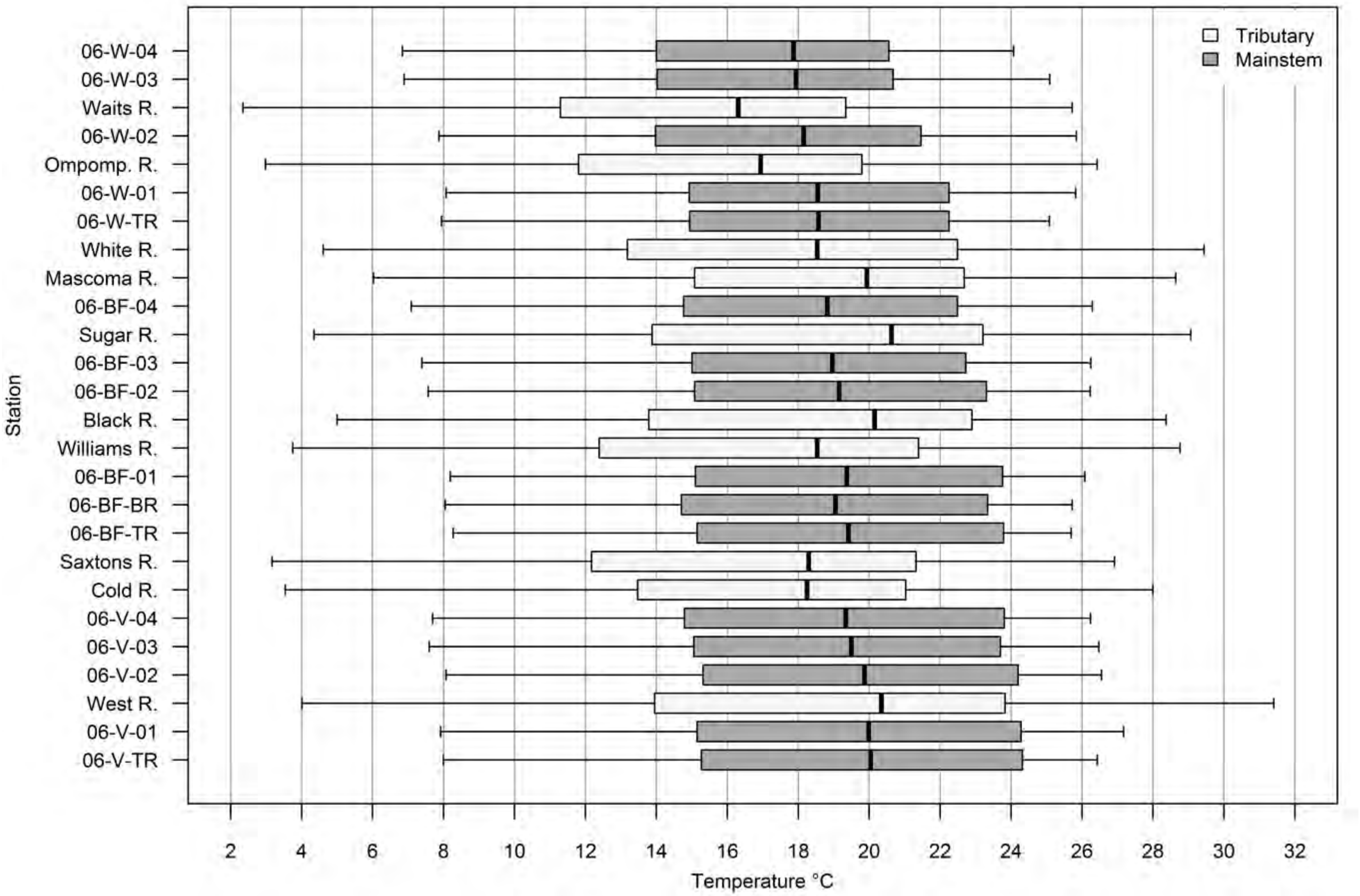

Figure 5.2.1-1. Box plots of continuous water temperature data collected at each tributary and mainstem water quality monitoring station over the common deployment period (21 May through 15 November).

5.2.2 Wilder Project

Temperature

Figure 5.2.1-1 presents the temperature distributions of each mainstem water quality monitoring station. The distribution of continuous temperature data for the Wilder mainstem monitoring stations show that the temperature of waters flowing from the upstream station (06-W-04) are cool, progressively warm through the impoundment, and are at their warmest at the forebay (06-W-01) and tailrace (06-W-TR) stations. On average, as water flows from upstream areas through the impoundment and out of the tailrace, water warmed by 1.3°C between the upstream (06-W-04) and the forebay (06-W-01) (Table 5.2.2-1). The greatest amount of warming through the impoundment occurred during August when mean monthly temperatures ranged from 21.5°C (06-W-03) to 23.2°C (06-W-01). During the study, water temperatures at the upstream and upper impoundment stations were generally cooler than at the middle impoundment, forebay, and tailrace stations (e.g., September 11 to September 16; Figure F-5 in Appendix F), but also were warmer (e.g., November 3 to November 8; Figure F-7 in Appendix F) or similar (e.g., July 6 to July 8; Figure F-3 in Appendix F) to stations downstream.

Figure 5.2.2-1 illustrates the temporal trend of water temperatures at all Wilder water quality monitoring stations, and Appendix F and Appendix O present mainstem continuous water temperature measured at each mainstem station along with inflow and project discharge, and impoundment water level fluctuations measured at the dam, respectively. All five stations followed a similar warming and cooling pattern. Upon deployment of equipment in early May, water temperatures began to steadily increase through May, but a rain event resulted in a decrease of approximately 5°C in water temperature in early June. River temperatures reached their maximum in late August and gradually decreased until the end of the study period. Upstream (06-W-04) and upper impoundment (06-W-03) monitoring stations exhibited larger diel fluctuations in temperature than the middle impoundment (06-W-02), forebay (06-W-01), or tailrace stations (06-W-TR), likely a reflection of air temperature fluctuations and shallower depths facilitating greater atmospheric mixing of the water column.

A temperature isopleth of the Wilder forebay station (06-W-01) shows progressive warming and cooling of the water column from June through September, with surface warming occurring in late August (August 29; Figure 5.2.2-2); the temperature difference measured between surface and bottom waters during that monitoring event was 1.5°C, with the greatest thermal discontinuity occurring between the surface and the 1-m depth (1.0°C). Mild surface warming was also observed at the middle impoundment station (06-W-02) in late July (July 30), late August (August 22), and in late September (September 23) when the difference between surface and bottom temperatures was 1.6°C with the greatest thermal discontinuity occurring between the surface and the 1-m depth (1.0°C). Appendix G presents a summary of each vertical profile for all stations as the average of the profile, and Appendix H illustrates water temperature vertical profiles for each station. Each profile began at the water surface at the time of measurement. Water temperature vertical profiles at the tailrace (06-W-TR), upper impoundment (06-W-03) and upstream (06-W-04) indicate that the water column was well-mixed at those stations. Summary statistics for water temperature vertical profile data are presented in Table 5.2.2-2.

The high temperature low-flow period monitoring occurred from August 30 through September 8, 2015. Table 5.2.2-3 presents summary statistics for each station and deployment depth stratum. Mean temperatures among all stations and deployment depths ranged between 22.1°C at the upstream station (06-W-04) and 24.0°C at the Wilder forebay station (06-W-01). Mean temperatures at river left, mid-channel, and river right locations at both upstream (06-W-04) and upper impoundment stations (06-W-03) were similar. At the middle impoundment station (06-W-02) temperatures were similar among deployment stratum (1 m below surface, mid-depth, and 1 m above bottom) and among the river left, mid-channel, and river right locations; mean bottom temperatures were 0.4°C cooler than those on the surface. The Wilder forebay station showed the greatest temperature difference of 0.9 to 1.0°C between surface and bottom temperatures where depths ranged from 6.9 m at river left to 13.0 m at river right. Appendix I provides the temperature time-series for all stations during the high temperature low-flow monitoring period.

Dissolved Oxygen

DO (mg/L; percent saturation) was continuously monitored in the Wilder forebay and tailrace stations from June through September and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem stations (Appendix F). DO concentrations measured continuously within the Wilder forebay ranged between 6.6 and 10.2 mg/L; percent DO saturation ranged between 78.0 and 111.4 percent (Table 5.2.2-4). DO concentrations at the Wilder forebay started high in June (10.2 mg/L; 100.3% saturation) then progressively decreased until reaching their lowest concentration in mid-September (6.6 mg/L; 78% saturation), but never falling below VT or NH surface water quality standards (Figure 5.2.2-3). The minimum daily mean of percent DO saturation in the Wilder forebay ranged from 81.1 percent (September) to 92.3 percent (June) (Table 5.2.2-4).

The DO concentrations continuously monitored in the Wilder tailrace ranged from 6.9 to 9.8 mg/L and 81.1 to 106.0 percent saturation (Table 5.2.2-5). Similar to DO concentrations measured in the Wilder forebay, concentration of DO in the Wilder tailrace started at their highest levels (9.8 mg/L) in June, then steadily decreased until mid-September (6.9 mg/L), whereas percent DO saturation levels remained fairly consistent (Figure 5.2.2-4). DO levels in the Wilder tailrace were above VT and NH surface water quality standards at all times (Figure 5.2.2-4; Table 5.2.2-5).

Concurrent with continuous monitoring of DO in the Wilder forebay and tailrace vertical profiles of DO were collected in the Wilder tailrace, impoundment, and upstream areas. Table 5.2.2-2 presents summary statistics of water quality vertical profiles performed throughout the Wilder study area. In the Wilder tailrace (06-W-TR) DO concentrations obtained from vertical profiles ranged from 7.4 to 9.2 mg/L with percent saturation values ranging from 86.3 to 100.0 percent. A DO (mg/L) isopleth of the Wilder forebay station (06-W-01) shows that DO concentrations were lowest in late August near the river bottom (7.2 mg/L), which corresponds to a period of mild surface warming (Figure 5.2.2-5). This period of weak mild surface warming resulted in DO concentrations differing by 1.2 mg/L between surface and bottom measurements, with the greatest difference occurring between the surface and 1 m below the surface (0.5 mg/L). DO vertical profiles collected at the middle, upper and upstream impoundment stations indicate that DO concentrations were generally uniform and mixed throughout the water column, with mean DO concentrations ranging from 8.5 to 9.0 mg/L, and percent DO saturation values from 93.1 to 97.8 percent saturation, respectively (Table 5.2.2-2). Appendix H presents the water quality profiles for each station.

During the high temperature low-flow monitoring period, DO levels were continuously recorded from August 30 through September 8 at all Wilder stations. Mean DO levels were higher at the upstream and upper impoundment stations than at the middle and forebay stations (Table 5.2.2-6). Mean DO concentrations at the upstream and upper impoundment stations were both 8.4 mg/L, and percent DO saturation levels were 96.3 and 96.9 percent, respectively. The minimum daily mean ranged from 94.3 percent (06-W-04) to 95.2 percent (06-W-03). Mean DO concentrations at the middle impoundment and forebay stations were slightly lower, which ranged from 7.9 mg/L (06-W-01) to 8.1 mg/L (06-W-02). Mean percent DO saturation levels were 93.2 percent (06-W-01) and 94.1 percent (06-W-02), and minimum daily mean percent DO saturation levels were between 87.3 to 98.3 percent at the forebay station (06-W-01), and 92.0 to 95.5 percent at the middle impoundment station (06-W-02). Appendix J provides DO time-series for all stations during the high temperature low-flow monitoring period, which show well-defined diel fluctuations in DO levels at the upstream (06-W-04) and upper impoundment (06-W-03) station, and little to no diel pattern of fluctuating DO levels at the middle impoundment (06-W-02) and forebay stations (06-W-01), respectively.

pH

pH was continuously monitored in the Wilder forebay (06-W-01) and tailrace (06-W-TR) from June through September, and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem Wilder monitoring stations (Appendix F). pH levels (all values in s.u) of the Wilder forebay (06-W-01) were generally similar and ranged from 7.19 to 7.84 from June through August, with mean monthly pH levels of 7.37, 7.40, and 7.41 for June, July, and August, respectively (Table 5.2.2-4). In September, the mean pH value increased slightly to 7.50 and the highest pH value of 8.02 recorded by the continuous sonde at the forebay station (06-W-01) (Table 5.2.2-4). The highest pH values were recorded in early September and resulted in one instance when the pH exceeded the NH surface water quality standard (Figure 5.2.2-3). As recorded by the continuous sonde deployed in the Wilder forebay (06-W-01), pH did not fall below VT or NH surface water quality standards (Figure 5.2.2-3).

Continuous pH recorded in the Wilder tailrace (06-W-TR) occurred from mid-June through September. pH levels in the Wilder tailrace were generally consistent, with minor fluctuations, and did not rise above or fall below VT or NH surface water quality standards (Figure 5.2.2-3). pH ranged from 7.23 to 7.68 (Table 5.2.2-5).

pH was also monitored during the collection of water quality vertical profiles at all Wilder monitoring stations (Appendix H). The pH vertical profiles indicate that pH through the water column was uniform at all Wilder water quality monitoring stations (Appendix H). During collection of the vertical profiles, pH levels were not observed to rise above or fall below VT or NH surface water quality standards; pH ranged from 7.22 to 7.61 among all Wilder stations (Table 5.2.2-5).

Mean pH during the high temperature low-flow period was 7.53 at both the upstream (06-W-04) and upper impoundment stations (06-W-03). pH measured at the middle impoundment station (06-W-02) was, on average 0.24 s.u. lower than the mean pH of the forebay, upper impoundment, and upstream stations (Table 5.2.2-6). The lowest pH recorded during the high temperature low-flow period was 7.11 at the middle impoundment station (06-W-02), and the highest pH recorded was 8.02 at the forebay station (06-W-01). Appendix J provides pH time-series for all stations during the high temperature low-flow monitoring period, which show well-defined diel fluctuations in pH levels at the upstream (06-W-04) and upper impoundment (06-W-03) stations, and little to no diel pattern of fluctuating pH levels at the middle impoundment (06-W-02) and forebay stations (06-W-01), respectively.

Specific Conductivity

Specific conductivity was continuously monitored in the Wilder forebay (06-W-01) and tailrace (06-W-TR) from June through September, and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem Wilder monitoring stations (Appendix F). Specific conductivity continuously monitored in the Wilder forebay shows a general increase from June through September (Figure 5.2.2-3). Over the 4-month deployment period maximum, minimum, and mean monthly specific conductivity increased, with the lowest specific conductivity measured in June (69 µS/cm) and the highest in September (163 µS/cm) (Table 5.2.2.4). Specific conductivity monitored in the Wilder tailrace also showed a generally increasing trend (Figure 5.2.2-4). Monthly minimum, maximum, and mean specific conductivity values in the tailrace were similar to those measured in the Wilder forebay (Table 5.2.2-5) and ranged from 70 to 161 µS/cm. Monthly mean specific conductivity in the tailrace ranged from 83 µS/cm in June to 133 µS/cm in September (Table 5.2.2-5).

Appendix H provides specific conductivity vertical profiles collected at all Wilder water quality monitoring stations. Across all stations, specific conductivity was uniform throughout the water column. In addition, specific conductivity vertical profiles suggest that specific conductivity increases from upstream areas to downstream areas. For example, specific conductivity measured at the upstream and upper impoundment stations exhibit a similar range (62 to 121 µS/cm), whereas the range at the middle impoundment and forebay stations were 68 to 126 µS/cm and 74 to 139 µS/cm, respectively (Table 5.2.2-2).

Specific conductivity collected during the high temperature low-flow period showed no diel pattern of fluctuating levels (Appendix J). During this period mean specific conductivity levels ranged from 111 µS/cm at the upstream station to 133 S/cm at the forebay station (Table 5.2.2-6).

Turbidity

Turbidity was monitored on a continuous basis from June through September at the Wilder forebay (06-W-01) and tailrace (06-W-TR) stations and at all mainstem Wilder stations during the high temperature low-flow monitoring period from August 30 to September 8 (Appendix F). Turbidity at the forebay (06-W-01) and tailrace (06-W-TR) stations was generally very low with increases occurring in response to high flows resulting from precipitation events (Figures 5.2.2-3 and 5.2.2-4; Appendix B; Appendix F). Turbidity at the forebay station (06-W-01) ranged from 0.0 to 28.3 NTU with an overall median and mean of 0.9 and 1.9 NTU, respectively (Table 5.2.2-4). Turbidity at the tailrace station (06-W-TR) ranged from 0.1 NTU to 64.0 NTU, with an overall median and mean of 1.3 and 2.5 NTU, respectively (Table 5.2.2-5).

Appendix G presents a summary of each vertical profile for all stations as the average of the profile, and Appendix F presents each profile average turbidity along with continuously measured turbidity at the forebay and tailrace stations with project inflows and discharge. Overall, the mean and median turbidity values among stations were low and ranged from 0.8 to 3.1 NTU and 0.5 to 1.2 NTU, respectively; however, turbidity levels varied depending on field conditions (Table 5.2.2-2; Appendix F). For example, the vertical profile on June 4, 2015 was collected in the Wilder forebay (06-W-01) during a high-flow event and through a debris field. The addition of sediment from runoff associated with the heavy rain event resulted in turbidity levels through the profile that ranged from approximately 10 to 60 NTU. Furthermore, turbidity was observed higher in the water column at 0.5 m above the river bottom relative to the water column above at the Wilder forebay station (06-W-01) and middle impoundment station (06-W-02) during some profiles (Appendix H).

Continuous turbidity data collected during the high temperature low-flow monitoring period indicate that turbidity was very low in upstream areas and through the Wilder impoundment (Table 5.2.2-6;Appendix F). In addition, turbidity summary statistics indicate that turbidity generally decreased from upstream riverine areas (06-W-04) through the impoundment to the Wilder forebay station (06-W-01) during this period. Median turbidity values recorded during this period ranged from 1.8 NTU (station 06-W-04) to 0.6 NTU (station 06-W-01), with a maximum of 4.2 NTU recorded at the upper impoundment station (06-W-03) (Table 5.2.2-6).

Overall, the continuous and vertical profile turbidity data collected at all mainstem Wilder monitoring stations indicate that turbidity did not exceed the NH surface water quality standard of 10 NTU beyond upstream waters, and that under low-flow conditions turbidity within the Wilder study area did not exceed the VT surface water quality standard for turbidity. Sporadic spikes observed in the turbidity time-series for each station that did not follow inflows (e.g., 06-W-TR July 6; Figure F-73 in Appendix F) most likely due to debris and vegetation caught in the instrument and drifting in front of the turbidity optics, based on field observations.

Nutrients and Chlorophyll-a

Table 5.2.2-7 presents the results of nutrient and chlorophyll-*a* sampling and analyses. Total nitrogen (TN) concentrations ranged from below the instrument detection limit of 0.5 mg/L to 1.50 mg/L, with a mean of 0.46 mg/L. Total phosphorus (TP) levels ranged from 0.008 to 0.026 mg/L, and averaged 0.013 mg/L. Collectively, the observed range and mean levels of TN and TP suggest the trophic state of Connecticut River at the Wilder forebay station is oligotrophic to mesotrophic (Dodds et al., 1998; NHDES, 1997, VTDEC, 2000). Nitrate/nitrite concentrations ranged from 0.09 to 0.30 mg/L, and a mean of 0.16 mg/L. Total Kjeldahl nitrogen (TKN) ranged from below the instrument detection limit of 0.50 mg/L to 1.20 mg/L and a mean of 0.40 mg/L. Chlorophyll-*a* levels were observed to range from 0.6 to 4.7 mg/m^3, and generally increased over the study period. Chlorophyll–*a* concentrations averaged 2.2 mg/m^3 suggesting that trophic state of the Connecticut River at the Wilder forebay monitoring station is oligotrophic (VTDEC, 2000; NHDES, 1997). Laboratory reports are included in Appendix K.

Table 5.2.2-1. Maximum, minimum, mean, and median monthly water temperatures for Wilder water quality monitoring stations.

Temperature (°C)	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**All**
06-W-04								
Max	18.25	18.44	22.90	24.07	23.94	17.46	11.32	24.07
Min	6.61	12.20	16.61	18.94	15.89	7.77	6.84	6.61
Median	11.53	16.25	19.67	21.25	20.72	12.90	8.84	17.25
Mean	11.82	15.98	19.58	21.37	20.46	12.62	9.19	16.36
06-W-03								
Max	18.46	18.39	23.45	25.09	24.41	17.34	11.20	25.09
Min	6.36	12.12	16.75	19.13	16.30	7.77	6.61	6.36
Median	11.69	16.27	19.77	21.37	20.84	13.02	8.87	17.32
Mean	11.95	16.03	19.72	21.52	20.57	12.62	9.20	16.45
06-W-02								
Max	19.58	18.75	23.38	25.84	24.64	17.49	10.76	25.84
Min	7.12	12.44	17.42	20.67	17.15	9.09	7.57	7.12
Median	12.46	16.68	20.44	22.06	21.18	13.11	8.89	17.77
Mean	12.67	16.41	20.37	22.35	21.23	12.60	9.15	16.94
06-W-01								
Max	18.89	18.98	23.80	25.82	25.19	17.72	10.17	25.82
Min	10.05	12.44	16.76	21.69	17.71	9.19	7.92	7.92
Median	14.10	16.82	20.91	23.19	22.22	13.26	9.41	18.18
Mean	13.92	16.72	20.73	23.18	21.99	12.97	9.31	17.67
06-W-TR								
Max	18.84	18.96	23.54	25.08	24.29	17.72	9.81	25.08
Min	10.12	12.46	16.78	21.74	17.72	9.11	7.85	7.85
Median	14.00	16.89	20.92	23.07	22.20	13.18	9.29	18.18
Mean	13.81	16.77	20.75	23.13	21.77	12.89	9.20	17.60

Table 5.2.2-2. Vertical profile summary statistics for Wilder water quality monitoring stations.

Statistic	**06-W-04**	**06-W-03**	**06-W-02**	**06-W-01**	**06-W-TR**
Mean Water Depth (m)[a]	0.8	2.2	7.2	10.6	8.6
Temperature (°C)					
Max	22.05	22.2	25.7	24.7	23.8
Min	14.9	14.5	14.2	13.4	18.0
Median	20.1	19.9	20.9	20.7	22.5
Mean	19.2	19.2	20.3	20.4	21.9
Dissolved Oxygen (mg/L)					
Max	10.1	10.4	10.3	10.2	9.2
Min	8.3	8.0	7.5	7.2	7.4
Median	8.9	8.9	8.1	8.0	8.0
Mean	9.0	8.9	8.5	8.2	7.9
Dissolved Oxygen (% saturation)					
Max	101.7	102.0	100.1	100.7	100.0
Min	93.3	91.0	87.8	82.3	86.3
Median	97.8	96.3	92.7	89.7	89.4
Mean	97.8	96.8	93.1	90.5	90.1
Specific Conductivity (µS/cm)					
Max	121	121	126	139	138
Min	62	63	68	74	94
Median	95.5	95.0	106	111	130
Mean	95.8	92.8	104	109	123
pH (s.u)					
Max	7.61	7.47	7.48	7.54	7.54
Min	7.24	7.22	7.26	7.24	7.33
Median	7.36	7.34	7.39	7.35	7.41
Mean	7.40	7.35	7.48	7.36	7.42
Turbidity (NTU)					
Max	2.7	2.9	5.0	59.3	2.7
Min	0.0	0.0	0.0	0.0	0.1
Median	0.9	0.7	0.5	1.2	1.2
Mean	1.0	0.8	0.9	3.1	1.3

a. Average of individual depths recorded during each station visit.

Table 5.2.2-3. Water temperatures of the Wilder impoundment and upstream area during the high temperature low-flow monitoring period.

Logger Location	**Statistic**	**Temperature** (°C)		
		River Left	**Mid-channel**	**River Right**
06-W-04				
Mid-depth	Max	24.8	24.3	23.6
	Min	20.3	20.3	20.4
	Mean	22.3	22.3	22.1
Depth to bottom (at first deployment, m)		0.2	0.3	1.0
06-W-03				
Mid-depth	Max	24.2	24.2	24.2
	Min	20.8	20.8	20.7
	Mean	22.4	22.4	22.4
Depth to bottom (at first deployment, m)		1.5	1.8	2.7
06-W-02				
1m below surface	Max	25.0	24.6	24.9
	Min	21.7	21.7	21.8
	Mean	23.1	23.0	23.2
Mid-depth	Max	--	23.6	24.1
	Min		21.6	21.7
	Mean		22.7	22.8
1m above bottom	Max	23.9	23.4	23.6
	Min	21.7	21.6	21.7
	Mean	22.7	22.6	22.8
Depth to bottom (at first deployment, m)		3.9	6.3	6.2
06-W-01				
1m below surface	Max	26.5	26.2	26.3
	Min	22.9	22.9	22.9
	Mean	24.0	23.9	23.9
Mid-depth	Max	24.4	24.2	23.8
	Min	22.7	22.7	22.7
	Mean	23.3	23.2	23.1
1m above bottom	Max	23.9	23.5	23.5
	Min	22.7	22.7	22.7
	Mean	23.0	23.0	23.0
Depth to bottom (at first deployment, m)		6.9	10.1	13

"--"indicates no logger deployed due to shallow water depths.

Table 5.2.2-4. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Wilder forebay water quality monitoring station, 06-W-01.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	18.98	23.80	25.82	25.19	25.82
Min	13.42	16.76	21.69	17.71	13.42
Median	16.98	20.91	23.19	22.22	21.74
Mean	16.97	20.73	23.18	21.99	20.85
Specific Conductivity (µS/cm)					
Max	107	142	142	163	163
Min	69	83	105	115	69
Median	78	104	118	134	114
Mean	81	104	120	136	111
Dissolved Oxygen (mg/L)					
Max	10.19	9.23	8.91	9.54	10.19
Min	8.82	7.77	7.19	6.63	6.63
Median	9.32	8.19	7.78	7.87	8.06
Mean	9.31	8.32	7.76	7.84	8.27
Dissolved Oxygen (% saturation)					
Max	100.3	97.0	108.4	111.4	111.4
Min	91.7	88.1	83.9	78.0	78.0
Median	96.2	93.0	90.5	88.8	92.2
Mean	96.2	92.7	90.8	89.6	92.2
Max Daily Mean	100.0	95.0	95.7	98.4	100.0
Min Daily Mean	92.3	89.3	87.3	81.1	81.1
pH (s.u)					
Max	7.54	7.64	7.84	8.02	8.02
Min	7.27	7.28	7.19	7.35	7.19
Median	7.36	7.39	7.40	7.48	7.41
Mean	7.37	7.40	7.41	7.50	7.42
Turbidity (NTU)					
Max	28.3	25.3	7.6	12.1	28.3
Min	0.0	0.7	0.3	0.0	0.0
Median	1.9	1.4	0.7	0.6	0.9
Mean	3.4	3.0	0.9	0.6	1.9

Table 5.2.2-5. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Wilder tailrace water quality monitoring station, 06-W-TR.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	18.96	23.54	25.08	24.29	25.08
Min	16.33	16.78	21.74	17.72	16.33
Median	18.25	20.92	23.07	22.20	22.08
Mean	18.06	20.75	23.13	21.77	21.46
Specific Conductivity (µS/cm)					
Max	102	145	145	161	161
Min	70	82	105	117	70
Median	84	106	117	131	116
Mean	83	105	119	133	115
Dissolved Oxygen (mg/L)					
Max	9.8	9.4	9.0	9.8	9.8
Min	8.2	7.8	7.4	6.9	6.9
Median	8.7	8.4	7.9	7.9	8.0
Mean	8.8	8.4	7.9	7.9	8.1
Dissolved Oxygen (% saturation)					
Max	101.8	106.0	104.6	105.6	106.0
Min	87.8	87.5	86.4	81.1	81.1
Median	92.2	93.6	91.4	89.1	91.4
Mean	92.9	93.9	92.0	89.7	92.0
Max Daily Mean	97.9	98.4	95.7	96.5	98.4
Min Daily Mean	89.2	89.6	88.6	83.5	83.5
pH (s.u)					
Max	7.54	7.57	7.62	7.68	7.68
Min	7.24	7.23	7.25	7.26	7.23
Median	7.36	7.37	7.37	7.44	7.39
Mean	7.36	7.38	7.38	7.44	7.40
Turbidity (NTU)					
Max	64.0	23.8	8.3	14.8	64.0
Min	0.3	0.3	0.8	0.1	0.1
Median	3.6	1.6	1.4	1.2	1.3
Mean	7.8	2.8	1.6	1.3	2.5

Table 5.2.2-6. Summary statistics of temperature, specific conductivity, dissolved oxygen, pH and turbidity for Wilder impoundment and upstream water quality monitoring stations during the high temperature low-flow monitoring period.

Statistic	**Station**			
	06-W-04	**06-W-03**	**06-W-02**	**06-W-01**
Temperature (°C)				
Max	23.6	23.9	24.3	24.8
Min	20.4	20.5	21.6	22.6
Median	22.1	22.1	22.8	23.3
Mean	22.1	22.1	22.8	23.4
Specific Conductivity (µS/cm)				
Max	120	125	164	151
Min	96	101	119	112
Median	112	114	131	132
Mean	111.4	114.7	133.0	132.6
Dissolved Oxygen (mg/L)				
Max	8.9	9.1	8.5	9.4
Min	8.0	7.9	7.8	7.2
Median	8.4	8.4	8.1	7.9
Mean	8.4	8.4	8.1	7.9
Dissolved Oxygen (% saturation)				
Max	102.5	106.2	101.5	111.4
Min	90.2	88.8	89.6	83.9
Median	95.9	95.9	93.9	92.6
Mean	96.3	96.9	94.1	93.2
Max Daily Mean	98.7	98.6	95.5	98.34
Min Daily Mean	94.3	95.2	91.9	87.3
pH (s.u)				
Max	7.69	7.74	7.47	8.02
Min	7.37	7.31	7.11	7.38
Median	7.52	7.53	7.29	7.55
Mean	7.53	7.53	7.30	7.56
Turbidity (NTU)				
Max	3.9	4.2	2.5	1.2
Min	1.4	0.7	0.3	0.1
Median	1.8	1.1	0.7	0.6
Mean	1.7	1.0	0.6	0.5

Table 5.2.2-7. Nutrients and chlorophyll-*a* data and summary statistics for the Wilder forebay water quality monitoring station, 06-W-01.

Date	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**Nitrate/Nitrite** (mg/L)	**Total Kjeldahl Nitrogen** (mg/L)	**Chlorophyll-*a*** (mg/m^3)
6/4/2015	<0.50	0.012	0.14	<0.50	0.7
6/11/2015	<0.50	0.026	0.14	<0.50	1.1
6/19/2015	<0.50	0.011	0.09	<0.50	1.5
6/28/2015	<0.50	0.018	0.09	<0.50	1.5
7/8/2015	<0.50	0.014	0.12	<0.50	1.1
7/16/2015	<0.50	0.009	0.30	<0.50	1.5
7/24/2015	<0.50	0.014	0.11	<0.50	0.6
7/30/2015	0.74	0.022	0.14	0.60	2.8
8/6/2015	<0.50	0.008	0.15	<0.50	3.1
8/11/2015	<0.50	0.009	0.17	<0.50	2.5
8/22/2015	0.77	0.012	0.27	0.50	2.4
8/29/2015	1.50	0.009	0.26	1.20	4.7
9/11/2015	<0.5	0.011	0.16	<0.50	2.5
9/23/2015	<0.5	0.009	0.14	<0.50	3.5
9/29/2015	1.15	0.008	0.15	1.00	3.9
Max	1.50	0.026	0.30	1.20	4.7
Min	<0.50	0.008	0.09	<0.50	0.6
Median[a]	<0.50	0.011	0.14	<0.50	2.4
Mean[a]	0.46	0.013	0.16	0.40	2.2

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for mean calculations for the associated analyte.

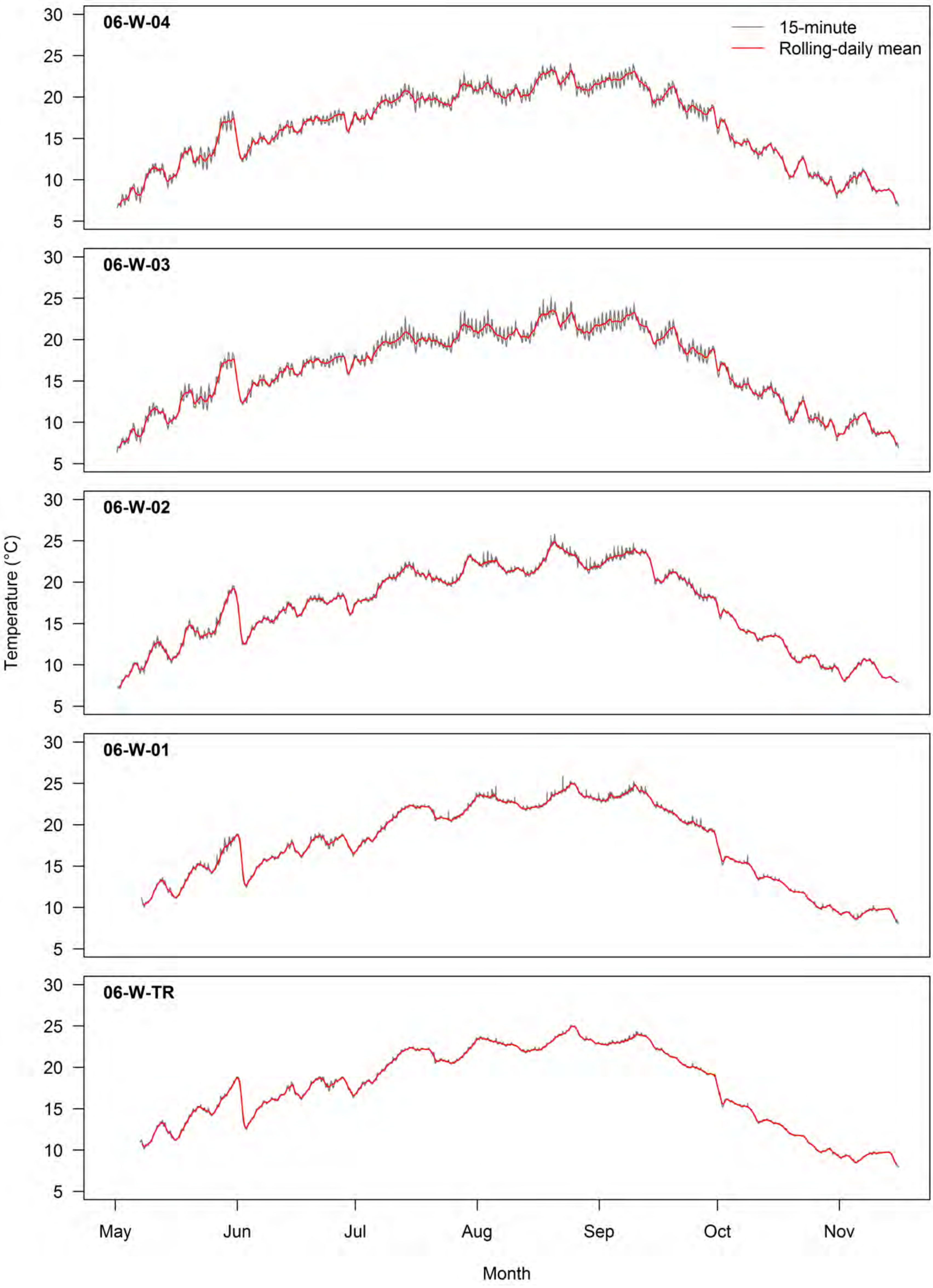

Figure 5.2.2-1. Continuous water temperature collected at 15-minute intervals and computed rolling-daily mean for Wilder water quality monitoring stations.

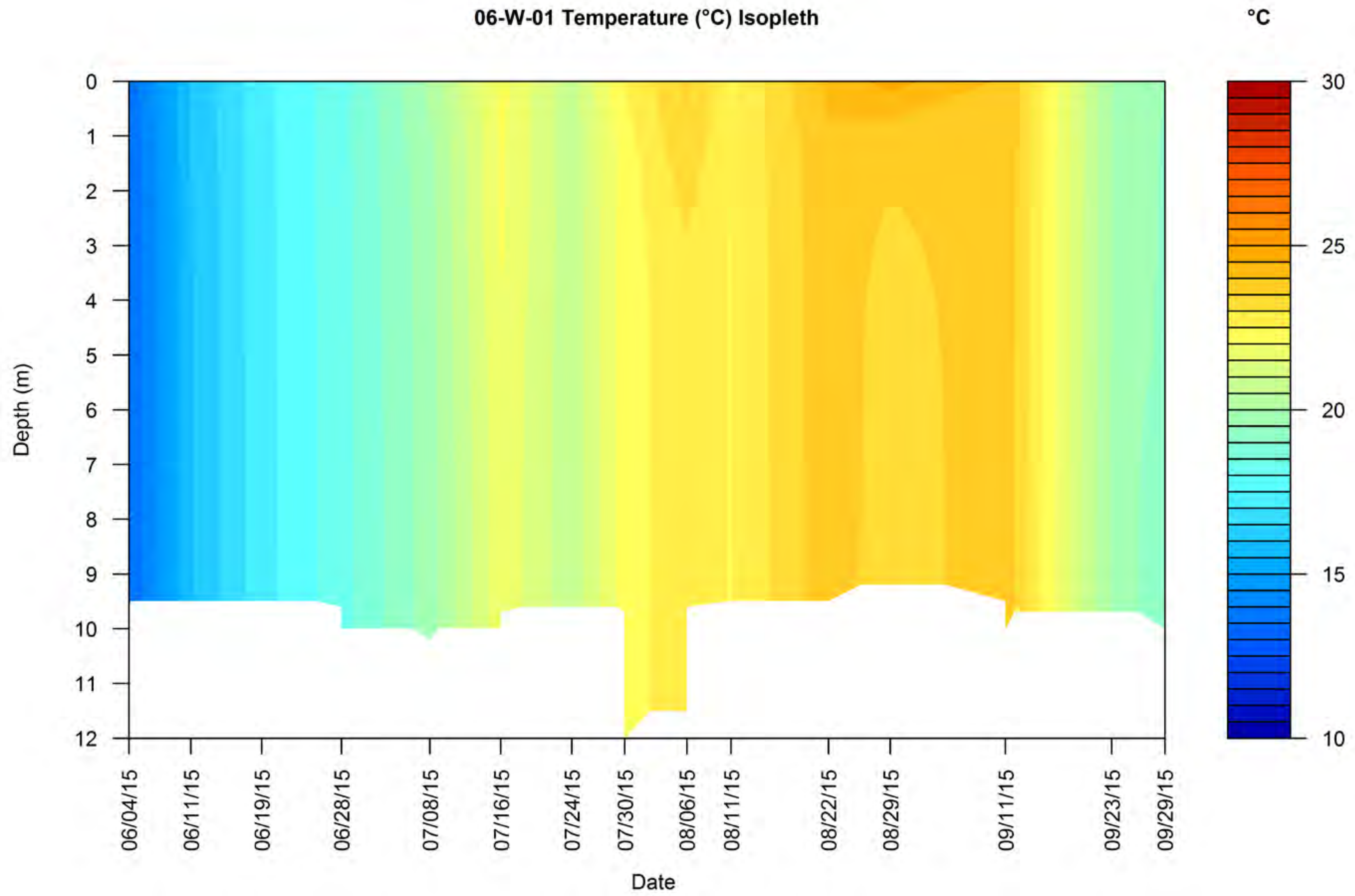

Figure 5.2.2-2. Wilder forebay (06-W-01) water quality monitoring station temperature isopleth. Tick marks indicate the dates when vertical profiles were collected.

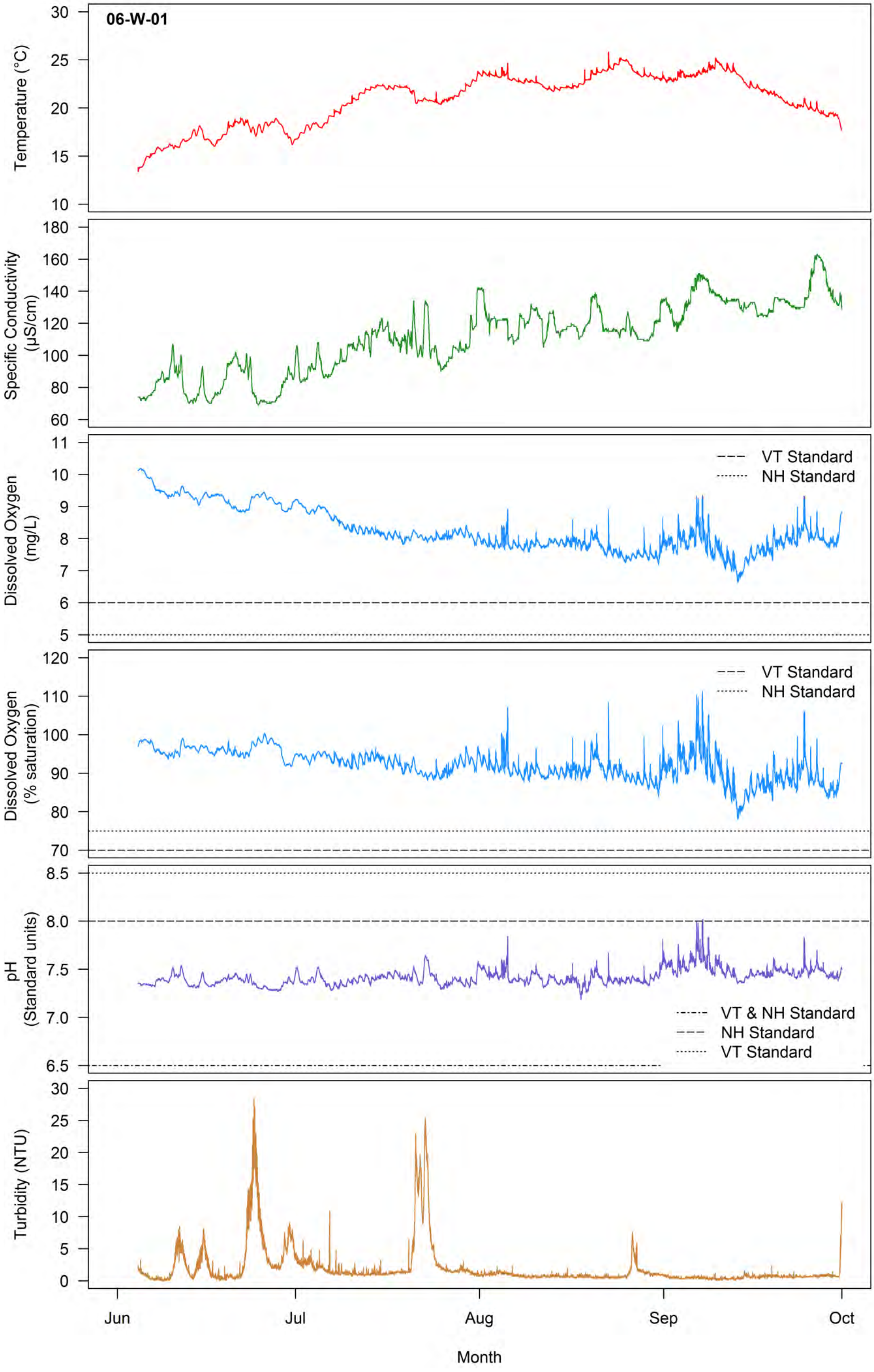

Figure 5.2.2-3. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Wilder forebay (06-W-01) water quality monitoring station.

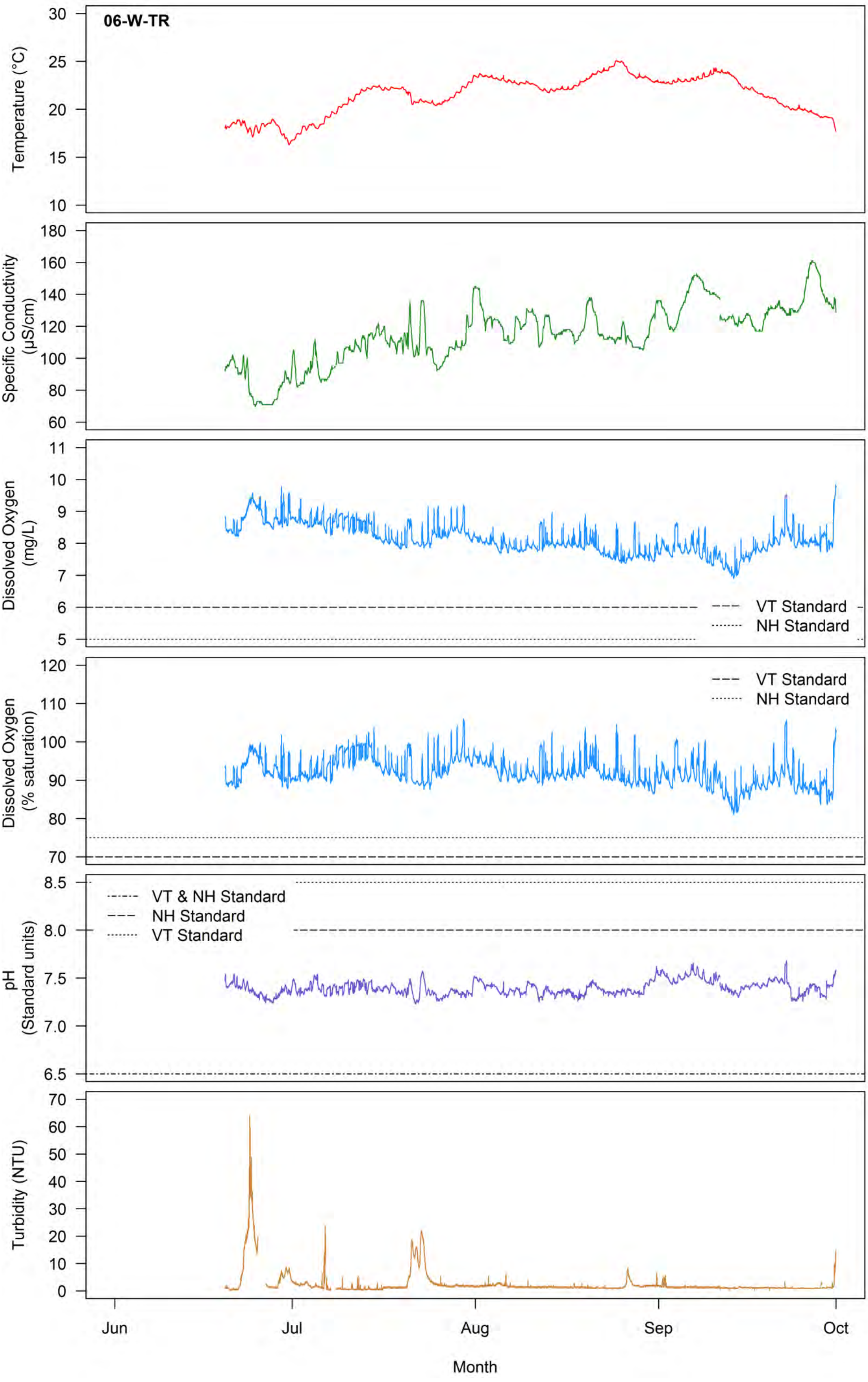

Figure 5.2.2-4. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Wilder tailrace (06-W-TR) water quality monitoring station.

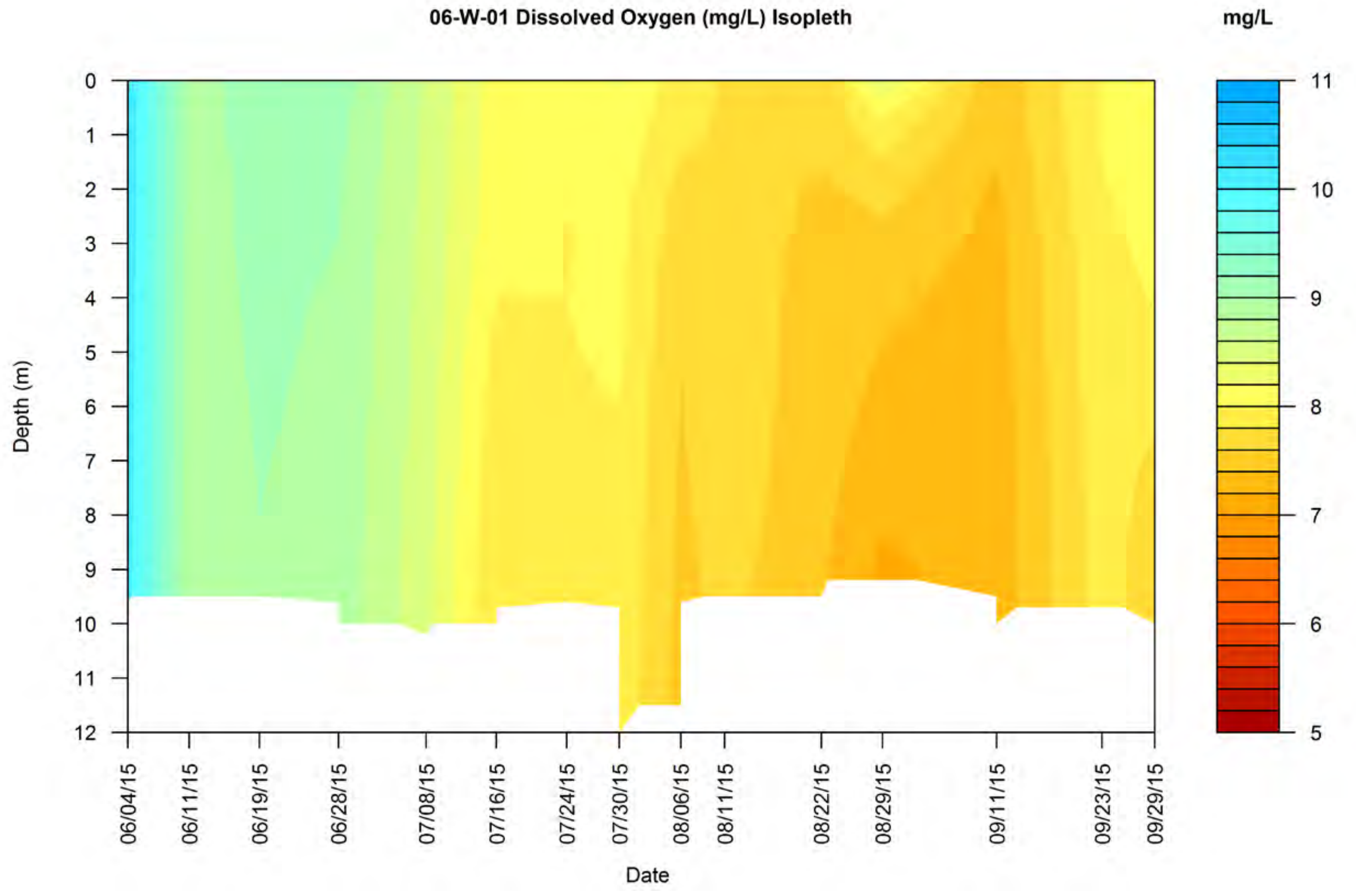

Figure 5.2.2-5. Wilder forebay (06-W-01) water quality monitoring station dissolved oxygen (mg/L) isopleth. Tick marks indicate the dates when vertical profiles were collected.

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5.2.3 Bellows Falls Project

Temperature

Figure 5.2.1-1 presents the temperature distribution of each Bellows Falls mainstem water quality monitoring station. The distribution of continuous water temperature data follows a general pattern of cooler waters flowing from the northern stations (06-BF-04 and 06-BF-03), which warm through the impoundment and are warmest as they flow out of Bellows Falls at the tailrace station (06-BF-TR). Table 5.2.3-1 summarizes monthly and overall water temperatures collected on a continuous basis at each Bellows Falls monitoring station over the study period. On average, water temperatures warmed by 1.1°C from the upstream station (06-BF-04) to the Bellows Falls forebay (06-BF-01). As water flowed from the Bellows Falls forebay through the powerhouse and was discharged at the Bellows Falls tailrace the mean overall water temperature difference was 0.3°C. Water flowing from the Bellows Falls impoundment through the Bellows Falls bypassed reach cooled on average by 0.3°C. The greatest amount of warming through the impoundment occurred during the month of August when mean monthly water temperatures ranged from 23.5°C (06-BF-04) to 24.4°C (06-BF-01), with the greatest amount of warming occurring between the Bellows Falls upper impoundment and middle impoundment stations. Furthermore, upstream and upper impoundment station water temperatures were generally cooler than the middle impoundment, forebay, bypassed reach, and tailrace stations with daily maximum temperatures being very similar or exceeding downstream stations (e.g., July 23 to July 29; Figure F-11 in Appendix F). Instances when upstream and upper impoundment stations were warmer than downstream stations also occurred during the study (e.g., October 20 to October 23; Figure F-14 in Appendix F) as well as when temperatures were similar throughout the Bellows Falls study area (e.g., October 6 to October 8; Figure F-14 in Appendix F).

Figure 5.2.3-1 illustrates the temporal trend of water temperatures at all Bellows Falls water quality monitoring stations, and Appendix F and Appendix O present mainstem continuous water temperature measured at each mainstem station along with inflow and project discharge, and impoundment water level fluctuations measured at the dam, respectively. The six stations followed a similar pattern of warming temperatures through spring, temperatures peaking during the summer, and cooling through the fall. Upon deployment of each logger, the water temperature began to increase rapidly until a large rain event in late May resulted in an overall decrease of approximately 5.0°C at all stations. Upstream (06-BF-04) and upper impoundment (06-BF-03) stations exhibited larger diel fluctuations in temperature than the middle impoundment (06-BF-02), forebay (06-BF-01), bypassed reach (06-BF-BR), or tailrace stations (06-BF-TR), likely a reflection of air temperature fluctuations and shallower depths facilitating greater atmospheric mixing of the water column.

A temperature isopleth of the Bellows Falls forebay station shows that temperatures throughout the water column were uniform through late July, and mild surface warming between the surface and 2-m depth interval occurred from late July through early September (Figure 5.2.3-2). The temperature difference between the surface and the 2-m depth interval during this period ranged from 0.2 to 0.9°C;

below the 2-m depth interval temperatures were uniform to a depth of 0.5 m above the bottom. The temperature difference between the surface and bottom during this time period ranged from 0.3°C (August 19) to 1.6°C (July 29). Appendix G presents a summary of each vertical profile for all stations as the average of the profile; Appendix H illustrates water temperature vertical profiles for each station. Water temperature vertical profiles collected at the upstream (06-BF-04), upper impoundment (06-BF-03), and tailrace (06-BF-TR) stations were well-mixed, whereas on July 29 at the middle impoundment station a strong thermal discontinuity of 3.4°C was present between the surface and the 1-m depth (see Figure H-45 in Appendix H). Summary statistics for water temperature vertical profile data are presented in Table 5.2.3-2.

The high temperature low-flow period monitoring occurred from August 30 through September 8, 2015. Table 5.2.3-3 presents summary statistics for each station and deployment depth stratum. Mean temperature at each deployment depth among deployment location (river left, mid channel, and river right) were similar. Locations where the depth was generally shallower than 4.5 m had a difference between surface and bottom temperatures of 0.3°C. Only when depths were 7.9 m or greater (06-BF-01 river right and mid-channel) were temperature differences observed between surface and bottom strata greater than or equal to 0.5°C. Appendix I provides the temperature time-series for all stations during the high temperature low-flow monitoring period.

Dissolved Oxygen

DO (mg/L; percent saturation) was continuously monitored in the Bellows Falls forebay (06-BF-01), bypassed reach (06-BF-BR), and tailrace station (06-BF-TR) from June through September, and at all mainstem Bellows Falls stations during the high temperature low-flow monitoring period from August 30 through September 8 (Appendix F). Table 5.2.3-4 presents monthly and overall summary statistics for water quality data continuously collected in the Bellows Falls forebay monitoring station (06-BF-01). DO concentrations within the Bellows Falls forebay (06-BF-01) ranged from 7.1 to 10.0 mg/L and percent saturation ranged from 84.3 to 115.4 percent. Minimum and maximum mean daily percent saturation values ranged from 86.5 to 108.5 percent, respectively. DO concentrations tended to decrease steadily through June until late July, and then remained relatively consistent from late July through mid-September when water temperatures within the forebay were highest (Figure 5.2.3-3). Mean monthly DO percent saturation values were similar over the study period, but larger fluctuations of percent DO saturation occurred from late July through mid-September when water temperatures were generally high (Table 5.2.3-4; Figure 5.2.3-3). The lowest DO concentration of 7.1 mg/L was measured in August while the lowest percent DO saturation was measured in September. Based on the continuous data collected within the Bellows Falls forebay, DO concentrations and percent saturation complied with VT and NH surface water quality standards over the deployment period.

DO concentrations and percent saturation levels within the Bellows Falls bypassed reach (06-BF-BR) demonstrated strong diel fluctuations over the deployment period except during periods of spill (Figure 5.2.3-4). DO concentrations generally decreased from initial deployment in June through mid-July, and remained at their lowest values until early September when concentrations began to increase. DO concentrations within the bypassed reach ranged from 8.0 to 10.3 mg/L with monthly mean concentrations between 8.4 mg/L (August) and 9.8 mg/L (June) (Table 5.2.3-5). DO percent saturation levels remained generally constant over the deployment period, ranging from 96.5 to 108.4 percent, with daily means ranging from 98.6 to 107.8 percent. Based on the continuous data collected within the Bellows Falls bypassed reach, DO concentrations and percent saturation levels complied at all times with VT and NH surface water quality standards.

DO concentrations and percent saturation levels continuously monitored within the Bellows Falls tailrace (06-BF-TR) followed a similar temporal pattern as was observed within the Bellows Falls forebay (06-BF-01), except that larger fluctuations of DO concentration and percent saturation values were prevalent from mid-July until the multiparameter sonde was removed and replaced with a continuous temperature logger at the end of September (Figure 5.2.3-5). DO concentrations within the Bellows Falls tailrace (06-BF-TR) ranged from 7.2 to 10.7 mg/L with the lowest values occurring in August; percent DO saturation ranged between 84.9 and 117.7 percent, with the lowest values occurring in September (Figure 5.2.3-5; Table 5.2.3-6). The minimum daily mean DO percent saturation observed in the Bellows Falls tailrace (06-BF-TR) was 87.9 percent. Continuous DO values collected within the Bellows Falls tailrace (06-BF-TR) complied with VT and NH surface water quality standards at all times.

Dissolved oxygen profiles were collected at each Bellows Falls mainstem water quality monitoring station, except the Bellows Falls bypassed reach. Figure 5.2.3-6 presents a DO isopleth of the Bellows Falls forebay station (06-BF-01). Overall, the water column of the Bellows Falls forebay area remained well-oxygenated. DO concentrations within the forebay area ranged from 7.1 to 10.0 mg/L and percent saturation ranged from 92.9 to 110.3 percent (Table 5.2.3-2). Surface warming from July through mid-September resulted in DO concentrations near the river bottom at the forebay station reaching their lowest recorded concentration (7.1 mg/L) in late August. DO concentrations and percent saturation levels within the Bellows Falls tailrace (06-BF-TR) ranged from 8.0 to 10.1 mg/L and percent saturation levels ranged from 92.9 to 110.3 percent. DO vertical profiles collected at the middle, upper and upstream stations indicate that DO concentrations were generally uniform and mixed throughout the water column, with mean concentrations and percent saturation values ranging from 8.9 to 9.1 mg/L, and 99.9 to 102.4 percent saturation, respectively (Table 5.2.3-2). Appendix H presents water quality profiles for each station.

During the high temperature low-flow monitoring period DO levels were continuously recorded from August 30 through September 8 at the Bellows Falls forebay (06-BF-01), middle impoundment (06-BF-02), upper impoundment (06-BF-03) and upstream (06-BF-04) water quality monitoring stations. Mean DO levels were higher at the upstream, upper, and middle impoundment stations than at the forebay station (Table 5.2.3-7). Mean DO concentrations at the upstream, upper, and middle impoundment stations ranged from 8.6 to 8.7 mg/L, and the mean daily percent DO saturation levels ranged from 97.3 to 108.7 percent. The mean DO concentration observed at the Bellows Falls forebay was 8.3 mg/L and the mean daily percent DO saturation ranged from 95.2 to 108.5 percent. Appendix E provides DO time-series for all stations during the high temperature low-flow monitoring period, which show well-defined diel fluctuations in DO levels at the upstream (06-BF-04), upper impoundment (06-BF-03), middle impoundment (06-BF-04), and little to no diel pattern of fluctuating DO levels at the forebay station (06-BF-01), respectively.

pH

pH was continuously monitored in the Bellows Falls forebay (06-BF-01), bypassed reach (06-BF-BR), and tailrace (06-BF-TR) from June through September, and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem Bellows Falls monitoring stations (Appendix F). pH levels (all values in (s.u) within the Bellows Falls forebay area ranged from 7.37 to 8.28 from June through September, with monthly mean pH levels ranging from 7.49 to 7.81 (Table 5.2.3-4). Instances when pH levels within the forebay area exceeded 8.0 were infrequent in July and August, but became more frequent in late September (Figure 5.2.3-3). Within the Bellows Falls bypassed reach pH levels ranged from 7.45 to 8.07 from June through September (Table 5.2.3-5). July was the only month when pH levels within the bypassed reach were greater than 8.0 (Figure 5.2.3-4). Mean monthly pH levels within the Bellows Falls tailrace increased from June through September (Table 5.2.3-6). In the tailrace, pH levels ranged from 7.19 in July to 8.10 in September. Only in September were pH levels observed to exceed 8.0 (Figure 5.2.3-5).

Vertical profiles indicate that mean pH levels were slightly higher at the upstream (7.78; 06-BF-04), upper impoundment (7.73; 06-BF-03), and middle impoundment (7.74; 06-BF-02) stations than at the forebay (7.60; 06-BF-01) or tailrace (7.66; 06-BF-TR) stations (Table 5.2.3-2). The maximum instantaneous pH measurement obtained were greater than 8.0 (the NH standard) but less than 8.5 (the VT standard) at the upstream, upper impoundment, and middle impoundment stations; pH levels never were observed to fall below 7.27. pH was not observed to be greater than 8.0 at either the forebay or tailrace areas in vertical profiles, and was uniform throughout the water column at all stations (Appendix H).

Mean pH levels measured during the 10-day period ranged from 7.75 at the forebay station (06-BF-01) to 8.05 at the middle impoundment station (06-BF-02) (Table 5.2.3-7). All four stations recorded pH levels greater than 8.0, but only the middle impoundment station recorded pH levels greater than 8.5 (8.56; Table 5.2.3-7). Appendix J presents the time-series of continuous pH readings collected during the 10-day high temperature low-flow monitoring period. At the upstream, upper, and middle impoundment stations strong diel fluctuations with the peaks of the fluctuation generally occurring during late afternoon; no strong or apparent diel pH trend was observed at the forebay station.

Specific Conductivity

Specific conductivity was continuously monitored in the Bellows Falls forebay (06-BF-01), bypassed reach (06-BF-BR) and tailrace (06-BF-TR) from June through September, and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem Bellows Falls monitoring stations (Appendix F). Specific conductivity at the Bellows Falls forebay station (06-BF-01) increased and decreased in June, increased through July, and plateaued from mid-July through September with some fluctuations (Figure 5.2.3-3). Over the 4-month deployment period monthly mean specific conductivity increased, and ranged from 78 to 176 µS/cm (Table 5.2.3-4). Specific conductivity within the Bellows Falls bypassed reach and tailrace exhibited a similar temporal pattern as was observed within the forebay (Figures 5.2.3-4 and 5.2.3-5). Monthly mean specific conductivity also increased in the bypassed reach, and minimum and maximum specific conductivity observed over the deployment period was 51 and 174 µS/cm, respectively (Table 5.2.3-5). Mean monthly specific conductivity within the tailrace also increased from June through September and ranged from 93 to 154 µS/cm (Table 5.2.3-6). The lowest specific conductivity observed in the tailrace occurred in June (77 µS/cm) while the greatest was observed in September (175 µS/cm) (Table 5.2.3-6).

Appendix H provides specific conductivity vertical profiles collected at all Bellows Falls water quality monitoring stations, except the Bellows Falls bypassed reach. Across all stations specific conductivity was uniform throughout the water column. Appendix G presents the time-series of each vertical profile by station as an average of the profile. The specific conductivity vertical profiles suggest that specific conductivity generally increased at each station over the duration of the vertical profile monitoring period. The average specific conductivity across stations ranged from 130 µS/cm at the forebay to 139 µS/cm at the upper impoundment station (Table 5.2.3-2).

Specific conductivity data collected during the high temperature low-flow period from August 30 through September 8 showed a diel pattern at the upstream (06-BF-04), upper impoundment (06-BF-03) and middle impoundment (06-BF-02) stations with peaks occurring midday and lows occurring early morning or late evening (Appendix J). During this period the mean specific conductivity ranged from 148 µS/cm at the forebay station (06-BF-01) to 154.7 µS/cm at the upper impoundment station (Table 5.2.3-7).

Turbidity

Turbidity was monitored on a continuous basis in the Bellows Falls forebay (06-BF-01), bypassed reach (06-BF-BR), and tailrace (06-BF-TR) from June through September, and at all Bellows Falls mainstem stations from August 30 to September 8 during the high temperature low flow monitoring period (Appendix F). Turbidity at the forebay (06-BF-01), bypassed reach (06-BF-BR), and tailrace (06-BF-TR) was generally very low except during high-flow and spill events resulting from precipitation (Figures 5.2.3-3, 5.2.3-4, 5.2.3-5; Appendix F). Among the three stations the highest recorded turbidity occurred during a high-flow and spill event in late June. At the forebay station (06-BF-01), turbidity levels ranged from 0.0 to 66.7 NTU with an overall median and mean of 1.5 and 2.5 NTU, respectively (Table 5.2.3-4). Within the bypassed reach (06-BF-BR) turbidity ranged from 0.0 to 82.3 NTU, but the overall median and mean levels were 2.0 and 3.7 NTU, respectively (Table 5.2.3-5). Turbidity in the tailrace (06-BF-TR) ranged from 0.0 to 46.0 NTU and had an overall median of 1.2 NTU and mean of 2.5 NTU (Table 5.2.3-6).

Turbidity was also collected as part of the vertical profile water quality monitoring at the upstream, impoundment, and tailrace stations. Appendix H presents each vertical profile for all stations. Turbidity levels for each profile were low and uniform throughout the water column, except for when sampling took place during or shortly after high-flow and precipitation events. Overall median and mean turbidity levels ranged from 0.5 to 0.9 NTU and 1.2 to 3.2 NTU, respectively (Table 5.2.3-2).

Continuous turbidity data collected during the high temperature low-flow monitoring period indicate that turbidity is generally low in upstream areas and through the Bellows Falls impoundment (Table 5.2.3-7;Appendix J). Median turbidity values recorded during the 10-day high temperature low-flow monitoring period ranged from 1.0 NTU (06-BF-04) to 0.7 NTU (06-BF-02), with a maximum of 9.9 NTU recorded at the upstream station (06-BF-04) (Table 5.2.3-7).

Overall, the continuous and vertical profile turbidity data collected at all mainstem Bellows Falls monitoring stations indicate that turbidity did not exceed the NH surface water quality standard of 10 NTU beyond upstream waters, and that under low-flow conditions turbidity within the Bellows Falls study area did not exceed the VT surface water quality standard for turbidity. Frequent and sporadic spikes in turbidity levels observed in the time series for all stations that did not follow inflows (e.g., 06-BF-TR July 2; Figure F-77 in Appendix F) were most likely due to debris and vegetation caught on and drifting in front of the turbidity optics, based on field observations.

Nutrients and Chlorophyll-a

Table 5.2.3-8 presents the results of nutrient and chlorophyll-*a* sampling and analyses. Total nitrogen concentrations ranged from below the instrument detection limit of 0.5 mg/L to 1.47 mg/L, with a mean of 0.49 mg/L. Total phosphorus concentrations ranged from 0.006 to 0.036 mg/L, with a mean of 0.014 mg/L. Collectively, the observed range and mean concentrations of TN and TP suggest the trophic state of Connecticut River at the Bellows Falls forebay station is oligotrophic to mesotrophic (Dodds et al., 1998; NHDES, 1997; VTDEC, 2000). Nitrate/nitrite concentrations ranged from 0.08 to 0.30 mg/L with a mean of 0.15 mg/L. Total Kjeldahl nitrogen concentrations ranged from below the instrument detection limit of 0.50 mg/L to 1.30 mg/L, with a mean of 0.44 mg/L. Chlorophyll-*a* concentrations ranged from below the instrument detection limit of 0.5 mg/m^3 to 6.8 mg/m^3, and general increased over the study period. Mean chlorophyll-*a* concentrations were 3.2 mg/m^3 suggesting that the trophic state of the Connecticut River at the Bellows Falls forebay monitoring station is oligotrophic (NHDES, 1997; VTDEC, 2000). Laboratory reports are included in Appendix K.

Table 5.2.3-1. Maximum, minimum, mean, and median monthly water temperatures for Bellows Falls water quality monitoring stations.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
06-BF-04									
Max	7.92	20.39	19.89	25.87	26.29	25.85	17.53	10.32	26.29
Min	6.71	7.32	12.48	16.63	21.25	17.58	8.22	5.80	5.80
Median	7.24	14.00	17.42	21.70	23.40	22.15	12.61	8.89	18.03
Mean	7.30	13.92	17.19	21.25	23.45	21.77	12.45	8.67	17.31
06-BF-03									
Max	8.00	20.36	19.84	25.67	26.25	25.82	17.82	10.61	26.25
Min	6.64	7.32	12.51	16.65	21.41	17.27	8.44	6.13	6.13
Median	7.19	14.09	17.51	21.84	23.57	22.25	12.80	8.99	18.15
Mean	7.23	14.00	17.24	21.35	23.62	21.81	12.49	8.73	17.49
06-BF-02									
Max	8.05	20.89	20.06	25.19	25.99	26.23	18.10	10.54	26.23
Min	6.86	7.59	12.75	16.70	22.32	17.99	8.62	6.08	6.08
Median	7.29	14.38	17.70	22.13	24.05	22.56	12.92	8.99	18.34
Mean	7.36	14.33	17.45	21.72	24.05	22.18	12.51	8.80	17.77
06-BF-01									
Max	–	21.25	20.45	25.99	26.08	25.71	18.49	10.44	26.08
Min	–	12.73	13.33	17.14	23.27	18.10	9.02	6.84	6.84
Median	–	15.72	18.05	22.54	24.33	22.51	13.67	9.11	18.92
Mean	–	16.03	17.77	22.02	24.43	22.46	12.80	9.09	18.44
06-BF-BR									
Max	–	21.20	20.48	25.15	25.72	25.32	18.49	10.78	25.72
Min	–	13.02	13.45	17.16	22.95	18.11	9.02	6.76	6.76
Median	–	16.15	18.20	22.73	24.31	21.47	13.55	9.09	18.76
Mean	–	16.59	17.87	22.28	24.36	21.52	12.79	9.11	18.15
06-BF-TR									
Max	–	21.25	20.51	25.24	25.69	25.34	18.41	10.47	25.69
Min	–	15.25	13.40	17.11	23.30	18.11	9.04	6.91	6.91
Median	–	17.15	18.08	22.49	24.35	22.48	13.71	9.16	19.32
Mean	–	17.88	17.80	22.04	24.44	22.46	12.84	9.14	18.75

"–"indicates high flows and spill conditions in April precluded data collection until May.

Table 5.2.3-2. Vertical profile summary statistics for Bellows Falls water quality monitoring stations.

Statistic	**06-BF-04**	**06-BF-03**	**06-BF-02**	**06-BF-01**	**06-BF-TR**
Mean Water Depth (m)[a]	2.1	3.1	3.2	11.0	4.9
Temperature (°C)					
Max	25.0	24.4	27.4	25.5	25.0
Min	15.2	15.1	14.8	14.7	17.4
Median	21.8	22.0	21.9	21.8	23.6
Mean	21.1	20.7	21.2	21.4	22.3
Dissolved Oxygen (mg/L)					
Max	10.4	10.1	10.1	10.0	10.1
Min	8.1	7.9	7.9	7.1	8.0
Median	9.1	9.0	8.9	8.3	9.1
Mean	9.1	9.0	8.9	8.4	9.0
Dissolved Oxygen (% saturation)					
Max	108.7	106.9	117.2	111.3	110.3
Min	93.3	92.3	91.2	85.1	92.9
Median	101.9	100.8	98.6	96.1	103.3
Mean	102.4	99.9	99.9	94.6	103.5
Specific Conductivity (µS/cm)					
Max	178	182	172	160	160
Min	85	58	62	87	92
Median	141	149	129	135	143
Mean	134	139	131	130	137
pH (s.u)					
Max	8.19	8.05	8.44	7.95	7.94
Min	7.41	7.47	7.40	7.35	7.27
Median	7.77	7.71	7.69	7.58	7.62
Mean	7.78	7.73	7.74	7.60	7.66
Turbidity (NTU)					
Max	13.1	17.7	24.9	14.1	13.8
Min	0.0	0.0	0.0	0.0	0.0
Median	0.9	0.7	0.5	0.7	0.8
Mean	3.2	3.2	2.5	1.6	1.2

a. Average of individual depths recorded during each station visit.

Table 5.2.3-3. Water temperatures of the Bellows Falls impoundment and upstream area during the high temperature low-flow monitoring period.

Deployment Depth	**Statistic**	**Temperature (°C)**		
		River Left	**Mid-channel**	**River Right**
06-BF-04				
Mid-depth	Max	25.7	25.5	26.3
	Min	22.4	22.4	21.8
	Mean	23.8	23.6	23.6
Depth to bottom (at first deployment, m)		0.8	1.3	0.6
06-BF-03				
Mid-depth	Max	25.6	26.0	25.6
	Min	22.5	22.7	22.8
	Mean	23.8	24.1	24.0
Depth to bottom (at first deployment, m)		2.1	0.8	2.9
06-BF-02				
1 m below surface	Max	26.4	25.5	26.1
	Min	23.3	23.4	23.4
	Mean	24.4	24.3	24.4
1 m above bottom	Max	25.2	25.0	25.2
	Min	23.3	23.3	23.3
	Mean	24.2	24.1	24.2
Depth to bottom (at first deployment, m)		3.1	3.3	4.0
06-BF-01				
1 m below surface	Max	26.5	26.2	26.8
	Min	25.9	23.9	24.1
	Mean	24.8	24.9	24.9
Mid-depth	Max	25.9	25.1	25.3
	Min	23.8	23.9	23.9
	Mean	24.6	24.4	24.9
1 m above bottom	Max	25.7	24.7	25.0
	Min	23.8	23.8	23.9
	Mean	24.5	24.3	24.4
Depth to bottom (at first deployment, m)		4.5	10.3	7.9

Table 5.2.3-4. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Bellows Falls forebay water quality monitoring station, 06-BF-01.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	20.45	25.99	26.08	25.71	26.08
Min	14.78	17.14	23.27	18.10	14.78
Median	18.19	22.54	24.33	22.51	22.74
Mean	18.16	22.02	24.43	22.46	21.93
Specific Conductivity (µS/cm)					
Max	119	158	169	176	176
Min	78	95	122	137	78
Median	94	129	146	157	141
Mean	95	127	146	157	133
Dissolved Oxygen (mg/L)					
Max	9.9	9.5	9.3	10.0	10.0
Min	8.7	7.4	7.1	7.2	7.1
Median	9.2	8.6	7.9	8.4	8.5
Mean	9.3	8.5	7.9	8.5	8.5
Dissolved Oxygen (% saturation)					
Max	103.0	115.2	111.7	115.4	115.4
Min	94.4	84.6	85.9	84.3	84.3
Median	98.0	97.8	94.6	98.4	97.5
Mean	98.1	97.1	95.0	97.7	96.9
Max Daily Mean	101.3	104.3	101.7	108.5	108.5
Min Daily Mean	95.6	86.7	91.2	86.5	86.5
pH (s.u)					
Max	7.66	8.12	8.08	8.28	8.28
Min	7.38	7.37	7.51	7.55	7.37
Median	7.48	7.60	7.71	7.78	7.66
Mean	7.49	7.62	7.71	7.81	7.67
Turbidity (NTU)					
Max	66.7	9.5	2.4	13.4	66.7
Min	0.0	1.0	0.8	0.9	0.0
Median	1.7	1.8	1.2	1.5	1.5
Mean	4.9	2.6	1.2	1.6	2.5

Table 5.2.3-5. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Bellows Falls bypassed reach water quality monitoring station, 06-BF-BR.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	20.48	25.15	25.72	25.32	25.72
Min	16.93	17.16	22.95	18.11	16.93
Median	18.86	22.73	24.31	21.47	22.93
Mean	18.76	22.28	24.36	21.52	22.27
Specific Conductivity (µS/cm)					
Max	118	154	170	174	174
Min	51	89	121	146	51
Median	97	130	148	157	143
Mean	94	128	147	159	137
Dissolved Oxygen (mg/L)					
Max	10.3	10.2	8.9	10.0	10.3
Min	8.9	8.1	8.0	8.0	8.0
Median	9.8	8.8	8.4	8.9	8.7
Mean	9.8	8.9	8.4	8.9	8.9
Dissolved Oxygen (% saturation)					
Max	108.4	107.9	105.9	108.1	108.4
Min	98.0	97.2	96.5	96.5	96.5
Median	106.0	101.9	99.5	100.1	101.0
Mean	104.7	102.0	100.4	100.8	101.5
Max Daily Mean	107.8	107.0	101.6	103.4	107.8
Min Daily Mean	100.4	100.0	99.0	98.6	98.6
pH (s.u)					
Max	7.90	8.07	7.96	7.98	8.07
Min	7.45	7.55	7.51	7.50	7.45
Median	7.60	7.79	7.73	7.71	7.73
Mean	7.63	7.80	7.74	7.72	7.74
Turbidity (NTU)					
Max	82.3	18.7	8.0	19.8	82.3
Min	0.5	0.0	1.4	0.3	0.0
Median	8.2	2.1	1.8	2.0	2.0
Mean	12.5	2.9	1.8	2.1	3.7

Table 5.2.3-6. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Bellows Falls tailrace water quality monitoring station, 06-BF-TR.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	20.51	25.24	25.69	25.34	25.69
Min	16.89	17.11	23.30	18.11	16.89
Median	18.57	22.49	24.35	22.48	23.03
Mean	18.57	22.04	24.44	22.46	22.17
Specific Conductivity (µS/cm)					
Max	117	155	168	175	175
Min	77	96	121	135	77
Median	92	127	146	154	140
Mean	93	126	147	154	133
Dissolved Oxygen (mg/L)					
Max	10.0	10.7	9.6	10.7	10.7
Min	9.0	7.6	7.3	7.2	7.2
Median	9.5	9.2	8.7	9.1	9.1
Mean	9.5	9.0	8.6	9.1	9.0
Dissolved Oxygen (% saturation)					
Max	106.9	114.4	144.9	117.7	117.7
Min	95.5	87.4	87.1	84.9	84.9
Median	101.0	102.3	104.3	107.5	103.1
Mean	101.1	102.7	102.9	104.3	102.9
Max Daily Mean	104.8	109.9	111.7	113.2	113.2
Min Daily Mean	97.2	92.2	93.4	87.9	87.9
pH (s.u)					
Max	7.65	7.95	7.90	8.10	8.10
Min	7.46	7.19	7.42	7.60	7.19
Median	7.54	7.61	7.63	7.79	7.65
Mean	7.54	7.59	7.65	7.80	7.67
Turbidity (NTU)					
Max	42.6	34.9	21.0	22.8	42.6
Min	0.0	0.0	0.0	0.1	0.0
Median	3.3	1.7	0.9	0.9	1.2
Mean	6.1	2.7	1.1	1.2	2.5

Table 5.2.3-7. Summary statistics of temperature, specific conductivity, dissolved oxygen, pH and turbidity for Bellows Falls impoundment and upstream water quality monitoring stations during the high temperature low-flow monitoring period.

Statistic	**Station**			
	06-BF-04	**06-BF-03**	**06-BF-02**	**06-BF-01**
Temperature (°C)				
Max	25.5	25.5	25.9	25.7
Min	22.4	22.6	23.3	23.8
Median	23.4	23.7	24.3	24.5
Mean	23.6	23.8	24.2	24.5
Specific Conductivity (µS/cm)				
Max	185	182	173	160
Min	121	127	133	135
Median	153	152	151	148
Mean	152.8	154.7	152.5	148
Dissolved Oxygen (mg/L)				
Max	10.0	9.9	10.0	9.5
Min	7.8	7.9	8.0	7.6
Median	8.5	8.6	8.6	8.2
Mean	8.6	8.7	8.6	8.3
Dissolved Oxygen (% saturation)				
Max	121.5	121.1	121.9	115.4
Min	89.7	91.1	94.7	91.0
Median	100.4	101.1	101.8	98.5
Mean	101.4	102.6	103.2	99.3
Max Daily Mean	104.1	106.1	108.7	108.5
Min Daily Mean	97.3	100.1	99.4	95.2
pH (s.u)				
Max	8.42	8.30	8.56	8.28
Min	7.57	7.52	7.86	7.55
Median	7.88	7.76	8.02	7.72
Mean	7.91	7.79	8.05	7.75
Turbidity (NTU)				
Max	9.9	3.3	3.2	2.1
Min	0.2	0.6	0.5	1.1
Median	1.0	1.0	0.7	1.5
Mean	1.2	1.2	0.8	1.5

Table 5.2.3-8. Nutrients and chlorophyll-*a* data and summary statistics for the Bellows Falls forebay water quality monitoring station, 06-BF-01.

Date	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**Nitrate/Nitrite** (mg/L)	**Total Kjeldahl Nitrogen** (mg/L)	**Chlorophyll-*a*** (mg/m^3)
6/5/2015	<0.50	0.011	0.14	<0.50	0.7
6/10/2015	1.47	0.012	0.17	1.30	1.4
6/18/2015	<0.50	0.012	0.1	<0.50	2.2
6/29/2015	<0.50	0.036	0.13	<0.50	1.5
7/7/2015	0.73	0.014	0.13	0.60	<0.5
7/15/2015	<0.50	0.009	0.30	<0.50	2.9
7/23/2015	<0.50	0.019	0.14	<0.50	3.6
7/29/2015	<0.50	0.009	0.13	<0.50	4.6
8/5/2015	0.63	0.006	0.13	0.50	3.9
8/12/2015	<0.50	0.012	0.16	<0.50	3.2
8/19/2015	0.69	0.009	0.19	0.50	4.2
8/28/2015	<0.50	0.012	0.17	<0.50	3.1
9/9/2015	0.8	0.024	0.12	0.70	6.8
9/22/2015	<0.50	0.009	0.11	<0.50	4.3
9/28/2015	0.78	0.009	0.08	0.70	5.0
Max	1.47	0.036	0.30	1.30	6.8
Min	<0.50	0.006	0.08	<0.50	<0.50
Median[a]	<0.50	0.012	0.13	<0.50	3.2
Mean[a]	0.49	0.014	0.15	0.44	3.2

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for mean calculations for the associated analyte.

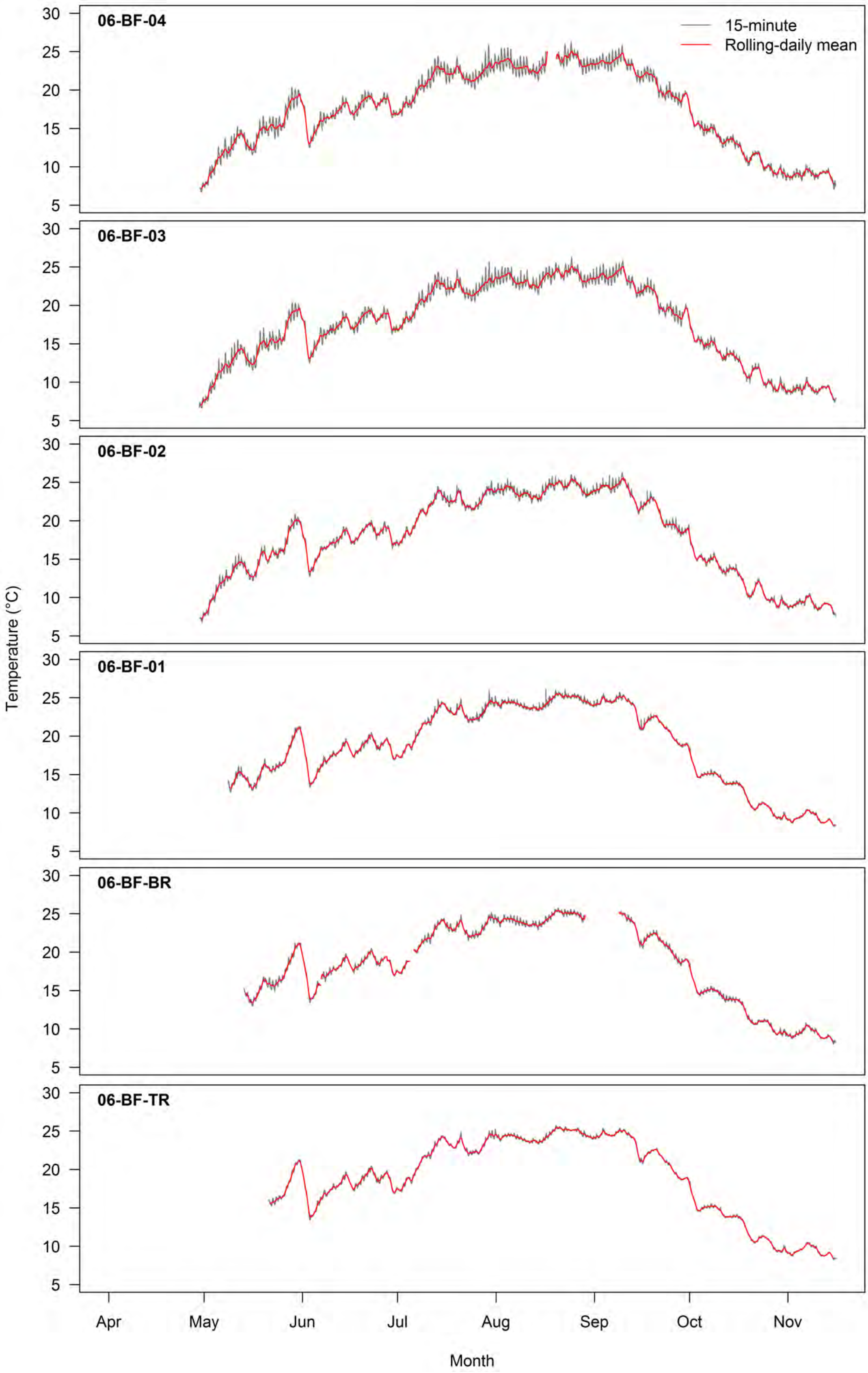

Figure 5.2.3-1. Continuous water temperature collected at 15-minute intervals and computed rolling-daily mean for Bellows Falls water quality monitoring stations. Data when temperature loggers for 06-BF-04 and 06-BF-BR were out of water are omitted.

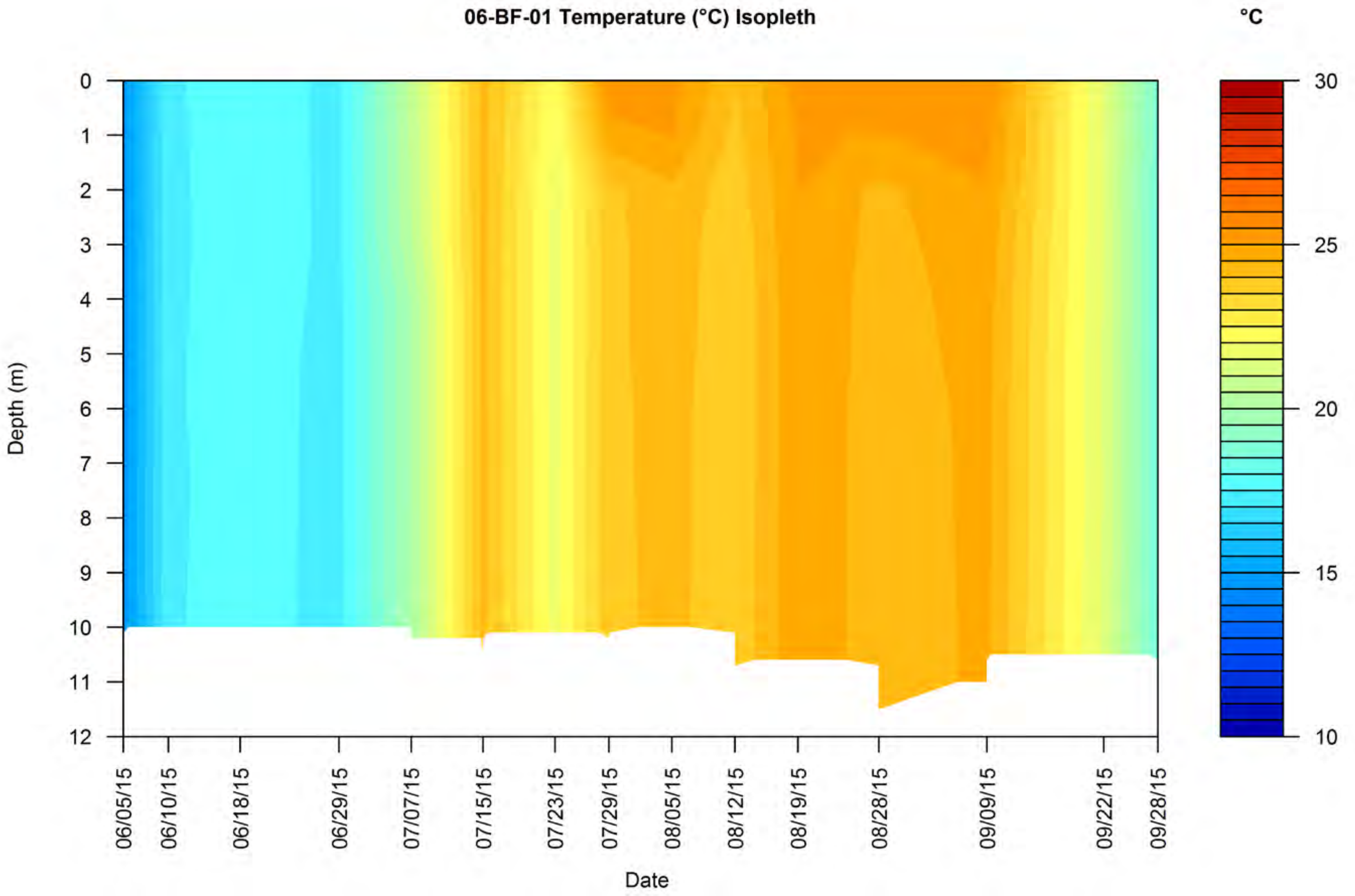

Figure 5.2.3-2. Bellows Falls forebay (06-BF-01) water quality monitoring station temperature (°C) isopleth. Tick marks indicate the dates when vertical profiles were collected.

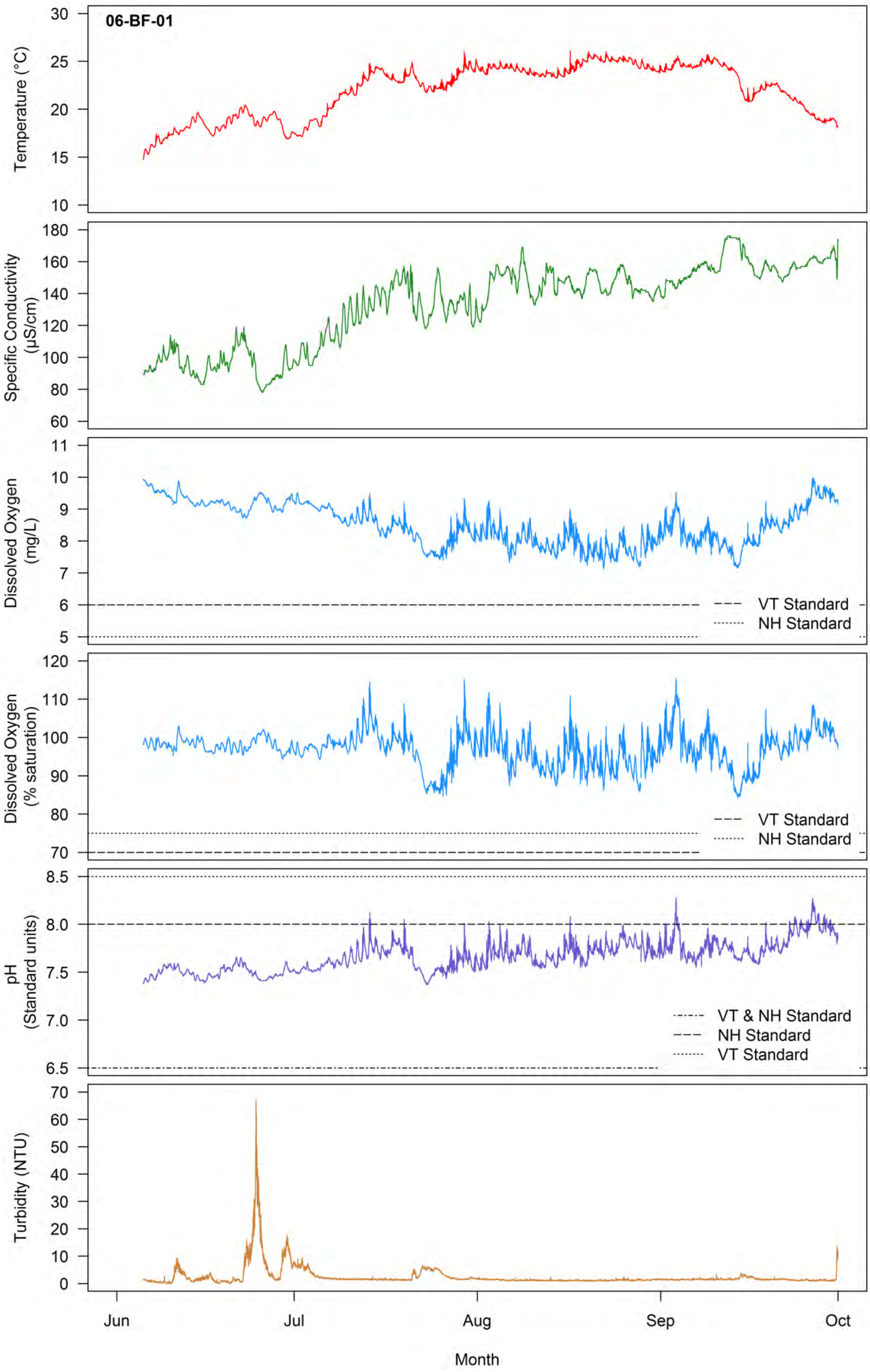

Figure 5.2.3-3. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Bellows Falls forebay (06-BF-01) water quality monitoring station.

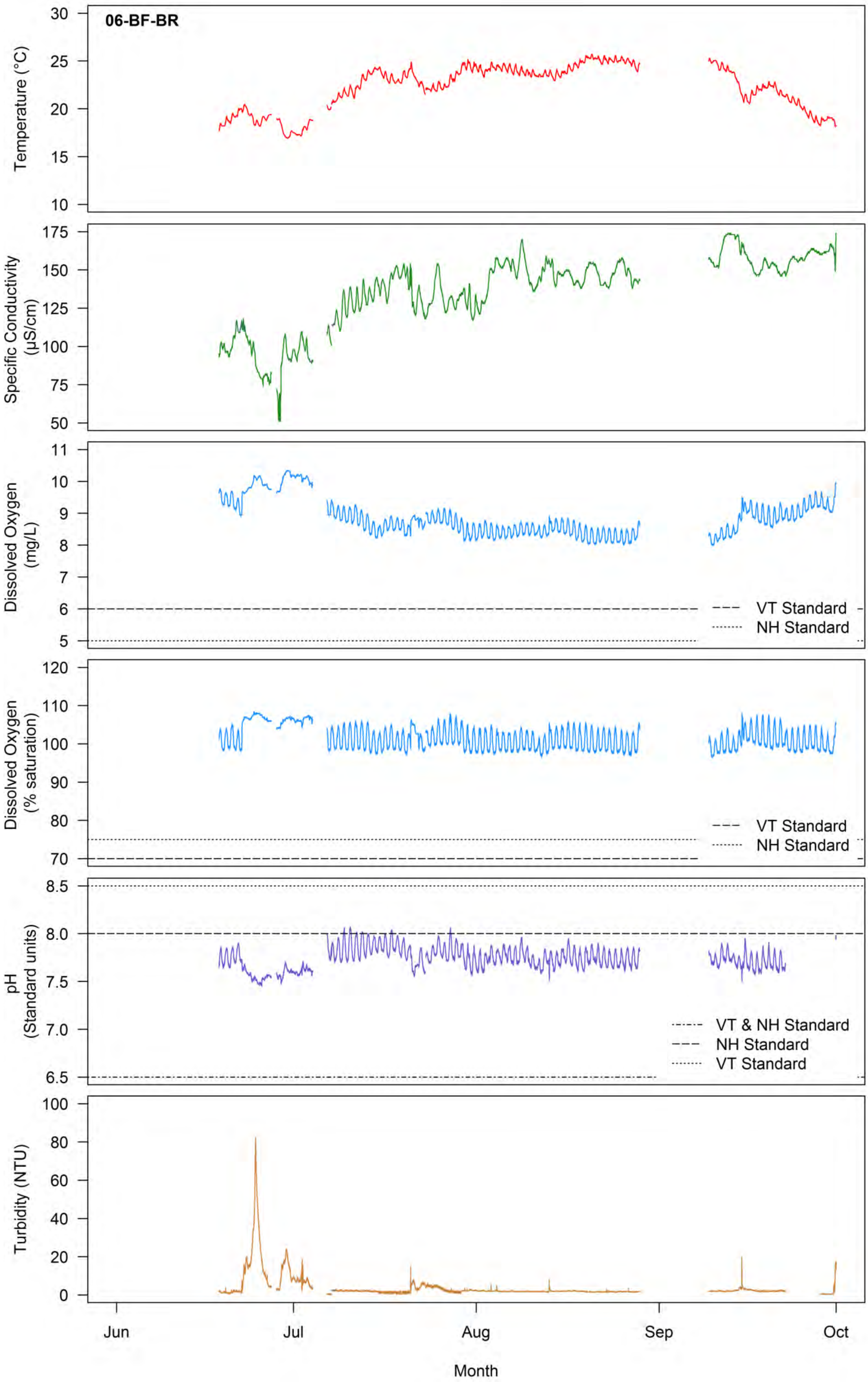

Figure 5.2.3-4. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Bellows Falls bypassed reach (06-BF-BR) water quality monitoring station.

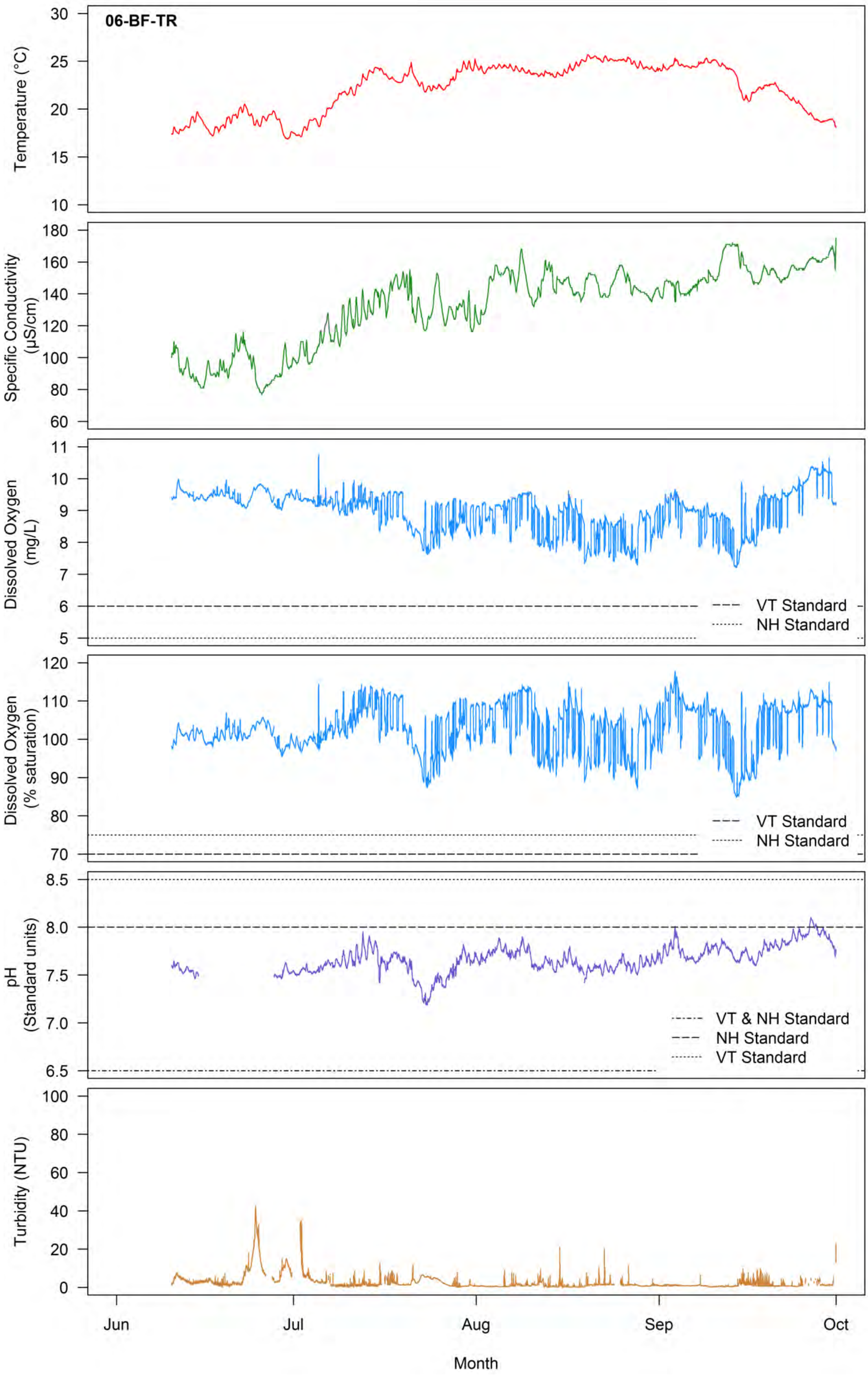

Figure 5.2.3-5. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Bellows Falls tailrace (06-BF-TR) water quality monitoring station.

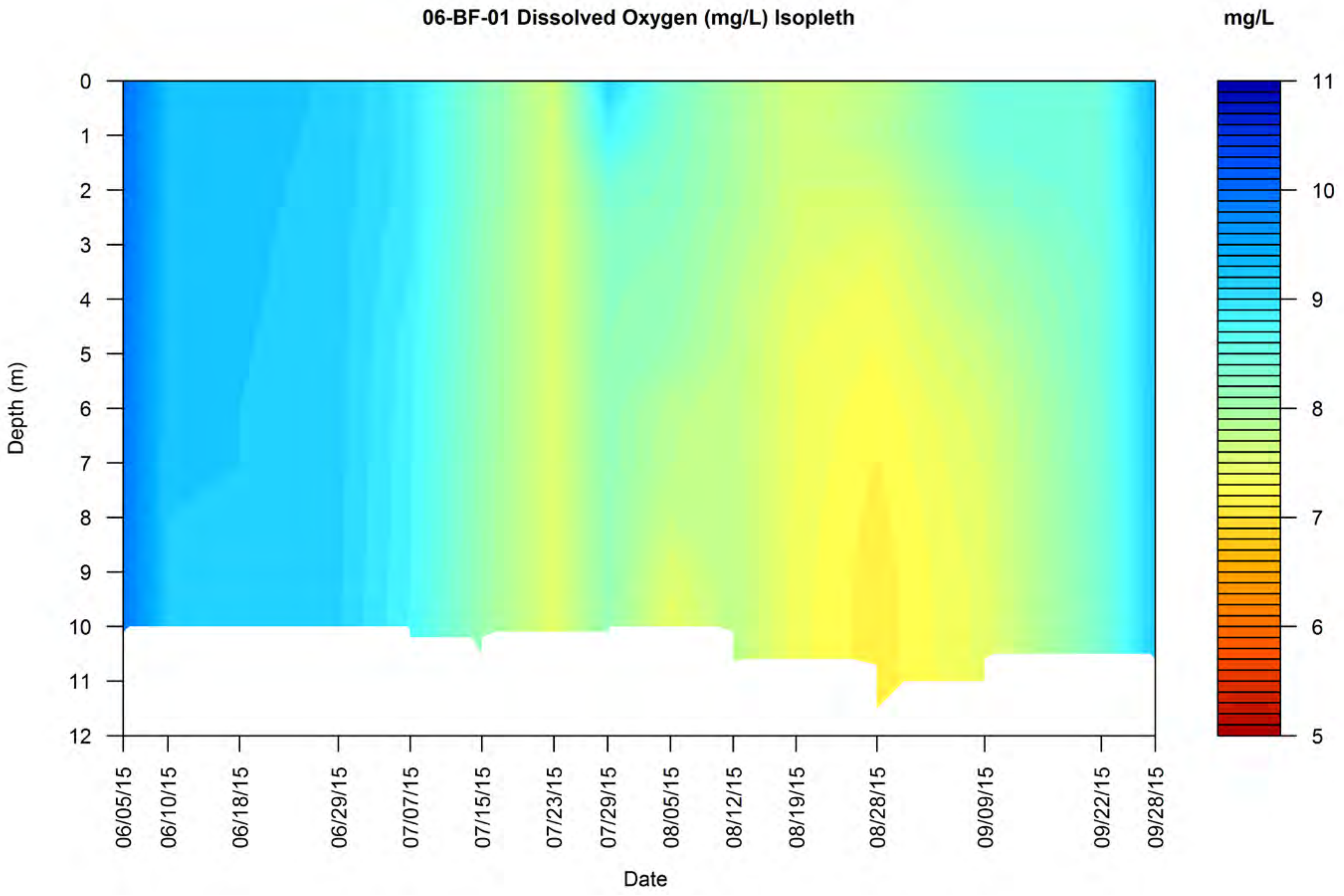

Figure 5.2.3-6. Bellows Falls forebay (06-BF-01) water quality monitoring station dissolved oxygen (mg/L) isopleth. Tick marks indicate the dates when vertical profiles were collected.

5.2.4 Vernon Project

Temperature

Figure 5.2.1-1 shows the water temperature distribution of each Vernon mainstem water quality monitoring station. The distribution of the continuous water temperature data generally shows that water warms as it flows from upstream areas and through the Vernon impoundment, and some cooling occurs as waters are discharged into the Vernon tailrace. On average, water temperatures warmed by 0.9°C from the upstream station (06-V-04) to the Vernon forebay station (06-V-01). Mean overall water temperatures were 0.1°C cooler in the tailrace than in the forebay. This effect is likely due to the deployment depth of the forebay instruments measuring slightly warmer waters near the surface than those near the intake structures. In addition, the month of May was warm and dry. During May mean temperatures were 0.6°C warmer in the forebay than those in the tailrace whereas mean monthly temperatures for the remainder of the study indicate very slight warming (0.01 to 0.07°C) occurred between the forebay and tailrace (Table 5.2.4-1). On average the warmest water temperatures were observed during the month of August (24.5 to 24.9°C). In addition, upstream and upper impoundment station water temperatures were generally cooler than middle impoundment, forebay, and tailrace stations (e.g., May 12 to May 17; Figure F-17 in Appendix F), but also were similar to stations downstream (e.g., May 26 to May 28; Figure F-17 in Appendix F) with daily maximum temperatures being similar or exceeding downstream station temperatures.

Figure 5.2.4-1 illustrates the temporal trend of water temperatures of all mainstem Vernon water quality monitoring stations, and Appendix F and Appendix O present mainstem continuous water temperature measured at each mainstem station along with inflow and project discharge, and water level fluctuations measured at the dam, respectively. All five stations followed a similar warming and cooling pattern. After deployment of the continuous water temperature loggers, water temperatures were observed to steadily increase through May, but a rain event resulted in an approximately 5°C decrease in water temperature in early June. Water temperatures reached their maximum in mid-August to early September, and gradually decreased until the end of the study period. Upstream (06-V-04) and upper impoundment (06-V03) monitoring stations exhibited well-defined diel fluctuations in temperature compared to the middle impoundment (06-V-02), forebay (06-V-01), or tailrace stations (06-V-TR), which is likely a reflection of air temperature fluctuations and shallower depths facilitating greater atmospheric mixing of the water column.

Figure 5.2.4-2 is a water temperature isopleth of the Vernon forebay station (06-V-01) water temperature vertical profiles. Water temperatures within the forebay were uniform and well-mixed from June through late July, and warmer temperatures were observed near the surface until mid-September when temperatures throughout the water column were uniform through the remainder of the vertical profile monitoring period. Differences between surface and bottom water temperatures from late July through August ranged from 0.8 to 1.6°C, with the zone of greatest thermal discontinuity occurring between the surface and the 2-m depth interval where temperatures decreased from 0.2 to 0.9°C. Appendix G presents a summary of each vertical profile for all stations as the average of the profile; Appendix H presents water temperature vertical profiles for each station. Water temperature vertical profiles for the middle impoundment station were generally uniform but surface warming from July through August temperatures resulted in temperature differences between the surface and the 2-m depth interval to range between 0.4 and 0.8°C; the upper impoundment and upstream stations were well-mixed over the duration of vertical profile monitoring (Appendix H). Summary statistics for water temperature vertical profile data are presented in Table 5.2.4-2.

Table 5.2.4-3 presents summary statistics for each station and deployment depth stratum, and Appendix I provides the temperature time-series for all stations during the high temperature low-flow monitoring period. Overall, mean water temperatures ranged from 24.5 to 25.5°C. At the upstream (06-V-04) and upper impoundment stations (06-V-03) mean water temperatures were similar among locations (river left, mid-channel, river right) and deployment depths. Temperatures recorded 1 m above bottom and at mid-depth were similar among locations at the middle impoundment station (06-V-02), but surface temperatures showed warming during the afternoon resulting in maximum temperatures of approximately 1°C greater than the maximum temperatures recorded at mid-depth. At the Vernon forebay (06-V-01) similar temperatures were recorded across locations but not deployment depths. Temperatures were similar at 1 m above bottom and mid-depth stratum and locations, but surface temperatures experienced warming of approximately 2.0°C greater than mid-depth instruments across locations.

Dissolved Oxygen

DO (mg/L; percent saturation) was continuously monitored in the Vernon forebay (06-V-01) and tailrace station (06-V-TR) from June through September, and at all mainstem Vernon stations during the high temperature low-flow monitoring period from August 30 through September 8 (Appendix F). Dissolved oxygen concentrations measured continuously at the Vernon forebay ranged from 6.9 to 10.0 mg/L and percent saturation levels ranged from 82.0 to 119.0 percent (Table 5.2.4-4). Maximum and minimum mean daily percent saturation levels ranged from 85.8 to 108.7 percent (Table 5.2.4-4). DO levels initially were at their highest levels in June then gradually decreased to their lowest levels at the beginning of September (Figure 5.2.4-3). DO concentration and percent saturation never fell below VT and NH surface water quality standards.

Dissolved oxygen concentrations and percent saturation levels measured on a continuous basis in the Vernon tailrace (06-V-TR) ranged from 7.3 to 10.1 mg/L and 86.0 to 111.2 percent, respectively (Table 5.2.4-5). Similar to DO levels observed in the Vernon forebay, DO levels in the tailrace gradually decreased to late July and remained at their lowest levels until water temperatures began to cool in early September (Figure 5.2.4-4). Maximum and minimum mean daily percent saturation levels ranged from 89.3 to 108.5 percent (Table 5.2.4-5). DO concentration and percent saturation never fell below VT and NH surface water quality standards.

Appendix G presents a summary of each vertical profile for all stations as the average of the profile. The average of each profile for each station indicate that the DO generally decreased through the study period until water temperatures began to cool in early September. The highest DO levels from vertical profiles were at the upper impoundment station (10.3 mg/L, 113.7% saturation; 06-V-04), and the lowest were within the Vernon forebay (7.1 mg/L, 84.9% saturation; 06-V-01) (Table 5.2.4-2). On average, upstream of the Vernon impoundment DO was lower than the upper impoundment area. From the upper impoundment area mean DO levels decreased toward the Vernon forebay, but increased in the Vernon tailrace (Table 5.2.4-2). Figure 5.2.4-5 presents an isopleth of DO concentrations within the Vernon forebay and shows that DO concentrations were generally uniform throughout the water column, but decreased over the summer. A high-flow event at the end of September mixed and re-oxygenated the entire water column. Dissolved oxygen vertical profiles at the upstream (06-V-04), upper impoundment (06-V-03), middle impoundment (06-V-02), and tailrace (06-V-01) were generally uniform with some gradual decreases with depth (Appendix H).

During the high temperature low-flow monitoring period DO levels were continuously recorded from August 30 through September 8 at all Vernon stations. Mean DO levels were higher at the upstream and upper impoundment stations than at the middle and forebay stations (Table 5.2.4-6). Mean DO concentrations at the upstream and upper impoundment stations were 8.7 and 8.4 mg/L, respectively. The minimum daily mean of DO percent saturation ranged from 98.9 percent (06-V-04) to 95.2 percent (06-V-03). Mean DO levels at the middle impoundment and forebay stations were slightly lower, ranging from 8.1 mg/L (06-V-02) to 7.8 mg/L (06-V-01). The minimum daily mean DO percent saturation levels were 95.0 percent at the middle impoundment station (06-V-02) and 90.5 percent at the forebay station (06-V-01). Appendix J provides DO time-series for all stations during the high temperature low-flow monitoring period, which show well-defined diel fluctuations in DO levels at the upstream (06-V-04) and upper impoundment (06-V-03) stations, and little to no diel pattern of fluctuating DO levels at the middle impoundment (06-V-02) and forebay (06-V-01) stations, respectively. Where diel fluctuations of DO were prevalent, DO levels peaked during midday and were lowest during the night or in the early morning.

pH

pH was continuously monitored in the Vernon forebay (06-V-01) and Vernon tailrace (06-V-TR) from June through September, and all other Vernon mainstem stations during the high temperature low-flow monitoring period from August 30 through September 8 (Appendix F). At the Vernon forebay (06-V-01) and tailrace stations (06-V-TR), pH levels (all values in s.u) were generally similar and ranged from 7.28 to 8.05 from June through September, with an overall mean of 7.54 (Table 5.2.4-4). In July, the highest pH value of 8.05 was recorded in the Vernon forebay (06-V-01) (Table 5.2.4-4; Figure 5.2.4-3). pH, as recorded by the continuous sonde deployed in the Vernon forebay (06-V-01), did not fall below VT or NH standards, nor exceed VT surface water quality standards (Figure 5.2.4-3). pH levels in the Vernon tailrace were generally very consistent with minor fluctuations, and did not rise above or fall below VT or NH surface water quality standards (Figure 5.2.4-4). pH ranged from 7.36 to 7.86, with an overall mean of 7.55 (Table 5.2.4-5).

The vertical profiles showed that pH was uniform through the water column at all Vernon water quality monitoring stations (Appendix H). pH was observed to be above the NH surface water quality standard during the collection of one vertical profile at the upstream station (06-V-04). Collection of that profile occurred on September 24, which had a maximum pH of 8.06 s.u.. The overall mean pH for each station ranged from 7.51 (06-V-01) to 7.65 (06-V-04), indicating a slight decrease in pH as waters flowed from the upstream area to the Vernon dam (Table 5.2.4-2). Mean pH levels were observed to be fairly consistent at each Vernon station over the duration of vertical profile monitoring (Appendix G).

The collection of continuous pH occurred during the high temperature low-flow monitoring period from August 30 through September 8 at the forebay (06-V-01), middle impoundment (06-V-02), upper impoundment (06-V-03) and upstream stations (06-V-04). Mean pH during the high temperature low-flow period was greatest at the upstream (7.73; 06-V-04) and upper impoundment stations (7.76; 06-V-3). Mean pH at the middle impoundment and forebay stations were 7.62 and 7.57, respectively (Table 5.2.4-6). Over the duration of the 10-day monitoring period pH never fell below 7.38, which was recorded at the Vernon forebay station (06-V-01). Appendix J provides pH time-series for all stations during the high temperature low-flow monitoring period, which show well-defined diel fluctuations in pH levels at the upstream (06-V-04) and upper impoundment (06-V-03) stations, and little to no diel pattern of fluctuating pH levels at the middle impoundment (06-V-02) and forebay stations (06-V-01), respectively. During midday on September 2, pH at the upper impoundment station exceeded 8.0 by 0.01 s.u., and during midday on September 3 pH at the upstream station exceeded 8.0 by 0.03 s.u. (Table 5.2.4-6;Appendix H).

Specific Conductivity

Specific conductivity was continuously monitored in the Vernon forebay (06-V-01), and tailrace (06-BF-TR) from June through September, and from August 30 through September 8 during the high temperature low-flow monitoring period at all mainstem Vernon monitoring stations (Appendix F). Specific conductivity levels within the forebay generally increased over the monitoring period with monthly means ranging from 96 µS/cm in June to 152 µS/cm in September (Figure 5.2.4-3; Table 5.2.4-4). Specific conductivity monitored within the Vernon tailrace shows a similar increasing trend, with monthly means ranging from 91 µS/cm in June to 154 µS/cm in September (Table 5.2.4-5).

Appendix H provides specific conductivity vertical profiles collected at all Vernon water quality monitoring stations and Appendix B provides an average of each vertical profile collected at each water quality monitoring station. Across all stations specific conductivity was uniform throughout the water column and increased over the deployment period. Mean specific conductivity was similar from the upstream area and within the impoundment, ranging from 126 to 127 µS/cm (Table 5.2.4-2). The mean specific conductivity was also slightly higher in the tailrace than the forebay station (Table 5.2.4-2).

Specific conductivity data collected during the high temperature low-flow period showed slight increases over the 10-day period at the upper impoundment and upstream stations, but no temporal pattern at the middle impoundment or forebay stations (Appendix J). Diel fluctuations of specific conductivity were also absent. During this period mean specific conductivity ranged from 146 µS/cm at the forebay station to 166 µS/cm at the upstream station, but no upstream to downstream trend was apparent (Table 5.2.4-6).

Turbidity

Turbidity was monitored on a continuous basis from June through September at the Vernon forebay (06-V-01) and tailrace (06-V-TR) stations, and at all Vernon mainstem stations from August 30 to September 8 during the high temperature low-flow monitoring period (Appendix F). The turbidity at both stations was generally very low with spikes occurring in response to high flows influenced by precipitation events (Figures 5.2.4-3 and 5.2-4-4; Appendix F). Turbidity at the forebay station (06-V-01) ranged from 0.0 to 32 NTU with an overall median and mean of 1.4 and 2.1 NTU, respectively (Table 5.2.4-4). Turbidity in the tailrace station (06-V-TR) ranged from 0.0 NTU to 35 NTU, with an overall median and mean of 1.4 and 2.4 NTU, respectively (Table 5.2.4-5).

Appendix G presents a summary of each vertical profile for all stations as the mean of the profile. Overall, the mean and median turbidity among stations was low and ranged from 0.8 to 1.6 NTU and 1.4 to 4.0 NTU, respectively (Table5.2.4-2). Appendix H presents each vertical profile for all stations. Turbidity levels for each profile were low and uniform throughout the water column, except when sampling took place during or shortly after high flow and precipitation events, when the turbidity varied throughout the water column.

Continuous turbidity data collected during the high temperature low-flow monitoring period indicate that turbidity was generally low in upstream areas and through the Vernon impoundment (Table 5.2.4-6;Appendix J). Median turbidity values recorded during the 10-day high temperature low-flow monitoring period ranged from 0.6 NTU (06-V-02) to 1.2 NTU (06-V-04), with a maximum of 7.8 NTU recorded at the upstream station (06-V-04) (Table 5.2.4-6).

Overall, the continuous and vertical profile turbidity data collected at all mainstem Vernon monitoring stations indicate that turbidity did not exceed the NH surface water quality standard of 10 NTU beyond upstream waters, and that under low-flow conditions turbidity within the Vernon study area did not exceed the VT surface water quality standard for turbidity. Sporadic turbidity spikes observed in the time-series for each station that did not follow inflows (e.g., 06-V-TR September 12; Figure F-83 in Appendix F) were most likely debris and vegetation caught in the instrument and drifting in front of the turbidity optics, based on field observations.

Nutrients and Chlorophyll-a

Table 5.2.4-7 presents the nutrient and chlorophyll-*a* concentrations at the Vernon forebay station (06-V-01). Total nitrogen concentrations ranged from below the instrument detection limit of 0.5 mg/L to 1.04 mg/L, with a mean of 0.45 mg/L. Total phosphorus concentrations ranged from 0.008 to 0.096 mg/L, with a mean of 0.019 mg/L. Collectively, the observed range and mean levels of TN and TP suggest the trophic state of Connecticut River at the Vernon forebay station is oligotrophic to mesotrophic (Dodds et al., 1998; NHDES, 1997). However, according to VTDEC (2000), TP concentrations greater than 0.14 mg/L could be considered eutrophic. Nitrate/nitrite concentrations ranged from 0.09 to 0.18 mg/L, with a mean of 0.13 mg/L. Total Kjeldahl nitrogen ranged from below the instrument detection limit of 0.50 mg/L to 0.90 mg/L, with a mean of 0.41 mg/L. Chlorophyll-*a* levels ranged from 0.7 to 9.0 mg/m^3, and generally increased over the study period. The mean chlorophyll-*a* concentration was 2.9 mg/m^3 suggesting that the trophic state of the Connecticut River at the Vernon forebay monitoring station is oligotrophic (NHDES, 1997; VTDEC, 2000). Laboratory reports are included in Appendix K.

Table 5.2.4-1. Maximum, minimum, mean, and median monthly water temperatures for Vernon water quality monitoring stations.

Temperature (°C)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	All
06-V-04									
Max	8.05	21.34	20.63	25.16	26.24	25.88	18.34	10.83	26.24
Min	7.85	7.67	13.50	17.13	22.92	18.03	8.89	7.19	7.19
Median	8.00	14.86	18.25	22.44	24.41	22.32	13.42	9.02	18.68
Mean	7.97	14.76	17.93	21.90	24.46	22.42	12.68	9.07	18.09
06-V-03									
Max	8.20	21.77	20.72	25.43	26.48	26.14	18.30	11.05	26.48
Min	7.72	7.67	13.67	17.15	22.92	17.89	8.87	7.17	7.17
Median	8.05	15.08	18.22	22.68	24.46	22.30	13.42	8.99	18.84
Mean	8.02	14.92	17.97	22.17	24.48	22.39	12.71	9.10	18.24
06-V-02									
Max	8.10	21.75	20.89	25.65	26.55	25.85	18.34	10.74	26.55
Min	7.32	7.97	13.95	17.20	23.40	18.37	9.11	7.87	7.32
Median	7.77	15.25	18.46	23.09	24.77	22.49	13.59	9.26	19.10
Mean	7.74	15.07	18.14	22.38	24.82	22.80	12.93	9.21	18.48
06-V-01									
Max	–	21.56	20.91	25.78	27.17	26.08	18.34	10.39	27.17
Min	–	14.15	14.46	17.44	23.54	18.40	8.99	7.65	7.65
Median	–	16.51	18.70	23.21	24.91	22.38	13.88	9.31	19.67
Mean	–	16.92	18.37	22.40	24.94	22.91	13.03	9.29	19.01
06-V-TR									
Max	–	21.15	20.84	25.66	26.43	25.76	18.40	10.37	26.43
Min	–	12.92	14.43	17.43	23.57	18.42	9.06	7.72	7.72
Median	–	16.06	18.73	23.35	25.00	22.34	13.95	9.39	19.48
Mean	–	16.37	18.38	22.47	24.97	22.94	13.10	9.35	18.91

"–"indicates high flows and spill conditions in April precluded data collection until May.

Table 5.2.4-2. Vertical profile summary statistics for Vernon water quality monitoring stations.

Statistic	**06-V-04**	**06-V-03**	**06-V-02**	**06-V-01**	**06-V-TR**
Mean Water Depth (m)[a]	2.4	3.3	5.6	16.2	7.4
Temperature (°C)					
Max	24.9	25.4	25.9	26.3	25.2
Min	16.0	16.1	16.3	15.4	15.9
Median	22.5	22.3	23.1	23.7	24.0
Mean	21.4	21.3	21.7	21.8	23.0
Dissolved Oxygen (mg/L)					
Max	10.2	10.3	10.0	9.9	10.1
Min	7.6	7.6	7.4	7.1	7.9
Median	8.9	9.3	8.4	8.3	8.9
Mean	8.9	9.2	8.6	8.4	8.9
Dissolved Oxygen (% saturation)					
Max	112.1	113.7	106.1	105.3	111.5
Min	87.8	87.7	87.2	84.9	94.6
Median	101.6	103.7	98.4	97.0	104.2
Mean	100.5	103.4	97.6	95.4	103.3
Specific Conductivity (µS/cm)					
Max	167	162	157	157	156
Min	86	60	95	84	83
Median	128	130	128	131	138
Mean	126	126	126	127	133
pH (s.u)					
Max	8.06	7.97	7.74	7.71	7.75
Min	7.42	7.48	7.36	7.29	7.25
Median	7.64	7.57	7.54	7.53	7.57
Mean	7.65	7.64	7.54	7.51	7.55
Turbidity (NTU)					
Max	23.0	25.2	27.2	21.3	4.1
Min	0.0	0.0	0.0	0.0	0.0
Median	1.5	1.3	0.8	1.3	1.6
Mean	4.0	4.3	2.3	2.0	1.4

a. Average of individual depths recorded during each station visit.

Table 5.2.4-3. Water temperatures of the Vernon impoundment and upstream area during the high temperature low-flow period monitoring period.

Logger Location	**Statistic**	**Temperature (°C)**		
		River Left	**Mid-channel**	**River Right**
06-V-04				
1m below surface	Max	--	--	25.9
	Min			23.7
	Mean			24.5
Mid-depth	Max	27.1	25.9	--
	Min	23.0	23.8	
	Mean	24.6	24.5	
1m above bottom	Max	--	--	26.0
	Min			23.8
	Mean			24.6
Depth to bottom (at first deployment, m)		0.8	2.3	4.1
06-V-03				
1m below surface	Max	26.3	--	--
	Min	22.2		
	Mean	24.5		
Mid-depth	Max	--	26.3	25.9
	Min		23.5	23.8
	Mean		24.6	24.7
1m above bottom	Max	26.2	--	--
	Min	23.4		
	Mean	24.6		
Depth to bottom (at first deployment, m)		3.4	2.7	2.1
06-V-02				
1m below surface	Max	26.3	26.1	26.1
	Min	24.4	24.4	24.4
	Mean	25.0	25.0	25.0
Mid-depth	Max	25.3	25.3	25.2
	Min	24.4	24.4	24.3
	Mean	24.8	24.8	24.8
1m above bottom	Max	25.1	25.2	25.3
	Min	24.4	24.4	24.4
	Mean	24.7	24.8	24.8
Depth to bottom (at first deployment, m)		4.8	5.6	6.3

Table 5.2.4-3. Continued.

Logger Location	Statistic	Temperature (°C)		
		River Left	Mid-channel	River Right
06-V-01				
1m below surface	Max	28.1	27.8	27.9
	Min	24.6	24.6	24.7
	Mean	25.5	25.4	25.5
Mid-depth	Max	26.0	26.6	25.6
	Min	24.4	24.6	24.5
	Mean	24.9	25.1	24.9
1m above bottom	Max	25.3	26.0	25.2
	Min	24.2	24.5	24.4
	Mean	24.6	24.9	24.7
Depth to bottom (at first deployment, m)		6.9	5.4	17.2

“--“indicates no logger deployed due to shallow water depths.

Table 5.2.4-4. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Vernon forebay water quality monitoring station, 06-V-01.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	20.90	25.78	27.17	26.08	27.19
Min	15.53	17.44	23.54	18.40	15.53
Median	18.91	23.21	24.91	22.38	23.45
Mean	18.78	22.40	24.94	22.91	22.45
Specific Conductivity (µS/cm)					
Max	115	151	159	170	170
Min	80	93	129	132	80
Median	96	129	145	152	139
Mean	96	125	145	152	131
Dissolved Oxygen (mg/L)					
Max	10.0	9.9	8.7	9.2	10.0
Min	8.6	7.2	7.0	6.9	6.9
Median	9.1	8.7	7.9	7.9	8.3
Mean	9.2	8.6	7.9	8.0	8.3
Dissolved Oxygen (% saturation)					
Max	104.1	119.9	105.2	110.5	119.9
Min	94.1	83.1	84.4	82.0	82.0
Median	98.2	99.0	94.9	93.2	96.4
Mean	98.2	98.6	94.9	92.6	96.0
Max Daily Mean	101.5	108.7	99.4	100.5	108.7
Min Daily Mean	95.9	87.1	89.2	85.8	85.8
pH (s.u)					
Max	7.60	8.05	7.86	7.92	8.05
Min	7.39	7.28	7.28	7.33	7.28
Median	7.47	7.51	7.55	7.57	7.52
Mean	7.48	7.53	7.55	7.58	7.54
Turbidity (NTU)					
Max	32.2	13.9	3.6	22.1	32.2
Min	0.0	0.7	0.3	0.2	0.0
Median	1.4	1.9	1.2	1.0	1.4
Mean	3.8	2.5	1.2	1.4	2.1

Table 5.2.4-5. Monthly summary statistics for continuous temperature, specific conductivity, dissolved oxygen, pH and turbidity collected at the Vernon tailrace water quality monitoring station, 06-V-TR.

Statistic	Jun	Jul	Aug	Sep	All
Temperature (°C)					
Max	20.84	25.66	26.43	25.76	26.43
Min	17.38	17.43	23.57	18.42	17.38
Median	19.27	23.35	25.00	22.34	23.81
Mean	19.22	22.47	24.97	22.94	22.74
Specific Conductivity (µS/cm)					
Max	106	153	156	170	170
Min	81	92	127	130	81
Median	91	129	145	153	142
Mean	91	125	144	154	134
Dissolved Oxygen (mg/L)					
Max	10.1	9.8	9.0	9.5	10.1
Min	9.0	7.8	7.4	7.3	7.3
Median	9.4	8.9	8.4	8.5	8.6
Mean	9.4	8.9	8.4	8.6	8.7
Dissolved Oxygen (% saturation)					
Max	109.7	111.2	108.0	107.6	111.2
Min	97.5	91.2	90.2	86.0	86.0
Median	101.6	102.6	101.7	100.8	101.7
Mean	102.0	102.2	101.1	99.8	101.2
Max Daily Mean	106.7	108.5	104.2	104.1	108.5
Min Daily Mean	99.3	94.4	94.4	89.3	89.3
pH (s.u)					
Max	7.62	7.78	7.73	7.86	7.86
Min	7.38	7.36	7.42	7.45	7.36
Median	7.48	7.53	7.54	7.59	7.53
Mean	7.48	7.55	7.55	7.61	7.55
Turbidity (NTU)					
Max	35.4	16.3	4.9	19.9	35.4
Min	0.0	0.9	0.4	0.1	0.0
Median	1.8	1.8	1.3	1.0	1.4
Mean	5.4	2.6	1.3	1.3	2.4

Table 5.2.4-6. Summary statistics of temperature, specific conductivity, dissolved oxygen, pH and turbidity for Vernon impoundment and upstream water quality monitoring stations during the high temperature low-flow monitoring period.

Statistic	**Station**			
	06-V-04	**06-V-03**	**06-V-02**	**06-V-01**
Temperature (°C)				
Max	25.9	26.1	25.7	26.1
Min	23.8	23.4	24.2	24.4
Median	24.5	24.4	24.7	24.8
Mean	24.5	24.5	24.7	24.9
Specific Conductivity (µS/cm)				
Max	184	163	163	152
Min	150	136	145	141
Median	165	150	154	146
Mean	165.9	150.4	154.1	145.6
Dissolved Oxygen (mg/L)				
Max	9.8	9.5	8.9	9.0
Min	7.9	7.4	7.7	6.9
Median	8.8	8.4	8.1	7.7
Mean	8.7	8.4	8.1	7.8
Dissolved Oxygen (% saturation)				
Max	117.5	116.5	108.0	110.5
Min	93.7	88.5	92.0	83.4
Median	103.5	100.1	98.6	93.8
Mean	104.6	101.0	98.3	94.3
Max Daily Mean	108.5	103.5	101.1	100.5
Min Daily Mean	98.9	95.2	95.0	90.5
pH (s.u)				
Max	8.03	8.01	7.81	7.92
Min	7.58	7.60	7.55	7.38
Median	7.72	7.70	7.62	7.57
Mean	7.73	7.76	7.62	7.57
Turbidity (NTU)				
Max	7.8	1.8	1.2	2.8
Min	0.2	0.4	0.4	0.4
Median	1.2	0.8	0.6	0.9
Mean	1.1	0.7	0.6	0.9

Table 5.2.4-7. Nutrients and chlorophyll-*a* data and summary statistics for the Vernon forebay water quality monitoring station, 06-V-01.

Date	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Nitrate/Nitrite (mg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Chlorophyll-*a* (mg/m^3)**
6/6/2015	<0.50	0.013	0.12	<0.50	0.7
6/12/2015	<0.50	0.021	0.13	<0.50	0.8
6/17/2015	<0.50	0.018	0.13	<0.50	1.1
6/27/2015	<0.50	0.019	0.09	<0.50	1.1
7/9/2015	<0.50	0.012	0.13	<0.50	1.1
7/17/2015	<0.50	0.009	0.14	<0.50	2.9
7/22/2015	1.04	0.011	0.14	0.90	1.1
7/31/2015	0.82	0.009	0.12	0.70	2.4
8/4/2015	0.72	0.009	0.12	0.60	4.6
8/13/2015	<0.50	0.023	0.14	<0.50	4.3
8/24/2015	0.88	0.009	0.18	0.70	3.2
8/31/2015	<0.50	0.01	0.14	<0.50	3.2
9/13/2015	<0.50	0.019	0.18	<0.50	4.0
9/24/2015	<0.50	0.008	0.13	<0.50	4.6
10/2/2015	0.81	0.096	0.11	0.70	9.0
Max	1.04	0.096	0.18	0.90	9.0
Min	0.72	0.008	0.09	0.60	0.7
Median[a]	<0.50	0.012	0.13	<0.50	2.9
Mean[a]	0.45	0.019	0.13	0.41	2.9

a. For values below the detection limit of 0.5 mg/L, a concentration of 0.25 mg/L was assumed for mean calculations for the associated analyte.

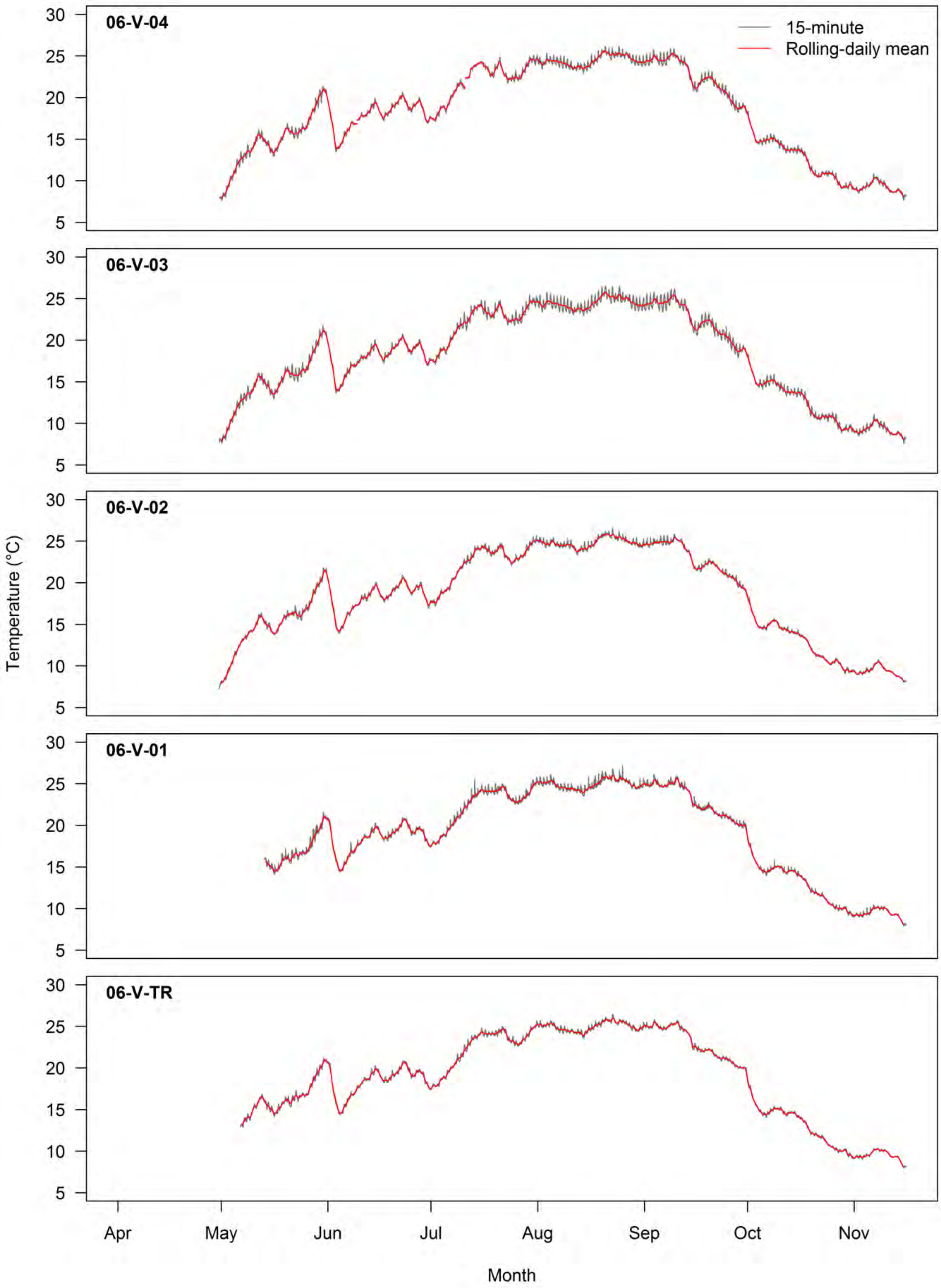

Figure 5.2.4-1. Continuous water temperature collected at 15-minute intervals and computed rolling-daily mean for Vernon water quality monitoring stations. Data when temperature loggers for 06-V-04 were out of water are omitted.

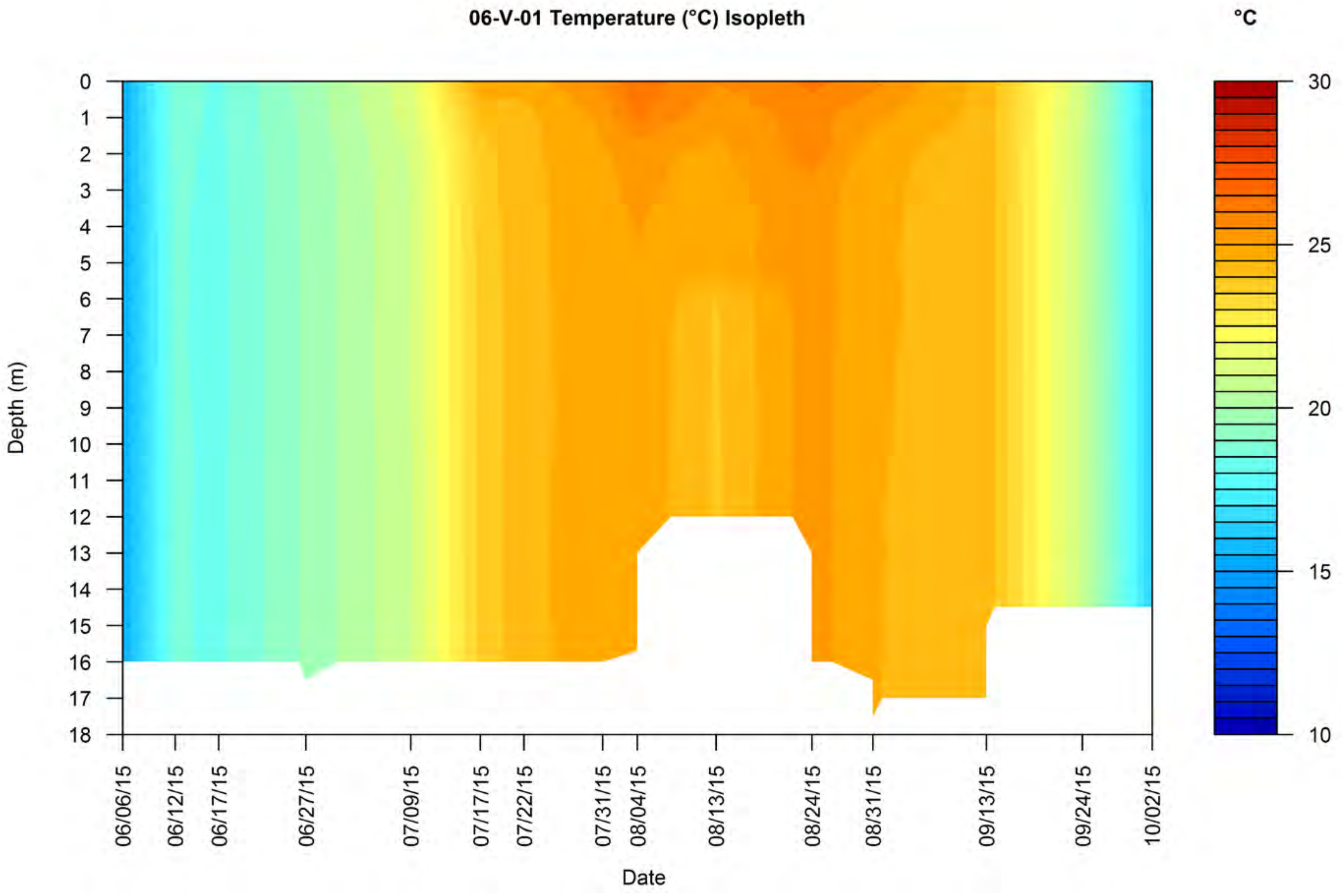

Figure 5.2.4-2. Vernon forebay (06-V-01) water quality monitoring station temperature (°C) isopleth. Tick marks indicate the dates when vertical profiles were collected.

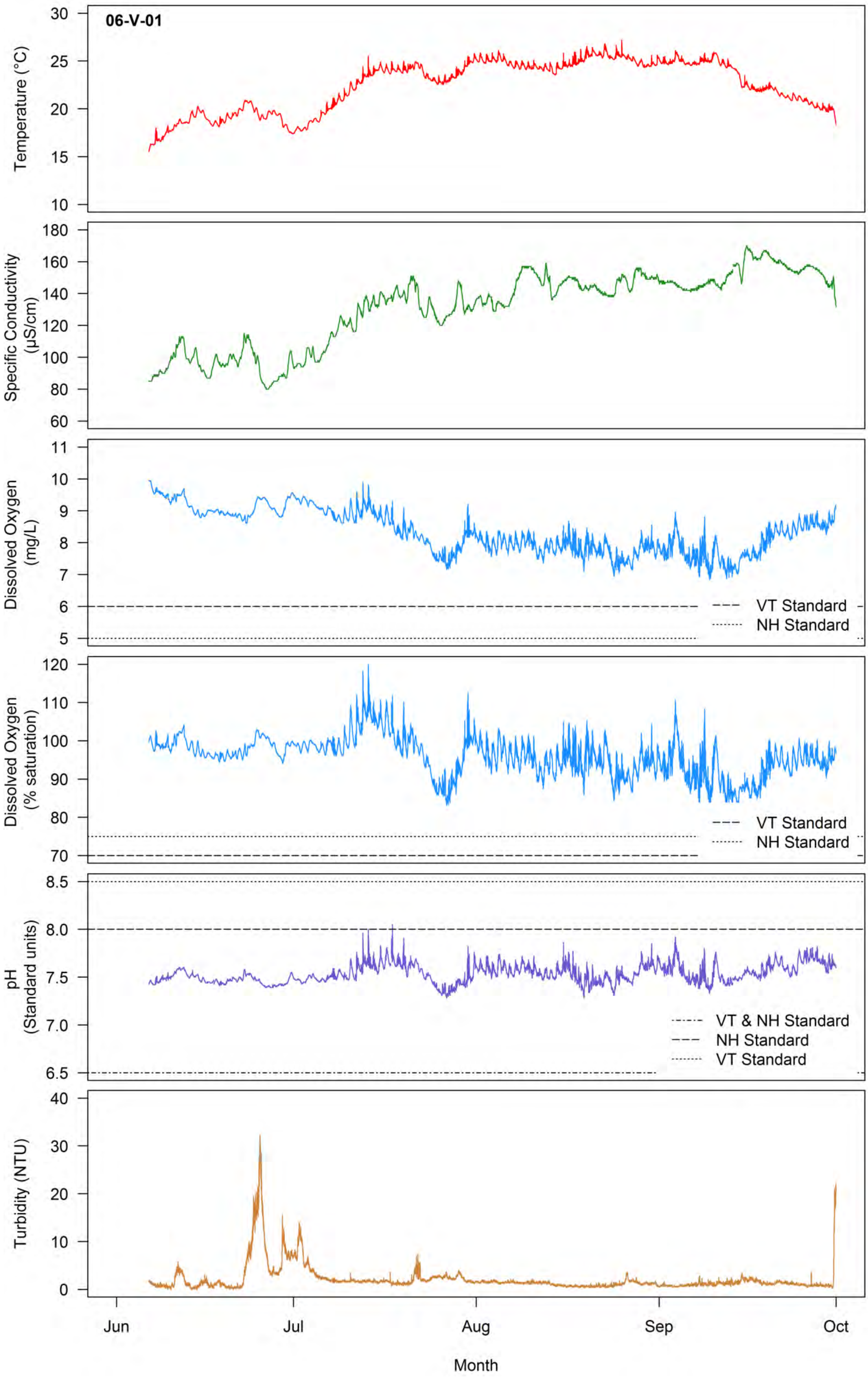

Figure 5.2.4-3. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Vernon forebay (06-V-01) water quality monitoring station.

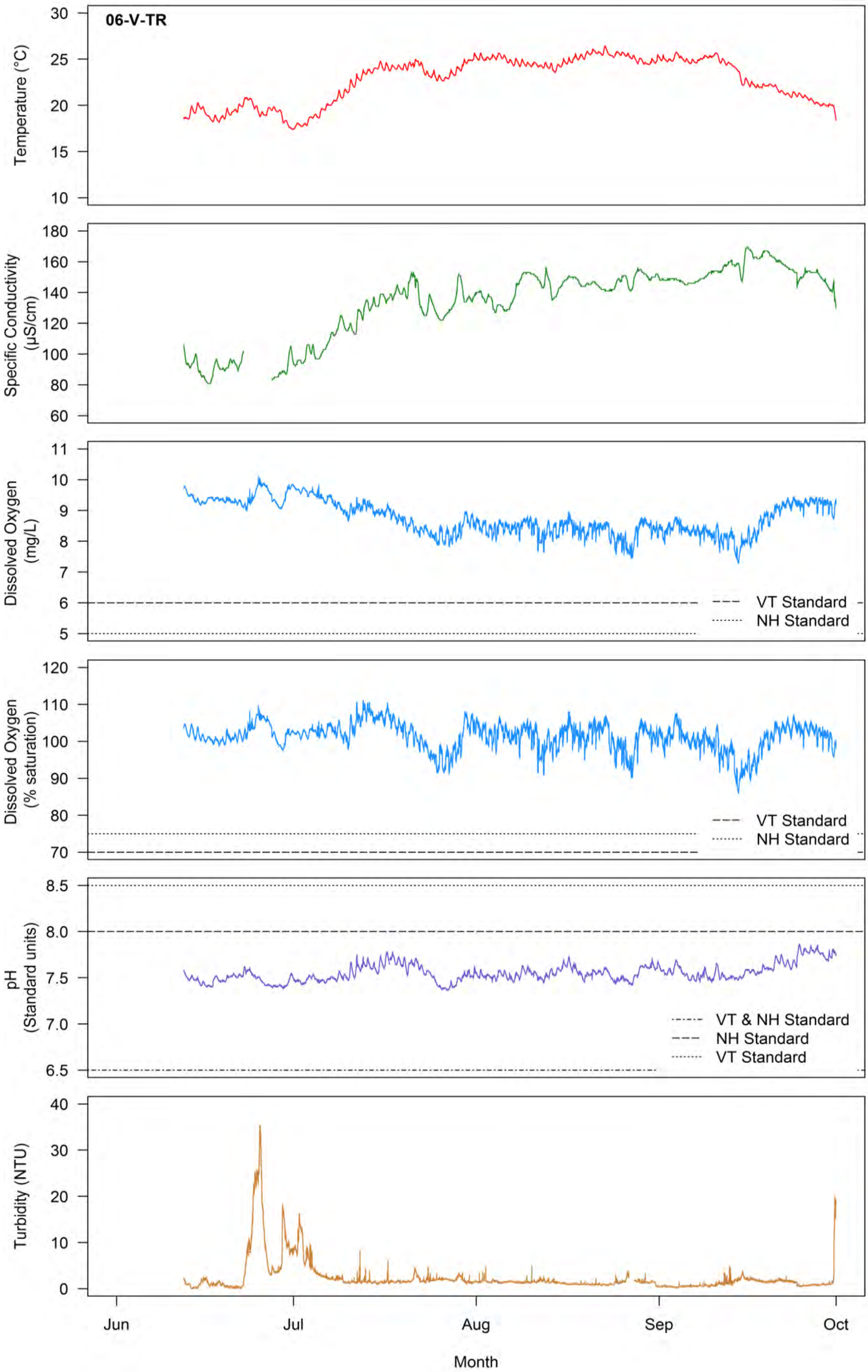

Figure 5.2.4-4. Continuous temperature, specific conductivity, dissolved oxygen, pH, and turbidity collected at the Vernon tailrace (06-V-TR) water quality monitoring station.

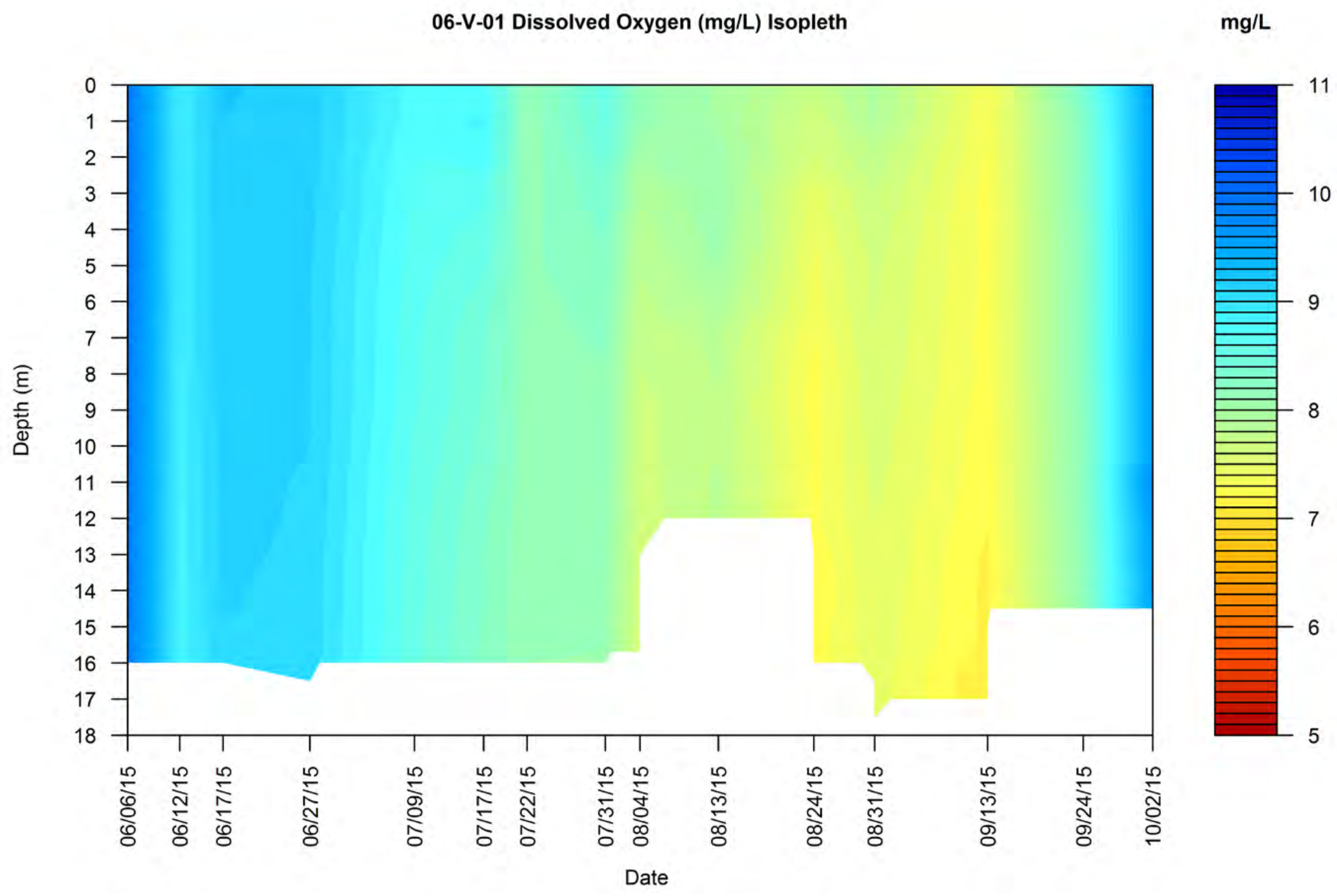

Figure 5.2.4-5. Vernon forebay (06-V-01) water quality monitoring station dissolved oxygen (mg/L) isopleth. Tick marks indicate the dates when vertical profiles were collected.

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5.3 Temporal Patterns of Water Quality

Over the duration of the water quality monitoring period, several temporal patterns were observed among the three projects. A similar temporal pattern of water temperatures increasing through the spring, reaching their highest in August, and cooling through the fall was common among all tributary and mainstem Connecticut River stations. DO levels were variable and generally decreased through late spring reaching their lowest in mid- to late summer (as temperatures were at their highest) before increasing again in mid-September (when temperatures began to cool). pH levels were fairly consistent and indicate that waters within the study area are slightly basic. Specific conductivity was variable throughout the study, and was generally lower in late spring and early summer and higher in mid- to late summer. Turbidity through the study area was very low at all stations and only increased to a noticeable difference during high-flow events as a result of heavy rains, such as those events that occurred in June.

During the hot summer period all three impoundments and tailraces were well-mixed, except for a few instances of mild surface warming or weak stratification.[2]. Typically, stratification can occur when depths are generally greater than 6 m, surface waters are heated rapidly, and wind-induced mixing is moderate but insufficient to mix the entire water column (Wetzel, 2001). However, stratification can be intermittent if the weather is calm and hot, resulting in strong thermal discontinuities at the surface (usually accepted as >1°C), and the calm hot weather alternates with periods of mixing by wind (Wetzel, 2001). At the Wilder forebay and middle impoundment stations, only mild surface warming was observed and short in duration. At the Bellows Falls forebay only mild surface warming was observed, whereas at the middle impoundment station weak and very brief stratification was observed (July 29); at the Vernon forebay and middle impoundment stations only mild surface warming occurred. The mild surface warming observed at the three projects did not result in depleted DO levels below state surface water quality standards within the hypolimnion or bottom waters, nor did the single instance of weak stratification observed at the Bellows Falls middle impoundment station.

Well-defined fluctuations of temperature, DO, and pH were observed at all upstream and upper impoundment stations as well as the Bellows Falls bypassed reach station. Middle impoundment, forebay, and tailrace stations also showed diel patterns of fluctuating levels of temperature, DO, and pH but were typically poorly-defined. Specific conductivity was also observed to fluctuate on a daily basis, but only for impoundment and upstream stations of Wilder and Bellows Falls, and the Bellows Falls bypassed reach station. Diel fluctuations in water temperature were also observed at the tributary stations. Diel fluctuation in temperature often resulted in peak temperatures being observed during mid- to late afternoon,

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[2] Stratification was determined if the temperature difference in the stratum of greatest thermal discontinuity exceeded 1°C per meter (Wetzel, 2001). If surface waters were warm compared to bottom water temperatures but did not fit the technical definition of stratification above, this was considered to be mild surface warming.

especially during the high temperature low-flow monitoring period. Similarly, DO levels also tended to peak during mid- to late afternoon, likely as a result of higher rates of photosynthesis. Another consequence of increased rates of photosynthesis are elevated pH levels. Photosynthesis can cause pH levels to rise because algae and aquatic plants remove carbon dioxide from water, which reduces the amount of carbonic acid, a weak acid that is formed when carbon dioxide and water combine.

At times, but infrequently, pH levels increased above state water quality standards for a short duration. The short duration, infrequent occurrence, and tendency for pH to peak during midday hours suggest that an increased rate of photosynthesis may contribute to elevated levels of pH above state surface water quality standards, especially because diurnal fluctuations in pH is most apparent at the upstream riverine stations than the impoundment stations, and the elevated pH levels coincided with elevated levels of chlorophyll-*a*. The station with the most observed exceedances of the upper limit of the NH state surface water quality standard was the Bellows Falls middle impoundment (06-BF-02), which exhibited similar diurnal fluctuations in pH to the upper riverine and upper impoundment stations (Figure J-7 in Appendix J; Figures F-54 and F-55 in Appendix F). Residence time in the impoundments appears to be unrelated to the pH exceedances in Bellows Falls. The gross storage capacity in the Wilder and Vernon impoundments is 29 percent and 49 percent larger than in the Bellows Falls impoundment, respectively. Considering also differences in flow (median daily discharge in cfs)[3], the average residence times in the Wilder and Vernon impoundments are roughly 33 percent and 45 percent longer, respectively, than in Bellows Falls; yet pH exceedances in these two impoundments were rare. Potential causes for the pH exceedances in the Bellows Falls impoundment could include elevated nutrient loading from the impoundment's watershed. See additional discussion in Section 5.5.1.

Concentrations of TN and TKN were frequently below the instrument detection limit. Concentration of TP and nitrate/nitrite were fairly consistent over the duration of the study with some variability. Chlorophyll-*a* concentrations exhibited some variability but overall tended to increase throughout the summer months.

5.4 Spatial Patterns of Water Quality

Water temperature consistently increased from upstream to downstream both within and among the projects. This effect is likely a result of increased solar insolation, monitoring station physical characteristics (e.g., depth), decrease in elevation and latitude as water travels from the most northern station (06-W-04) through the impoundments and riverine reaches, and leaves the study area at the Vernon tailrace (06-V-TR). Figure 5.2.1-1 shows the temperature distribution of both tributary and mainstem monitoring stations. Median temperatures in the tributaries were generally lower than median temperatures at the mainstem

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[3] From USGS water data based on 74-year record at North Walpole USGS gage #01144500; 102-year record at West Lebanon USGS gage #01154500.

stations; however, the nearest mainstem stations downstream of a tributary confluence were usually warmer than the nearest mainstem station upstream of a tributary confluence. Furthermore, Figure 5.2.1-1 also shows that tributary water temperatures generally encompass mainstem water temperatures, and that cooler tributary water temperatures would result in mainstem cooling and warmer tributary temperatures would result in mainstem warming. During summer low-flow conditions water temperatures at a mainstem station typically were similar to the next upstream mainstem station. (Tables 5.4-1, 5.4-2, 5.4-3). Further, when precipitation events resulted in high flows, such as in June, water temperatures in the tributaries decreased as did mainstem water temperatures among all stations.

The instantaneous vertical profile data, continuous monitoring, and high temperature low-flow monitoring suggest DO generally decreases as water travels from upstream areas through the impoundments toward each dam. As water travels from each forebay through the powerhouse and into the tailrace overall mean DO levels increased in the Bellows Falls and Vernon tailraces, but not the Wilder tailrace. From the tailrace stations downstream to the next upstream impoundment station, DO increased slightly or remained very similar as water flowed through un-impounded riverine reaches.

Average pH values were lowest at the Wilder monitoring stations, and highest at the Bellows Falls stations. The pH generally decreased from the Bellows Falls upstream station (06-BF-04) to the Vernon tailrace station (06-V-TR). There was no apparent pattern for pH as water flowed from upstream areas of Wilder, through the impoundment, and tailrace. The pH of each project forebay was generally similar to the pH measured in each project tailrace. pH was also higher within the Bellows Falls bypassed reach than at the project’s forebay or tailrace stations.

In general, specific conductivity increased from upstream Wilder areas through the impoundment and tailrace. In addition, the mean specific conductivity was generally higher in upstream and upper impoundment areas of Bellows Falls, but mean specific conductivities were similar at the Vernon upstream and impoundment stations. The continuous specific conductivity data collected at the forebay and tailrace stations were typically similar for each project. Overall, average specific conductivity was lowest for Wilder stations and highest for Bellows Falls stations.

Turbidity among all water quality monitoring stations was generally very low among all stations, except during periods of high flow as a consequence of heavy rains within the watershed.

No strong or consistent spatial patterns of nutrient or chlorophyll-*a* concentrations was observed. However, mean TN and TKN concentrations were higher in the Wilder forebay than in the Bellows Falls or Vernon forebays, which were similar to each other. Mean chlorophyll-*a* concentrations were higher in the Bellows Falls forebay than in the Vernon or Wilder forebays. Nitrate/nitrite concentrations were similar among the three sampling forebay stations.

Table 5.4-1. Weekly and monthly mean water temperatures (°C) for Wilder tributary and mainstem stations.

Week Starting and Month	**Mean Temperature** (°C)							**Difference**[a]	
	06-W-04	**06-W-03**	**Waits River**	**06-W-02**	**Ompomp. River**	**06-W-01**	**06-W-TR**	**06-W-04 to 06-W-TR**	**06-W-01 to 06-W-TR**
29-Mar	–	–	0.2	–	–	–	–	–	–
April									
5-Apr	–	–	1.2	–	2.4*	–	–	–	–
12-Apr	–	–	3.7	–	4.7	–	–	–	–
19-Apr	–	–	4.4	–	5.1	–	–	–	–
26-Apr	7.4*	7.4*	7.7	7.9*	8.6	–	–	–	–
Apr	–	–	**3.2**	–	**4.8**	–	–	–	–
May									
3-May	9.3	9.5	15.0	10.1	13.9	10.9*	10.9*	***1.6****	0.1*
10-May	10.9	11.0	13.4	11.6	13.6	12.2	12.3	***1.3***	0.0
17-May	12.9	13.0	13.8	13.9	14.1	14.4	14.4	***1.5***	0.0
24-May	15.7	16.0	17.5	16.6	18.0	16.6	16.3	0.5	-0.3
31-May	13.9	14.0	13.1	14.4	13.8	14.8	14.8	***0.9***	0.0
May	**11.8**	**12.0**	**14.6**	**12.7**	**14.4**	**13.9**	**13.8**	***2.0****	-0.1*
June									
7-Jun	15.6	15.6	16.3	16.2	16.9	16.5	16.5	***0.9***	0.1
14-Jun	16.7	16.8	15.9	17.2	16.7	17.4	17.4	***0.7***	0.0
21-Jun	17.4	17.5	16.5	17.9	17.3	18.2	18.3	***0.8***	0.1
28-Jun	17.4	17.4	15.4	17.5	16.2	17.6	17.6	0.2	0.1
Jun	**16.0**	**16.0**	**15.4**	**16.4**	**16.1**	**16.7**	**16.8**	***0.8***	-0.1
July									
5-Jul	19.5	19.6	18.7	20.2	19.2	20.3	20.3	***0.8***	0.1
12-Jul	20.0	20.2	19.1	21.3	19.4	22.2	22.2	***2.1***	0.0
19-Jul	19.5	19.6	18.2	20.1	19.9	20.9	20.9	***1.4***	0.0
26-Jul	21.2	21.3	20.7	22.1	21.5	22.5	22.4	***1.3***	0.0
Jul	**19.6**	**19.7**	**18.6**	**20.4**	**19.4**	**20.7**	**20.8**	***1.2***	-0.1

Table 5.4-1. Continued.

Week Starting and Month	**Mean Temperature** (°C)							**Difference**†	
	06-W-04	**06-W-03**	**Waits River**	**06-W-02**	**Ompomp. River**	**06-W-01**	**06-W-TR**	**06-W-04 to 06-W-TR**	**06-W-01 to 06-W-TR**
August									
2-Aug	20.6	20.8	19.1	22.0	19.9	23.1	23.0	***2.4***	-0.1
9-Aug	20.8	21.0	19.5	21.4	20.1	22.2	22.2	***1.3***	0.0
16-Aug	22.6	22.8	22.0	23.8	22.1	23.4	23.3	***0.8***	-0.1
23-Aug	21.5	21.6	19.4	22.4	19.7	23.9	23.9	***2.4***	0.0
30-Aug	22.0	22.1	20.3	22.7	20.2	23.2	22.9	***0.9***	-0.3
Aug	**21.4**	**21.5**	**20.0**	**22.3**	**20.5**	**23.2**	**23.1**	***1.7***	-0.1
September									
6-Sep	22.2	22.3	20.5	23.5	20.4	24.1	23.6	***1.4***	-0.4
13-Sep	20.3	20.5	18.0	20.8	18.1	21.9	21.9	***1.6***	-0.1
20-Sep	18.6	18.6	14.0	19.4	14.1	20.1	20.0	***1.4***	-0.1
27-Sep	17.0	17.1	12.6	17.0	13.2	17.4	17.4	0.3	0.0
Sep	**20.5**	**20.6**	**17.8**	**21.2**	**17.8**	**22.0**	**21.8**	***1.3***	-0.2
October									
4-Oct	14.1	14.1	9.6	14.1	10.3	14.9	14.9	***0.8***	-0.1
11-Oct	13.1	13.2	9.2	13.2	9.7	13.3	13.2	0.1	-0.1
18-Oct	11.1	11.1	7.3	10.8	7.7	11.5	11.4	0.3	-0.1
25-Oct	9.5	9.5	6.3	9.6	6.6	9.8	9.7	0.2	-0.1
Oct	**12.6**	**12.6**	**8.6**	**12.6**	**9.1**	**13.0**	**12.9**	0.3	-0.1
November									
1-Nov	10.2	10.2	7.8	9.7	8.2	9.2	9.1	***-1.1***	-0.1
8-Nov	8.5	8.5	5.5	8.8	6.0	9.5	9.4	***0.9***	-0.1
15-Nov	7.0	6.7	3.7	7.7	3.8	8.0	7.9	***0.9***	-0.1
Nov	**9.2**	**9.2**	**6.5**	**9.1**	**7.0**	**9.3**	**9.2**	0.0	-0.1
Mean Weekly Difference								***1.1***	0.1
Max Weekly Cooling Difference								***-1.1***	-0.4
Max Weekly Warming Difference								***2.4***	0.1

a. Positive values indicate warming; negative values indicate cooling. Values in ***bold italic*** face indicate the difference in weekly mean temperatures exceeded ±0.56°C (1°F).

"–"indicates no data.

"*" indicates incomplete data available due to late deployment.

Table 5.4-2. Weekly and monthly mean water temperatures for Bellows Falls tributary and mainstem stations.

Week Starting and Month	Mean Temperature (°C)											Difference[a]	
	White River	Mascoma River	06-BF-04	Sugar River	06-BF-03	06-BF-02	Black River	Williams River	06-BF-01	06-BF-BR	06-BF-TR	06-BF-04 to 06-BF-TR	06-BF-01 to 06-BF-TR
29-Mar	–	2.1	–	–	–	–	2.0	1.9	–	–	–	–	–
April													
5-Apr	2.8*	2.2	–	2.3*	–	–	2.6	2.5	–	–	–	–	–
12-Apr	5.3	3.9	–	5.4	–	–	5.3	5.5	–	–	–	–	–
19-Apr	5.5	4.8	–	6.1	–	–	5.9	5.8	–	–	–	–	–
26-Apr	9.2	8.2	8.2*	9.9	8.1*	8.4*	9.5	9.6	–	–	–	–	–
Apr	**5.3**	**3.8**	–	**5.5**	–	–	**4.7**	**4.7**	–	–	–	–	–
May													
3-May	15.2	13.1	11.7	16.0	11.8	12.2	16.0	15.1	13.7	–	–	–	–
10-May	14.9	14.3	13.3	16.7	13.3	13.7	16.9	15.8	14.3	14.0*	–	–	–
17-May	16.2	15.6	15.1	17.5	15.2	15.5	17.3	15.8	15.7	15.8	15.9*	–	–
24-May	18.6	19.3	17.8	21.6	18.0	18.5	20.9	19.6	18.8	19.0	18.9	***1.1***	0.1
31-May	14.8	17.0	15.2	16.2	15.2	15.4	16.6	15.0	15.7	15.8	15.8	***0.6***	0.1
May	**15.5**	**15.0**	**13.9**	**17.3**	**14.0**	**14.3**	**17.1**	**16.0**	**16.0**	**16.6**	**17.9**	**–**	**–**
June													
7-Jun	18.2	19.5	17.2	21.0	17.2	17.5	20.3	19.6	17.8	17.9	17.9	***0.7***	0.0
14-Jun	17.9	19.8	18.0	20.5	18.0	18.2	19.7	18.4	18.5	18.6	18.5	0.5	0.0
21-Jun	17.6	20.4	18.5	21.3	18.6	18.9	21.3	19.1	19.2	19.1	19.2	***0.7***	0.0
28-Jun	16.1	19.9	17.6	18.4	17.6	17.7	18.2	16.5	17.9	17.7	17.9	0.3	0.0
Jun	**16.9**	**19.2**	**17.2**	**19.6**	**17.2**	**17.5**	**19.3**	**17.9**	**17.8**	**17.9**	**17.8**	***0.6***	0.0
July													
5-Jul	20.8	22.2	20.8	22.5	20.9	21.2	22.4	20.6	21.3	21.5	21.4	0.5	0.0
12-Jul	22.1	22.2	22.5	23.3	22.6	23.1	23.4	21.6	23.5	23.5	23.5	***1.0***	0.0
19-Jul	22.4	23.4	21.6	23.7	21.8	22.2	23.8	22.3	22.7	22.7	22.7	***1.1***	0.0
26-Jul	24.1	24.8	23.1	25.5	23.2	23.8	24.8	23.4	23.9	23.9	24.0	***0.8***	0.0
Jul	**21.4**	**22.7**	**21.3**	**22.9**	**21.4**	**21.7**	**22.8**	**21.1**	**22.0**	**22.3**	**22.0**	***0.7***	0.0

Table 5.4-2. Continued.

Week Starting and Month	Mean Temperature (°C)											Difference	
	White River	Mascoma River	06-BF-04	Sugar River	06-BF-03	06-BF-02	Black River	Williams River	06-BF-01	06-BF-BR	06-BF-TR	06-BF-04 to 06-BF-TR	06-BF-01 to 06-BF-TR
August													
2-Aug	23.1	22.7	23.3	23.5	23.4	23.9	23.1	21.5	24.3	24.1	24.3	***0.9***	0.0
9-Aug	22.8	22.9	22.7	23.6	22.9	23.3	22.9	21.8	23.7	23.6	23.7	***1.0***	0.0
16-Aug	25.1	24.8	24.2	25.1	24.2	24.7	24.6	23.2	25.1	25.0	25.1	***0.9***	0.0
23-Aug	23.2	23.1	23.9	23.0	23.9	24.4	22.9	21.2	24.8	24.9	24.8	***0.9***	0.0
30-Aug	24.3	23.1	23.5	23.7	23.7	24.3	23.0	21.9	24.4	–	24.4	***0.9***	0.0
Aug	**23.5**	**23.4**	**23.4**	**23.8**	**23.6**	**24.1**	**23.4**	**21.9**	**24.4**	**24.4**	**24.4**	***1.0***	0.0
September													
6-Sep	23.9	22.6	23.7	22.8	23.8	24.3	22.4	21.1	24.7	24.4	24.6	***0.9***	0.0
13-Sep	20.8	20.7	21.8	19.7	21.9	22.2	19.7	18.4	22.0	21.9	22.0	0.2	0.0
20-Sep	17.5	16.7	19.4	16.9	19.3	19.7	17.0	15.2	20.5	20.4	20.5	***1.1***	0.0
27-Sep	15.0	16.3	17.2	14.8	17.2	17.0	14.7	13.6	17.0	17.0	17.0	-0.2	0.0
Sep	**21.2**	**20.4**	**21.8**	**20.2**	**21.8**	**22.2**	**20.0**	**18.7**	**22.5**	**21.5**	**22.5**	***0.7***	0.0
October													
4-Oct	11.8	13.3	14.4	12.4	14.5	14.6	12.3	11.3	14.9	14.8	14.9	***0.6***	0.0
11-Oct	11.4	13.0	12.8	11.4	12.9	13.0	11.6	10.6	13.6	13.5	13.6	***0.8***	0.0
18-Oct	8.7	11.0	10.9	8.9	10.9	10.8	8.8	8.3	11.0	11.0	11.0	0.1	0.0
25-Oct	7.4	9.4	9.2	7.8	9.2	9.2	7.7	7.1	9.6	9.6	9.6	0.4	0.0
Oct	**10.4**	**12.3**	**12.4**	**10.6**	**12.5**	**12.5**	**10.6**	**9.8**	**12.8**	**12.8**	**12.8**	0.4	0.0
November													
1-Nov	8.9	9.7	9.1	9.4	9.3	9.5	9.3	9.0	9.7	9.7	9.7	0.6	0.0
8-Nov	7.0	7.9	8.8	7.0	8.8	8.8	7.4	6.7	9.0	9.0	9.0	0.2	0.0
15-Nov	4.4	6.7	6.8	5.4	6.9	7.0	5.2	5.3	7.8	7.7	7.8	***1.0***	0.1
Nov	**7.8**	**9.0**	**8.7**	**8.0**	**8.7**	**8.8**	**7.9**	**7.6**	**9.1**	**9.1**	**9.1**	0.4	0.0
Mean Difference												***0.7***	0.0
Max Cooling Difference												-0.2	0.0
Max Warming Difference												***1.1***	0.2

a. Positive values indicate warming; negative values indicate cooling. Values in ***bold italic*** face indicate the difference in weekly mean temperatures exceeded ±0.56°C (1°F).

"–"indicates no data.

"*" indicates incomplete data available due to late deployment.

Table 5.4-3. Weekly and monthly mean water temperatures for Vernon tributary and mainstem stations.

Week Starting and Month	**Mean Temperature** (°C)								**Difference**[a]	
	Saxtons River	**Cold River**	**06-V-04**	**06-V-03**	**06-V-02**	**West River**	**06-V-01**	**06-V-TR**	**06-V-04 to 06-V-TR**	**06-V-01 to 06-V-TR**
29-Mar	1.9	1.2	–	–	–	–	–	–	**–**	**–**
April										
5-Apr	2.8	2.2	–	–	–	–	–	–	**–**	**–**
12-Apr	5.8	5.1	–	–	–	–	–	–	**–**	**–**
19-Apr	6.3	5.6	–	–	–	5.6*	–	–	**–**	**–**
26-Apr	9.9	9.1	8.8*	8.8*	8.7*	10.1	–	–	**–**	**–**
Apr	**4.9**	**4.3**	**–**	**–**	**–**	**–**	**–**	**–**	–	–
May										
3-May	15.4	14.5	12.7	12.8	12.9	16.8	–	14.1*	***1.40***	**–**
10-May	16.0	15.3	14.5	14.6	14.9	18.0	15.0*	15.5	***1.0***	0.4
17-May	15.3	15.2	15.8	15.9	16.0	17.7	16.2	16.2	0.4	0.0
24-May	19.8	18.9	19.0	19.0	19.1	21.9	18.9	18.9	-0.1	0.0
31-May	15.2	14.9	15.7	15.9	16.1	16.7	16.5	16.5	***0.8***	0.0
May	**16.2**	**15.4**	**14.8**	**14.9**	**15.1**	**18.0**	**16.9**	**16.4**	***1.6****	-0.5*
June										
7-Jun	19.9	19.1	18.2	18.0	18.2	21.6	18.3	18.3	0.1	0.0
14-Jun	18.8	18.5	18.6	18.7	18.8	20.1	19.0	19.1	0.5	0.0
21-Jun	19.8	19.5	19.3	19.3	19.6	21.8	19.8	19.7	0.5	0.0
28-Jun	17.2	17.3	18.0	18.0	18.2	17.6	18.2	18.3	0.3	0.0
Jun	**18.3**	**17.9**	**17.9**	**17.9**	**18.1**	**19.8**	**18.4**	**18.4**	0.5	0.0
July										
5-Jul	20.6	20.6	21.1	21.5	21.5	22.8	21.3	21.4	0.3	0.1
12-Jul	–	20.9	23.4	23.6	23.9	24.0	24.0	24.0	***0.7***	0.0
19-Jul	21.8	21.6	22.8	22.9	23.3	24.8	23.6	23.7	***0.9***	0.1
26-Jul	23.1	22.4	24.0	24.1	24.5	26.0	24.4	24.4	0.4	0.1
Jul	**20.9**	**20.8**	**21.9**	**22.2**	**22.4**	**23.3**	**22.4**	**22.5**	***0.6***	0.1

Table 5.4-3. Continued.

Week Starting and Month	**Mean Temperature** (°C)								**Difference**	
	Saxtons River	**Cold River**	**06-V-04**	**06-V-03**	**06-V-02**	**West River**	**06-V-01**	**06-V-TR**	**06-V-04 to 06-V-TR**	**06-V-01 to 06-V-TR**
August										
2-Aug	21.3	20.7	24.3	24.3	24.6	23.9	24.8	24.9	***0.6***	0.0
9-Aug	21.5	21.3	23.7	23.8	24.2	24.1	24.3	24.3	***0.6***	0.0
16-Aug	23.0	22.5	25.1	25.1	25.5	25.5	25.5	25.5	0.4	0.0
23-Aug	21.1	20.8	24.8	24.8	25.0	23.3	25.1	25.1	0.3	0.0
30-Aug	21.4	21.0	24.5	24.5	24.7	24.4	24.9	25.0	0.5	0.1
Aug	**21.7**	**21.3**	**24.5**	**24.5**	**24.8**	**24.2**	**24.9**	**25.0**	0.5	0.0
September										
6-Sep	21.1	20.6	24.6	24.6	24.8	23.6	24.9	24.9	0.3	0.0
13-Sep	18.5	18.3	22.0	22.0	22.2	20.2	22.4	22.4	0.4	0.0
20-Sep	15.3	15.1	20.5	20.4	21.2	17.6	21.0	21.0	0.5	0.0
27-Sep	13.8	14.1	17.0	17.0	17.4	15.4	17.8	17.8	***0.8***	0.0
Sep	**18.6**	**18.4**	**22.4**	**22.4**	**22.8**	**21.0**	**22.9**	**22.9**	0.5	0.0
October										
4-Oct	11.3	11.0	14.7	14.8	14.9	13.0	14.7	14.8	0.1	0.1
11-Oct	10.5	11.8	13.4	13.4	13.8	11.3	14.0	14.0	***0.6***	0.1
18-Oct	8.2	9.0	10.9	10.9	11.1	8.5	11.4	11.5	***0.6***	0.1
25-Oct	7.2	7.5	9.5	9.5	9.8	7.6	9.7	9.8	0.3	0.1
Oct	**9.8**	**10.0**	**12.7**	**12.7**	**12.9**	**10.7**	**13.0**	**13.1**	0.4	0.1
November										
1-Nov	9.2	9.0	9.6	9.6	9.7	9.5	9.6	9.7	0.1	0.1
8-Nov	6.7	6.7	8.8	8.9	9.0	7.2	9.2	9.3	0.4	0.0
15-Nov	5.1	4.9	7.8	7.9	8.0	5.2	8.0	8.0	0.1	0.0
Nov	**7.7**	**7.5**	**9.1**	**9.1**	**9.2**	**8.0**	**9.3**	**9.3**	0.3	0.1
Mean Difference									0.5	0.1
Max Cooling Difference									-0.1	0.0
Max Warming Difference									***1.4***	0.4

a. Positive values indicate warming; negative values indicate cooling. Values in ***bold italic*** face indicate the difference in weekly mean temperatures exceeded ±0.56°C (1°F).

"–"indicates no data.

"*" indicates incomplete data available due to late deployment.

5.5 2015 Compliance with State Water Quality Standards

The border between New Hampshire and Vermont is the low-water mark on the western side of the Connecticut River as it existed before the creation of reservoirs on the river. Because discharges from project facilities occur in both states, the projects are subject to the water quality standards of both states.

5.5.1 New Hampshire Water Quality Standards

Applicable New Hampshire surface water quality standards and designated uses for Class B waters are presented in Table 4.3-1. Temperature, DO, and turbidity varied both temporally and spatially, but no observations were made of either parameter that would interfere with the specified designated uses of the Connecticut River, or were in noncompliance with applicable surface water quality standards. Turbidity did exceed 10 NTU, but the measurements of turbidity greater than 10 NTU were only made during high-flow periods during and following precipitation events (e.g., Figures F-72, F-76, and F-80 in Appendix F). The continuous and vertical profile turbidity data collected at all mainstem monitoring stations indicate that turbidity would most likely comply with NH surface water quality standard of 10 NTU beyond upstream waters under normal project operations. Further, TransCanada only passes inflows from receiving waters through the projects, which are at times turbid on their own. TransCanada does not ‘discharge’ a ‘pollutant’ as defined in 40 CFR §122.2. The sporadic turbidity spikes observed in the time-series for each station that do not appear to be related to inflow and precipitation are likely due to debris and vegetation caught in the instrument and drifting in front of the turbidity optics.

Concentrations of TN and TP indicate the waters of the forebay stations are oligotrophic to mesotrophic. Even when the maximum TN and TP concentrations were observed, there appeared to be no visual impairment, such as algal blooms, or measurable effects of depleted DO levels as a result of aerobic respiration from decomposing organic materials. There is no surface water quality standard for specific conductivity.

The only water quality parameter that exceeded NH surface water quality standards on occasion was pH. Table 5.5.1-1 presents the frequency of NH water quality standard pH exceedances (> 8.0 s.u.). pH was exceeded infrequently at the Wilder forebay (06-W-01) and Vernon forebay (06-V-01) stations. pH was most frequently above the NH surface water quality standard during the months of August and September at the Bellows Falls upstream (06-BF-04) and impoundment stations (06-BF-03, 06-BF-02, and 06-BF-01). Most of these exceedances occurred during the high temperature low-flow monitoring period and were recorded with the continuous multiparameter sondes. Chlorophyll-*a* concentrations were elevated during this period and well-defined diel fluctuations of pH were also observed, especially at the upstream and middle impoundment stations where most of the exceedances were observed (Tables 5.2.2-7, 5.2.3-8, 5.2.4-7; Appendix J). This suggests that elevated levels of pH are related to photosynthesis of algae and aquatic vegetation. However, at the upstream and upper impoundment stations where diurnal fluctuations in pH were observed characteristic of increase photosynthetic activity, depths are fairly shallow and water velocities are higher than at the middle impoundment, forebay and tailrace stations. Further, all three projects operate as daily run-of-river projects and do not store most inflow for longer than a day. Most of the exceedances were observed within the Bellows Falls study area, which is approximately 29 RM in length and includes the 26-mile impoundment and the upstream monitoring station. The impoundment itself has a total gross storage capacity of 26,900 acre-ft, and a surface area of 2,804 acres, and it takes water approximately 9 hours to travel from Wilder dam to Bellows Falls dam. By comparison, the Wilder study area is approximately 46 RM in length and includes the impoundment and the upstream monitoring station. The impoundment has a total gross storage capacity of 34,600 acre-ft, and a surface area of 3,100 acres, and it also takes water approximately 8 hours to travel from Woodsville NH (upstream of station 06-W-04) to Wilder dam. Even though the storage volume is 29 percent larger in the Wilder impoundment than in the Bellows Falls impoundment, and the travel time is similar compared to Bellows Falls, there were no exceedances in Wilder (after rounding to a single digit as in state water quality standards; Table 5.5.1-1). Further, the pH time-series during the high temperature low-flow period shows similar pH levels and patterns at the station upstream of Bellows Falls (06-BF-04) and the upper and mid-impoundment stations (06-BF-03 and 06-BF-02) (Figures F-54 and F-55 in Appendix F). Therefore, water residence time in the impoundments is not considered to be a factor in pH exceedances observed in the study area.

Table 5.5.1-1. NH pH surface water quality standard exceedances[a].

Station	July			August			September		
	N[b]	Min	Max	N[b]	Min	Max	N[b]	Min	Max
Wilder									
06-W-04	0	--	--	0	--	--	0	--	--
06-W-03	0	--	--	0	--	--	0	--	--
06-W-02	0	--	--	0	--	--	0	--	--
06-W-01	0	--	--	0	--	--	1[1]	8.02	8.02
06-W-TR	0	--	--	0	--	--	0	--	--
Bellows Falls									
06-BF-04	1	8.01	8.01	72	8.01	8.27	239	8.01	8.42
06-BF-03	0	--	--	9	8.01	8.05	136	8.01	8.3
06-BF-02	0	--	--	116	8.01	8.13	459	8.01	8.56
06-BF-01	6	8.01	8.12	2	8.03	8.08	311	8.01	8.28
06-BF-BR	94	8.01	8.07	0	--	--	0	--	--
06-BF-TR	0	--	--	0	--	--	99	8.01	8.1
Vernon									
06-V-04	0	--	--	0	--	--	9	8.01	8.06
06-V-03	0	--	--	0	--	--	3[1]	8.01	8.01
06-V-02	0	--	--	0	--	--	0	--	--
06-V-01	2	8.01	8.05	0	--	--	0	--	--
06-V-TR	0	--	--	0	--	--	0	--	--

a. Note that the NH and VT standards are based on single digits. Thus, several of the exceedances listed here would not be considered exceedances after rounding to a single digit.

b. The total number of observations from the continuously recording multiparameter sondes and instantaneous vertical profile multiparameter sondes that exceeded the NH surface water quality standard for pH.

"—"no data because no exceedances occurred.

5.5.2 Vermont Water Quality Standards

Applicable Vermont surface water quality standards for Class B waters are presented in Table 4.3-1. Dissolved oxygen and turbidity varied both temporally and spatially, but no observations were made of either parameter that would interfere with the specified designated uses of the Connecticut River or were in noncompliance with applicable surface water quality standards. Turbidity did exceed 10 NTU, but the measurements of turbidity greater than 10 NTU were only made during high-flow periods following precipitation events and higher flows (e.g., Figures F-72, F-76, and F-80 in Appendix F). Under lower flows and normal project operations conditions, Turbidity within the study area did not exceed the VT surface water quality standard. Concentrations of TN and TP indicate the waters of the forebay stations are generally oligotrophic to mesotrophic. Even when the maximum TN and TP concentrations were observed there appeared to be no visual impairment, such as algal blooms, or measurable effects of depleted DO levels as a result of aerobic respiration from decomposing organic materials.

The surface water quality standard for water temperature states the change or rate of change either upward or downward shall not exceed 1.0°F (0.56°C) from ambient temperatures. For this analysis, ambient temperatures were considered those measurements collected at the upstream stations (06-W-04, 06-BF-04, and 06-V-04) and were used to assess the effect and degree of temperature change as water flows through the impoundment and powerhouses, and is discharged at the tailraces. It is noted that the entire study area spans approximately 120 RM and the distance water travels from the upstream riverine monitoring stations to the Wilder, Bellows Falls, and Vernon tailraces are approximately 46, 29, and 30 RM, respectively. Throughout the study, upstream station water temperatures were generally cooler and exhibited larger daily fluctuations in temperature than middle impoundment, forebay, and tailrace stations (Appendix F). However, upstream riverine station water temperatures occasionally were greater than or similar to middle impoundment, forebay, and tailrace station water temperatures, with daily maximum temperatures being similar to daily maximum temperatures among downstream stations (see Section 5.2 Monitoring Results). An examination of air temperatures and precipitation presented in Appendix B, along with the continuous temperature data in Appendix P demonstrates that air temperature also generally increases from north to south, and upstream riverine stations respond more quickly to changes in air temperature than impoundment and tailrace stations. This resulted in upstream riverine stations exhibiting temperatures that were more than 0.56°C higher or lower to temperatures of downstream stations, which suggests that the magnitude of north to south warming or cooling between upstream riverine stations and downstream stations is largely dependent on prevailing air temperatures and how quickly air temperatures change or remain consistent (Appendix P). Latitudinal warming is also reflected by the water temperature difference between the northern and southern tributaries (Figure 5.2.1-1). Furthermore, because the range of upstream station water temperatures over the duration of the study was similar to the range of water temperatures observed downstream, applicable designated uses would be supported throughout the project areas (Tables 5.2.2-1, 5.2.3-1, and 5.2.4-1).

The observed pH values never fell below the VT surface water quality standard lower limit of 6.5 at any station. pH was observed to exceed the upper VT surface water quality standard of 8.5 s.u. on September 7 and September 8, 2015 at the Bellows Falls middle impoundment station (06-BF-02). Specifically, on September 7 the highest pH value was 8.56 for a few hours in late afternoon; on September 8, the highest pH value was 8.55. Thus, on both days the pH barely exceeded the Vermont standard, considering rounding to a single digit. These exceedances were measured by the continuous sonde deployed at the station during the high temperature low-flow monitoring period. At that time, chlorophyll-*a* concentrations were elevated and well-defined diel fluctuations of DO and pH were also observed (Tables 5.2.2-7, 5.2.3-8, 5.2.4-7;Appendix J). This suggests that elevated levels of pH are due to causes related to photosynthesis of algae and aquatic vegetation. Residence times in the impoundments are not considered the primary cause for pH exceedances for reasons discussed in Section 5.5.1 above.

5.6 Comparison of 2015 Results to 2012 Water Quality Study Results

In 2012, TransCanada conducted a baseline water quality study on the Connecticut River at the Wilder, Bellows Falls, and Vernon hydroelectric projects (Normandeau, 2013). The 2012 study shared identical sampling stations and similar data collection methodologies as this study; however, the 2015 study also included tributaries, stations upstream of the impoundments, and an intensive high temperature low-flow monitoring period monitoring components. The 2012 baseline water quality data are presented in Appendix L and the weather conditions during the 2012 study are presented in Appendix M. Figure 5.6-1 presents the hydrographs for the common study period, which show that mean daily flows were higher through mid-August in 2015 than in 2012, while from mid-August through September mean daily flows were generally similar between the two years.

Over the common study period of June through September both studies identified that water temperatures were observed to increase to their greatest in mid- to late summer before decreasing in the fall. In addition, both studies determined that water temperatures increased from upstream to downstream. Overall mean 2012 water temperatures were warmer than water temperatures measured in 2015. In 2012, water temperatures generally ranged from approximately 20 to 30°C, whereas in 2015 water temperatures ranged approximately 13 to 27°C. The relatively cooler temperatures observed in 2015 were likely due to the heavy rains and high flows that occurred throughout June, which mixed and cooled the river by approximately 5°C before warming through July. In addition, both the 2012 and 2015 continuous water temperature data indicate that project effects associated with periods of high generation discharges and minimum flows on water temperatures are relatively indistinguishable from normal diurnal fluctuations, such that peaks in temperature of upstream riverine stations and Bellows Falls bypassed reach coincide with peaks in temperature of impoundment and tailrace stations (e.g., Figure L-7 in Appendix L and Figure F-12 in Appendix F).

Dissolved oxygen followed a similar temporal pattern in 2012 and in 2015. In both studies, DO concentrations in June were higher than in September, and DO was observed to generally decrease from upstream to downstream. Mean DO concentrations were slightly lower in 2012 than in 2015. Tables 5.6-1, 5.6-2, 5.6-3, and 5.6-4 present the 2012 and 2015 results for common continuous monitoring stations, and common impoundment stations. The mean DO concentrations in 2012 at the continuous monitoring stations ranged from 7.6 to 8.8 mg/L and mean profile DO concentrations ranged from 7.7 to 8.5 mg/L. In 2015, mean DO concentrations at the same continuous monitoring stations ranged from 8.1 to 9.0 mg/L and mean profile DO ranged 8.2 to 9.2 mg/L. The overall lower mean DO concentrations observed in 2012 were likely caused by warmer water temperatures and lower DO observed in the hypolimnion during instances of stratification. For example, stratification was observed in the Bellows Falls forebay in 2012 in mid-July with low DO observed in the hypolimnion; weak stratification was observed in the Wilder forebay, which did not result low DO concentrations. Furthermore, DO concentrations in the tailrace during 2012 and 2015 decreased when projects began discharging higher generation flows; DO concentrations increased when discharges decreased again to minimum flows. This decrease was likely caused by slightly lower DO water being drawn from the water column during generation and a lower percentage of water being oxygenated compared to minimum flow operations (Appendix L; Appendix F). Specific conductivity and pH levels encompassed similar ranges between the 2012 and the 2015 studies (Tables 5.6-1, 5.6-2, 5.6-3, and 5.6-4; Appendix L and Appendix F). Specific conductivity was also observed to generally increase through the Wilder impoundment toward Wilder dam, but was fairly consistent through the Bellows Falls and Vernon impoundments. In addition, both studies found that specific conductivity was lower for the Wilder stations and highest for Bellows Falls stations. In 2012, pH was consistently lower at upper impoundment stations, but in 2015, pH was either similar among stations or exhibited a slight decrease from upstream to downstream stations. No stratification of specific conductivity or pH were observed in 2012 or 2015. In contrast, the 2012 study detected only a slight decreasing trend in chlorophyll-*a* concentrations throughout the study period, whereas in 2015, chlorophyll-*a* concentration generally increased throughout the study period.

In 2012, DO levels at the Wilder and Bellows Falls forebays fell below VT and NH state surface water quality standards briefly during a period of high temperature and low flows. Within the Wilder forebay DO levels fell below the VT state surface water quality standard briefly the morning of August 12, 2012 when concentrations ranged from 5.66 to 5.96 mg/L and 69.3 percent saturation, but never fell below NH state surface water quality standards (Appendix L). Similarly, DO levels within the Bellows Falls forebay and bypassed reach exceeded VT surface water quality standard when DO concentrations briefly fell to 5.97 mg/L on July 16, 2012 and 5.94 mg/L on July 23, 2012, respectively (Appendix L). As measured by vertical profiles, DO levels in the Bellows Falls forebay were below state surface water quality standards and ranged between 5.9 mg/L (71 percent saturation) to 3.3 mg/L (39 percent saturation) at depths of 8 to 11.7 m on July 18, 2012. These observations coincided with periods of stratification during high water temperature and low flow and were brief in duration (observed only on one day on July 18, 2012); the water was re-oxygenated during discharge through the powerhouses and no exceedances in DO surface water quality standards were observed in the project tailraces. In 2015, DO levels never fell below VT or NH state surface water quality standards at any station.

pH values in 2012 were observed to fall below the VT and NH state surface water quality standard at the Wilder impoundment stations and rise above the VT and NH state surface water quality standard at the Bellows Falls forebay, bypassed reach and tailrace stations, and the Vernon forebay On June 26, 2012, vertical profile pH was measured at the Wilder middle (06-W-02) and upper impoundment (06-W-03) stations to be 6.4, and 5.7 to 6.1 s.u., respectively. On July 10, 2012, profile pH fell below both VT and NH surface water quality standards and ranged from 5.8 to 6.0 s.u. at the Wilder upper impoundment station. The continuous pH data for the Bellows Falls forebay, bypassed reach, and tailrace indicated exceedances of the VT and NH upper state surface water quality standard which occurred throughout the study duration (BF-01, n=337, range = 8.01 to 8.53 s.u.; BF-BR, n=35 range = 8.01 to 8.06 s.u.; BF-TR n=72 range = 8.01 to 8.16 s.u.; Appendix L). Within the Vernon forebay, pH was observed to exceed the upper NH standard briefly on June 21 (exceedance range 8.01 to 8.04 s.u.; Appendix L). In 2015, pH at the Bellows

Falls bypassed reach and forebay stations and Vernon forebay station were observed to rise above the NH state water quality standard during several instances in July, but pH most frequently exceeded the NH surface water quality standard during the high temperature low-flow monitoring period in late August and September at the three projects (Table 5.5.1-1). Only during the high temperature low-flow monitoring period did pH exceed the VT surface water quality standard for pH at the Bellows Falls middle impoundment station.

Table 5.6-1. Summary statistic comparison among the continuous water quality monitoring stations for the 2012 and 2015 water quality studies over the common study period of June through September.

Statistic	**Temperature (°C)**		**Dissolved Oxygen (mg/L)**		**Dissolved Oxygen (% saturation)**		**Specific Conductivity (µS/cm)**		**pH (s.u)**	
	2012	**2015**	**2012**	**2015**	**2012**	**2015**	**2012**	**2015**	**2012**	**2015**
06-W-01										
Max	26.5	25.8	9.7	10.2	119	111	132	163	7.8	8.0
Min	21.1	13.4	5.7	6.6	69	78	88	69	7.0	7.2
Median	24.1	21.7	7.6	8.1	91	92	109	114	7.2	7.4
Mean	24.0	20.8	7.6	8.3	92	92	110	111	7.2	7.4
06-W-TR										
Max	25.4	25.1	9.3	9.8	110	106	134	161	7.7	7.7
Min	19.2	16.3	6.5	6.9	76	81	80	70	7.1	7.2
Median	23.6	22.1	7.3	8.0	87	91	109	116	7.3	7.4
Mean	23.2	21.5	7.5	8.1	89	92	109	115	7.3	7.4
06-BF-01										
Max	27.0	26.1	10.3	10.0	124	115	168	176	8.5	8.3
Min	21.3	14.8	5.9	7.1	73	84	114	78	7.2	7.4
Median	24.9	22.7	7.9	8.5	96	98	142	141	7.7	7.7
Mean	24.7	21.9	7.8	8.5	95	97	142	133	7.7	7.7
06-BF-BR										
Max	27.2	25.72	9.7	10.3	121	108	167	174	8.1	8.1
Min	20.9	16.9	6.0	8.0	74	97	115	51	7.5	7.5
Median	25.0	22.9	8.5	8.7	103	101	144	143	7.7	7.7
Mean	24.8	22.3	8.5	8.9	104	102	143	137	7.7	7.7
06-BF-TR										
Max	26.3	25.7	10.7	10.7	130	118	170	175	8.2	8.1
Min	20.8	16.9	6.5	7.2	79	85	111	77	6.9	7.2
Median	24.2	23.0	8.9	9.1	106	103	141	140	7.4	7.7
Mean	24.0	22.2	8.8	9.0	106	103	141	133	7.4	7.7
06-V-01										
Max	29.3	27.2	9.1	10.0	115	120	162	170	7.8	8.1
Min	22.9	15.5	6.3	6.9	81	82	115	80	7.1	7.3
Median	26.7	23.5	7.9	8.3	98	96	143	139	7.4	7.5
Mean	26.6	22.5	7.8	8.3	98	96	142	131	7.4	7.5
06-V-TR										
Max	28.6	26.4	9.8	10.1	118	111	163	170	8.0	7.9
Min	22.8	17.4	7.4	7.3	94	86	116	81	7.2	7.4
Median	26.4	23.8	8.7	8.6	107	102	142	142	7.6	7.5
Mean	26.1	22.7	8.7	8.7	108	101	141	134	7.6	7.6

Table 5.6-2. Summary statistic comparison among vertical water quality profiles collected at the Wilder impoundment stations for the 2012 and 2015 water quality studies over the common study period of June through September.

Statistic	06-W-03		06-W-02		06-W-01	
	2012	2015	2012	2015	2012	2015
Temperature (°C)						
Max	22.6	22.2	25.1	25.7	26.0	24.7
Min	17.3	14.5	19.8	14.2	19.8	13.4
Median	20.9	19.9	21.9	20.9	23.4	20.7
Mean	20.4	19.2	21.9	20.3	22.7	20.4
Dissolved Oxygen (mg/L)						
Max	9.1	10.4	8.8	10.3	9.0	10.2
Min	7.9	8.0	7.4	7.5	6.0	7.2
Median	8.7	8.9	7.9	8.1	7.8	8.0
Mean	8.5	8.9	8.1	8.5	7.7	8.2
Dissolved Oxygen (% saturation)						
Max	104	102	104	100	109	101
Min	90	91	87	88	72	82
Median	95	96	93	93	90	90
Mean	96	97	93	93	91	91
Specific Conductivity (µS/cm)						
Max	106	121	141	126	137	139
Min	88	63	81	68	85	74
Median	93	95	95	106	103	111
Mean	94	93	100	104	108	109
pH (s.u)						
Max	7.7	7.5	7.6	7.5	7.5	7.5
Min	5.7	7.2	6.4	7.3	6.6	7.2
Median	7.0	7.3	7.2	7.4	7.2	7.4
Mean	6.9	7.4	7.2	7.5	7.1	7.4

Table 5.6-3. Summary statistic comparison among vertical water quality profiles collected at the Bellows Falls impoundment stations for the 2012 and 2015 water quality studies over the common study period of June through September.

Statistic	06-BF-03		06-BF-02		06-BF-01	
	2012	2015	2012	2015	2012	2015
Temperature (°C)						
Max	24.7	24.4	25.6	27.4	26.5	25.5
Min	18.7	15.1	19.4	14.8	21.0	14.7
Median	22.5	22.0	23.6	21.9	24.1	21.8
Mean	22.4	20.7	23.1	21.2	23.7	21.4
Dissolved Oxygen (mg/L)						
Max	9.3	10.1	9.4	10.1	10.6	10.0
Min	7.4	7.9	7.1	7.9	3.3	7.1
Median	8.1	9.0	8.1	8.9	8.2	8.3
Mean	8.2	9.0	8.3	8.9	8.0	8.4
Dissolved Oxygen (% saturation)						
Max	103	107	105	117	122	111
Min	89	92	87	91	40	85
Median	95	101	98	99	96	96
Mean	96	100	98	100	95	95
Specific Conductivity (µS/cm)						
Max	183	182	165	172	162	160
Min	107	58	111	62	118	87
Median	132	149	136	129	141	135
Mean	133	139	136	131	142	130
pH (s.u)						
Max	7.8	8.1	7.8	8.4	7.7	8.0
Min	6.1	7.5	6.9	7.4	6.5	7.4
Median	7.2	7.7	7.6	7.7	7.5	7.6
Mean	7.2	7.7	7.5	7.7	7.4	7.6

Table 5.6-4. Summary statistic comparison among vertical water quality profiles collected at the Bellows Falls impoundment stations for the 2012 and 2015 water quality studies over the common study period of June through September.

Statistic	06-V-03		06-V-02		06-V-01	
	2012	2015	2012	2015	2012	2015
Temperature (°C)						
Max	25.1	25.4	27.4	25.9	28.3	26.3
Min	20.2	16.1	21.4	16.3	21.7	15.4
Median	23.8	22.3	24.6	23.1	25.3	23.7
Mean	23.6	21.3	24.2	21.7	24.9	21.8
Dissolved Oxygen (mg/L)						
Max	10.2	10.3	9.8	10.0	9.6	9.9
Min	7.2	7.6	7.0	7.4	6.4	7.1
Median	8.6	9.3	8.2	8.4	7.9	8.3
Mean	8.5	9.2	8.1	8.6	7.9	8.4
Dissolved Oxygen (% saturation)						
Max	121	114	116	106	117	105
Min	89	88	87	87	80	85
Median	100	104	97	98	97	97
Mean	102	103	98	98	97	95
Specific Conductivity (µS/cm)						
Max	161	162	164	157	158	157
Min	122	60	113	95	123	84
Median	146	130	138	128	141	131
Mean	143	126	139	126	141	127
pH (s.u)						
Max	7.6	8.0	7.6	7.7	7.9	7.7
Min	6.6	7.5	7.1	7.4	6.7	7.3
Median	7.2	7.6	7.4	7.5	7.3	7.5
Mean	7.2	7.6	7.4	7.5	7.3	7.5

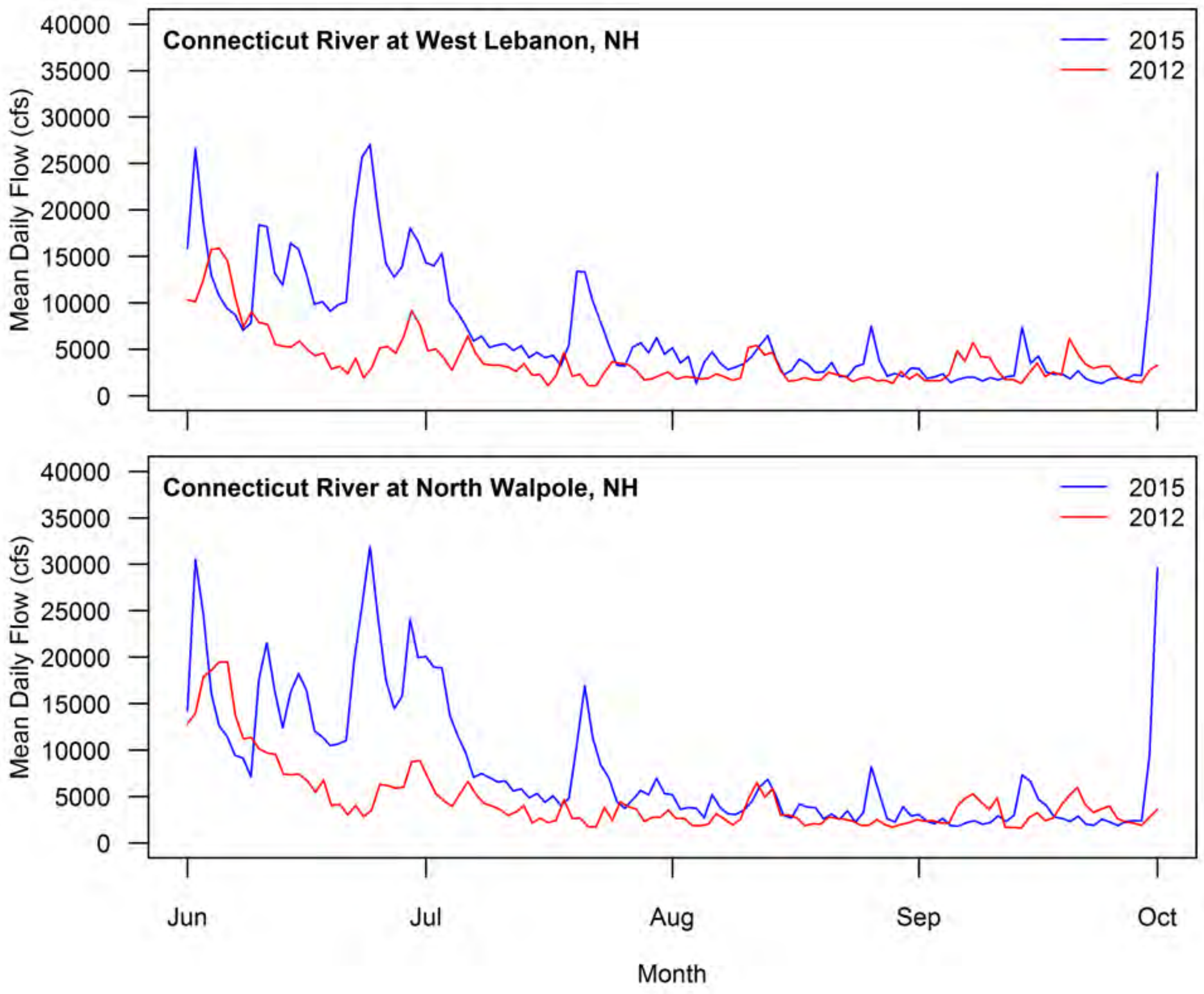


Figure 5.6-1. Mean daily flow (cfs) at the USGS West Lebanon, NH (01144500), and USGS North Walpole, NH (01154500) stream flow gages during the 2012 and 2015 water quality monitoring studies over the common study period of June through September.

6.0 ASSESSMENT OF PROJECT EFFECTS

Evaluation of project effects on water quality within the study area was investigated by deploying continuous temperature loggers, continuous water quality multiparameter sondes, collecting instantaneous vertical profiles and nutrient and chlorophyll-*a* water column composite samples. Collectively, these data facilitated both quantitative and qualitative assessments of how the water quality parameters of interest vary temporally and spatially. Assessment of project effects examined how water quality varied spatially as waters flow from upstream areas, through the project impoundments, and then discharged at the project tailraces. In addition, the assessment of project effects examined how water quality varied temporally in response to varying flows at the project tailraces due to varying generation levels.

The overall pattern and trend of waters increasing in temperature as they flow from upstream areas and through the impoundments demonstrate the impoundments have some effect on water temperature. However, it is unclear how the magnitude of warming temperatures may be attributed to effects of the impoundment, effects of latitude, weather, or tributary contributions. For example, the continuous mainstem temperature data show that upstream riverine stations respond more quickly to changes in air temperature than do lower impoundment and tailrace stations, which results in downstream impoundment and tailrace stations to either be warmer or cooler relative to upstream riverine stations (Appendix P). Further, when air temperatures are consistent for a long period of time or gradually warm and cool, mainstem water temperatures become similar. This, coupled with general north to south increases in air temperature and tributary water temperatures effects, suggests that the north to south warming observed over the approximate120 river mile study area is strongly influenced by weather and latitude, and tributary contributions than by project impoundments.

DO was also observed to generally decrease as waters flow from upstream areas through the impoundments. Dissolved oxygen concentrations likely follow this pattern because of shallower depths and greater atmospheric mixing at the upstream and upper impoundment areas than the deeper middle impoundment and forebay stations. In addition, an indirect effect of the impoundments was the surface warming and very weak stratification at the forebay (06-W-01, 06-BF-01, and 06-V-01) and middle impoundments stations (06-W-02, 06-BF-02, and 06-V-02). The occurrences of mild surface warming from late July into September and the single event of weak stratification on July 29 at the Bellows Fall middle impoundment station occurred during short periods when the weather was fairly calm and temperatures were hot; these occurrences were not observed in subsequent sampling events. Several large rain events through June and one in mid-July resulted in spill conditions at the three projects, which likely mixed the water column.

The continuous water temperature loggers and continuous water quality multiparameter sondes deployed in the forebays and tailraces allows for the assessment of project effects on water quality as water is passed through the powerhouses for generation and is discharged into the tailraces. Overall mean water temperatures were generally very similar among forebay and tailrace stations and differences varied between -0.31 and 0.10°C (Tables 5.2.2-1, 5.2.3-1, 5.2.4-1). Over the duration of the study, any effect of generation levels on water temperature was generally indistinguishable from the daily water temperature fluctuations (e.g., Figure L-7 in Appendix L and Figure F-12 in Appendix F). However, during the high temperature low-flow monitoring period, water temperatures in the tailraces generally increased very slightly during higher generation flows. When only minimum flows were being passed, water temperatures in the tailraces decreased very slightly (Figure 6.0-1).

Within the project impoundments in a given day WSE at the dams exhibited either a single maximum and minimum level, multiple maxima and minima, or relatively no change (Appendix O). Although the data indicates water temperature fluctuates over the course of each day as does WSE, inflow and discharge, water temperatures in the impoundments during the study period did not correlate well with WSE fluctuations measured at the dams. Water temperatures in the impoundments consistently exhibited diurnal fluctuations regardless of WSE fluctuations or lack thereof (either single or multiple daily maxima or minima or relatively no change for a given day). This is most notable at the upstream and upper impoundment stations. At the middle impoundment and forebay stations diurnal fluctuations in water temperature were comparatively small but also did not appear to respond to changes in WSE. When WSE did not fluctuate, water temperatures at all stations exhibited similar patterns to periods when WSE fluctuated. This suggests WSE fluctuations have a negligible effect on water temperature throughout the study area and that water temperature patterns are driven by factors other than project operations, such as weather and longitudinal effects.

Overall, mean DO levels were slightly lower in the Bellows Falls and Vernon forebays than in the tailraces, but slightly higher in the Wilder forebay than at the tailrace. The overall mean decreases in DO levels between the Wilder forebay and tailrace were 0.2 mg/L and 0.2 percent saturation (Tables 5.2.2-4 and 5.2.2-5). In contrast, DO levels increased on average by 0.5 mg/L and 6.0 percent saturation as water travelled from the Bellows Falls forebay through the powerhouse to the tailrace (Table 5.2.3-4 and 5.2.3-6). Similar increases in overall mean DO levels (0.4 mg/L, 5.2% saturation) were observed from the Vernon forebay to the tailrace (Tables 5.2.4-4 and 5.2.4-5). During periods of high generation flows and no spill, DO levels abruptly decreased coincident with increasing discharge, but also abruptly increased when discharges decreased quickly (Figure 6.0-2; Appendix F). This effect was observed in the tailraces of all three projects but was most prominent within the Bellows Falls tailrace where DO levels generally decreased by approximately 1.0 mg/L when discharges increased rapidly, and DO levels increased quickly by approximately 1.0 mg/L when discharges decreased (Figure 6.0-2; Appendix F). For instances in 2012 when DO levels fell below state surface water quality standards within the hypolimnion of the Wilder and Bellows Falls forebays, project discharges remained well-oxygenated even with increasing and decreasing project discharges (e.g., July 18, 2012; Figure L-18 in Appendix L). This suggests that as lower DO water is passed through the powerhouse for generation it becomes oxygenated and that designated uses are retained with continued project operation.

pH, specific conductivity, and turbidity values were very similar among forebay and tailrace stations. The overall mean difference in pH between forebay and tailrace stations was negligible: -0.02 s.u. for Wilder (Tables 5.2.2-4 and 5.2.2-5), 0.00 s.u. for Bellows Falls (Tables 5.2.3-4 and 5.2.3-6), and 0.01 s.u. for Vernon (Tables 5.2.4-4 and 5.2.4-5). Over the duration of the study, potential effects of generation on pH were generally indistinguishable from daily fluctuations similar to water temperature (Figure F-49 in Appendix F). However, very slight pH increases (0.05 to 0.1 s.u.) when discharges increased, and slight pH decreases when discharges decreased, were observed most noticeably in the Wilder tailrace during the high temperature low-flow monitoring period (Figure 6.0-3; Appendix F). The mean overall difference in specific conductivity between the Wilder, Bellows Falls, and Vernon forebay and tailrace stations was negligible, differing by 4.0, 0.0, and 3.0 µS/cm, respectively (Tables 5.2.2-4, 5.2.2-5, 5.2.3-4, 5.2.3-6, 5.2.4-4, 5.2.4-5). During high generation flows specific conductivity generally did not vary with operations (Figure 6.0-4; Appendix F). Overall mean and median turbidity value differences at all three projects were negligible between the forebay and tailrace stations, ranging between -0.6 and 0.3 NTU (forebay) and between -0.4 and 0.3 NTU (tailrace). When the three projects were generating above minimum flows, turbidity was very low in the tailrace and did not change with increasing and decreasing discharges (Figure 6.0-5; Appendix F). Sporadic turbidity spikes characteristic of single spikes with no gradual increase or decrease observed in the time-series within the tailrace station were most likely due to debris and vegetation caught in the instrument and drifting in front of the turbidity optics, based on field observations.

When flows in the Connecticut River are high and exceed each station's generating capacity and each station begins to spill water at the dams, the water column becomes uniformly mixed. The mixed water column results in similar water quality conditions observed throughout each project area.

Although the presence and operation of the projects appeared to have some minor effects on temperature and DO, and at most negligible effects on pH, specific conductivity, and turbidity, all water quality parameters were generally within VT and NH state water quality standards. Instances when upstream water temperatures were more or less than 0.56°C (1°F) of downstream impoundment and tailrace stations are a reflection of those shallow, swift areas being influenced by weather and latitude. Exceedances in pH were likely related to increased rates of photosynthesis and lower rates of respiration; exceedances were mostly observed in the Bellows Falls impoundment suggesting that they are not directly related to increased residence time. Occasional turbidity increases above 10 NTU appeared to be caused by higher flows resulting from precipitation in the project area. Overall, the data from both the 2012 and 2015 studies suggest that, irrespective of the effects of project operations, water quality for the parameters which were sampled in project-affected waters met applicable Class B VT and NH surface water quality standards for the majority of the study period and throughout the entire study area.

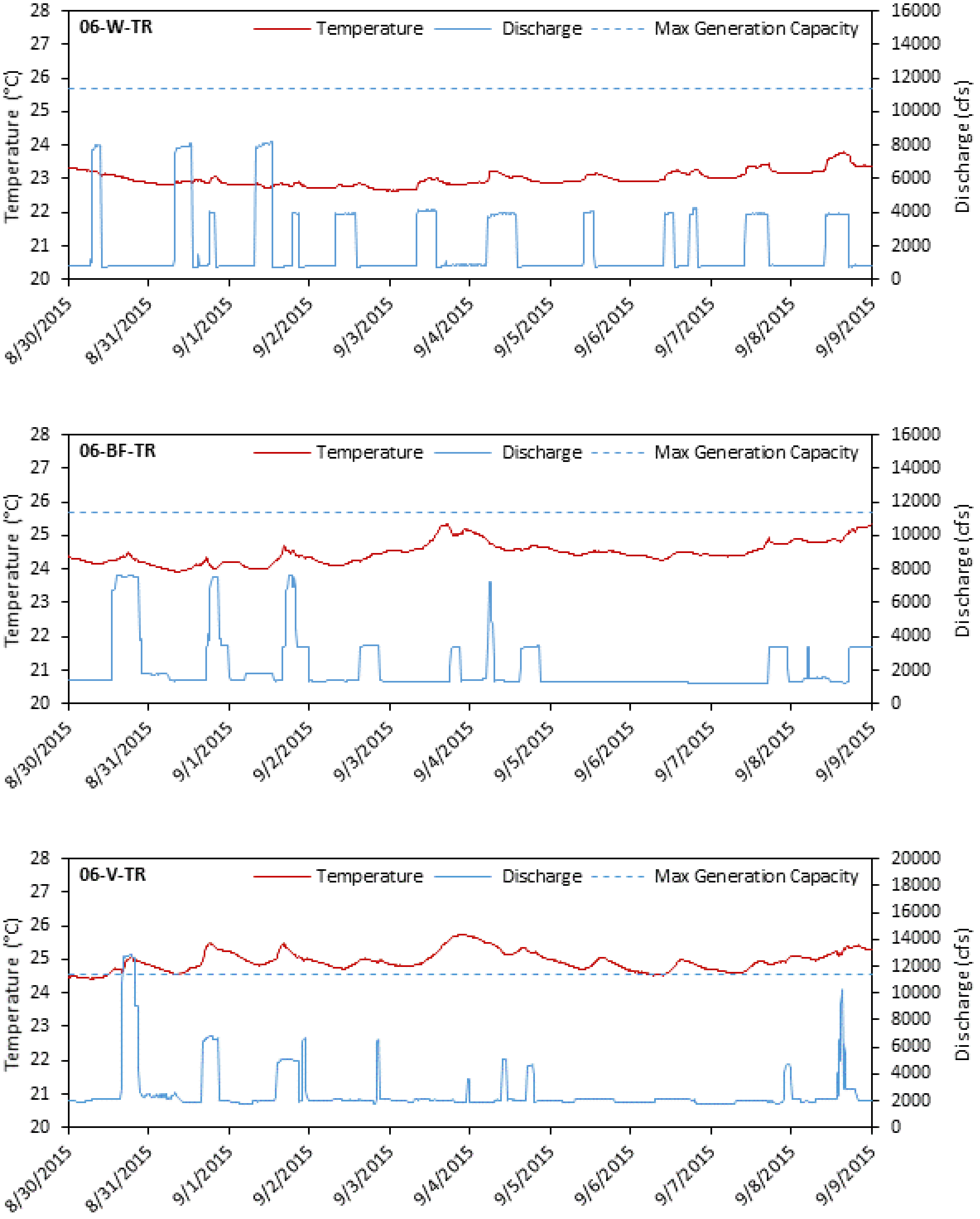


Figure 6.0-1. Tailrace water temperature (°C) in relation to project discharge at Wilder, Bellows Falls, and Vernon, 2015.

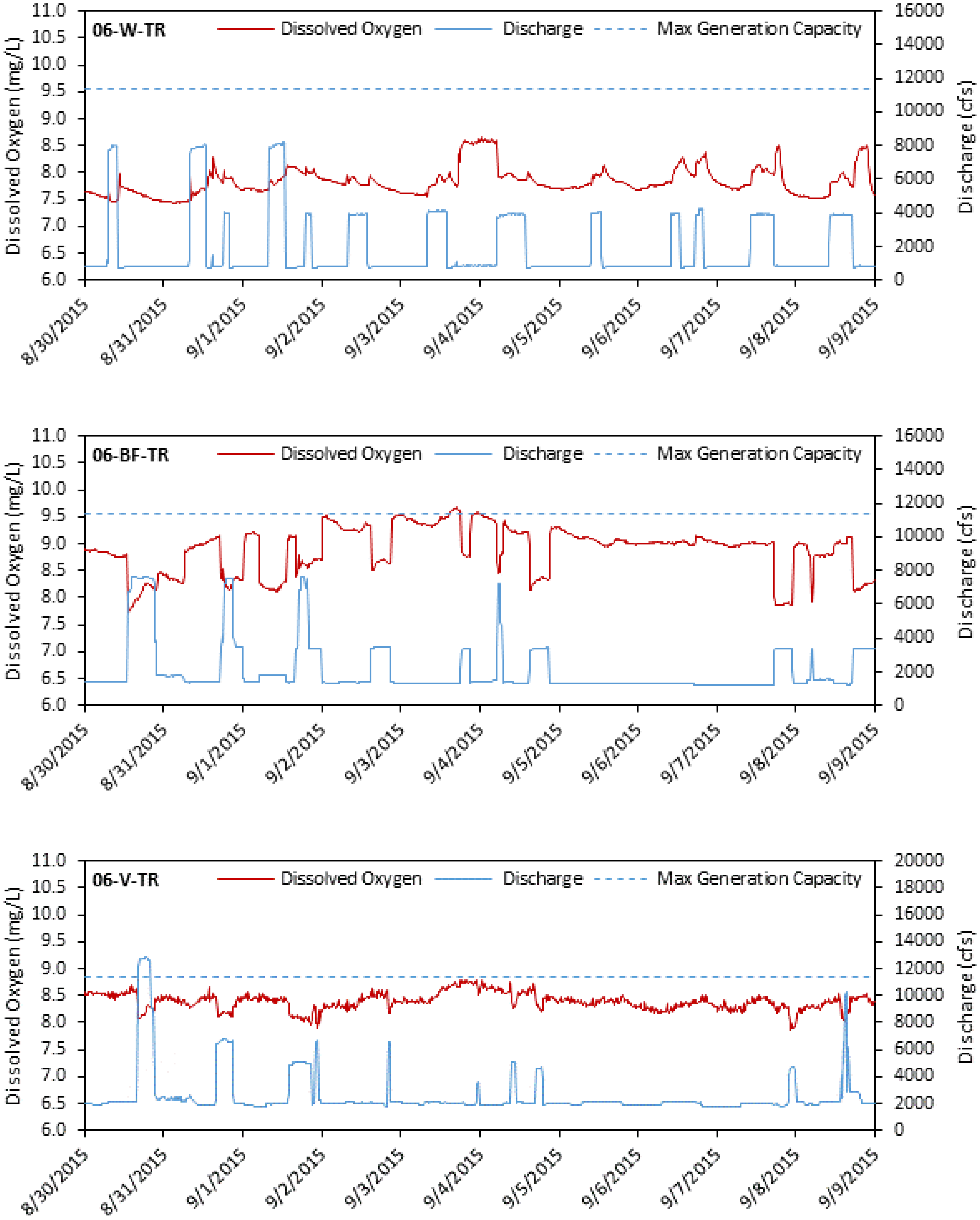
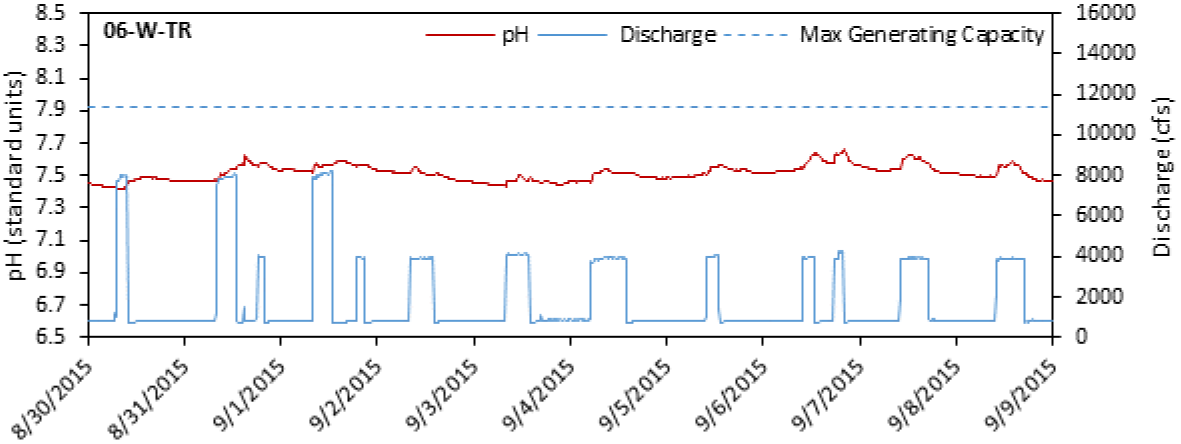
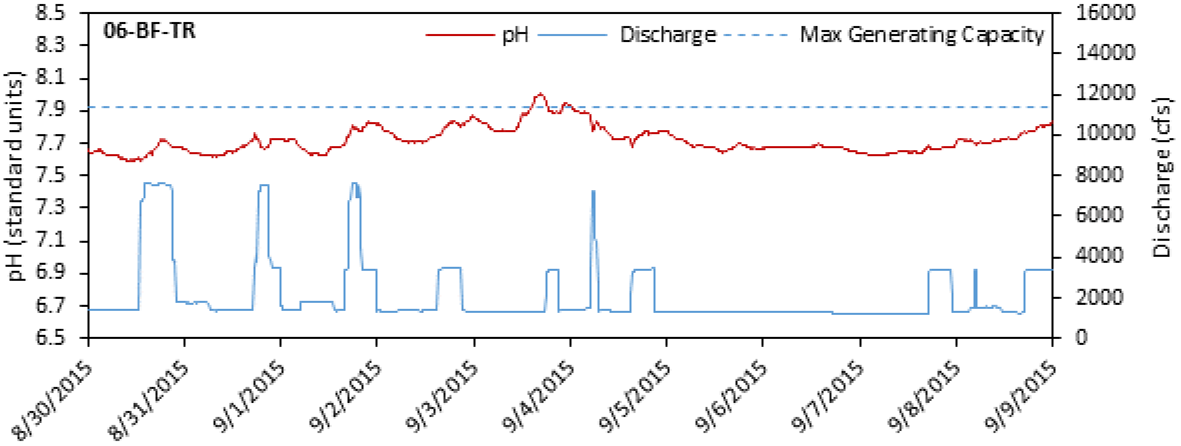


Figure 6.0-2. Tailrace dissolved oxygen (mg/L) in relation to project discharge at Wilder, Bellows Falls, and Vernon, 2015.





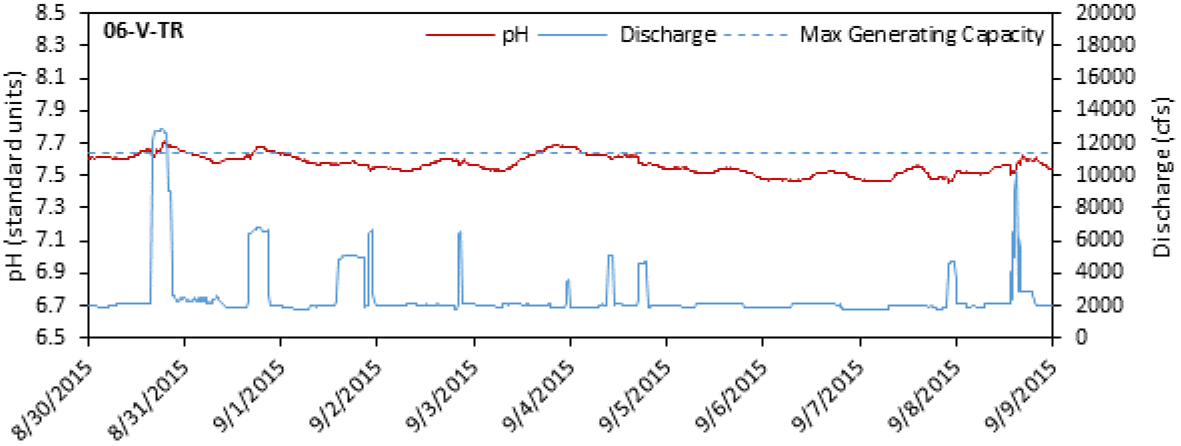


Figure 6.0-3. Tailrace pH (s.u) in relation to project discharge at Wilder, Bellows Falls, and Vernon, 2015.

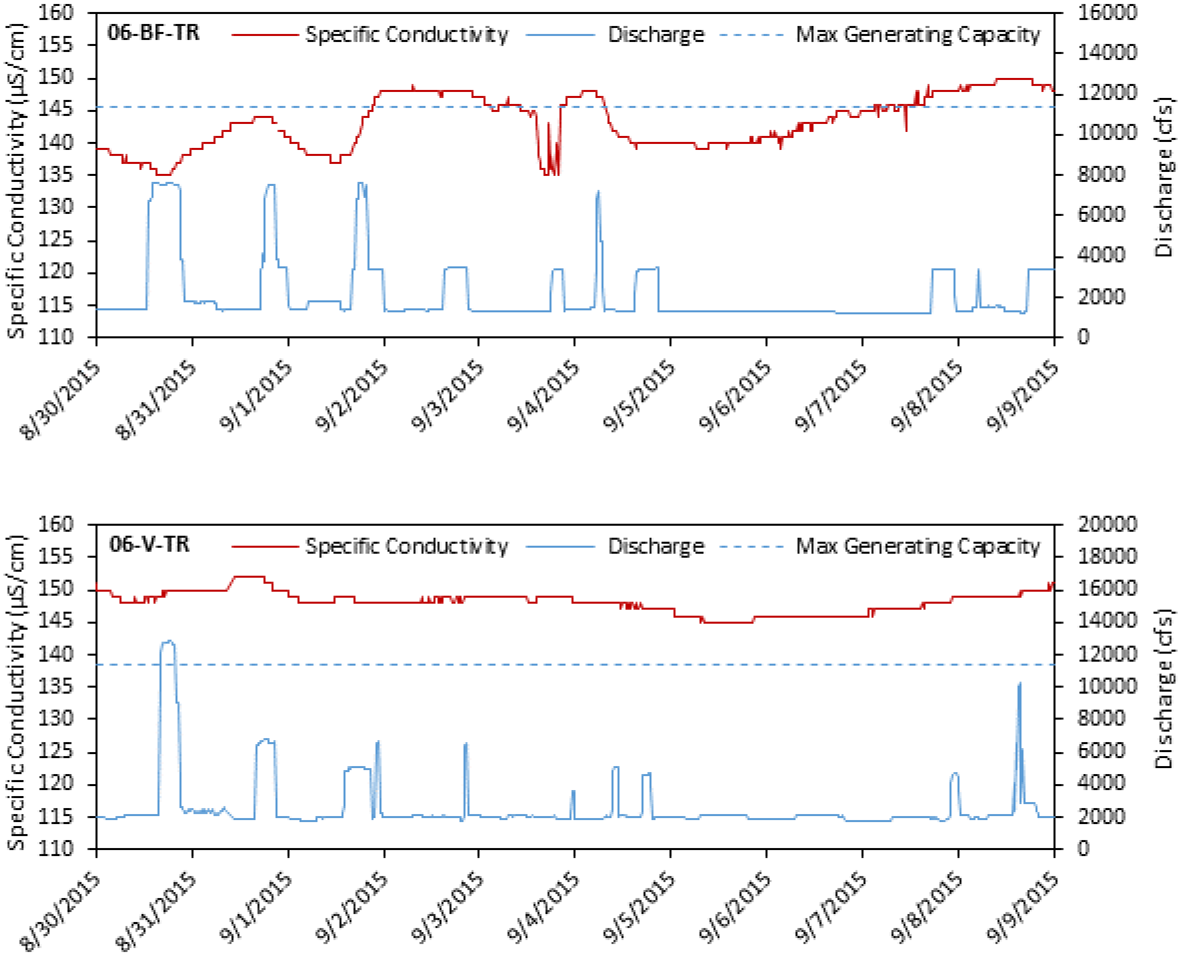


Figure 6.0-4. Tailrace specific conductivity (µS/cm) in relation to project discharge at Wilder, Bellows Falls, and Vernon, 2015.

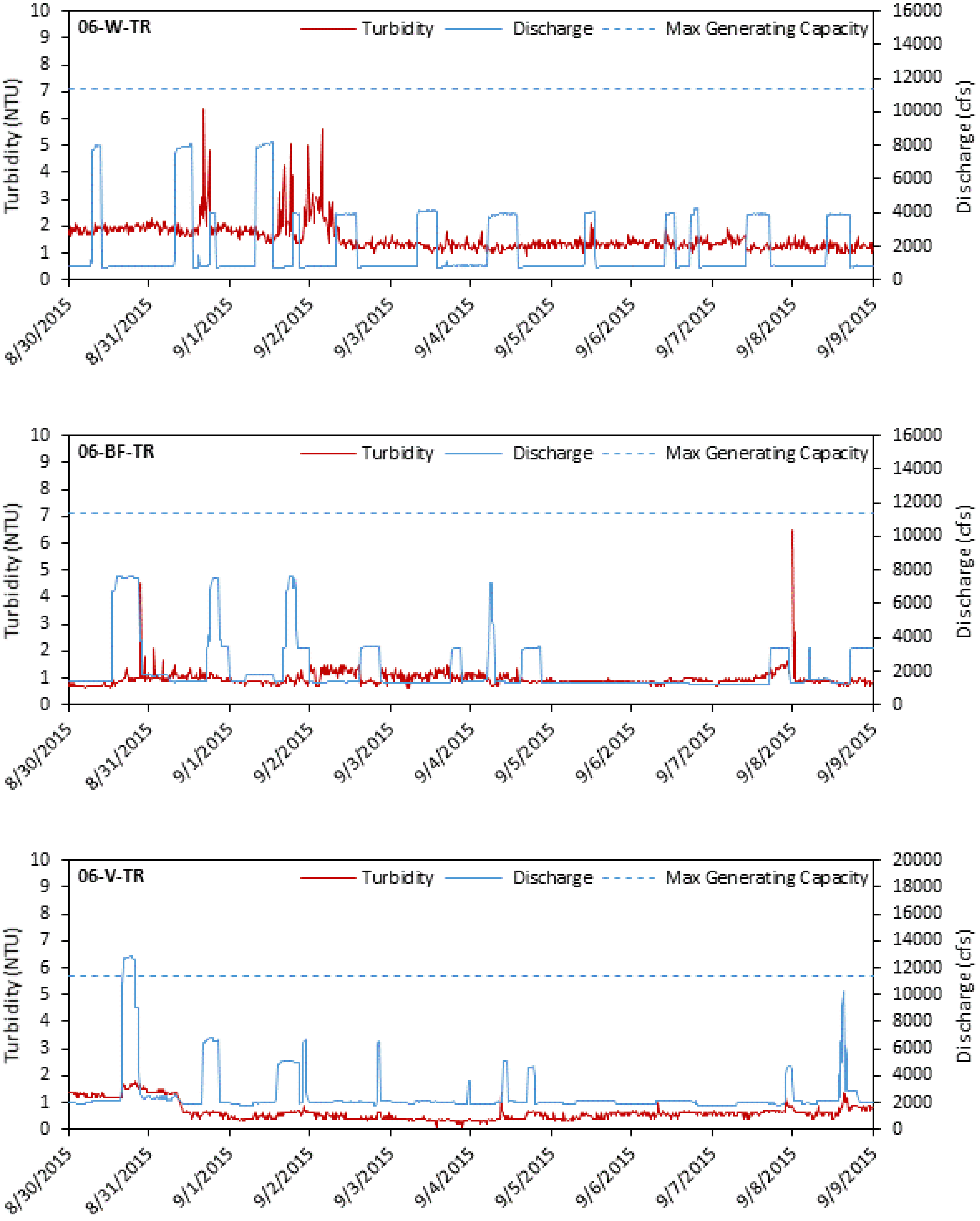


Figure 6.0-5. Tailrace turbidity (NTU) in relation to project discharge at Wilder, Bellows Falls, and Vernon, 2015.

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APPENDIX A

2015 Continuous Water Quality Data Correction Tables and Figures

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Table A-1. Data collection intervals corrected for specific conductivity (µS/cm). Note: not all intervals are presented, only the corrected intervals as requested by NHDES

Station	Correction Interval		Fouling and Drift Error (absolute)	Fouling and Drift Error (percent absolute)	Correction Factor (percent)
	Start	End			
Wilder					
06-W-04	8/21/2015 17:00	9/12/2015 12:30	13	2.08	-0.29
06-W-02	8/22/2015 19:00	9/11/2015 13:30	46	4.82	4.82
06-W-01	6/11/2015 11:00	6/19/2015 8:30	19	1.94	1.94
06-W-01	6/19/2015 10:30	6/28/2015 13:15	7	1.88	-1.88
06-W-01	7/8/2015 18:15	7/16/2015 11:00	28	2.88	2.88
06-W-01	7/16/2015 13:00	7/24/2015 9:00	25	5.99	-1.70
06-W-01	7/24/2015 11:00	7/30/2015 8:45	29	3.62	-3.62
06-W-01	7/30/2015 10:30	8/6/2015 11:45	15	2.31	0.53
06-W-01	8/6/2015 13:30	8/22/2015 11:45	8	1.54	-1.54
06-W-01	8/22/2015 13:45	8/29/2015 15:30	34	3.29	-3.29
06-W-01	8/29/2015 17:30	9/23/2015 10:45	13	1.32	1.32
06-W-01	9/23/2015 12:45	10/6/2015 9:45	26	2.53	-2.53
06-W-TR	7/8/2015 10:30	7/16/2015 8:00	22	2.25	2.25
06-W-TR	7/16/2015 8:30	7/24/2015 11:45	27	4.45	0.68
06-W-TR	7/24/2015 14:15	8/6/2015 8:30	15	2.25	-2.25
06-W-TR	8/6/2015 10:30	8/20/2015 16:00	36	3.47	-3.47
06-W-TR	8/20/2015 16:00	8/29/2015 11:45	18	4.18	-4.18
06-W-TR	8/29/2015 12:15	9/11/2015 8:45	20	2.67	1.20
06-W-TR	9/11/2015 9:00	9/23/2015 8:30	26	3.37	3.37
06-W-TR	9/23/2015 8:30	9/29/2015 8:45	28	2.72	-2.72
06-W-TR	9/29/2015 9:15	10/6/2015 8:15	32	3.10	-3.10
Bellows Falls					
06-BF-04[1]	8/20/2015 12:30	9/10/2015 13:00	28	16.15	16.15
06-BF-03	8/20/2015 9:31	9/10/2015 8:45	12	1.21	1.21
06-BF-02	8/19/2015 17:00	9/9/2015 13:30	16	1.57	-1.57
06-BF-01	6/5/2015 11:45	6/10/2015 9:45	17.0	2.48	-0.67
06-BF-01	6/10/2015 11:45	6/18/2015 10:15	62.0	6.61	6.61
06-BF-01	6/18/2015 12:00	6/29/2015 7:45	18.0	1.77	-1.77
06-BF-01	7/7/2015 15:30	7/15/2015 12:15	24.0	3.12	1.59
06-BF-01	7/15/2015 14:00	7/23/2015 11:45	26.0	3.43	3.43
06-BF-01	7/23/2015 13:45	7/29/2015 12:45	8.0	0.79	-0.79
06-BF-01	7/29/2015 7:45	8/5/2015 8:15	9.0	0.89	-0.89
06-BF-01	8/5/2015 15:15	8/12/2015 13:00	24.0	3.57	0.92
06-BF-01	8/12/2015 15:00	8/28/2015 14:00	50.0	5.33	-5.33
06-BF-01	8/28/2015 15:45	9/22/2015 11:30	11.0	1.68	1.68
06-BF-01	9/22/2015 13:45	10/5/2015 9:15	42.0	4.03	-4.03
06-BF-BR	6/18/2015 9:15	7/7/2015 10:30	13.0	1.28	-1.28
06-BF-BR	7/7/2015 11:15	7/15/2015 9:45	16.0	3.95	-1.53
06-BF-BR	7/15/2015 10:15	7/23/2015 8:15	42.0	6.60	1.52
06-BF-BR	7/23/2015 10:45	7/29/2015 10:00	37.0	6.01	-6.01
06-BF-BR	7/29/2015 10:15	8/5/2015 10:30	19.0	2.49	1.18
06-BF-BR	8/5/2015 12:30	8/12/2015 10:15	16.0	1.63	1.63
06-BF-BR	8/12/2015 12:15	8/28/2015 10:30	52.0	6.59	-6.59
06-BF-BR	9/22/2015 10:00	10/5/2015 11:45	35.0	4.33	-4.33
06-BF-TR	6/10/2015 8:15	6/27/2015 16:45	48.0	5.04	5.04
06-BF-TR	6/27/2015 17:00	7/7/2015 7:30	17.0	2.50	2.50
06-BF-TR	7/15/2015 7:45	7/22/2015 17:45	25.0	3.27	1.65
06-BF-TR	7/22/2015 19:30	7/29/2015 7:30	31.0	3.64	-3.64
06-BF-TR	7/29/2015 14:30	8/5/2015 13:30	25.0	3.13	3.13
06-BF-TR	8/12/2015 10:00	8/19/2015 7:45	61.0	5.75	-5.75
06-BF-TR	8/19/2015 8:00	8/28/2015 8:00	12.0	1.19	-1.19
06-BF-TR	8/28/2015 10:30	9/9/2015 8:00	21.0	2.15	2.15

Station	Correction Interval		Fouling and Drift Error (absolute)	Fouling and Drift Error (percent absolute)	Correction Factor (percent)
	Start	End			
06-BF-TR	9/9/2015 8:15	9/22/2015 7:45	33.0	6.40	6.40
06-BF-TR	9/22/2015 8:15	9/28/2015 7:45	6.0	0.60	-0.60
06-BF-TR	9/28/2015 8:00	10/5/2015 7:45	10.0	1.01	1.01
Vernon					
06-V-04	8/23/2015 18:00	9/14/2015 11:30	15	2.74	-0.31
06-V-03	8/23/2015 15:45	9/14/2015 9:15	8	0.81	0.81
06-V-02	8/23/2015 12:30	9/13/2015 13:30	11	1.64	0.39
06-V-01	6/6/2015 11:45	6/12/2015 10:30	56.0	5.93	5.93
06-V-01	6/12/2015 12:15	6/17/2015 11:15	6.0	0.60	0.60
06-V-01	6/17/2015 12:30	6/27/2015 11:15	11.0	1.09	-1.09
06-V-01	6/27/2015 13:00	7/9/2015 11:30	53.0	8.54	1.76
06-V-01	7/9/2015 13:30	7/17/2015 11:45	25.0	3.65	-3.65
06-V-01	7/17/2015 14:00	7/22/2015 11:30	7.0	0.70	0.70
06-V-01	7/22/2015 13:30	7/31/2015 11:30	15.0	2.13	-0.63
06-V-01	7/31/2015 13:30	8/4/2015 12:30	28.0	2.88	2.88
06-V-01	8/4/2015 14:30	8/13/2015 12:00	23.0	2.81	-1.49
06-V-01	8/13/2015 14:00	8/24/2015 13:45	13.0	1.88	-1.88
06-V-01	8/24/2015 16:00	8/31/2015 12:15	13.0	1.83	-1.83
06-V-01	8/31/2015 14:15	9/24/2015 10:15	6.0	1.16	1.16
06-V-01	9/24/2015 12:30	10/2/2015 9:00	23.0	2.85	-2.85
06-V-TR	6/12/2015 9:30	6/17/2015 8:15	17	2.76	0.49
06-V-TR	6/27/2015 8:30	7/9/2015 8:30	15	1.52	1.52
06-V-TR	7/9/2015 10:45	7/17/2015 8:45	17	2.36	0.90
06-V-TR	7/17/2015 9:00	7/22/2015 8:30	17	1.73	1.73
06-V-TR	7/22/2015 8:45	7/31/2015 8:15	29	3.63	2.13
06-V-TR	7/31/2015 10:30	8/4/2015 8:45	31	3.66	-3.66
06-V-TR	8/4/2015 11:30	8/13/2015 8:30	14	2.51	-2.51
06-V-TR	8/24/2015 10:30	8/31/2015 8:30	17	2.77	-2.77
06-V-TR	8/31/2015 10:30	9/13/2015 8:45	30	4.17	4.17
06-V-TR	9/24/2015 8:45	10/7/2015 8:00	50	5.57	-5.57

1. Applied 0.7% calibration correction only, because suspect recording error for fouling drift correction.

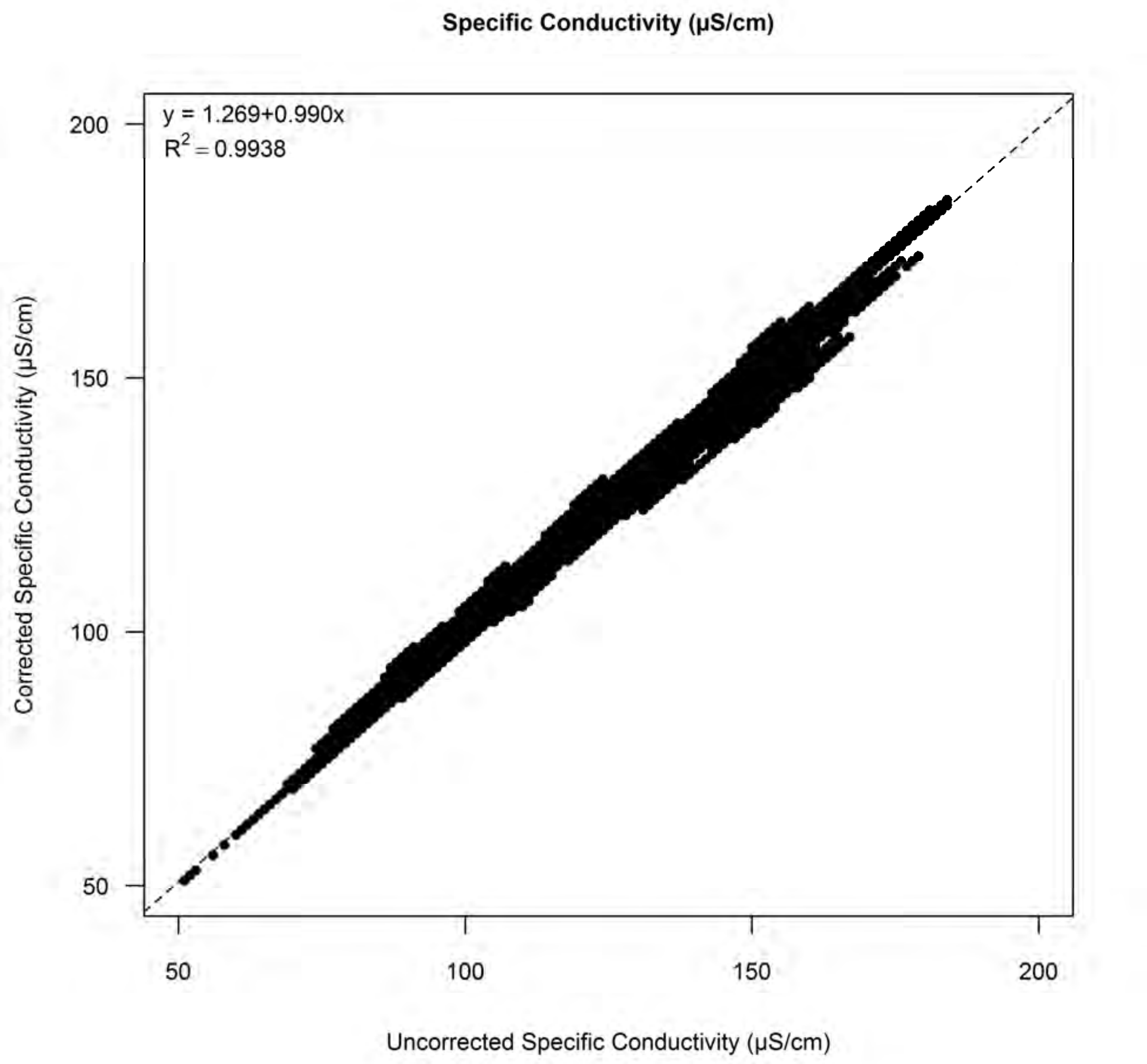

Figure A-1. Comparison of uncorrected and corrected specific conductivity (µS/cm).

Table A-2. Data collection intervals corrected for dissolved oxygen (mg/L).

Station	Correction Interval		Fouling and Drift Error (absolute)	Correction Factor (percent)
	Start	End		
Wilder				
06-W-01	6/4/2015 11:45	6/11/2015 9:00	0.38	0.91
06-W-TR	6/19/2015 16:00	7/8/2015 8:00	0.39	4.59
06-W-TR	8/29/2015 12:15	9/11/2015 8:45	0.39	-3.42
Bellows Falls				
06-BF-01	6/29/2015 10:00	7/7/2015 13:30	0.59	4.87
06-BF-BR	7/7/2015 11:15	7/15/2015 9:45	0.61	5.61
06-BF-BR	7/23/2015 10:45	7/29/2015 10:00	0.59	-7.30
06-BF-TR	6/27/2015 17:00	7/7/2015 7:30	0.43	-4.67
Vernon				
06-V-04	9/14/2015 11:30	8/23/2015 18:00	0.43	-0.43
06-V-02	9/13/2015 13:30	8/23/2015 12:30	0.85	-9.35
06-V-01	6/12/2015 10:30	6/6/2015 11:45	0.31	-3.86
06-V-TR	6/27/2015 7:45	6/17/2015 8:45	0.34	-2.40
06-V-TR	7/9/2015 8:30	6/27/2015 8:30	0.38	-4.27
06-V-TR	9/13/2015 8:45	8/31/2015 10:30	0.4	5.21

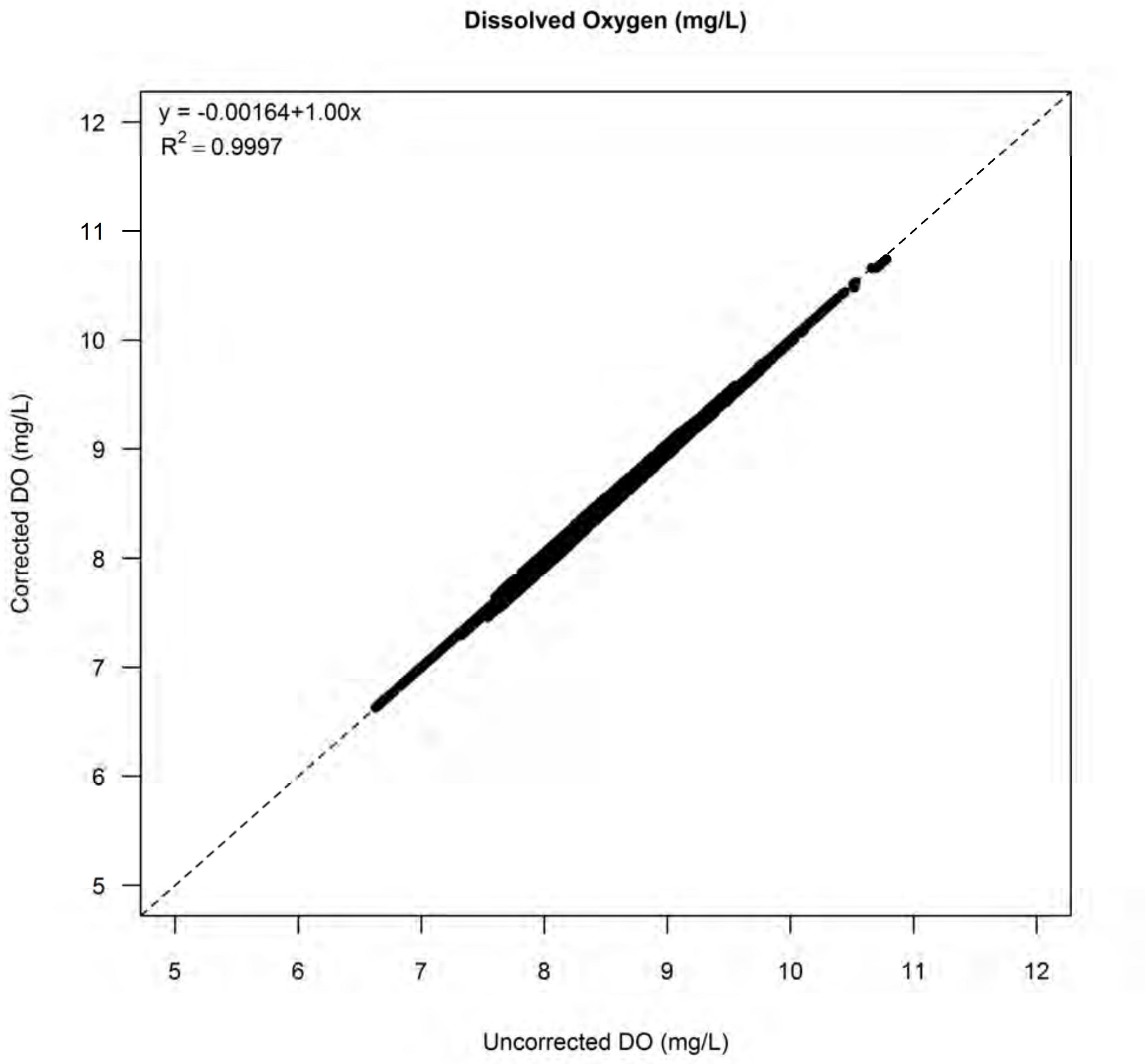

Figure A-2. Comparison of uncorrected and corrected dissolved oxygen (mg/L).

Table A-3. Data collection intervals corrected for pH (standard units).

Station	Correction Interval		Fouling and Drift Error (absolute)	Correction Factor
	Start	End		
Wilder				
06-W-03	8/21/2015 14:00	9/12/2015 9:45	0.22	0.16
Bellows Falls				
06-BF-01	8/12/2015 15:00	8/28/2015 14:00	0.24	0.21
06-BF-TR	7/22/2015 19:30	7/29/2015 7:30	0.21	0.18
06-BF-TR	9/28/2015 8:00	10/5/2015 7:45	0.40	-0.40
Vernon				
06-V-03	8/23/2015 15:45	9/14/2015 9:15	0.23	-0.13
06-V-TR	6/17/2015 8:45	6/27/2015 7:45	0.22	-0.22

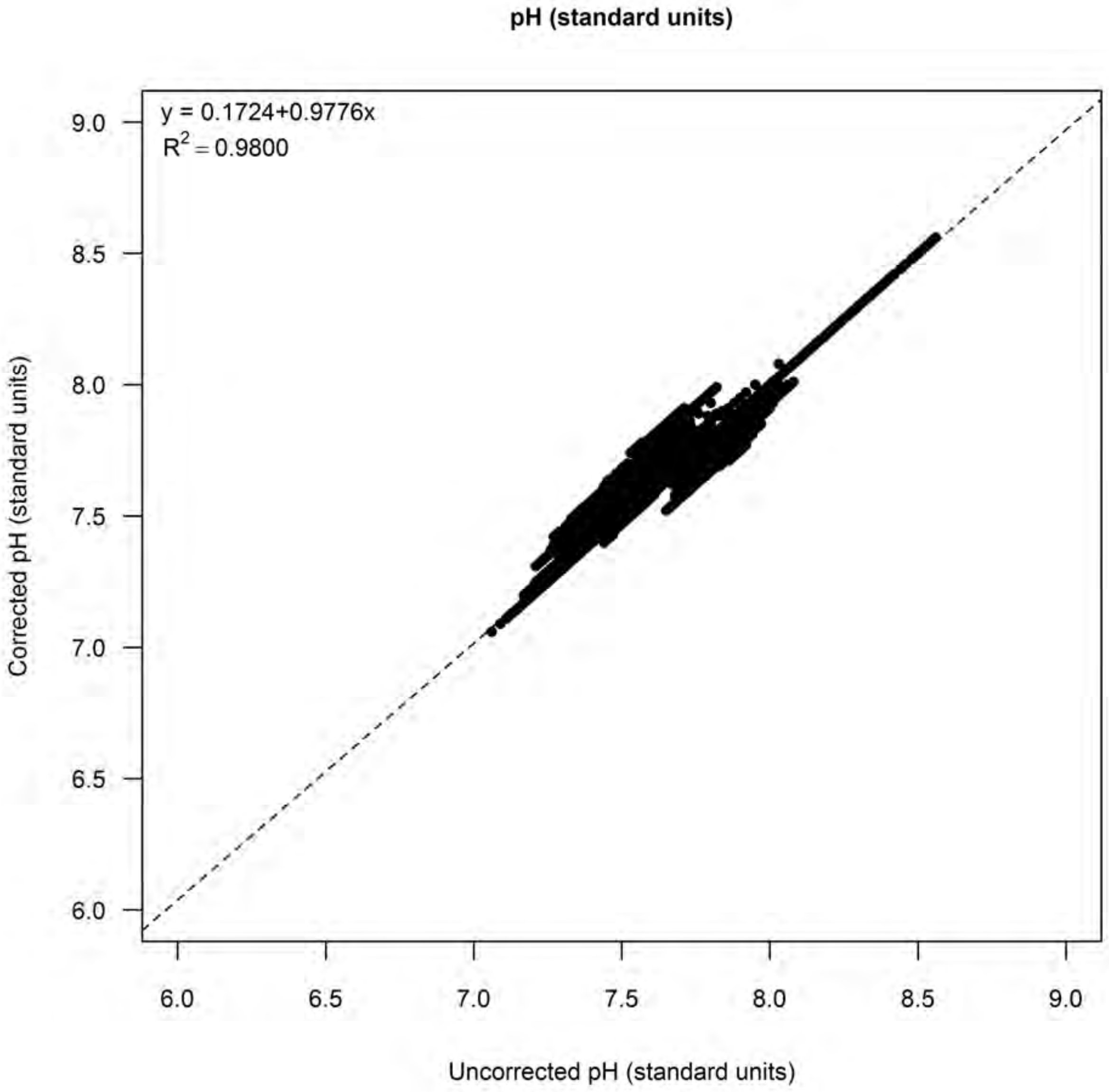

Figure A-3. Comparison of uncorrected and corrected pH (standard units).

Table A-4. Data collection intervals corrected for turbidity (NTU).

Note: Developing correction criteria following USGS 2006 would result in correction factors that would make positive turbidity measurements negative, which make no sense. This is because the river is very clear and we used 0 NTU standard. Most of this issue was in the beginning of the data collection prior to applying the calibration offset. Overall, USGS 2006 states that applying a data correction is ultimately based on the professional judgment of the observer; we used our best judgment on how to correct and QA the data.

Station	Correction Interval		Fouling and Drift Error (absolute)	Correction Criteria Threshold	Correction Factor (2-point)	Correction Factor (1-point)	Correction Factor Applied	Note
	Start	End						
Wilder								
06-W-04	8/21/2015 17:00	9/12/2015 12:30	33.0	7.9	-98.49	-32.3	See note	No correction applied prior to 9/7/2015 7:30; 2-point correction applied from 9/7/2015 7:30 to 9/12/2015 12:30
06-W-01	6/4/2015 11:45	6/11/2015 9:00	8.3	5.5	-91.84	6.9	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-W-01	6/11/2015 11:00	6/19/2015 8:30	9.7	7.0	8.11	-9.7	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-W-01	6/19/2015 10:30	6/28/2015 13:15	1.8	6.3	22.08	1.4	1-point	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval then applied 1-point correction to interval
06-W-TR	6/19/2015 16:00	7/8/2015 8:00	14.3	7.4	-148.47	-5.9	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-W-TR	8/6/2015 10:30	8/20/2015 16:00	3.4	6.8	-2.28	-3.4	See note	Added 0.7 NTU to each measurement to correct, 0.7 NTU is the average of the first and last measurements in the interval.
Bellows Falls								
06-BF-01	6/5/2015 11:45	6/10/2015 9:45	5.1	5.8	4.59	5.1	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-BF-01	6/10/2015 11:45	6/18/2015 10:15	5.5	5.9	31.07	5.5	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-BF-01	6/18/2015 12:00	6/29/2015 7:45	10.5	7.8	-16.56	-10.5	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-BF-BR	6/18/2015 9:15	7/7/2015 10:30	8.5	8.1	-4.58	-7.9	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval

Table A-4. Continued.

Station	Correction Interval		Fouling and Drift Error (absolute)	Correction Criteria Threshold	Correction Factor (2-point)	Correction Factor (1-point)	Correction Factor Applied	Note
	Start	End						
06-BF-TR	6/10/2015 8:15	6/27/2015 16:45	1.9	6.2	-0.71	1.9	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-BF-TR	7/7/2015 7:45	7/15/2015 7:30	1.9	6.2	-6.08	1.7	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-BF-TR	7/22/2015 19:30	7/29/2015 7:30	1.7	6.5	-28.86	-1.7	-1.7	Applied 1-point correction to adjust interval to improve consistency with observed readings previous and former intervals
06-BF-TR	8/12/2015 10:00	8/19/2015 7:45	1.2	6.4	-62.59	-1.2	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
Vernon								
06-V-01	6/6/2015 11:45	6/12/2015 10:30	10.3	5.4	-26.99	9.5	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-V-01	6/12/2015 12:15	6/17/2015 11:15	3.2	6.6	-14.57	-2.8	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-V-01	6/17/2015 12:30	6/27/2015 11:15	9.5	7.5	-14.02	-9.5	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval
06-V-TR	6/12/2015 9:30	6/17/2015 8:15	3.3	6.6	147.59	-3.3	See note	Negative turbidity readings present in interval, correction would make positive readings negative, did not correct using correction factor, data corrected using best professional judgement by taking minimum turbidity reading and adding its absolute value to each measurement in the interval

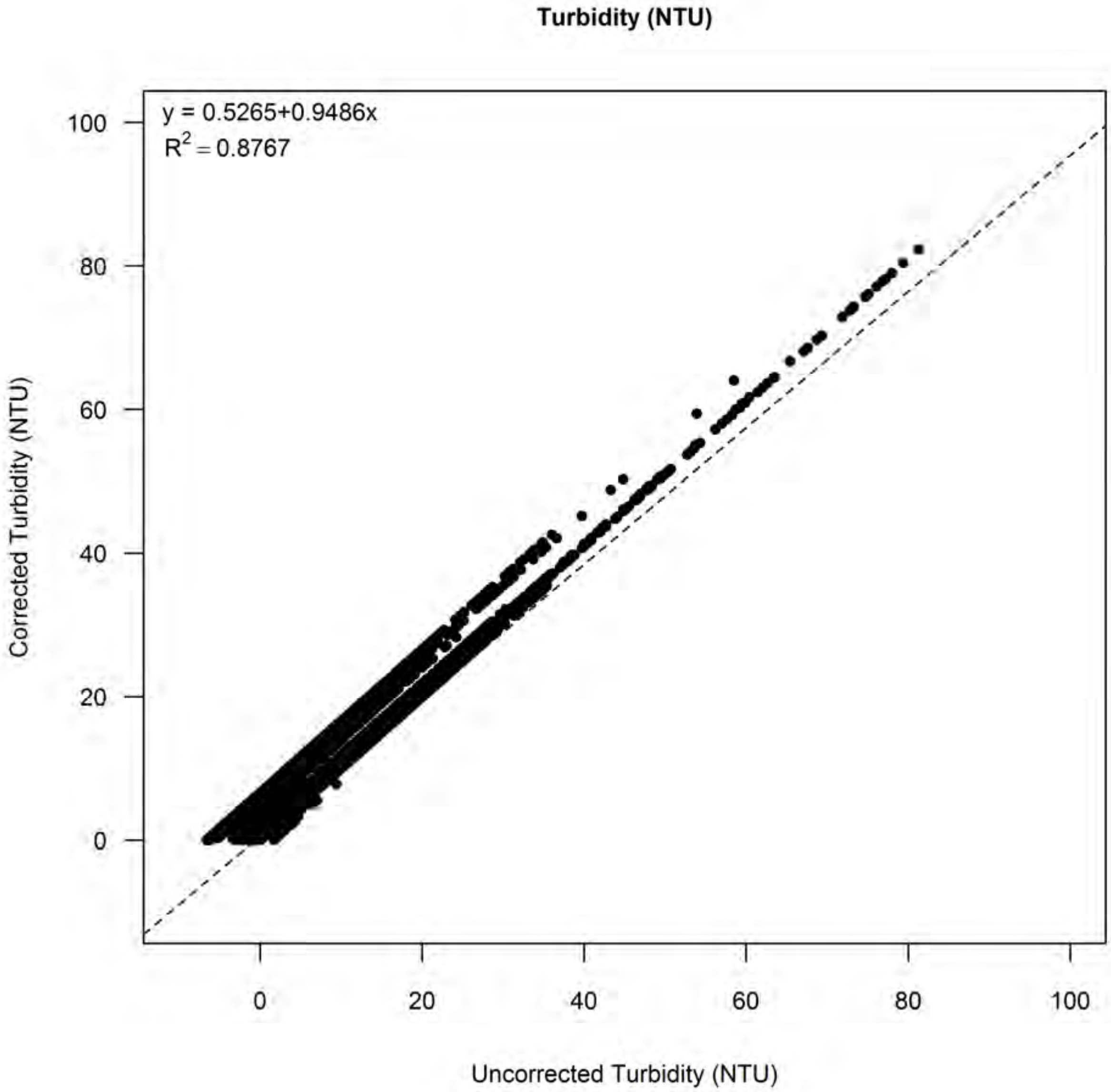

Figure A-4. Comparison of uncorrected and corrected turbidity (NTU).

APPENDIX B

2015 Mean Daily Air Temperature and Total Daily Precipitation

Upper Watershed: NOAA NOWData for Station USC00274556, Lancaster, NH

Wilder Project Area: NOAA NOWData for Station USC00438556, Union Village Dam, VT

Bellows Falls Project Area: NOAA NOWData for Station USC00435982, North Springfield Lake, VT

Vernon Project Area: NOAA NOWData for Station USC00274399, Keene, NH

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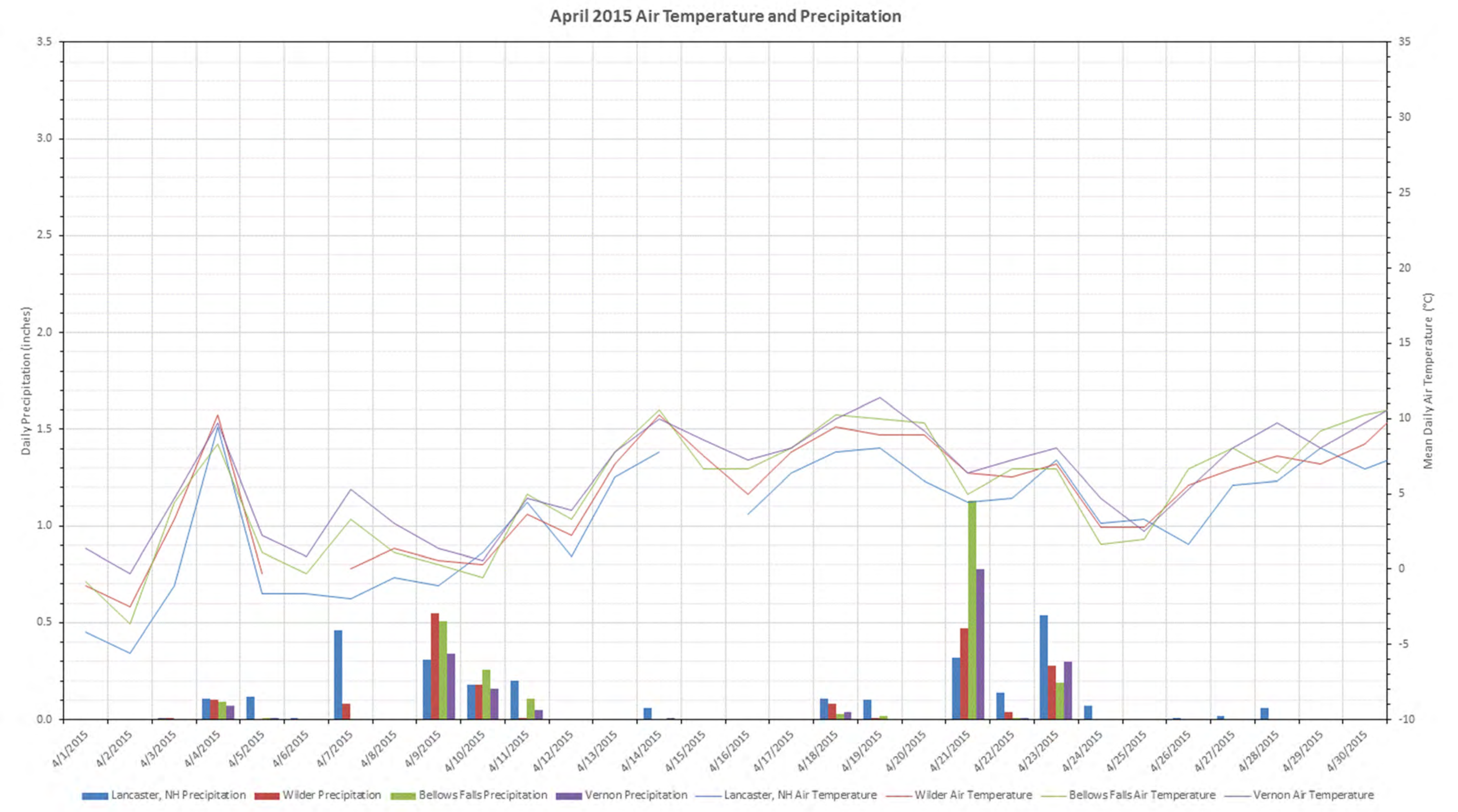

Figure B-1. 2015 April daily mean air temperature (°C) and daily precipitation (inches) for the study area.

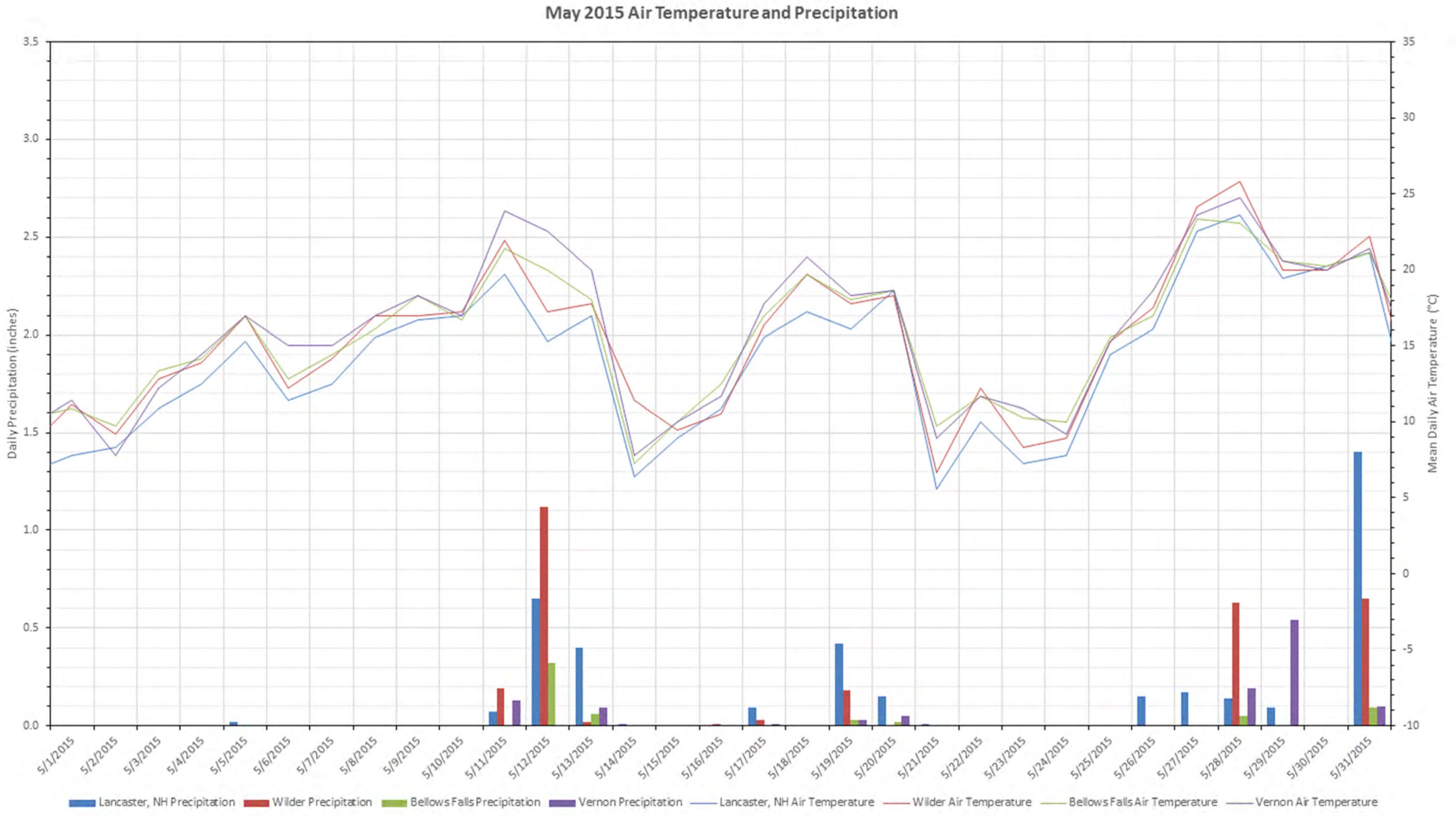

Figure B-2. 2015 May daily mean air temperature (°C) and daily precipitation (inches) for the study area.

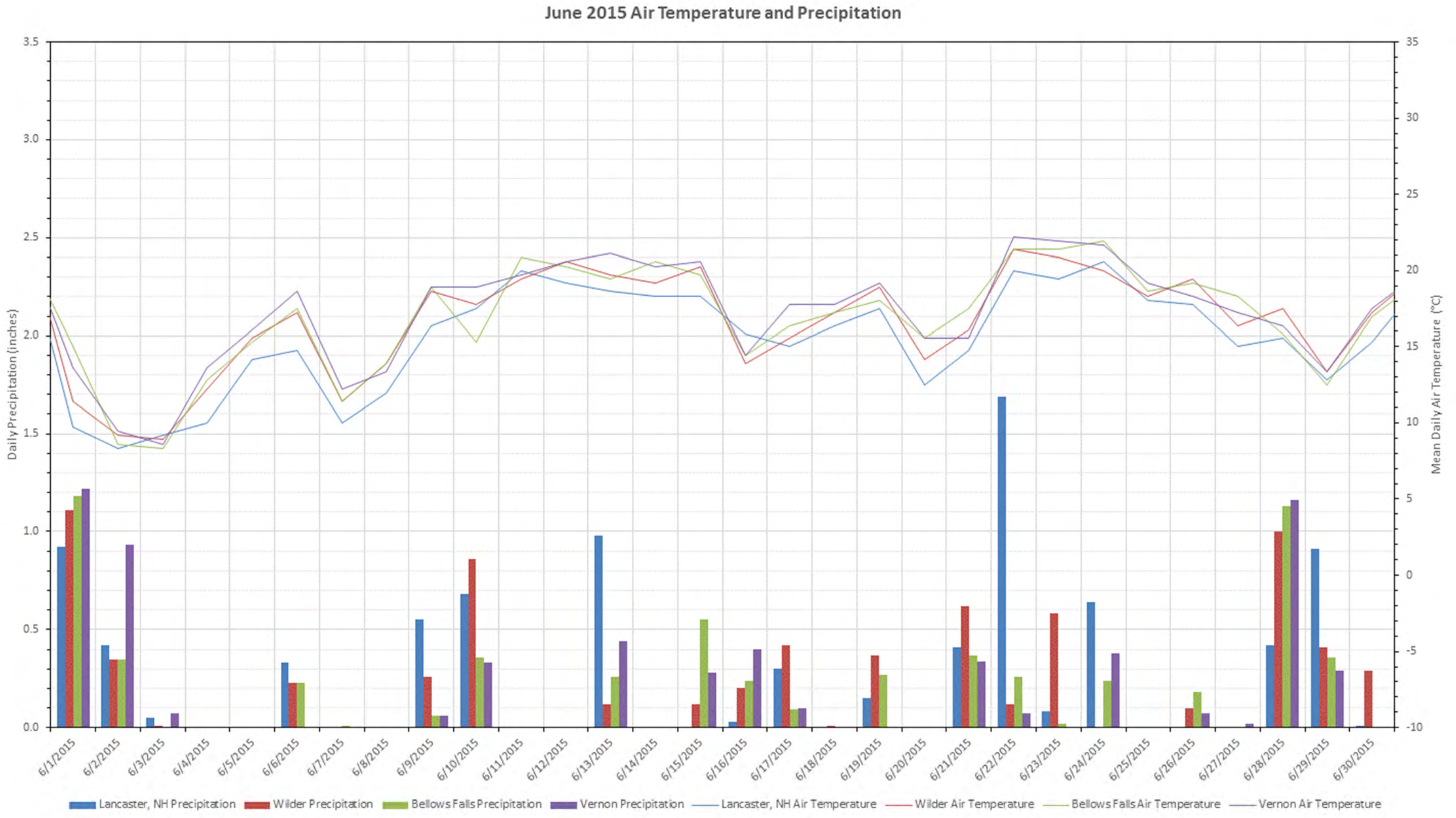

Figure B-3. 2015 June daily mean air temperature (°C) and daily precipitation (inches) for the study area.

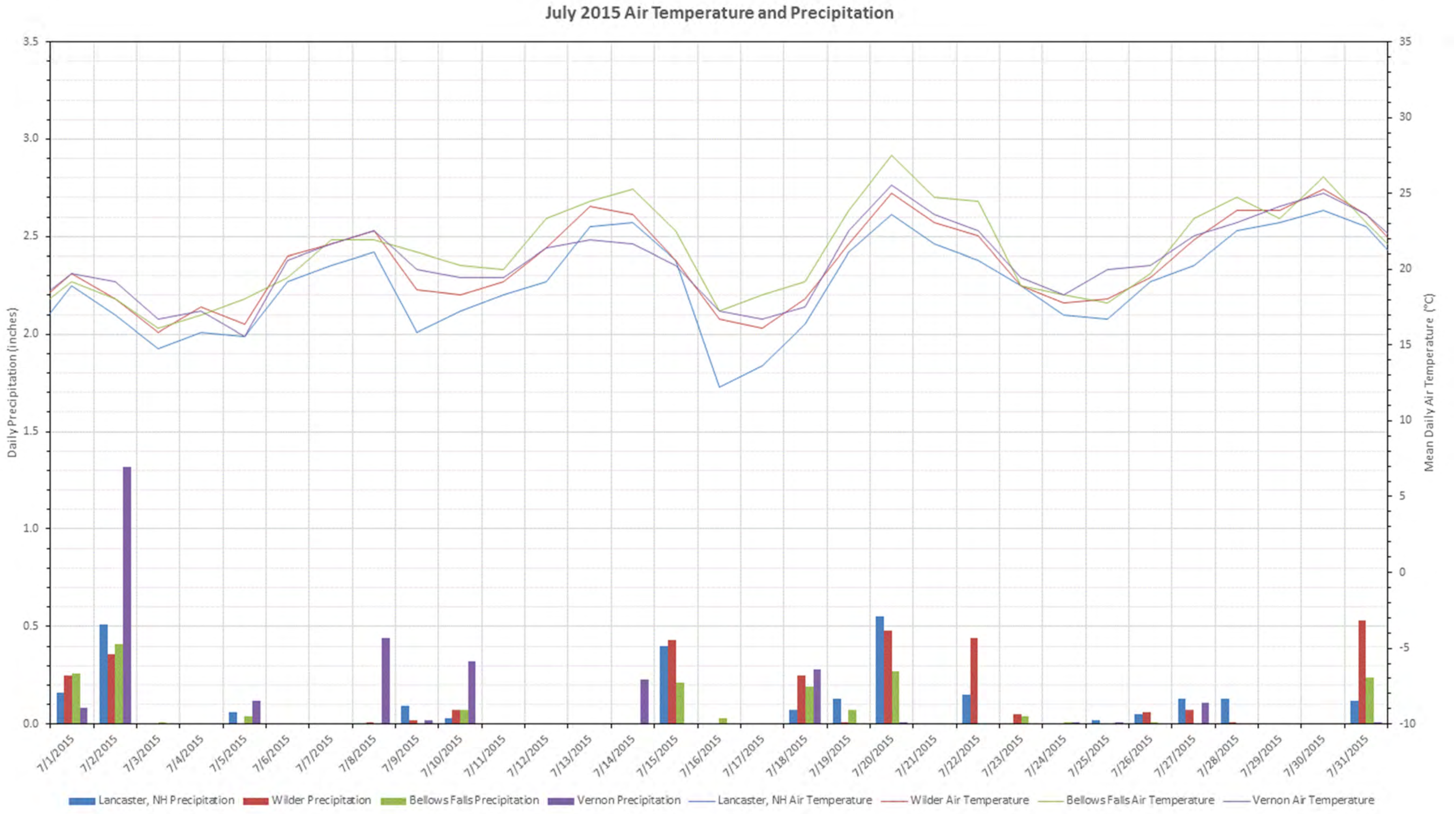

Figure B-4. 2015 July daily mean air temperature (°C) and daily precipitation (inches) for the study area.

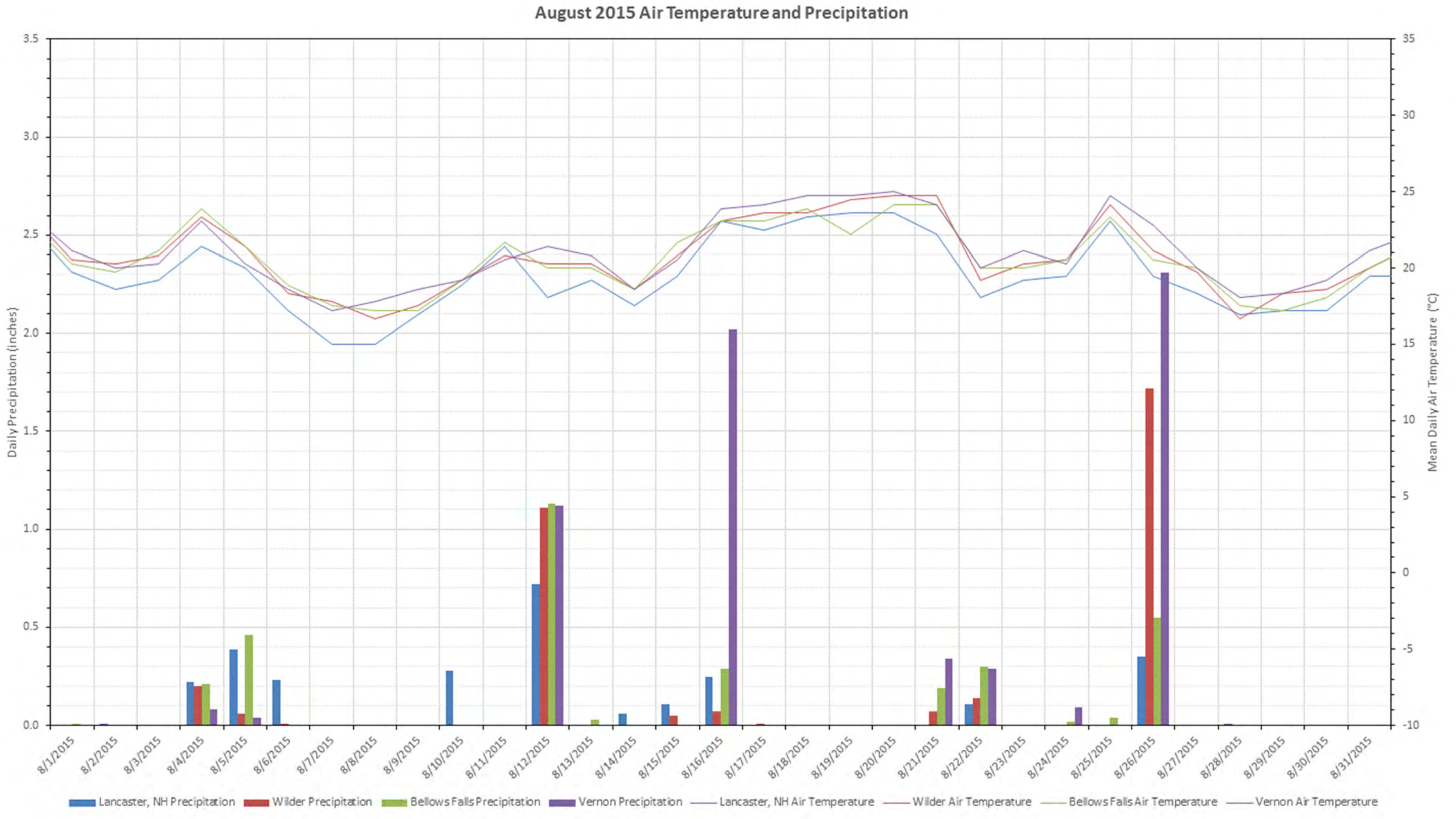

Figure B-5. 2015 August daily mean air temperature (°C) and daily precipitation (inches) for the study area.

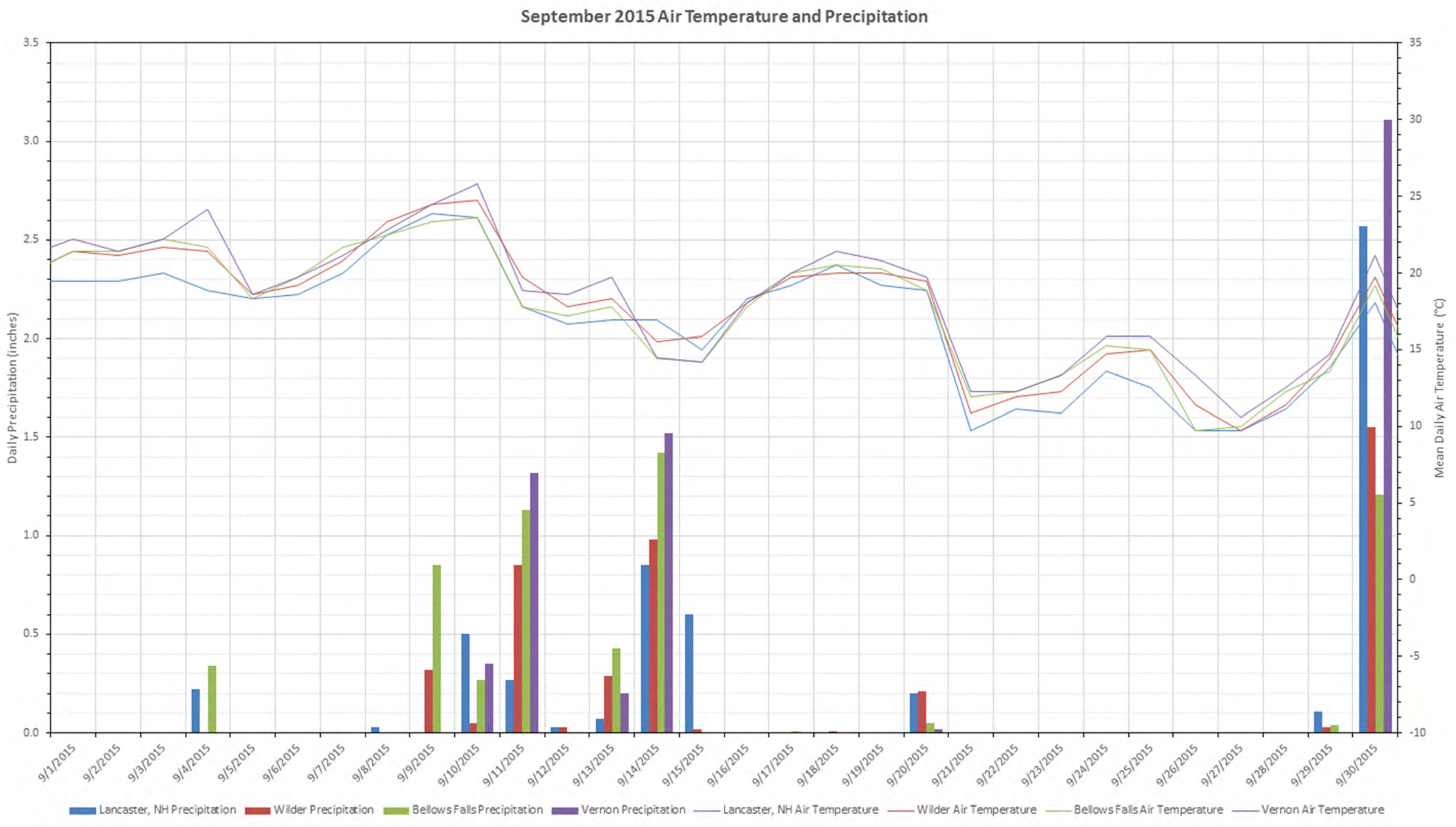

Figure B-6. 2015 September daily mean air temperature (°C) and daily precipitation (inches) for the study area.

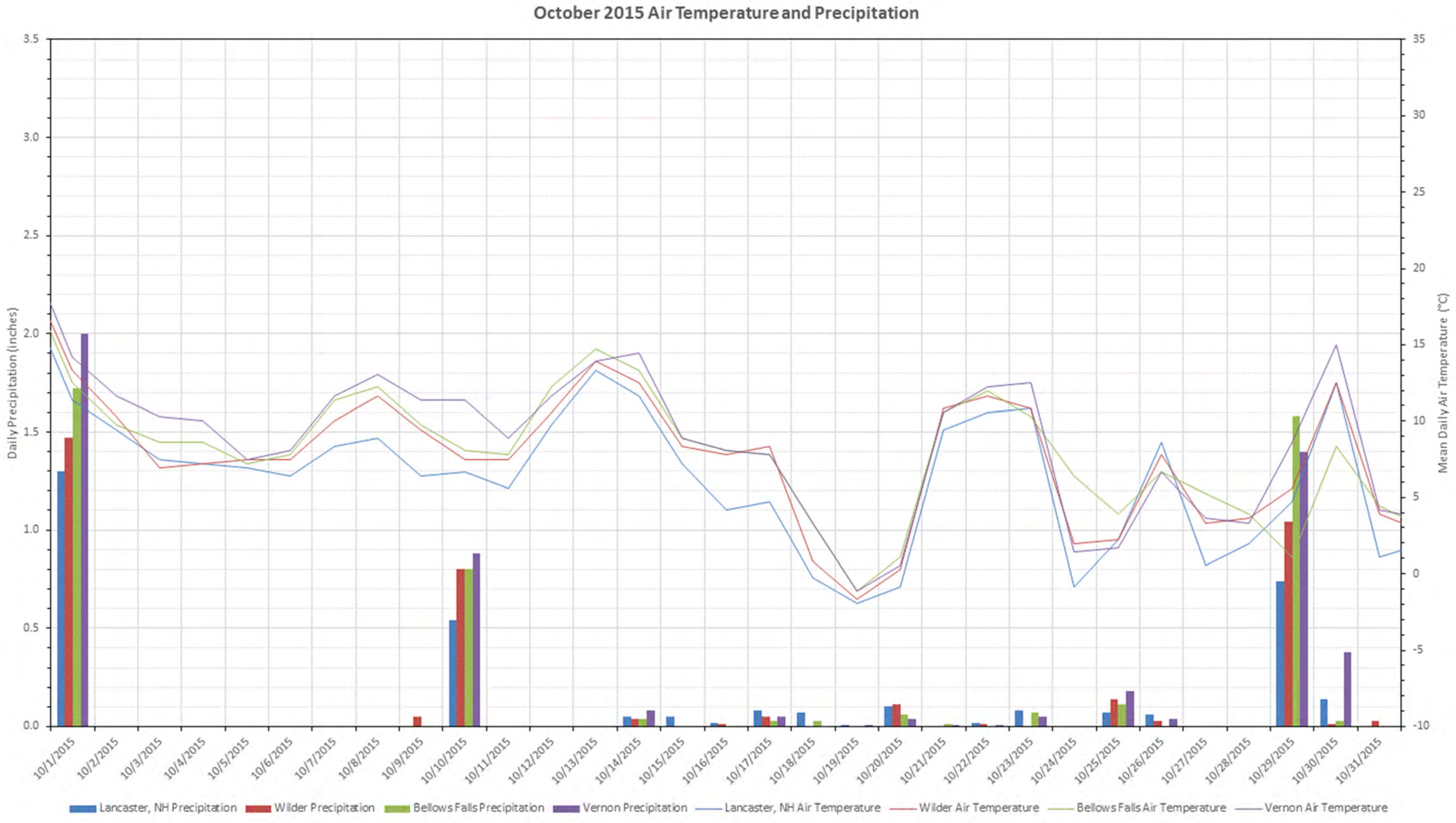

Figure B-7. 2015 October daily mean air temperature (°C) and daily precipitation (inches) for the study area.

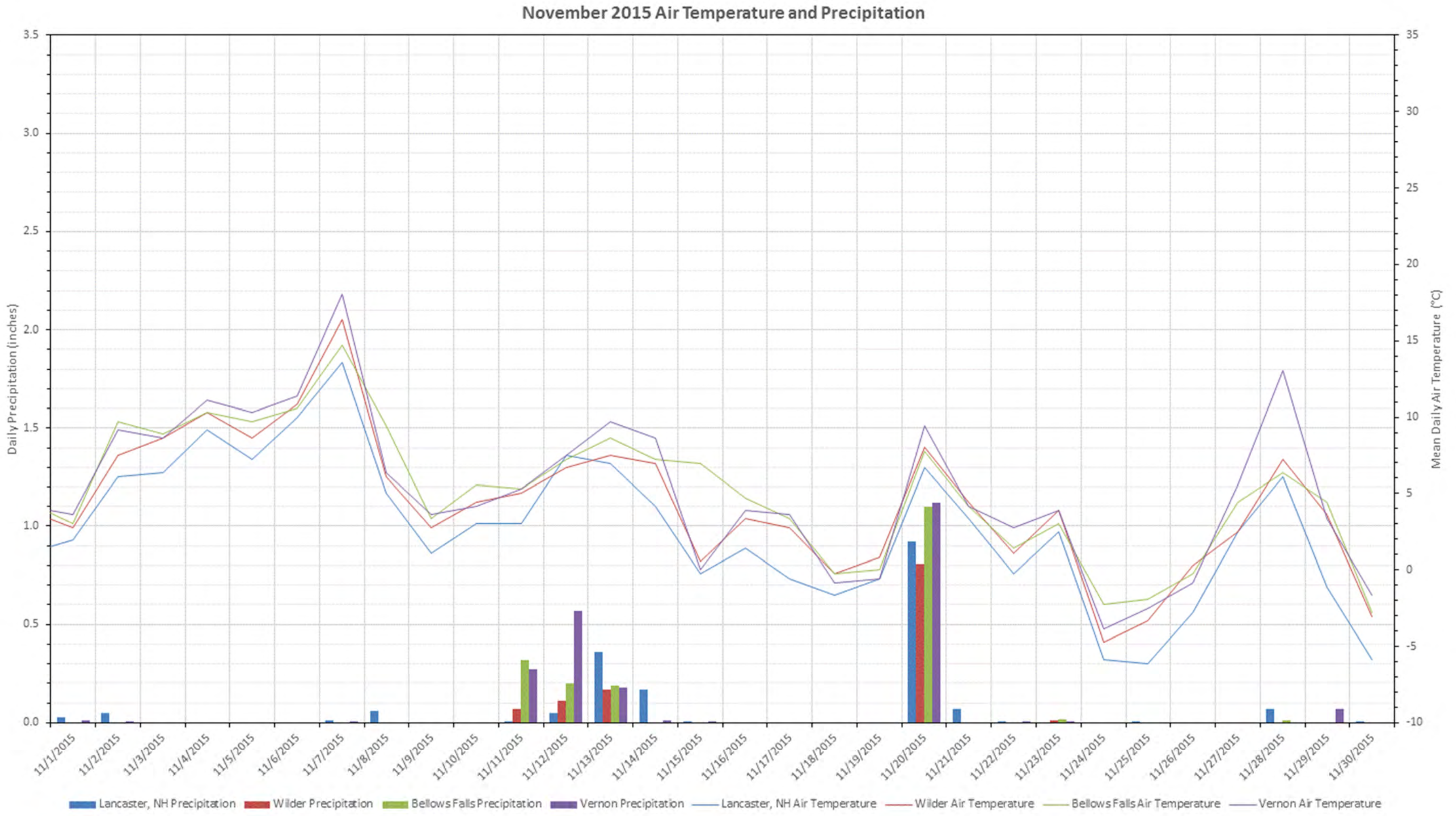

Figure B-8. 2015 November daily mean air temperature (°C) and daily precipitation (inches) for the study area.