



Total Maximum Daily Loads for the Willamette Subbasins

Technical Support Document
Appendix K: Tetra Tech Model
Scenario Report

August 2024



To: Jim Bloom, Ryan Michie, Ben Cope, Becky Veiga Nascimento, Gunnar Johnson

From: Aileen Molloy, Sen Bai, Mustafa Faizullahoy

Date: March 8, 2024

Subject: Willamette River Model Point Source Updates and Scenario Simulation

1.0 INTRODUCTION

This document discusses the point source updates made to the Willamette River model. In addition, a scenario with point sources at current thermal loads (current condition calibration scenario) which serves as the baseline condition and a scenario without point sources (no point sources scenario) are also discussed. The recently updated Willamette River W2 v4.2 models provided by the USGS (Stratton et.al., 2022) and the W2 v4.2 models updated by Tetra Tech (Tetra Tech, 2023) were used for scenario simulation to support the Willamette River Temperature TMDL. The following are the USGS models used for the scenarios:

1. Coast Fork Willamette River (includes the Coast Fork, Middle Fork, Row River, and Fall Creek)
2. McKenzie River,
3. North Santiam River (includes the Santiam River),
4. South Santiam River,
5. Upper Willamette River, and
6. Middle Willamette.

The following are the Tetra Tech models used for scenarios:

1. Lower Willamette River,
2. Long Tom River, and
3. Clackamas River.

Error! Reference source not found. shows all the modeled river reaches in the Willamette River watershed. The models were configured and calibrated for March 21 to November 1, 2015. This period covered the critical summer and spawning periods.

Model scenario interpretation in terms of calculation metrics that applied to the scenarios simulated are discussed first, followed by a description of the scenarios and the corresponding results.

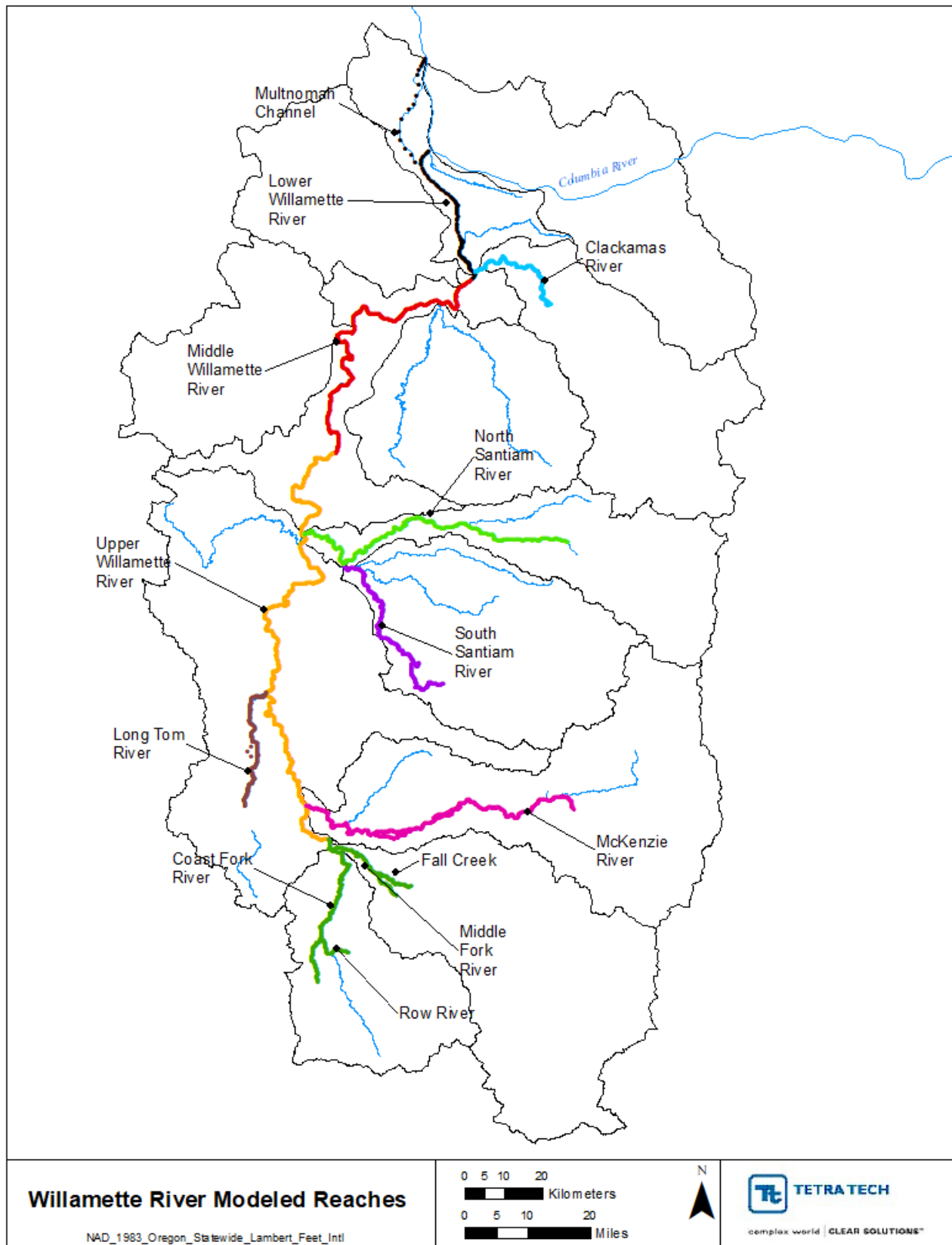


Figure 1-1. Location of modeled river reaches in the Willamette River watershed.

2.0 MODEL SCENARIO INTERPRETATION

This section discusses the calculation metrics that were used when evaluating the scenarios.

2.1 SIGNIFICANT DIGITS AND ROUNDING

The TMDL analysis, interpretation of the model results, and all scenarios account for significant digits and rounding. For evaluation of the attainment of the human use allowance (HUA), Oregon Department of Environmental Quality (DEQ) tracks values to the hundredths. Because DEQ is providing some of the HUA allocations out to the hundredths, attainment must be tracked in a similar manner. DEQ has a permit related internal management directive (IMD) on rounding and significant digits (DEQ 2013). The TMDL analysis follows the rounding procedures outlined in this IMD. The significant figures IMD says that for “calculated values” (which includes model results), if the digit being dropped is a “5,” it is rounded up. For example, if the model shows warming equal to 0.014 °C it gets rounded down to 0.01 °C and the result would attain. If the model shows warming equal to 0.015 °C, it gets rounded up to 0.02 °C, and the result would not attain.

2.2 CALCULATING THE 7-DAY AVERAGE MAXIMUM TEMPERATURE

For each scenario, the 7-day average maximum (7DADM) temperature was calculated using the hourly model output. The 7DADM was calculated using the procedure outlined in DEQ’s Temperature IMD (DEQ 2008). As outlined in the document, the 7DADM temperature is calculated by first calculating the daily maximum for each day, followed by calculating a moving average of the daily maximums, the result for which lands on the 7th day.

2.3 COMPARING TEMPERATURE BETWEEN TWO SCENARIOS

When comparing the hourly results from two model scenarios to determine the temperature changes, the following steps were taken:

1. Calculate the 7DADM temperatures for scenario 1 at every model output for every day during the model period.
2. Calculate the 7DADM temperatures for scenario 2 at every model output for every day during the model period.
3. Compute the difference between the 7DADM temperatures of scenario 1 and scenario 2 only for days that exceed the Biologically Based Numeric Criteria (BBNC). In this manner at each segment a ΔT is computed for every 7DADM temperature from each scenario for each day where the BBNC is exceeded. Finally, the max ΔT for each segment location was taken and plotted longitudinally as 7DADM delta plots.
 - a. Since the HUA is based on an increase above the applicable criteria, the difference between two scenarios is only calculated for each time step when the 7DADM of either scenario exceeds the BBNC. This step was necessary to ensure that we only consider the maximum change in temperatures when the river exceeds the BBNC criteria for analysis. Note that the BBNC varied spatially and temporally and are evaluated based on the 7DADM.

2.4 BIOLOGICALLY BASED NUMERIC CRITERIA

The following are applicable criteria extracted from Oregon Rules (email communication from DEQ):

- The 7DADM temperature of a stream identified as having core cold water habitat use may not exceed 16.0 deg C;
- The 7DADM temperature of a stream identified as having salmon and trout rearing and migration use may not exceed 18.0 deg C;
- The 7DADM temperature of a stream identified as having a migration corridor use may not exceed 20.0 deg C;
- The 7DADM temperature of a stream identified as having salmon and steelhead spawning use may not exceed 13.0 deg C;

The BBNC vary spatially and temporally and are evaluated based on the 7DADM. The Long Tom River downstream from Fern Ridge Lake is an exception. It is the only reach that is part of the “mainstem” which is not designated for core cold water habitat use, salmon and trout rearing and migration use, migration corridor use, or salmon and steelhead spawning. Therefore, no applicable criteria are provided by Oregon rules for the Long Tom downstream from Fern Ridge Lake. However, DEQ’s Standards and Assessments section recently recommended that the following site-specific temperature criteria apply to the Long Tom River based on species present – 18 deg C from December 1 through May 31 (24 deg C for the remainder of the year).

Appendix A shows the variation of the BBNC along the various waterbodies.

2.5 RUNNING THE WILLAMETTE MODELS

The calibrated Clackamas River, Long Tom River, and the Lower Willamette River models updated by Tetra Tech are currently not linked to the USGS models for simultaneous model runs. For scenario simulation, the USGS and Tetra Tech models needed to be run sequentially and passing model outputs from upstream models to downstream models. For scenario development the Long Tom River and Clackamas River model tributary outputs were linked to the Upper Willamette and Lower Willamette models, respectively, by adding the modeled flow and water temperature results from their most downstream segments as inputs to the mainstem models. In addition, the Lower Willamette River was also linked to the Middle Willamette River. The Middle Willamette River model flow and water temperature output were linked to the Lower Willamette River model by adding results from the most downstream segment of the Middle Willamette River model.

To run the USGS models and Tetra Tech models together, two changes were made to the USGS models. The first involved turning off water quality simulation and simulating only water temperature to save computation time and speed up the simulation. The second involved turning off the multiple waterbody option feature in the existing USGS models. Instead, the models were run using the W2 version 4.2 model, downloaded from Portland State University website and run in a batch mode using a batch file to run all headwater models at the same time and then run the downstream models in a sequential order.

A batch file was developed for running all nine W2 models sequentially from upstream to downstream. Model simulation for all nine models involves using five general steps to copy output files from upstream models as input files for the corresponding downstream model during run time. Figure 2-1 shows the overall workflow of the batch file. An exception to running all the headwater models first was the Coast Fork Middle Fork model which was run in the second pass as step two in the batch file. This was done to optimize the run times by running it along with the North Santiam model in the second pass which had similar run times.

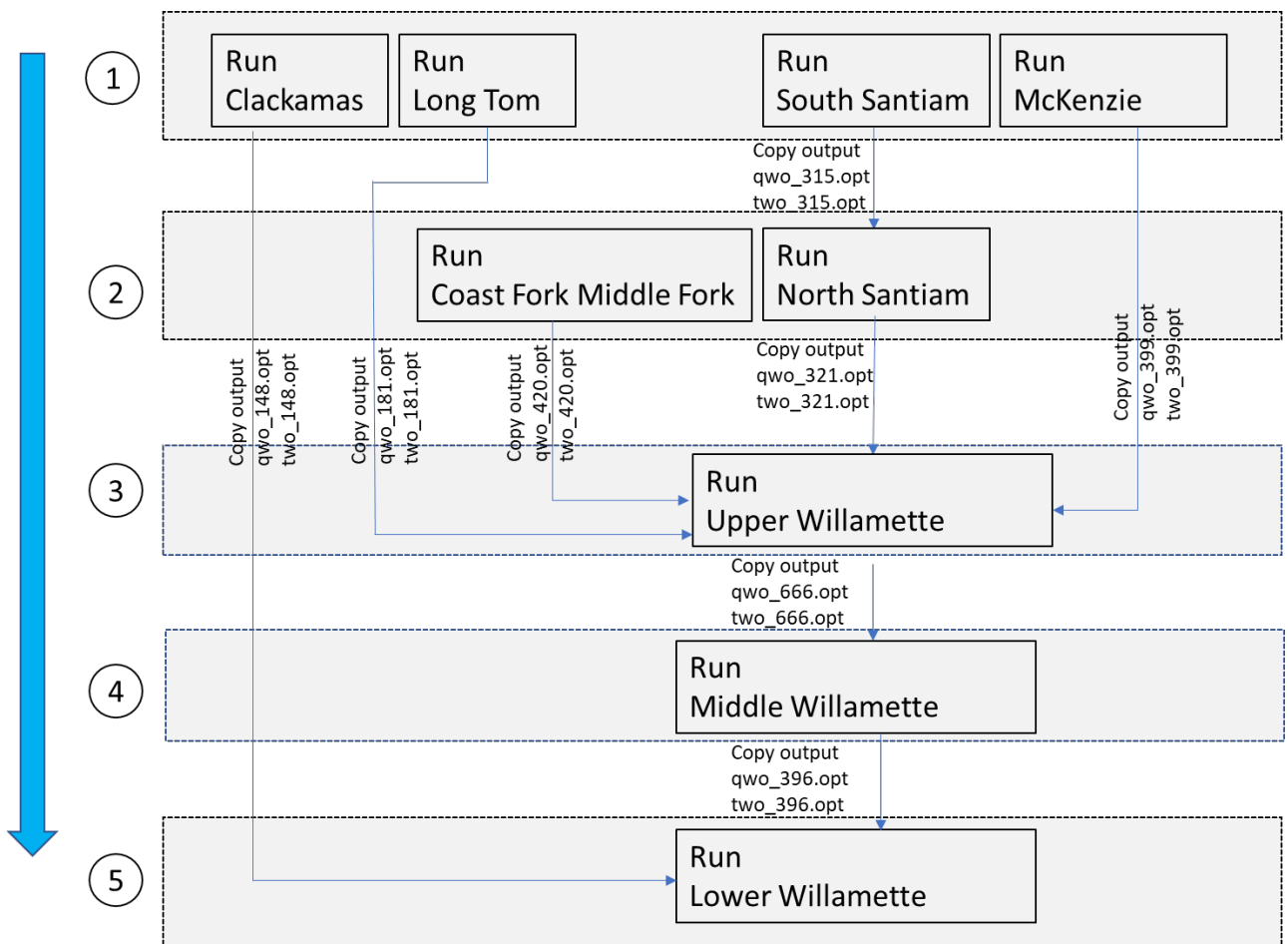


Figure 2-1. Workflow of batch file used to run the nine W2 models

The following steps need to be followed to run the models using the batch file.

- Copy the following batch files – *runallmodels_setvar_5-12-2023.bat*, *timer.bat*, and *waiter.bat* in the same location where all the nine model file folders exist (Figure 2-2).
 - Note that the *timer.bat* and *waiter.bat* are supporting files that are called by the main batch file i.e. *runallmodels_setvar_5-12-2023.bat*

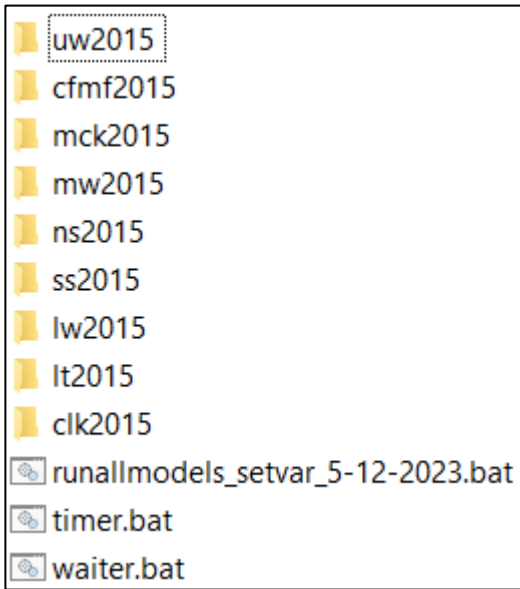


Figure 2-2. Suggested file folder structure and naming convention

- If a different folder naming convention is used other than the suggested folder names in Figure 2-2, then the user can update the names of the folders in the *runallmodels_setvar_5-12-2023.bat* file as follows:
 - Open the *runallmodels_setvar_5-12-2023.bat* file in a text editor and update the files names in lines 4 through 12 (Figure 2-3) as needed and save the batch file.

```

1  @echo off
2  ::run all models from u/s to d/s. MF-5-10-2023; updated timer 5-12-2023
3  ::update the model folder names if necessary.
4  Set Clackamas_folder=clk2015
5  Set Longtom_folder=lt2015
6  Set SouthSantiam_folder=ss2015
7  Set McKenzie_folder=mck2015
8  Set NorthSantiam_folder=ns2015
9  Set CoastForkMiddleFork_folder=cfmf2015
10 Set UpperWillamette_folder=uw2015
11 Set MiddleWillamette_folder=mw2015
12 Set LowerWillamette_folder=lw2015
13  ::-----
14 Set start_time=%TIME%
15 echo Start time: %start_time%
16 cd .\%Clackamas_folder%\

```

Figure 2-3. Location in batch file where the folder name can be updated

- Open a DOS prompt by typing “cmd” in the Windows start menu. Navigate to the folder location where the batch files reside using the change directory command “cd”. Type *runallmodels_setvar_5-12-2023.bat* in the DOS window. This will start running all the models in a sequential order as shown in Figure 2-1.

2.6 PROCESSING MODEL OUTPUT RESULTS

Post processors were developed to summarize and visualize the hourly flow and temperature output from the various models in the Willamette River watershed. Specifically, a Python script and an Excel spreadsheet tool were developed to process the results. It is recommended that a folder be created where the processing scripts/tools can reside and where the resulting output summaries can be stored.

A Python script (load_tsr_process_08252023_to_csv.py) was developed to read through the W2 model tsr.opt files within each of the model folders and generate the following model output summaries.

- 7DADM temperature
- Daily maximum temperature
- 7-day average flow
- Daily average flow
- Daily average temperature.
- Hourly temperature

The Python script requires that a file called control.csv reside in the same location as the script. The control.csv file is used to specify the location of the model folders and specify the name of the output desired. Table 2-1 shows an example of the structure of the control.csv file. If a particular output file is not needed, then it can be left blank in the control file. For ease of use it is recommended that the file be opened and saved using Excel. Running the script will generate csv files for each of the summary items specified in the control file.

Table 2-1 Example structure of the control file (control.csv)

FolderName	7DADM_Temp	DMAX_Temp	7-day_Avg_Flow	DAVG_Flow	Hr_Temp_ts
C:\Willamette\W2_Models\Scenarios\Existing\clk2015	clk_Ex_7DADM	clk_Ex_dmax	clk_Ex_7DAVG_Q	clk_Ex_davgQ	
C:\Willamette\W2_Models\Scenarios\Existing\cfmf2015	cfmf_Ex_7DADM	cfmf_Ex_dmax	cfmf_Ex_7DAVG_Q	cfmf_Ex_davgQ	cfmf_Ex_ts
C:\Willamette\W2_Models\Scenarios\Existing\lt2015	lt_Ex_7DADM	lt_Ex_dmax	lt_Ex_7DAVG_Q	lt_Ex_davgQ	
C:\Willamette\W2_Models\Scenarios\Existing\lw2015	lw_Ex_7DADM	lw_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\Existing\mck2015	mck_Ex_7DADM	mck_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\Existing\mw2015	mw_Ex_7DADM	mw_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\Existing\ns2015	ns_Ex_7DADM	ns_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\Existing\ss2015	ss_Ex_7DADM	ss_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\Existing\uw2015	uw_Ex_7DADM	uw_Ex_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\clk2015	clk_7DADM	clk_dmax	clk_7DAVG_Q	clk_davgQ	
C:\Willamette\W2_Models\Scenarios\NoPtSrc\cfmf2015	cfmf_7DADM	cfmf_dmax	cfmf_7DAVG_Q	cfmf_davgQ	cfmf_ts
C:\Willamette\W2_Models\Scenarios\NoPtSrc\lt2015	lt_7DADM	lt_dmax	lt_7DAVG_Q	lt_davgQ	
C:\Willamette\W2_Models\Scenarios\NoPtSrc\lw2015	lw_7DADM	lw_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\mck2015	mck_7DADM	mck_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\mw2015	mw_7DADM	mw_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\ns2015	ns_7DADM	ns_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\ss2015	ss_7DADM	ss_dmax			
C:\Willamette\W2_Models\Scenarios\NoPtSrc\uw2015	uw_7DADM	uw_dmax			

The second post processing tool is an Excel spreadsheet tool called *Summarize_tsr_7DADM_delta_criteria.xlsb*. This spreadsheet tool is used to read in the 7DADM summaries (csv files) from two scenarios and calculate the maximum 7DADM deltas at each segment (details on calculating the deltas are provided in Section 2.3). The spreadsheet assumes that the user has already run the Python script discussed earlier and generated the necessary 7DADM output csv files. The spreadsheet should be placed in the same location as the summary csv files. The *Index* tab within the spreadsheet is used to specify the names of the 7DADM csv files that are pulled into the spreadsheet. There are three tabs associated with each model within the spreadsheet i.e., a criteria tab, an CCC or exiting condition 7DADM tab, and a scenario 7DADM tab. Click on the “Load 7DADM Results” button to populate the 7DADM output into the spreadsheet and generate plots and tables. Figure 2-4 shows a screen grab of the post processing spreadsheet.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Filename	Sheet No	Sheet Name	Remarks											
2	cfmf_Ex_7DADM.csv	1	cfmf_Ex_7DADM	Existing											
3	cfmf_7DADM.csv	2	cfmf_7DADM	No point sources Scn											
4	clk_Ex_7DADM.csv	3	clk_Ex_7DADM	Existing											
5	clk_7DADM.csv	4	clk_7DADM	No point sources Scn											
6	lt_Ex_7DADM.csv	5	lt_Ex_7DADM	Existing											
7	lt_7DADM.csv	6	lt_7DADM	No point sources Scn											
8	mck_Ex_7DADM.csv	7	mck_Ex_7DADM	Existing											
9	mck_7DADM.csv	8	mck_7DADM	No point sources Scn											
10	ns_Ex_7DADM.csv	9	ns_Ex_7DADM	Existing											
11	ns_7DADM.csv	10	ns_7DADM	No point sources Scn											
12	ss_Ex_7DADM.csv	11	ss_Ex_7DADM	Existing											
13	ss_7DADM.csv	12	ss_7DADM	No point sources Scn											
14	uw_Ex_7DADM.csv	13	uw_Ex_7DADM	Existing											
15	uw_7DADM.csv	14	uw_7DADM	No point sources Scn											
16	mw_Ex_7DADM.csv	15	mw_Ex_7DADM	Existing											
17	mw_7DADM.csv	16	mw_7DADM	No point sources Scn											
18	lw_Ex_7DADM.csv	17	lw_Ex_7DADM	Existing											
19	lw_7DADM.csv	18	lw_7DADM	No point sources Scn											
20															

* This spreadsheet along with the script load_tsr_process_08252023_to_csv.py and control.csv file should reside in the same folder.
 * Run the script load_tsr_process_08252023_to_csv.py first before using this spreadsheet.
 * Enter the name of the csv file under "Filename" and the corresponding "Sheet Name" in the Index tab. The csv files are generated using the python script.
 * If new scenarios are generated, the spreadsheet can be saved with a new file name and the appropriate file names for each of the waterbodies can be updated for the scenario before running the tool. This will update all the tables and plots.
 * The formatted delta table of the 7DADM deficits can be found starting column AWW in the Scenario tab e.g. cfm_7DADM, ck_7DADM, lt_7DADM and so on. The min/max/mean deltas can be found under columns BFK, BFL, and BFM.

Figure 2-4. Post processing spreadsheet tool

3.0 POINT SOURCE UPDATES

DEQ provided Tetra Tech with DMR data for permitted NPDES facilities in the Willamette River watershed. These facilities discharge to various tributaries of the Willamette River and the mainstem Willamette River, and in some instances the USGS models needed to be updated to include new facilities and/or new data. The USGS models were reviewed to ascertain if all the facilities present in 2015 were included in the models after checking data made available to Tetra Tech by DEQ. Tetra Tech provided a list of point source data in the existing USGS models to DEQ and EPA and also facilities that were either not included in the USGS models, or represented in the USGS models at a coarser resolution than data that are currently available. In addition, DEQ identified fish hatcheries that were not represented in the USGS models but needed to be added.

DEQ and EPA provided the following guidance for point source updates to the models.

Point Source Update Methodology

- When a point source was already in the model and more refined data were available from DEQ during this model update, then it was updated with the new digital data. Refined data refers to data that are available at a higher resolution for the point source. Digital data were available from two sources - data from DEQ’s electronic database referred to as the Discharge Monitoring System (DMS) and data from the 2021 DEQ temperature data solicitation effort. The flow and water temperature data from the DMS were typically available at a daily time step and, the data from the DEQ data solicitation effort were available at either an hourly or 30-minute frequency.
- When the point source was already in the model and no new digital data were available, then the point source already in the USGS model was used.
- When a point source was identified as not being in the USGS model and had no digital data, then the calculated spring, summer, and fall max effluent flow and max 7DADM water temperature (provided by DEQ) were used to create the point source inputs.

The USGS models represent time of travel offsets for point sources by adding an artificial withdrawal immediately upstream of a corresponding point source that removes the same volume of water as is added by the point source (Stratton et.al., 2022). Only the flow rates are specified for withdrawals within W2. The model removes heat associated with the flow, based on the simulated water temperature at the withdrawal location. All USGS models had this representation, and it was maintained when any model updates were made to the point sources. The

USGS models include both actual and artificial withdrawals. The actual withdrawals include the fish hatcheries and some industrial facilities. The artificial withdrawals are for other point sources without actual withdrawals at the immediate upstream locations, which may represent actual diversions or withdrawals some distance upstream of these facilities. For the Tetra Tech updated W2 models (Long Tom and Lower Willamette), the point sources were represented as direct tributary inputs without artificial withdrawals for time of travel offset which reflects the actual discharging conditions. The Clackamas River W2 model updated by Tetra Tech included a point source which was represented using withdrawals for a hatchery point source and was left unchanged.

Fish Hatchery Boundary Input Methodology

Flow and water temperature data were not available for the year 2015 for any of the fish hatcheries that were added to the models. The hatcheries identified for inclusion in the model were configured using 2016 half-hourly DMR data that were available from the hatcheries. The following approach was used based on recommendations provided by DEQ to configure the inputs from the hatchery in the models.

- Effluent flows used for the hatcheries were based on the maximum effluent flows. DEQ provided maximum effluent flows based on historical DMR data for summer, spring spawning and fall spawning periods. These effluent flows were used to configure the flows for the hatcheries.
- Effluent water temperatures for the hatcheries were based on temperature deltas derived using available historical effluent and influent hatchery temperatures plus the hourly water temperature from the model segment upstream of where the hatchery discharges. The temperature deltas were based on the 95th percent effluent 7DADM temperature minus the influent 7DADM temperature for the spring spawning, summer, and fall spawning periods. The model was run first to extract the hourly temperature from the model segment upstream of where the hatchery discharges. The modeled hourly timeseries from the upstream segment plus the calculated deltas for the appropriate spawning and summer period were then used to create the hatchery water temperature timeseries inputs.

The point sources within each model and any updates/additions made for each of the Willamette models are discussed below by waterbody. Plots are only presented when point source updates were made.

3.1 SOUTH SANTIAM RIVER UPDATES

Point sources to the South Santiam River USGS model include wastewater treatment plants (WWTPs) for the cities of Lebanon and Sweet Home for the year 2015. The effluent flows and water temperatures for both of these facilities in the USGS model were configured using monthly values. The daily average flows and daily maximum water temperatures from the 2015 DMR data were used to update the model boundaries.

The DMR data were complete with a few exceptions. Effluent flow data for the Lebanon WWTP were not available, so influent flows were used to configure the model boundary. In addition, a typographical error in the water temperatures DMR for Sweet Home on July 1, 2015 was also corrected from 470.48 deg F to 70.48 deg F based on a review of the previous and next day values in the dataset.

In updated model setup, the corresponding travel-time offset withdrawals for the Sweet Home and Lebanon WWTPs were also updated accordingly. Table 3-1 shows the details of all the point sources and Figure 3-1 shows the location of all the point sources in the South Santiam River model. Figure 3-2 and Figure 3-3 show the updates made to the Lebanon and Sweet Home WWTPs.

Table 3-1. Point Sources represented in the South Santiam Model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Sweet Home WWTP	44.4	-122.7364	86840	34	33	32.49	Updated from monthly to daily
Lebanon WWTP	44.5488	-122.8956	49764	182	181	16.30	Updated from monthly to daily

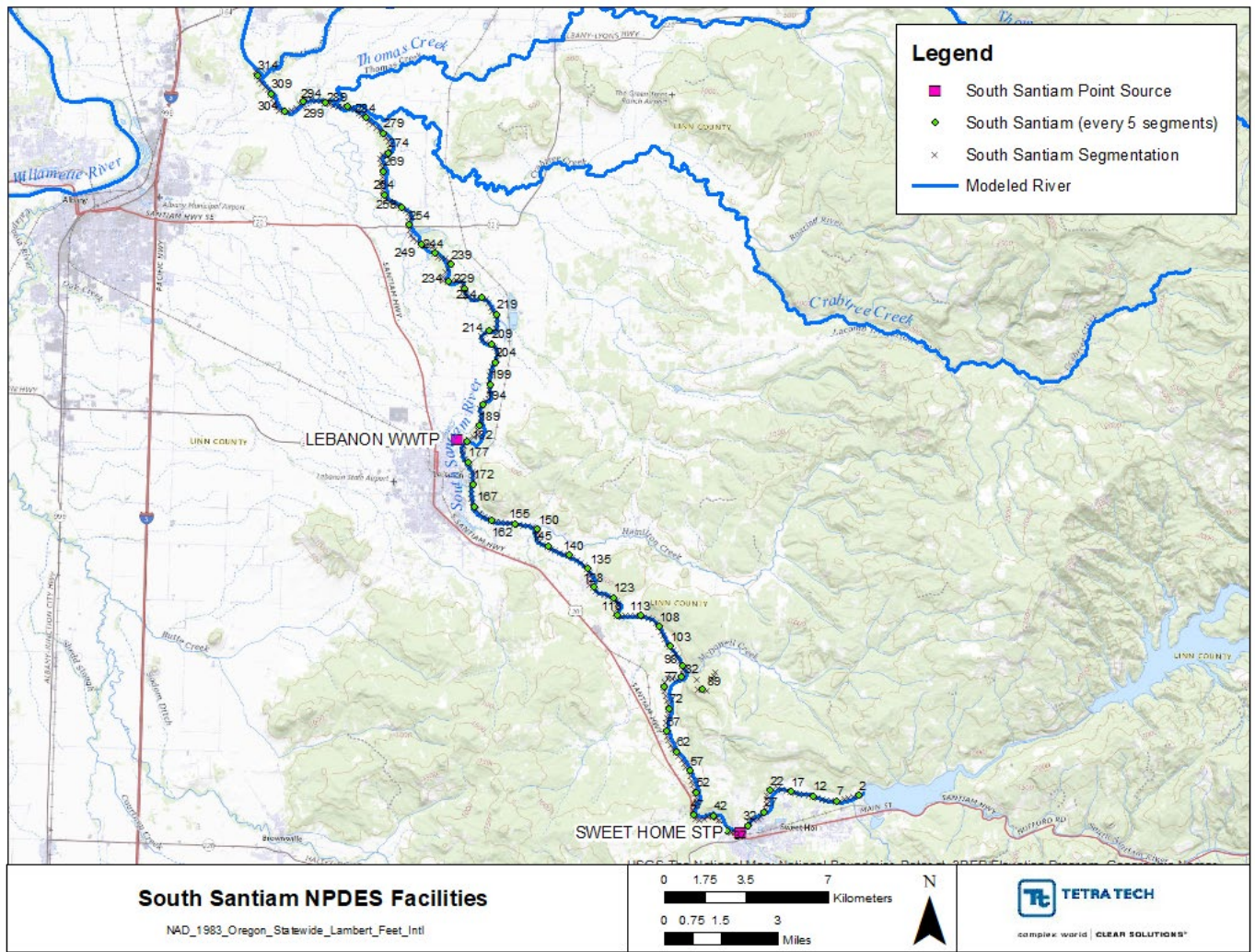


Figure 3-1. South Santiam River point source facility locations

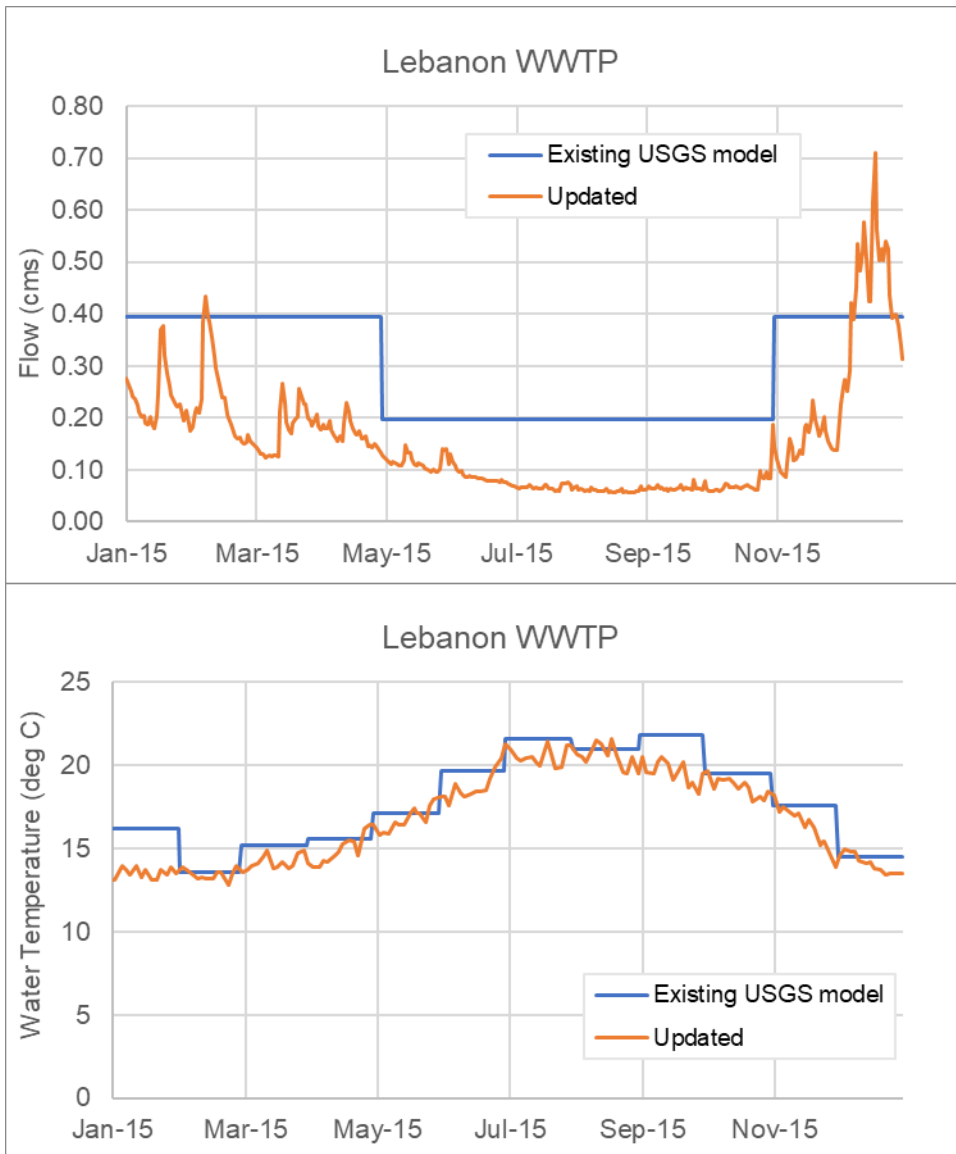


Figure 3-2. Updates made to the flow and water temperature boundary inputs for Lebanon WWTP

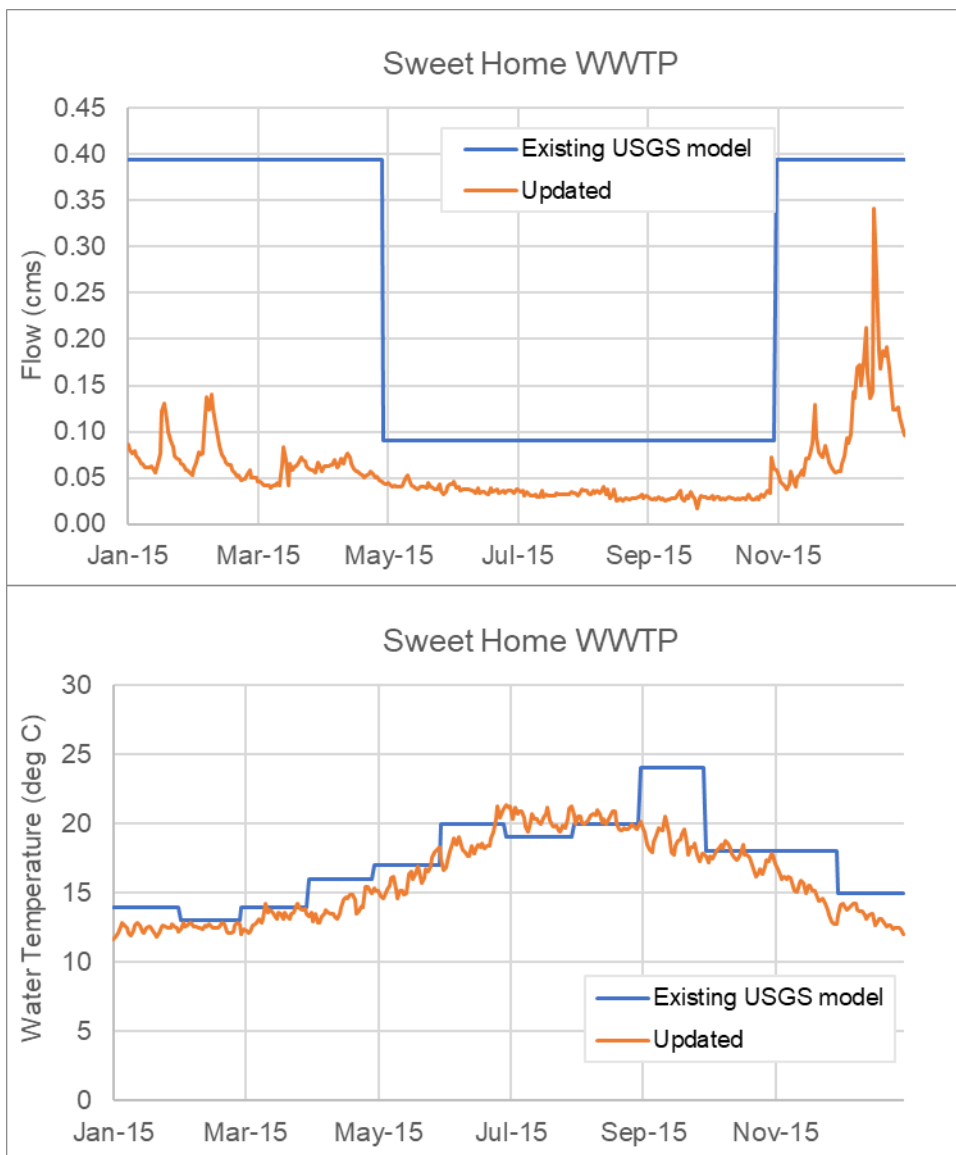


Figure 3-3. Updates made to the flow and water temperature boundary inputs for Sweet Home WWTP

3.2 NORTH SANTIAM RIVER UPDATES

Point sources to the North Santiam River USGS model include sewage treatment plants (STPs) for the cities of Stayton and Jefferson for the year 2015. The Stayton facility discharges to the North Santiam River, whereas the Jefferson facility discharges to the Santiam River. The flows for both these facilities in the USGS model were configured using monthly values. The water temperature for both facilities were set at a constant 30 deg C. Daily average flows and daily maximum water temperatures from the 2015 DMR data were available and were used to update the model boundaries.

The daily DMR data were complete with some minor gaps which were filled. The Stayton WWTP flow data showed a typographical error on October 1, 2015, where the data showed flow reported as 81 MGD. This was corrected to 0.81 MGD based on a review of the previous and next day in the dataset. The Jefferson WWTP water temperature data were missing for the entire month of September 2015. This gap was filled using September 2016 water temperature data.

Two new point source facilities were added to the North Santiam model based on input provided by DEQ. These included the ODFW Minto Fish Facility (also known as Marion Forks Hatchery) and Frank Lumber Company. The fish hatchery and point source facility were added based on the methodology discussed above.

The corresponding travel-time offset withdrawals for each of the point sources were also updated accordingly in the model. Table 3-2 shows the details of all the point sources and Figure 3-4 shows the location of all the point sources in the North Santiam River model. Figure 3-5 and Figure 3-6 show the updates made to the Stayton and Jefferson WWTPs. Figure 3-7 and Figure 3-8 show the flow and water temperature boundaries for the Minto Fish Facility and Frank Lumber Co added to the model.

Table 3-2. Point Sources represented in the North Santiam Model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Minto Fish Facility (Marion Forks Hatchery)	44.7576	-122.36075	64495	26	25	87.63	Added
Frank Lumber Co	44.7491	-122.5039	30904	69	68	74.52	Added
Stayton WWTP	44.7914	-122.8042	84781	166	165	45.57	Updated from monthly to daily
Jefferson WWTP	44.724	-123.0102	43129	274	273	14.48	Updated from monthly to daily

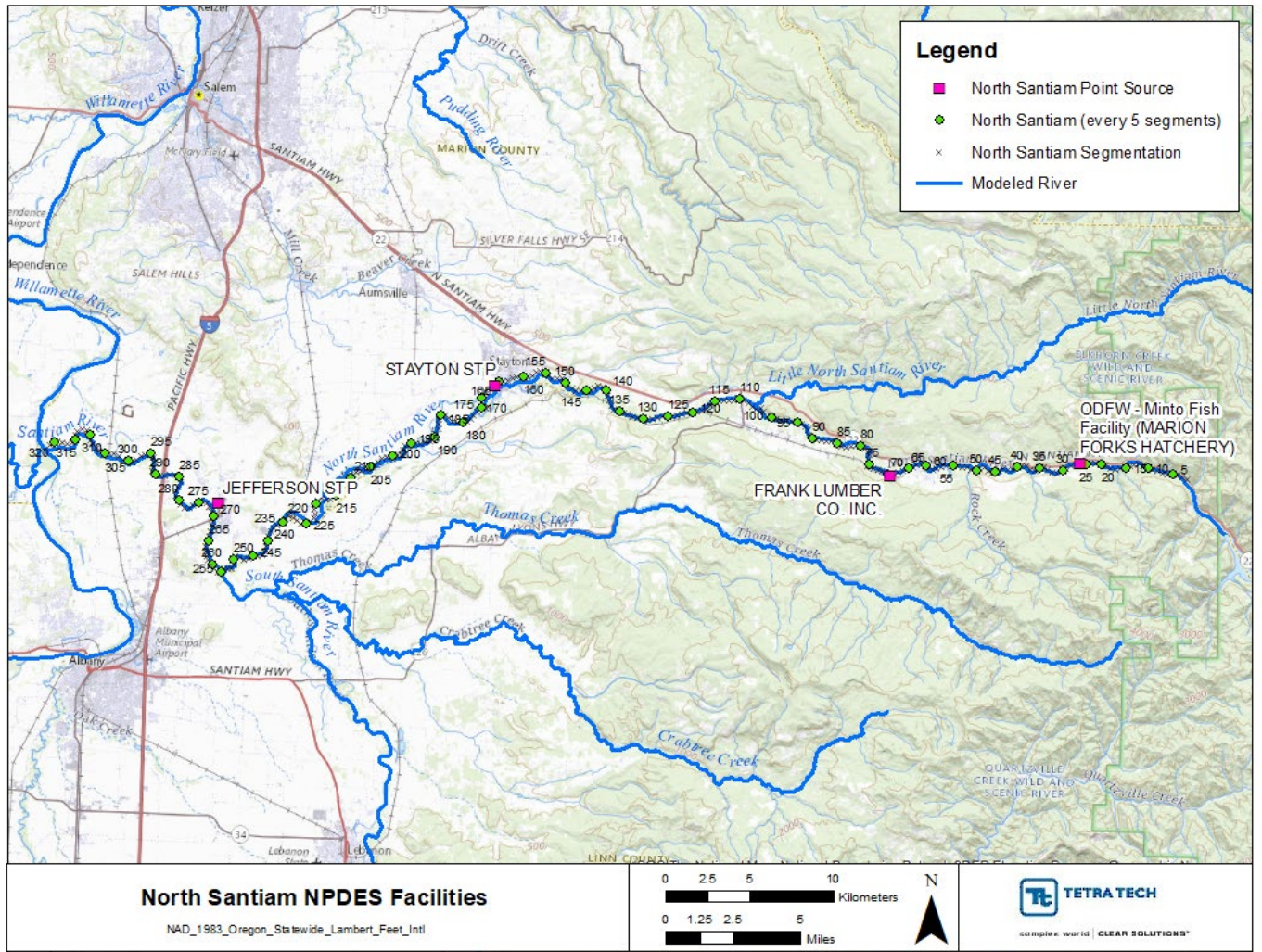


Figure 3-4. North Santiam River point source facility locations

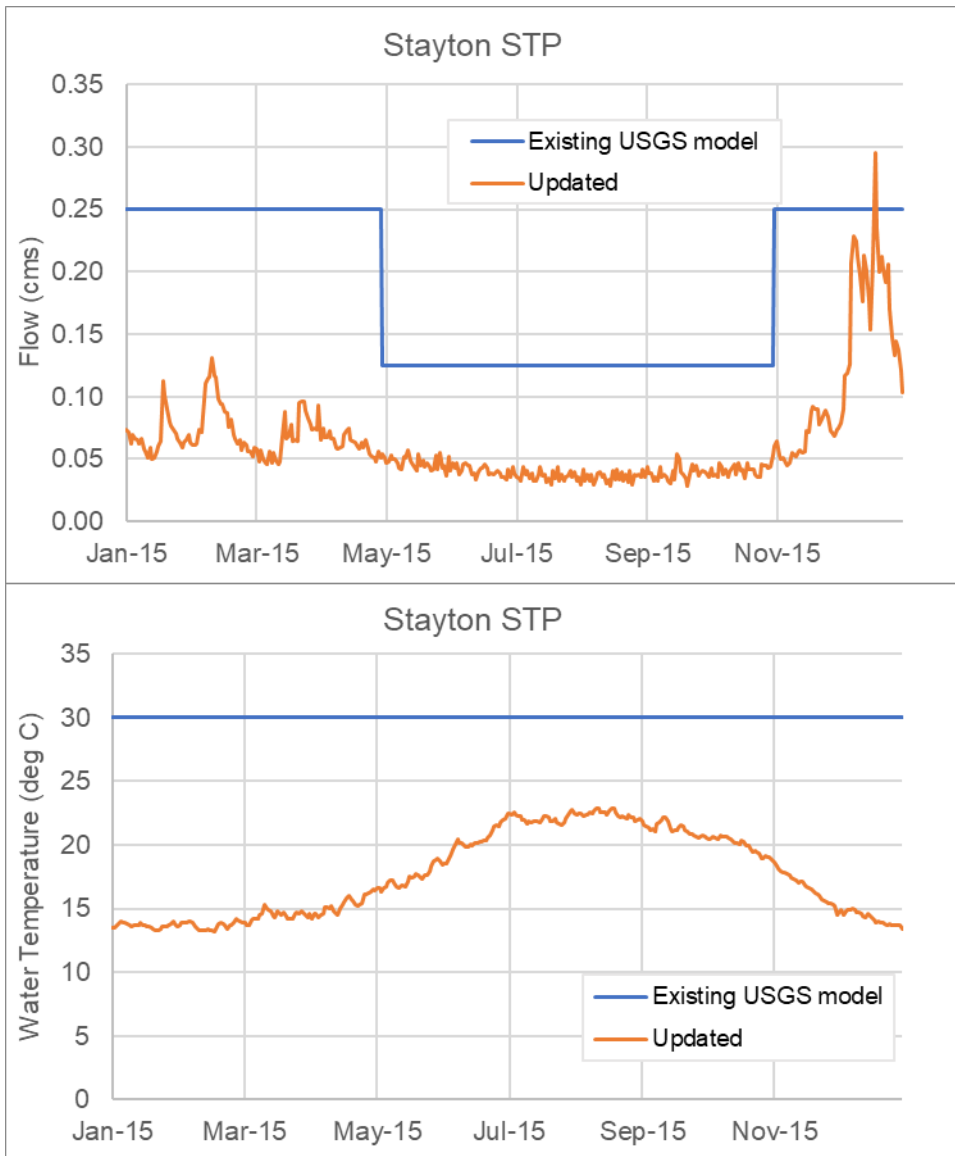


Figure 3-5. Updates made to the flow and water temperature boundary inputs for Stayton STP

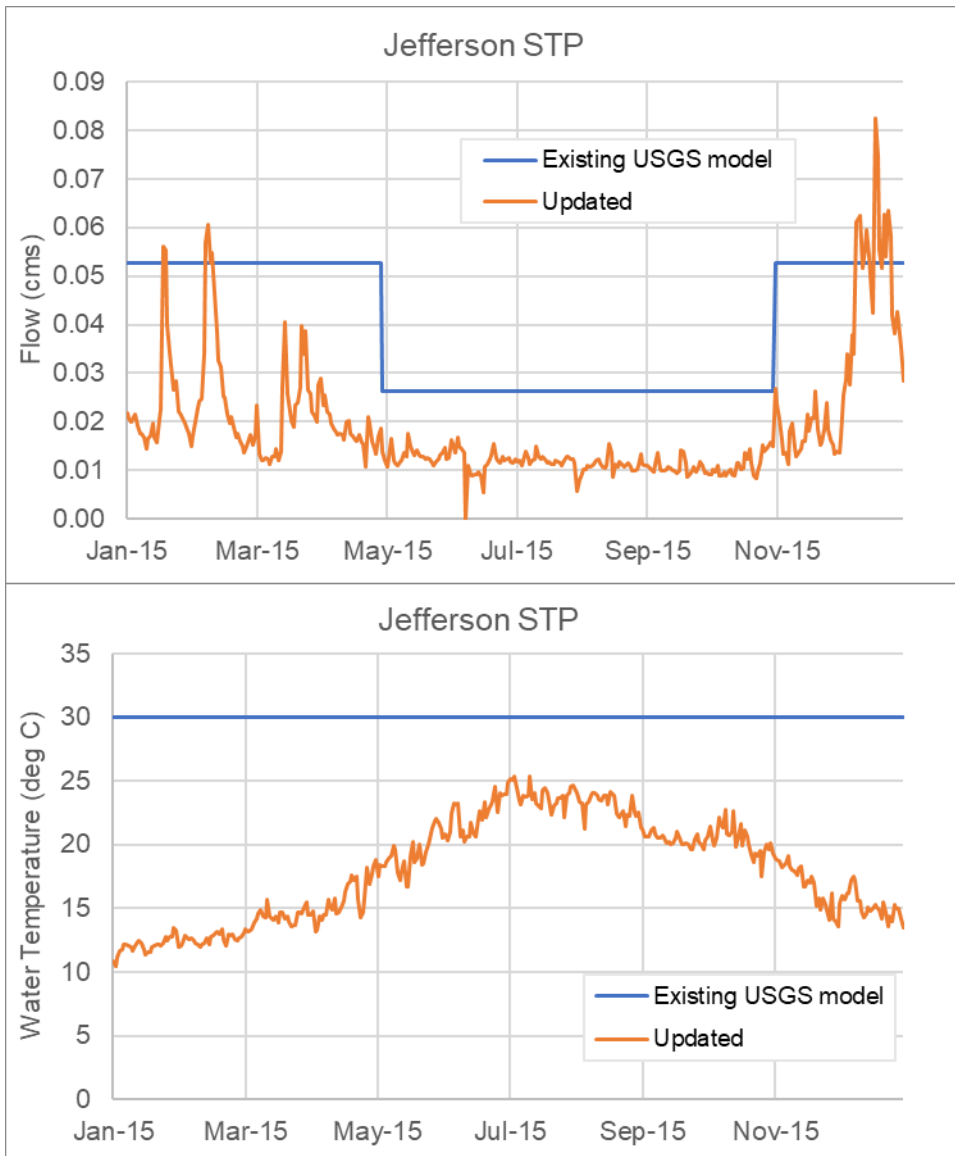


Figure 3-6. Updates made to the flow and water temperature boundary inputs for Jefferson STP.

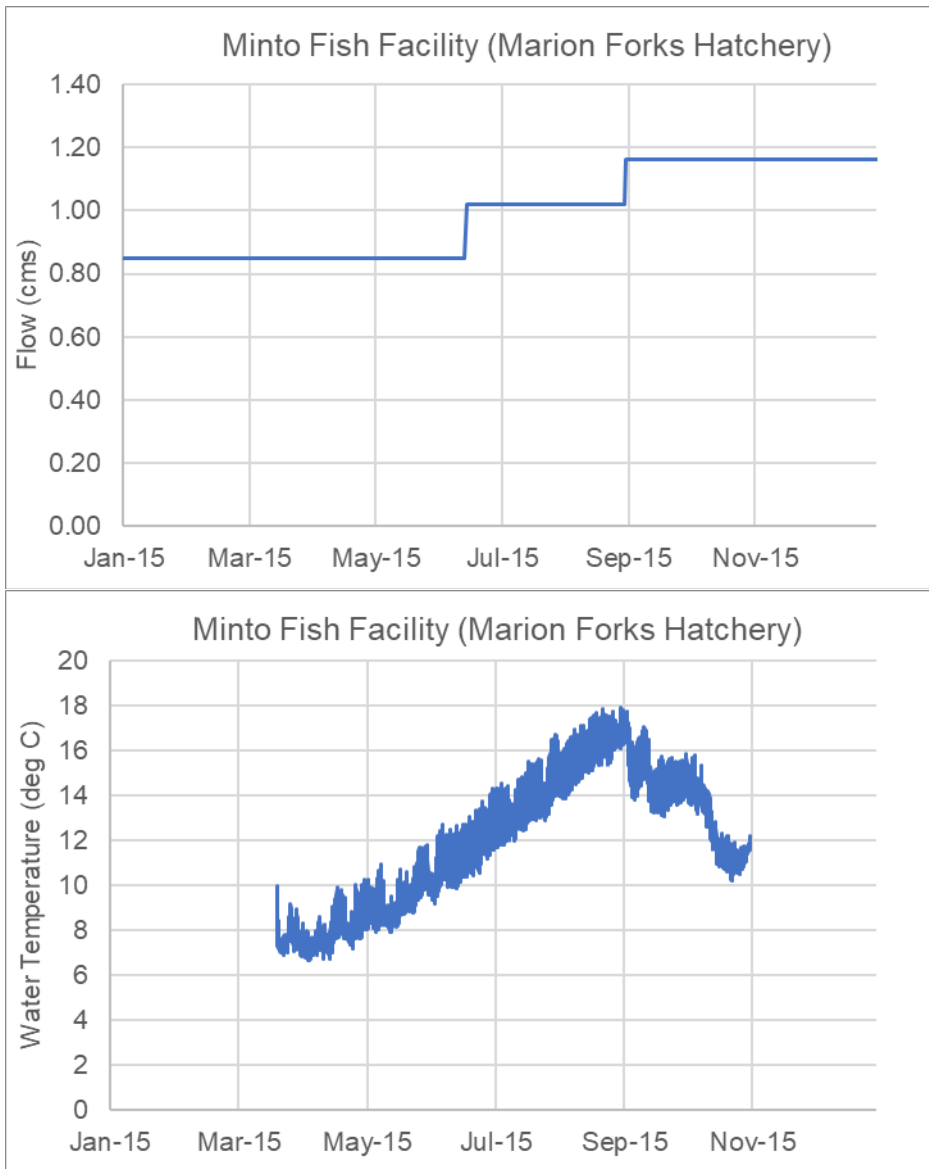


Figure 3-7. Flow and water temperature boundary inputs for Minto Fish Facility (new point source)

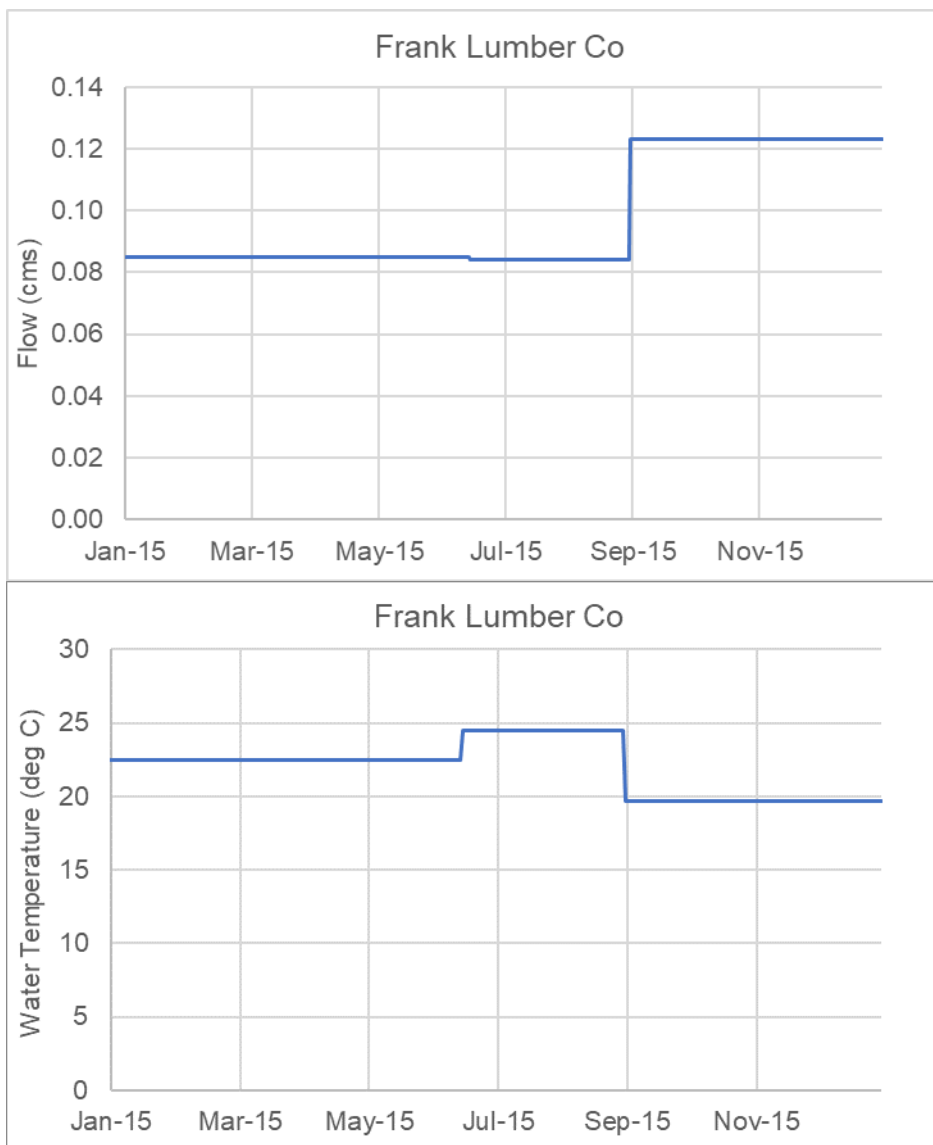


Figure 3-8. Flow and water temperature boundary inputs for Frank Lumber Co (new point source)

3.3 MCKENZIE RIVER UPDATES

The McKenzie River USGS model included one point source for the year 2015, the International Paper facility. No updates were made to this point source. Two new hatchery point source facilities were added to the McKenzie River model based on input provided by DEQ. These included the ODFW Leaburg Hatchery Facility and McKenzie River Hatchery. Both the fish hatcheries were added based on the methodology discussed above. Since these two hatcheries are near each other, an additional model run was made to configure the water temperature for the McKenzie River Hatchery. The model was first configured and run after adding the inputs from the Leaburg Hatchery. The results of the model with the Leaburg Hatchery included, were then used to configure the McKenzie River Hatchery.

The corresponding travel-time offset withdrawals for each of the point sources were also updated accordingly in the model. Table 3-3 shows the details of all the point sources and Figure 3-9 shows the location of all the point sources in the McKenzie River model. Figure 3-10 and Figure 3-11 show the model boundary inputs for the two hatcheries that were added in the model.

Table 3-3. Point Sources represented in the McKenzie River model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Leaburg Hatchery	44.1203	-122.6092	64490	168	167	35.42	Added
McKenzie River Hatchery	44.1166	-122.636	64500	184	183	33.24	Added
International Paper	44.0539	-122.9593	96244	321	320	12.22	No change

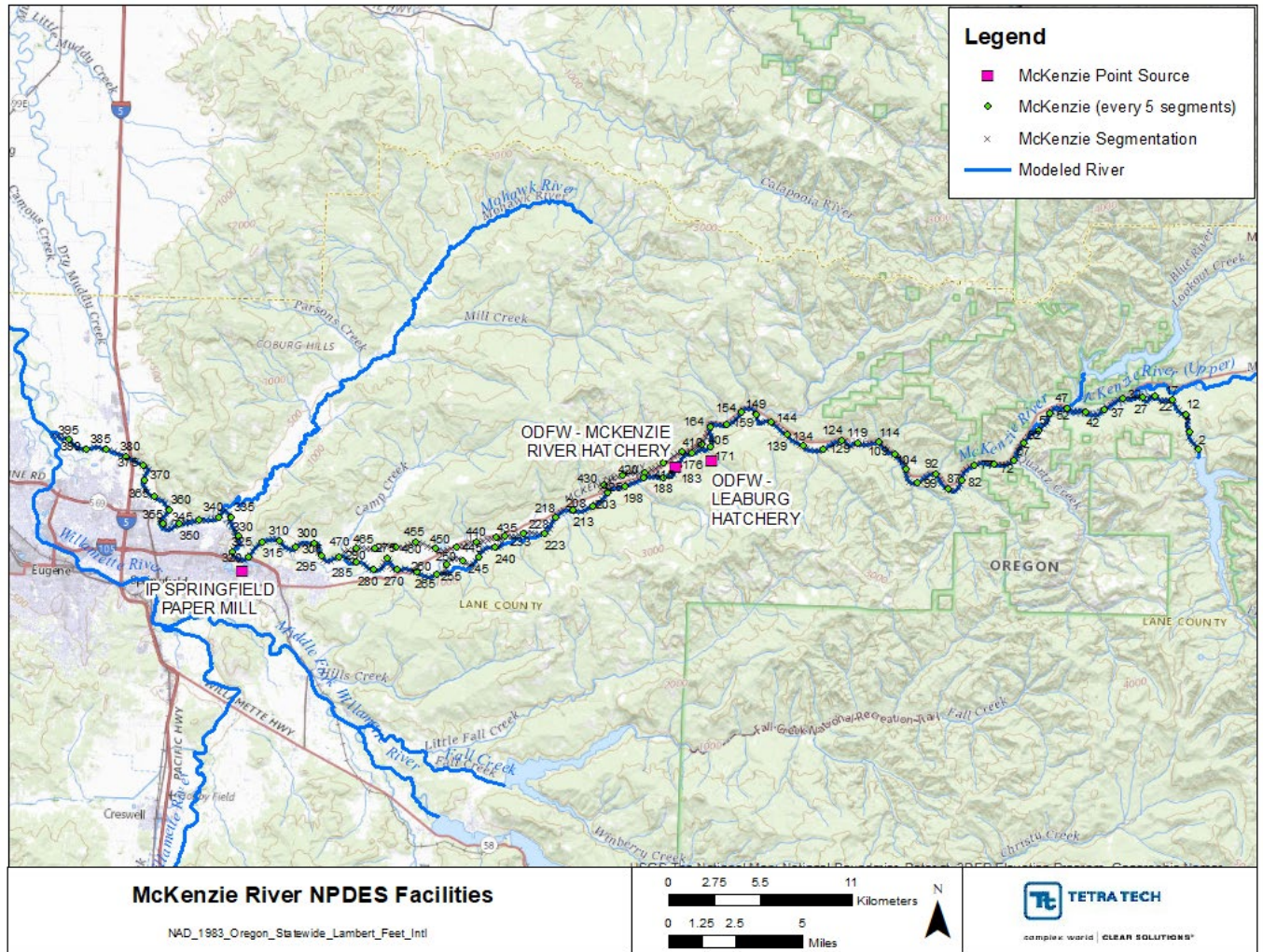


Figure 3-9 McKenzie River point source facility locations

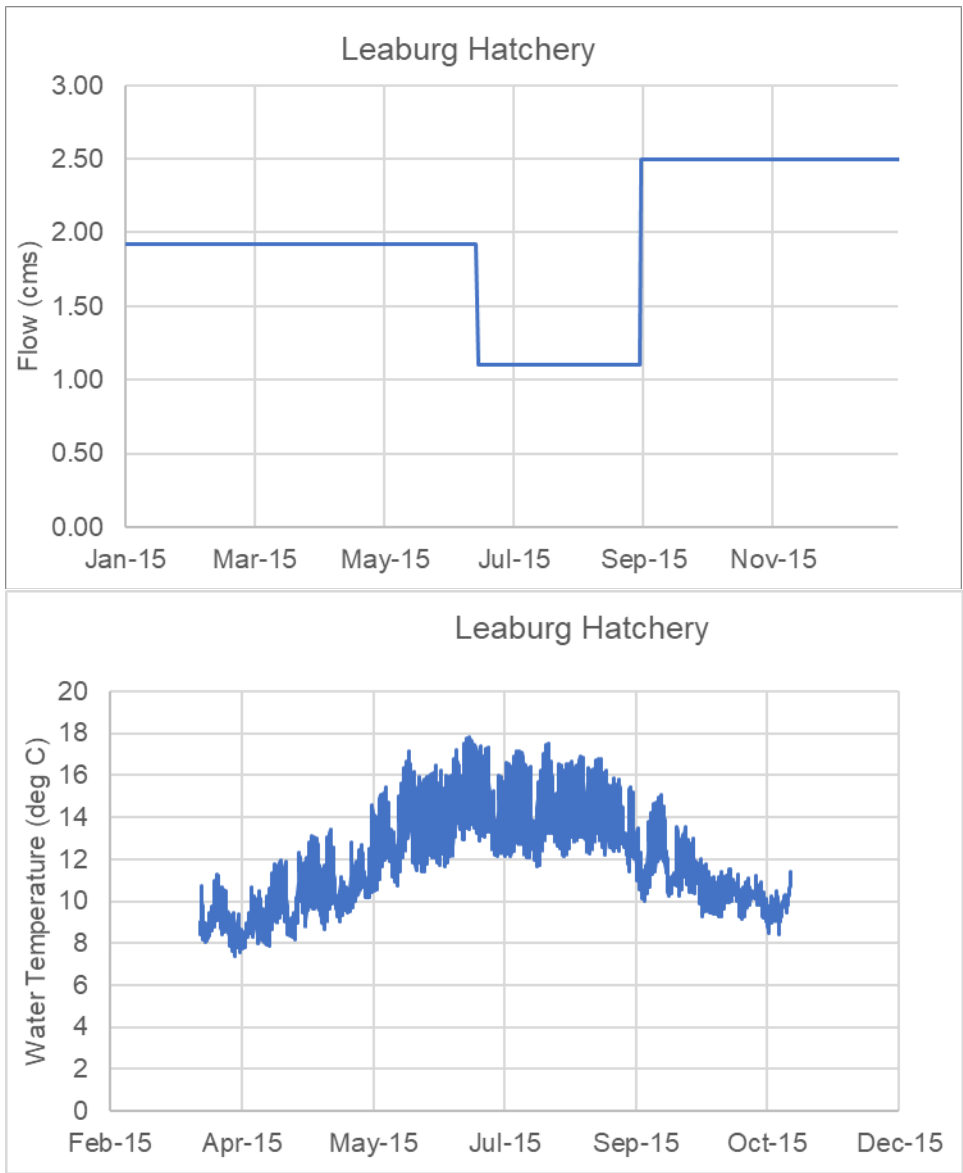


Figure 3-10. Flow and water temperature boundary inputs for Leaburg Hatchery (new point source)

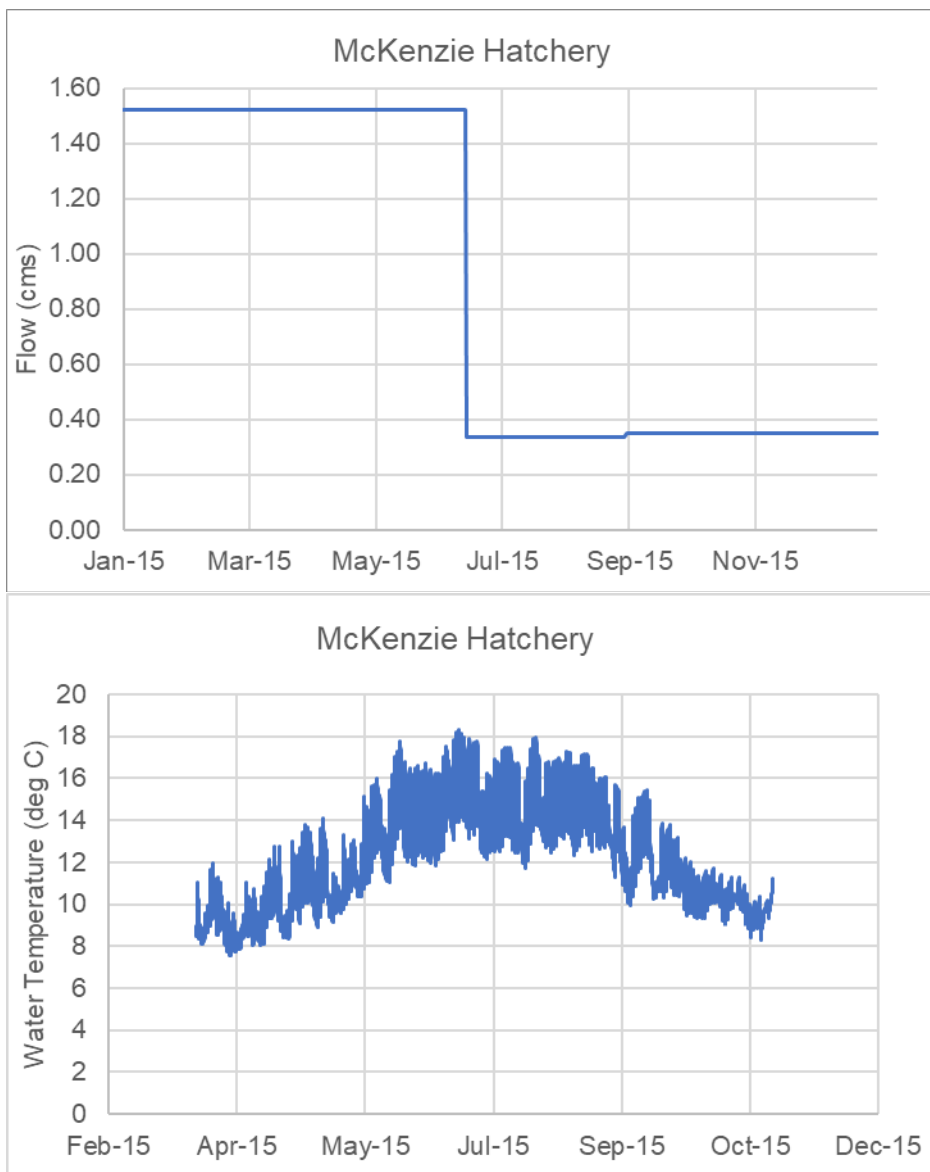


Figure 3-11. Flow and water temperature boundary inputs for McKenzie River Hatchery (new point source)

3.4 COAST FORK MIDDLE FORK RIVER UPDATES

The Coast Fork Middle Fork River USGS model included one point source, the Cottage Grove STP facility, for the year 2015. The effluent flows and water temperatures for this facility were configured using monthly values. The daily average flows and daily maximum water temperatures from the 2015 DMR data were used to update the model boundaries. Effluent flows were not available, so influent flows were used to configure the Cottage Grove STP flow boundary.

Based on input provided by DEQ, a new point source, the ODFW Dexter Ponds Hatchery, was added to the Coast Fork Middle Fork River model upstream of Middle Fork Willamette River in the model. The fish hatchery was added following the methodology discussed above, under the fish hatchery boundary input methodology for inclusion into the model. Figure 3-13 and Figure 3-14 show the model boundary inputs for the two point sources in the model.

The corresponding travel-time offset withdrawals for each of the point sources were also updated accordingly in the model. Table 3-4 shows the details of all the point sources model and Figure 3-12 shows the location of all the point sources in the Coast Fork Middle Fork River.

Table 3-4. Point Sources represented in the Coast Fork Middle Fork model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Cottage Grove STP	43.8077	-123.0481	20306	52	51	21.37	Updated from monthly to daily
Dexter Pond Hatchery	43.9252	-122.808	64450	253	252	16.27	Added

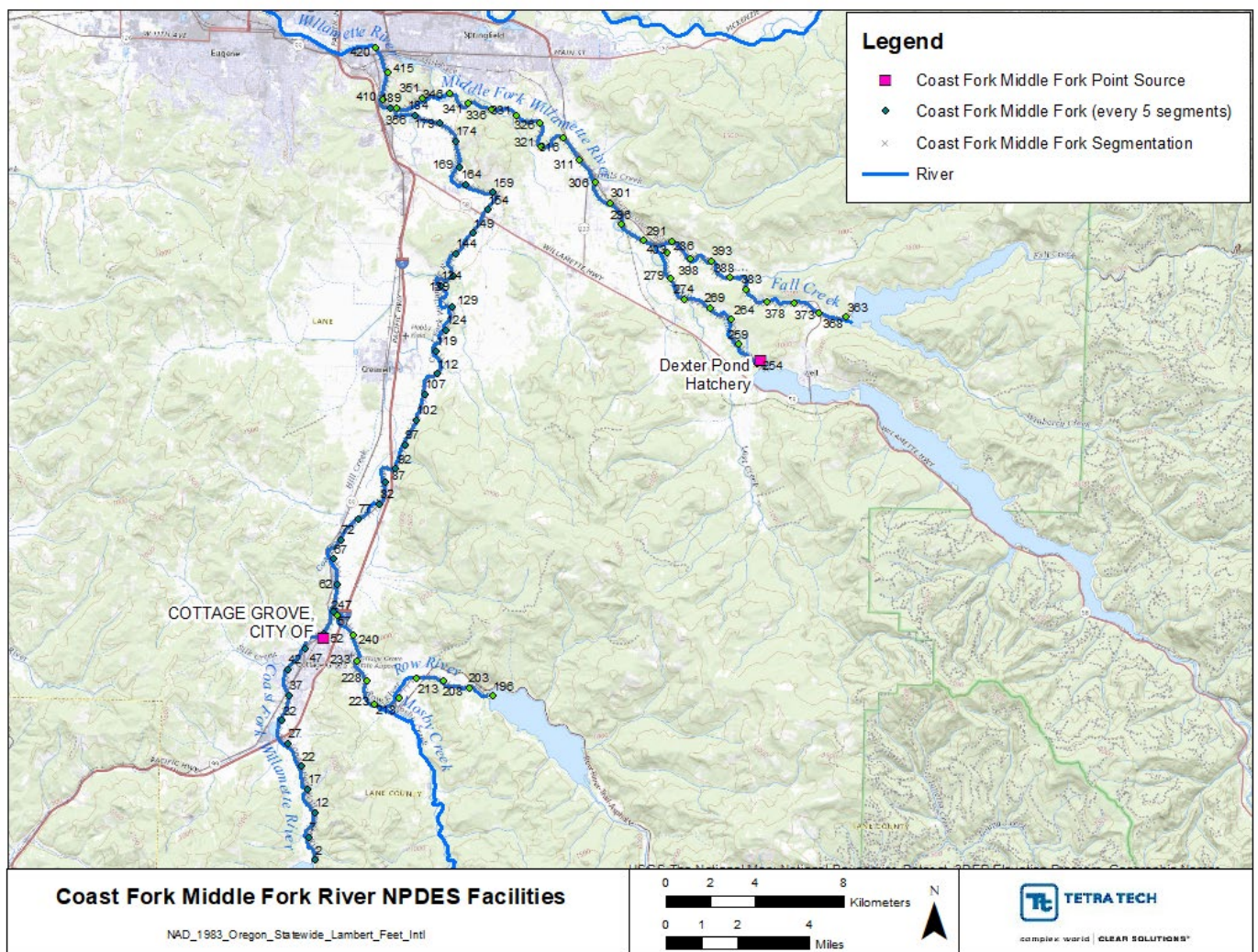


Figure 3-12 Coast Fork Middle Fork River point source facility locations

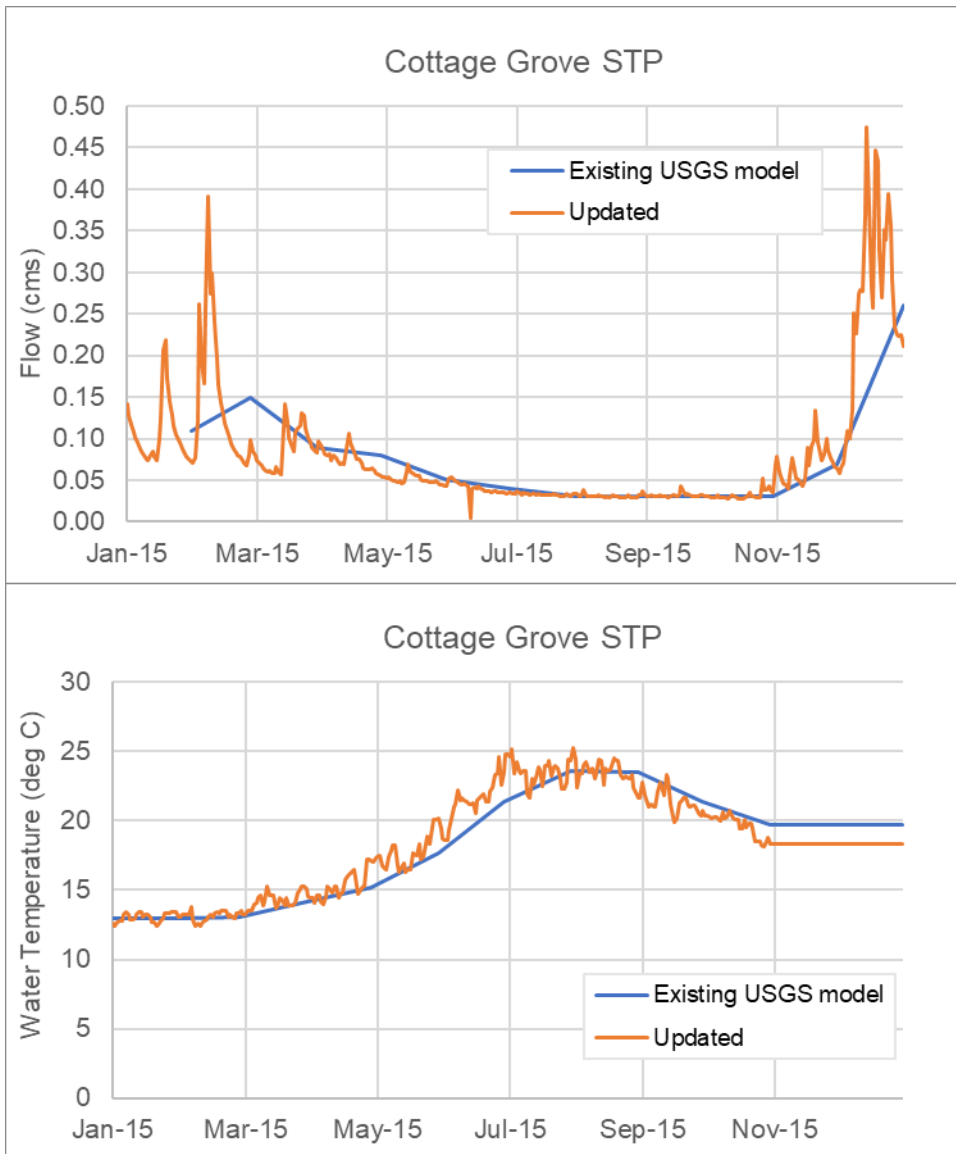


Figure 3-13. Updates made to the flow and water temperature boundary inputs for Cottage Grove STP

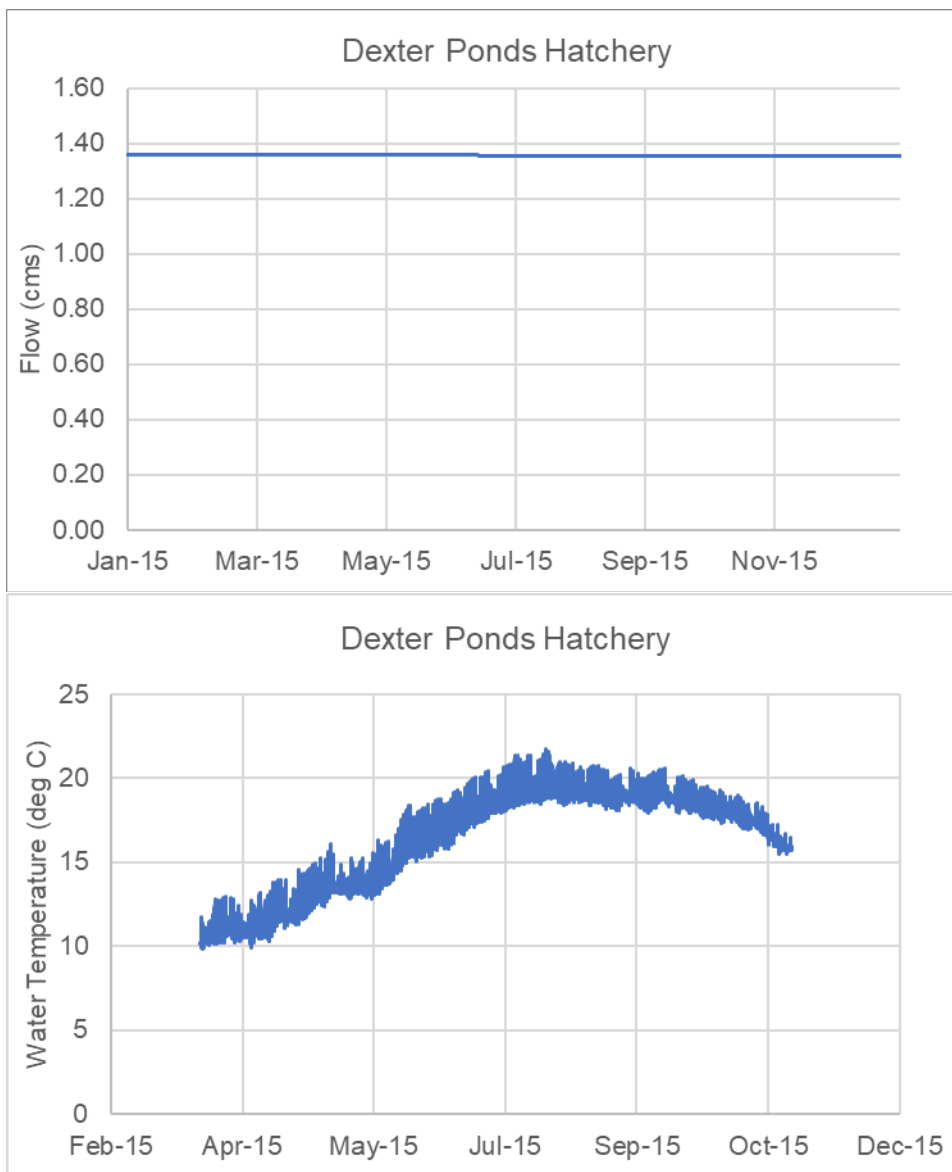


Figure 3-14. Flow and water temperature boundary inputs for Dexter Ponds Hatchery (new point source)

3.5 UPPER WILLAMETTE RIVER POINT UPDATES

There are eight existing point sources discharging to the Upper Willamette River in the USGS model. Table 3-5 shows the details of all the point sources and Figure 3-15 shows the location of all the point sources in the Upper Willamette River model. Outfall locations may differ from the facility locations shown. No updates were made to six of the point sources. Updates were made to Cascade Pacific Pulp, LLC and Albany-Millersburg Water Reclamation facility. Hourly flow and water temperature data received from these two facilities during DEQs data solicitation effort were used to update the model boundary inputs from daily to hourly. Figure 3-16 and Figure 3-17 show the updated flow and water temperature used to configure the Cascade Pacific Pulp, LLC and Albany-Millersburg Water Reclamation facility.

Three new point sources were added to the Upper Willamette River model based on input provided by DEQ. These included the OSU John L. Fryer Aquatic Animal Health Lab, Independence STP, and City of Monmouth STP. The point source facilities were configured using the calculated spring, summer, and fall max effluent flow

and max 7DADM water temperature (provided by DEQ). Figure 3-18, Figure 3-19, and Figure 3-20 show the flow and water temperature used to represent the three new point sources.

The corresponding travel-time offset withdrawals for all the point sources were also updated accordingly in the model.

Table 3-5. Point Sources represented in the Upper Willamette River Model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
University Of OR ^a	44.0554	-123.0813	N/A	22	21	182.33	No change
Metropolitan Wastewater Management Commission	44.0961	-123.1199	55999	46	45	178.59	No change
Cascade Pacific Pulp, LLC	44.3827	-123.1605	36335	252	251	148.07	Updated using hourly data received during data solicitation from DEQ
Hollingsworth & Vose Fiber Company	44.5538	-123.2606	28476	347	346	133.28	No change
OSU John L. Fryer Aquatic Animal Health Lab	44.5676	-123.2452	103919	354	353	132.19	Added
City of Corvallis	44.5758	-123.2552	20151	358	357	131.56	No change
Albany-Millersburg Water Reclamation Facility	44.6430	-123.0767	1098	444	443	118.80	Updated using hourly data received during data solicitation from DEQ
ATI Wah Chang ^a	44.6639	-123.0752	N/A	453	452	117.71	No change
Albany Paper Mill ^a	44.6621	-123.0722	N/A	454	453	117.55	No change
City of Independence	44.8583	-123.1958	41513	597	596	96.22	Added
City of Monmouth	44.8583	-123.2167	57871	597	596	96.22	Added

a: Facilities do not discharge anymore. Included as part of USGS models received with flows set to zero.

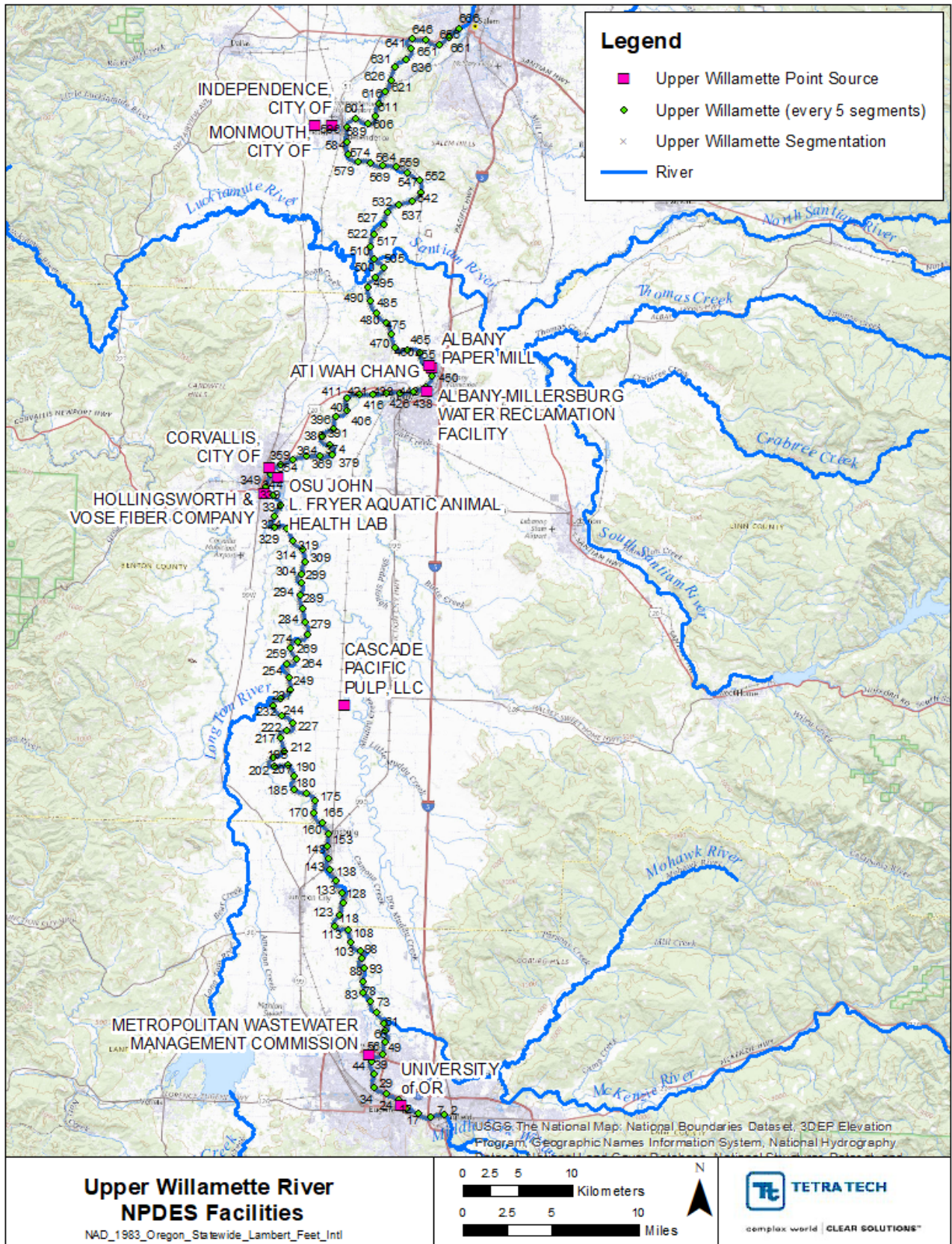


Figure 3-15. Upper Willamette River point source facility locations. Locations shown are facility locations, not outfall locations, which may differ.

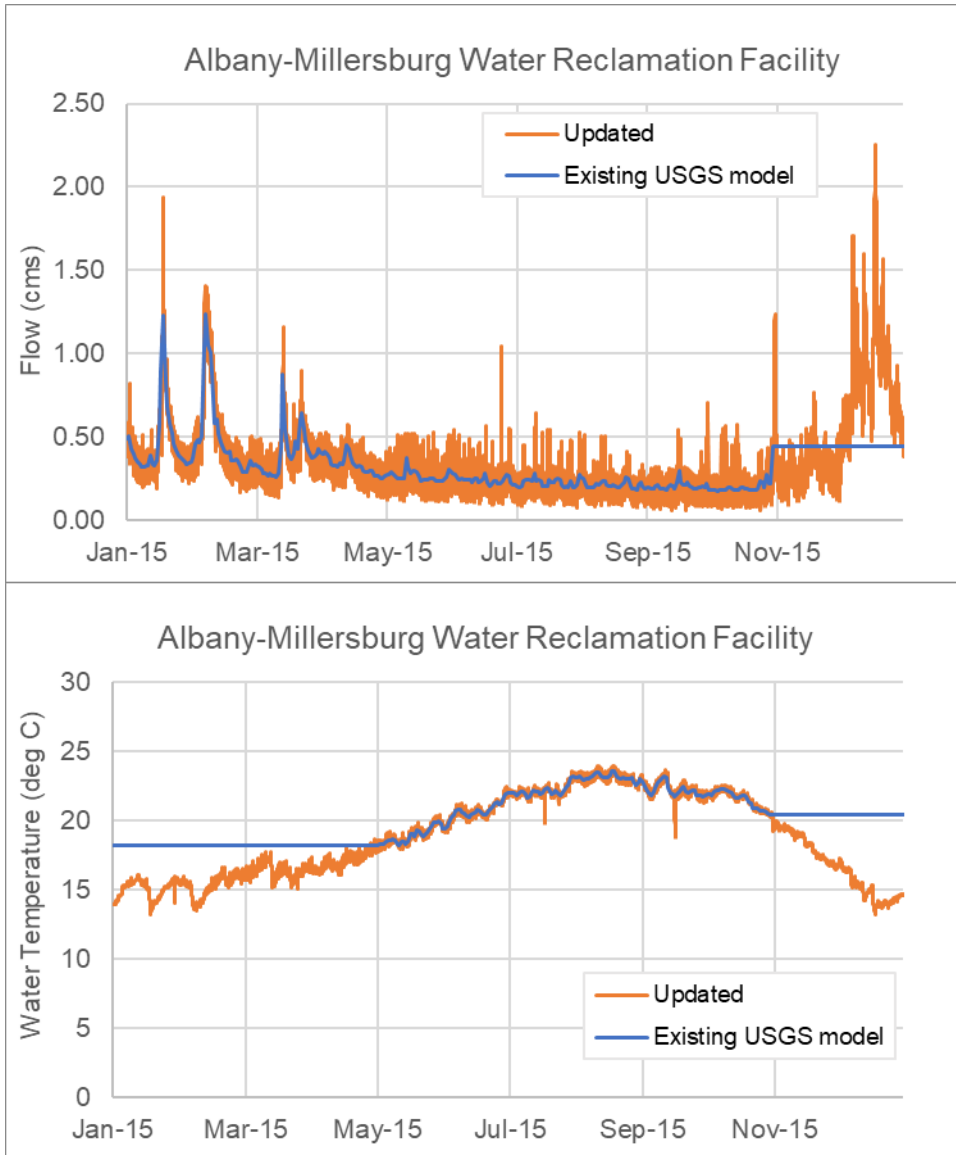


Figure 3-16. Updates made to the flow and water temperature boundary inputs for Albany Millersburg WRF

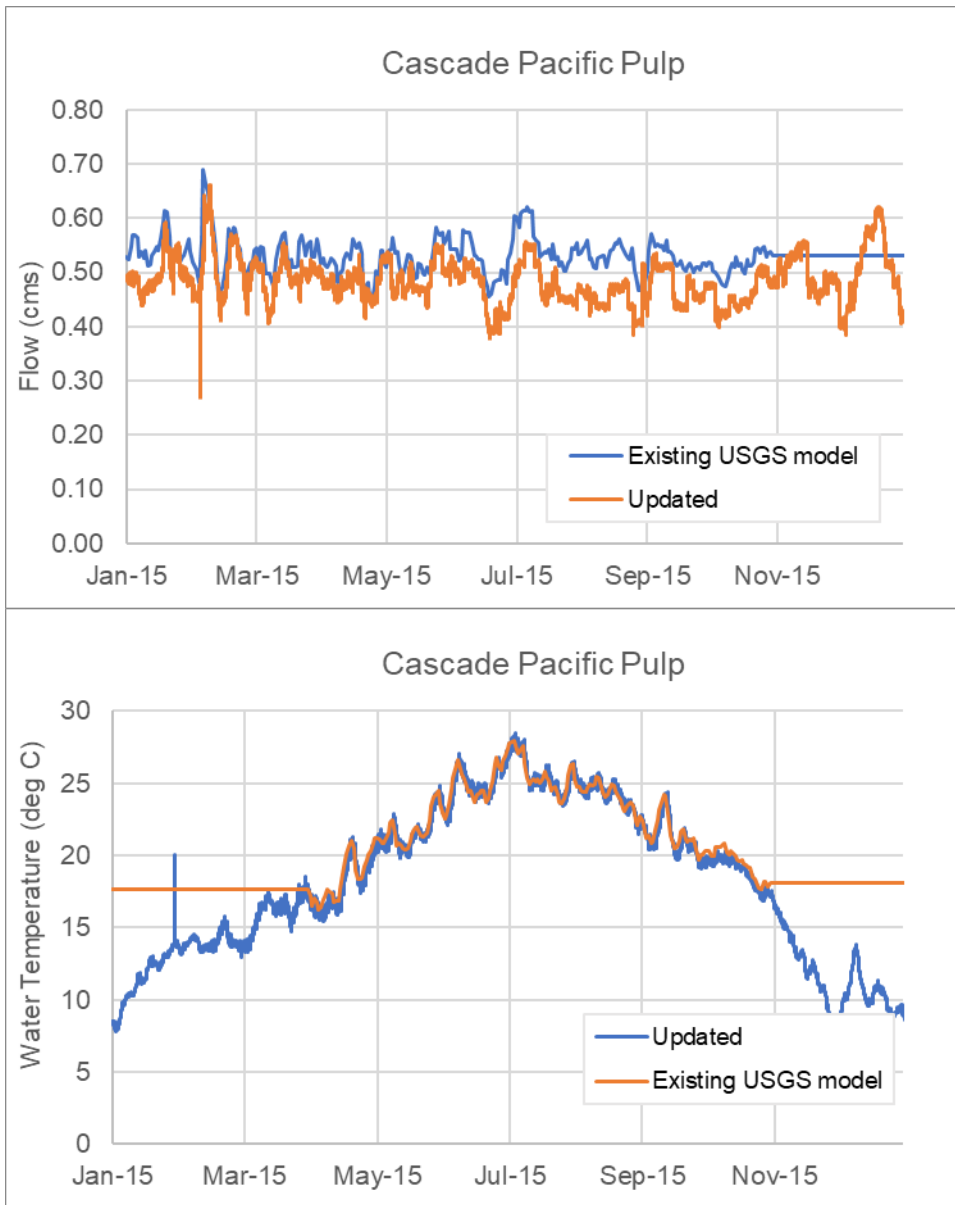


Figure 3-17. Updates made to the flow and water temperature boundary inputs for Cascade Pacific Pulp

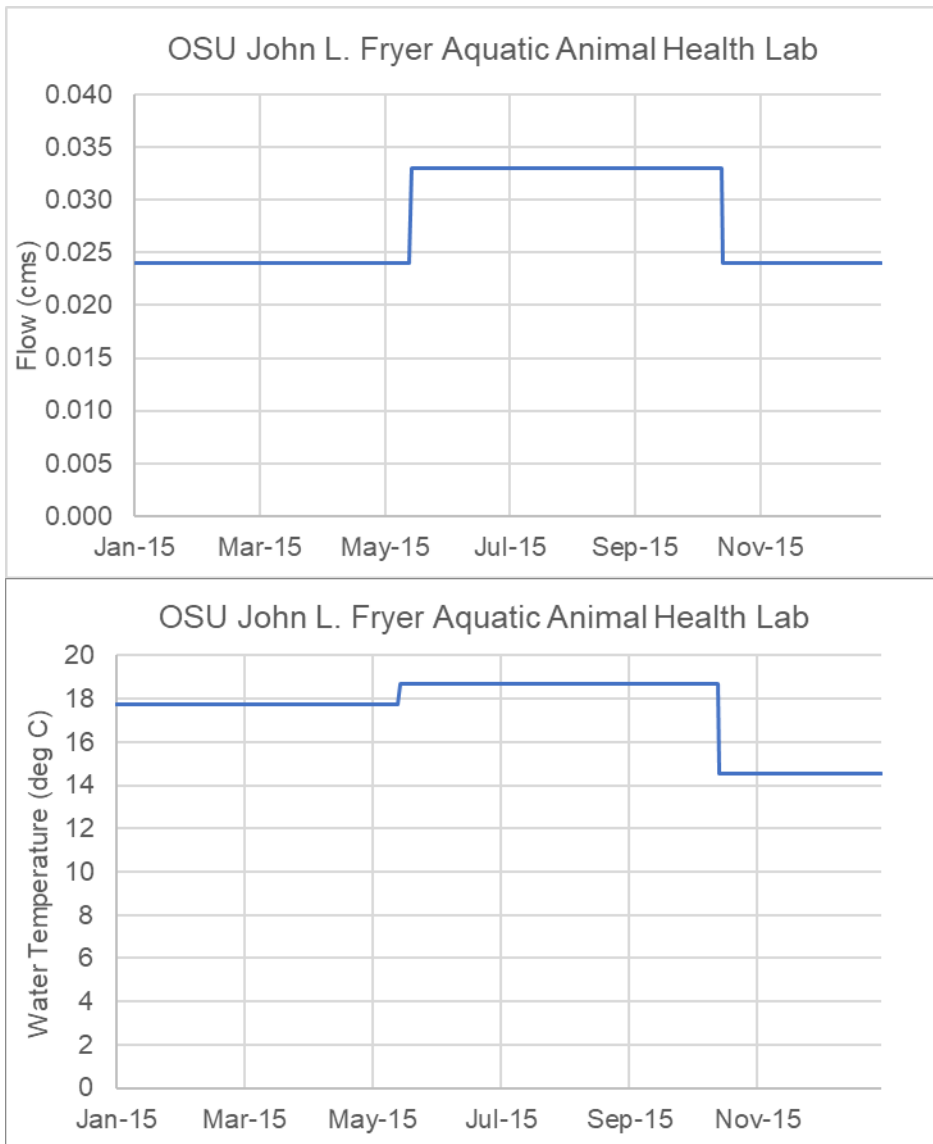


Figure 3-18. Flow and water temperature boundary inputs for OSU John L. Fryer Aquatic Animal Health Lab (new point source)

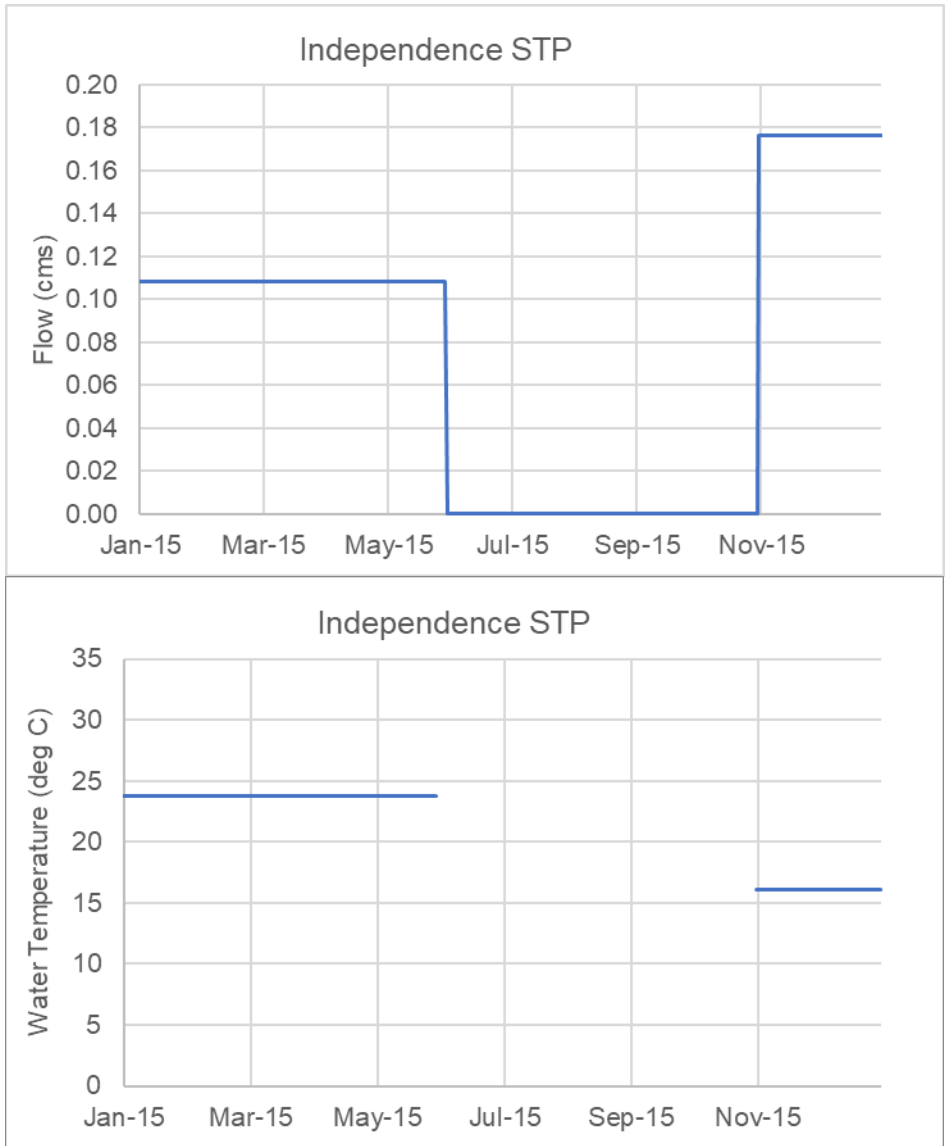


Figure 3-19. Flow and water temperature boundary inputs for Independence STP (new point source)

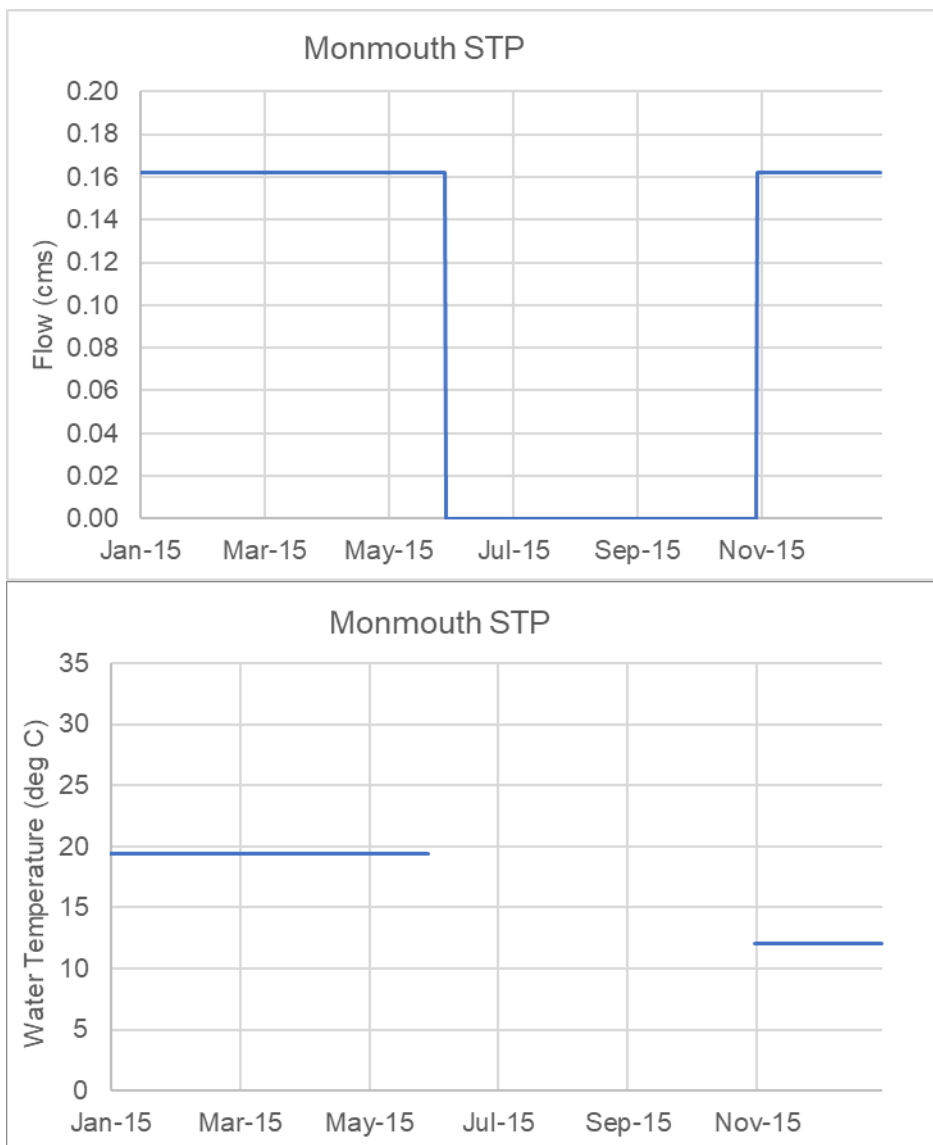


Figure 3-20. Flow and water temperature boundary inputs for Monmouth STP (new point source)

3.6 MIDDLE WILLAMETTE RIVER UPDATES

There are six existing point sources discharging to the Middle Willamette River in the USGS model. Table 3-6 shows the details of all the point sources, and Figure 3-21 shows the location of all the point sources in the Middle Willamette River model. Updates were only made to the Canby STP. The flow and water temperature inputs for Canby STP in the USGS model were configured using 2016 data which were updated using the 2015 DMR data provided by DEQ. Figure 3-22 shows the flow and water temperature used to configure the 2015 Canby STP.

An additional point source, the Covanta Marion Inc. facility, was added to the Middle Willamette River model based on input provided by DEQ. The point source facility was configured using the calculated spring, summer, and fall max effluent flow and max 7DADM water temperature (provided by DEQ). Figure 3-23 shows the flow and water temperature for Covanta Marion Inc. facility used in the model.

The corresponding travel-time offset withdrawals for the new and updated point sources were also updated accordingly in the model.

Table 3-6. Point Sources represented in the Middle Willamette River model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Salem Willow Lake STP	45.01	-123.055	78140	42	41	79.10	No change
Covanta Marion, Inc	45.049	-122.964	89638	62	61	76.00	Added
Westrock, Newberg Mill (Formerly SP Newsprint)	45.289	-122.961	72615	245	244	50.41	No change
Newberg - Wynooski Road STP	45.286	-122.953	102894	246	245	50.26	No change
Wilsonville STP	45.295	-122.772	97952	319	318	38.86	No change
Canby STP	45.289	-122.681	13691	354	353	33.35	Updated using DMR data from DEQ
West Linn Paper Company	45.356	-122.615	21489	396	395	26.76	No change

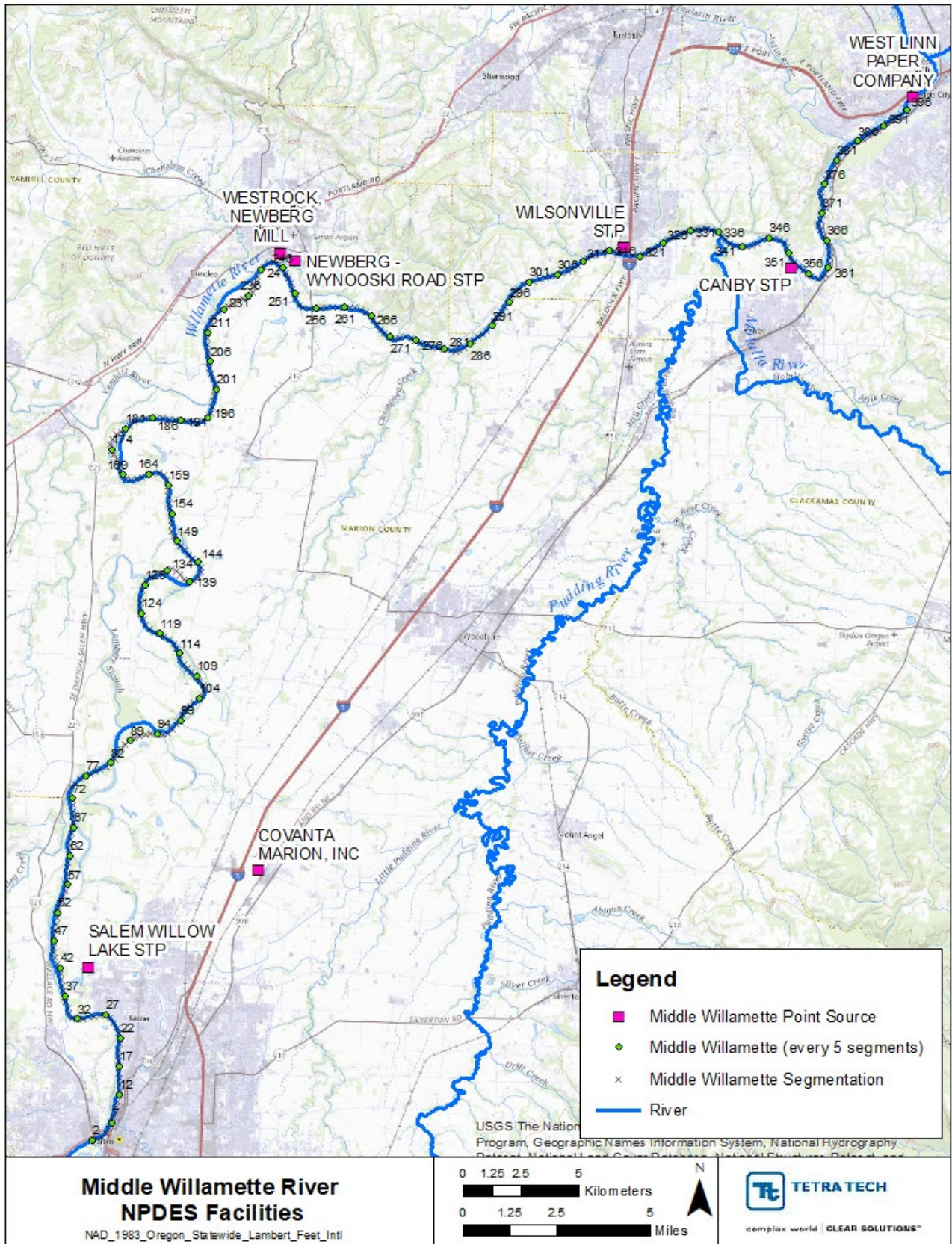


Figure 3-21. Middle Willamette River point source facility locations

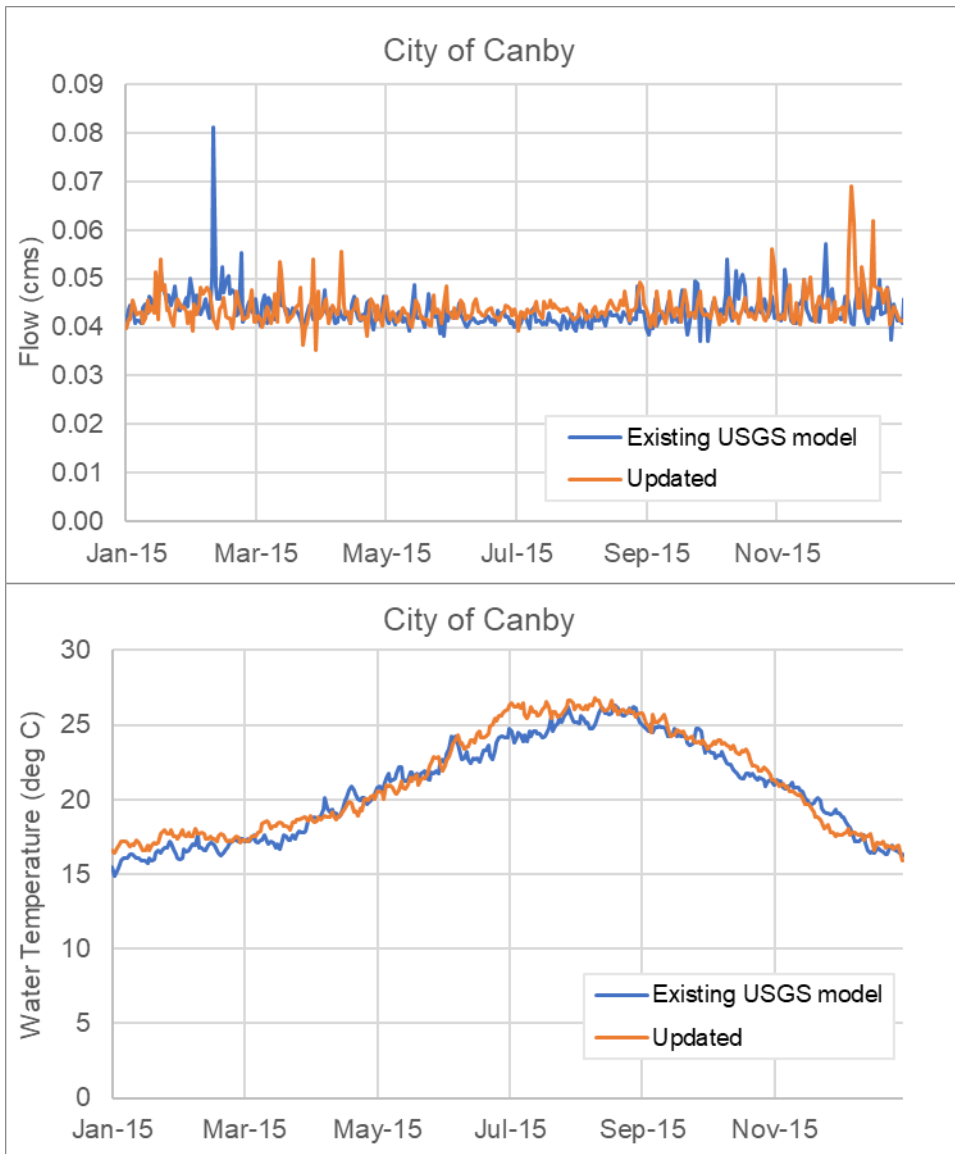


Figure 3-22. Updates made to the flow and water temperature boundary inputs for City Canby STP.

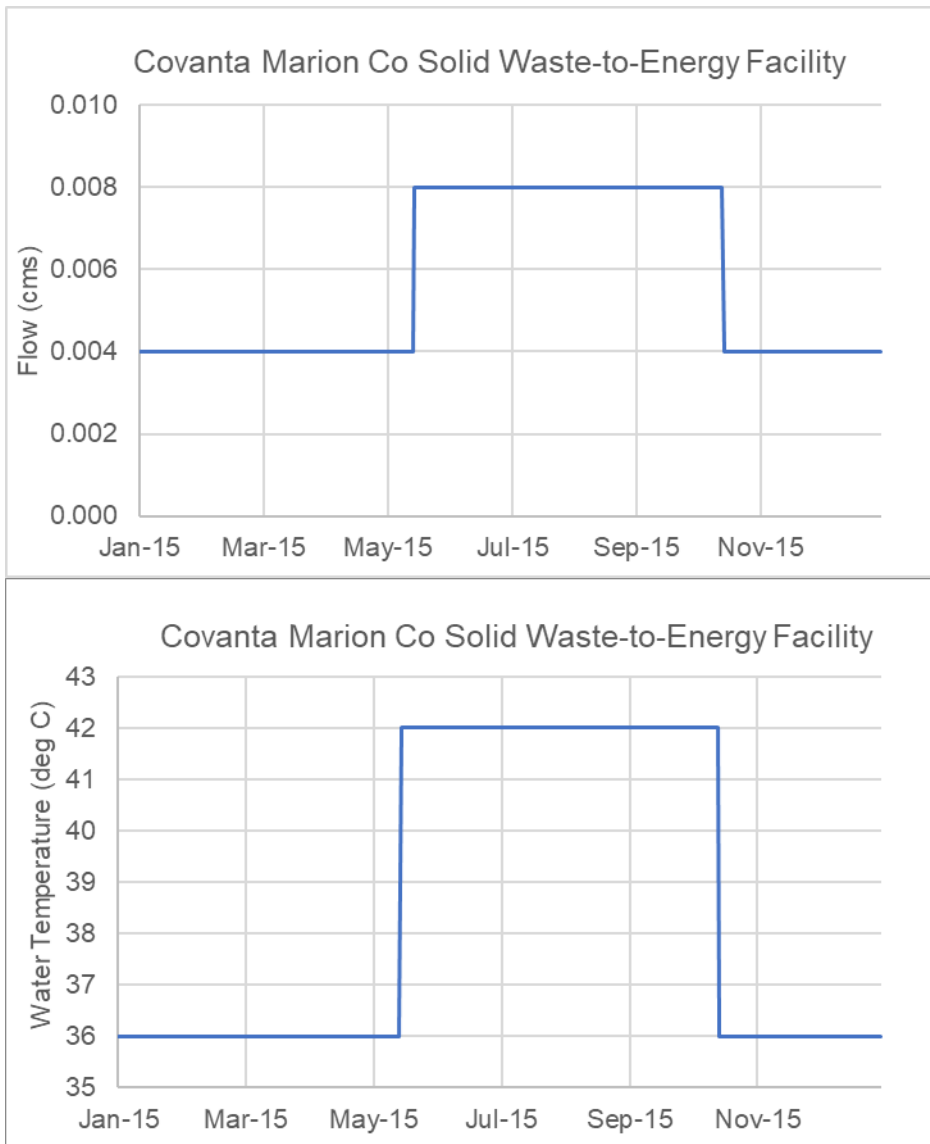


Figure 3-23. Flow and water temperature boundary inputs for Covanta Marion Co (new point source)

3.7 LOWER WILLAMETTE RIVER UPDATES

There are 11 existing point sources discharging to the Lower Willamette River and one point source that discharges to the Multnomah Channel in the Lower Willamette River model. Table 3-7 shows the details of all the point sources, and Figure 3-24 shows the location of all the point sources in the Lower Willamette River model. No updates were made to the existing point sources in the model. An additional point source, the Vigor Industrial facility, was added as a direct discharge without a withdrawal to the Lower Willamette River model. Inputs for this facility were configured based on data provided by DEQ. The point source facility was configured using the summer max effluent flow and summer max 7DADM water temperatures provided by DEQ. Figure 3-25 shows the flow and water temperature for Vigor Industrial used in the model.

Table 3-7. Point Sources represented in the Lower Willamette River model

Point Source	Latitude	Longitude	File Number	Segment	RM	Remarks
Blue Heron Paper Co.	45.3562	-122.6105	72634	2	26.60	No change
Wes (Tri-City WPCP)	45.3759	-122.5892	89700	6	25.28	No change
Tryon Creek WWTP	45.4213	-122.6579	70735	35	20.30	No change
Oak Lodge Water Services Water Reclamation Facility	45.4241	-122.6518	62795	36	20.07	No change
WES (Kellogg Creek WWTP)	45.4398	-122.6424	16590	47	18.62	No change
OHSU Center For Health and Healing	45.4994	-122.6706	113611	60	14.15	No change
Scappoose STP	45.7526	-122.8559	78980	108	8.75	No change. Discharges to the Multnomah Channel
Vigor Industrial	45.5625	-122.7163	70596	79	8.57	Added
Arkema	45.5713	-122.7446	68471	83	7.07	No change
Siltronic Corporation	45.5775	-122.7552	93450	84	6.57	No change
NW Natural Gas Site Remediation	45.5791	-122.7572	120589	84	6.57	No change
Ash Grove Cement Company	45.6229	-122.7838	3690	91	3.15	No change
Evrax Oregon Steel	45.6256	-122.7794	64905	92	2.85	No change

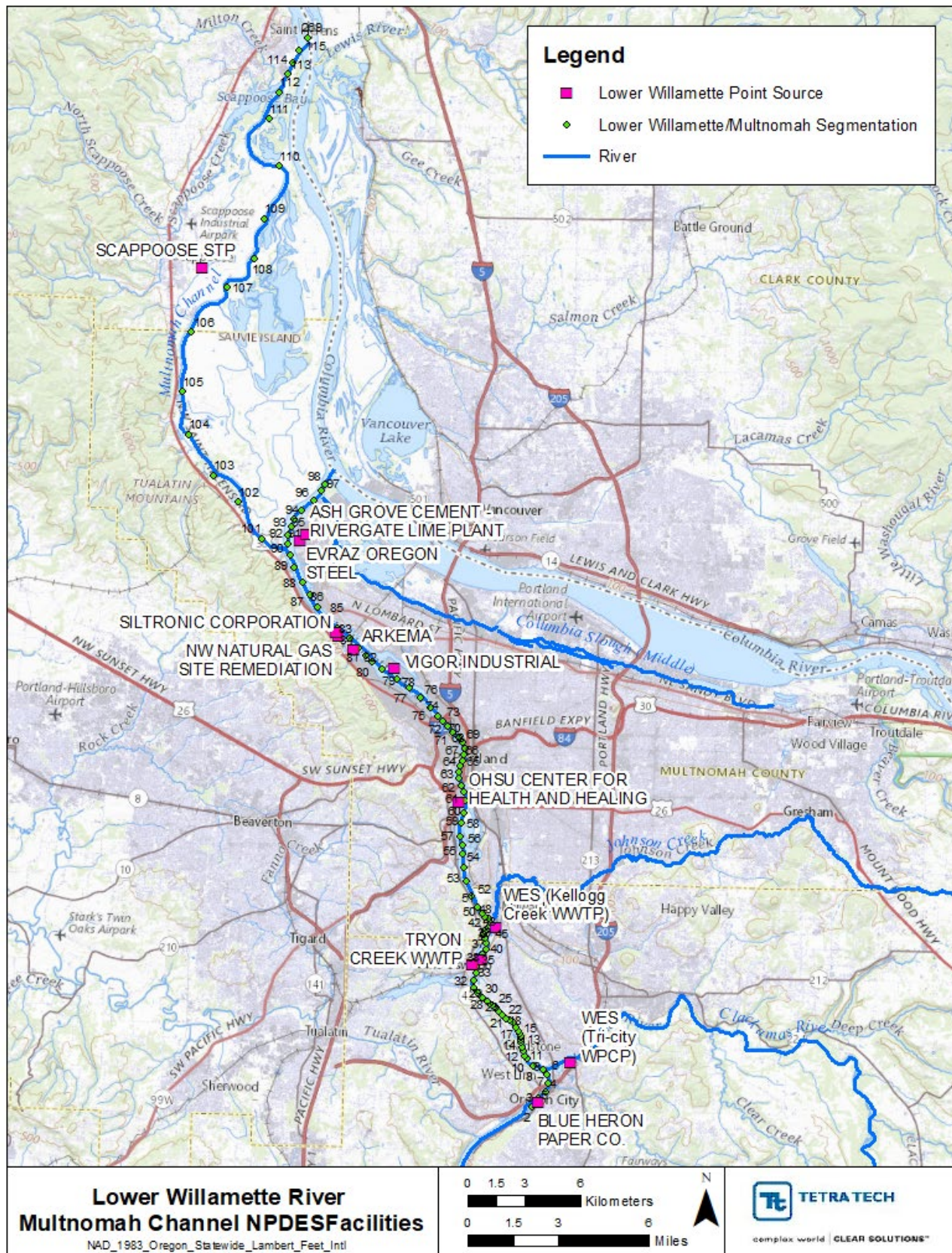


Figure 3-24. Lower Willamette River and Multnomah Channel point source facility locations

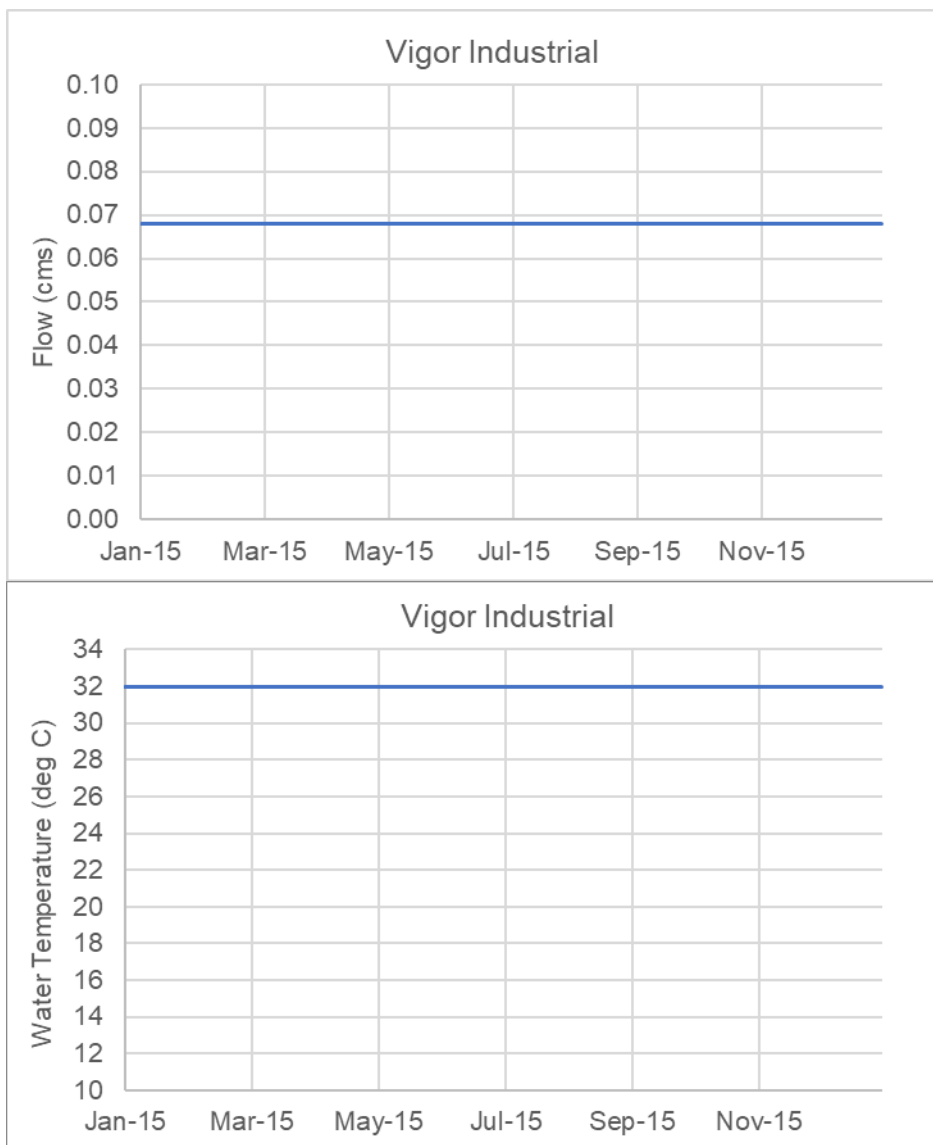


Figure 3-25. Flow and water temperature boundary inputs for Vigor Industrial (new point source).

3.8 LONG TOM RIVER UPDATES

The Long Tom River model includes one point source, the Monroe STP, that discharges to the system. Table 3-8 and Figure 3-26 provide additional details and locational information for the point source. The facility is configured as a direct discharge with no withdrawal. No updates were made to this facility, and no new facilities were identified to be added to the model.

Table 3-8. Point Sources represented in the Long Tom River model

Point Source	Latitude	Longitude	File Number	Segment	RM	Remarks
Monroe STP	44.315	-123.293	57951	133	6.96	No change

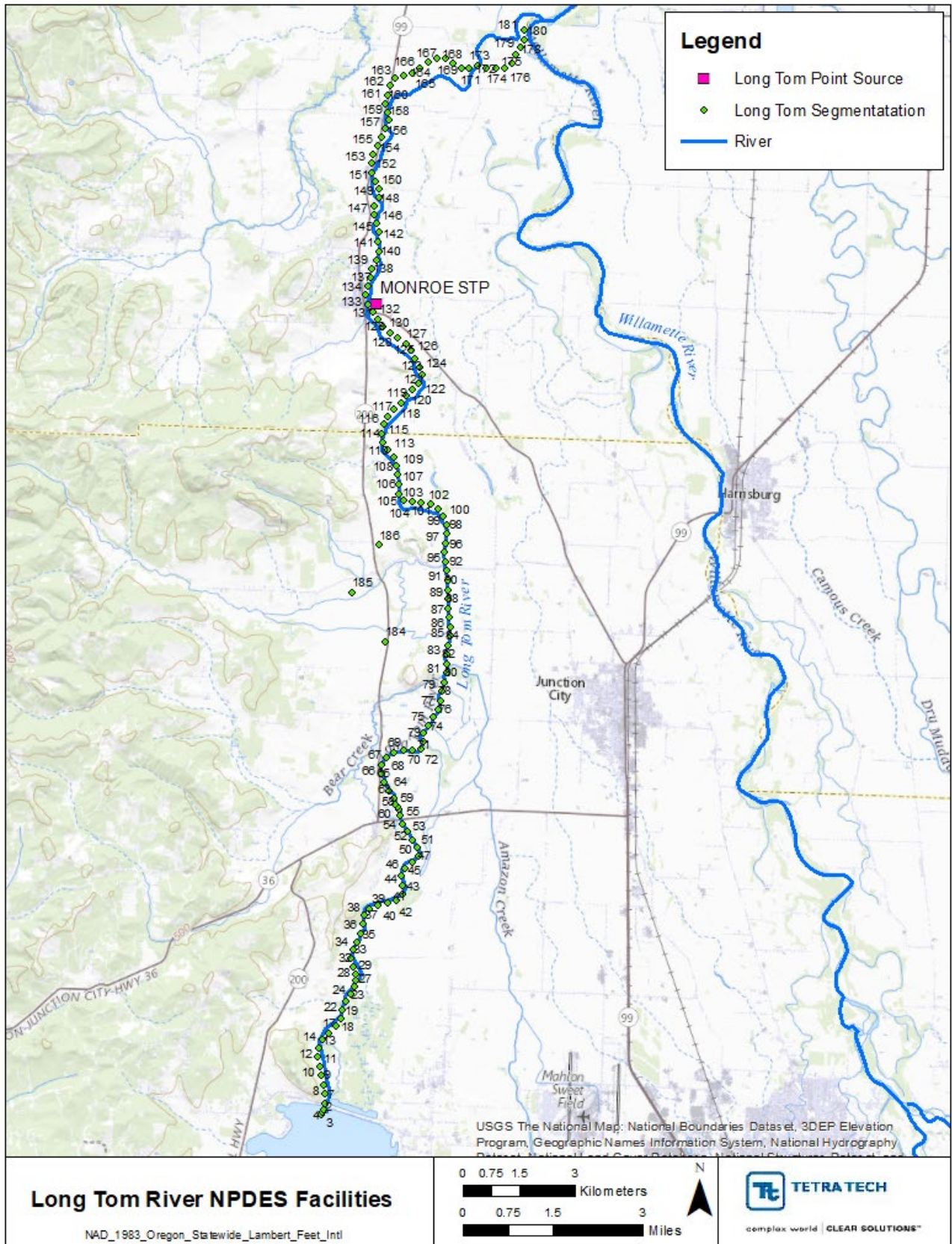


Figure 3-26. Long Tom River point source facility locations

3.9 CLACKAMAS RIVER UPDATES

The Clackamas River model includes one point source in the form of the Clackamas River Hatchery that discharges to the system. Table 3-9 and Figure 3-27 provide additional details and locational information for the point source. The Clackamas Hatchery is configured with a travel-time offset withdrawal. No updates were made to this facility.

Table 3-9. Point Sources represented in the Clackamas River model

Point Source	Latitude	Longitude	File Number	Segment	Withdrawal Segment ID	RM	Remarks
Clackamas River Hatchery	45.2959	-122.3617	64442	4	3	22.23	No change

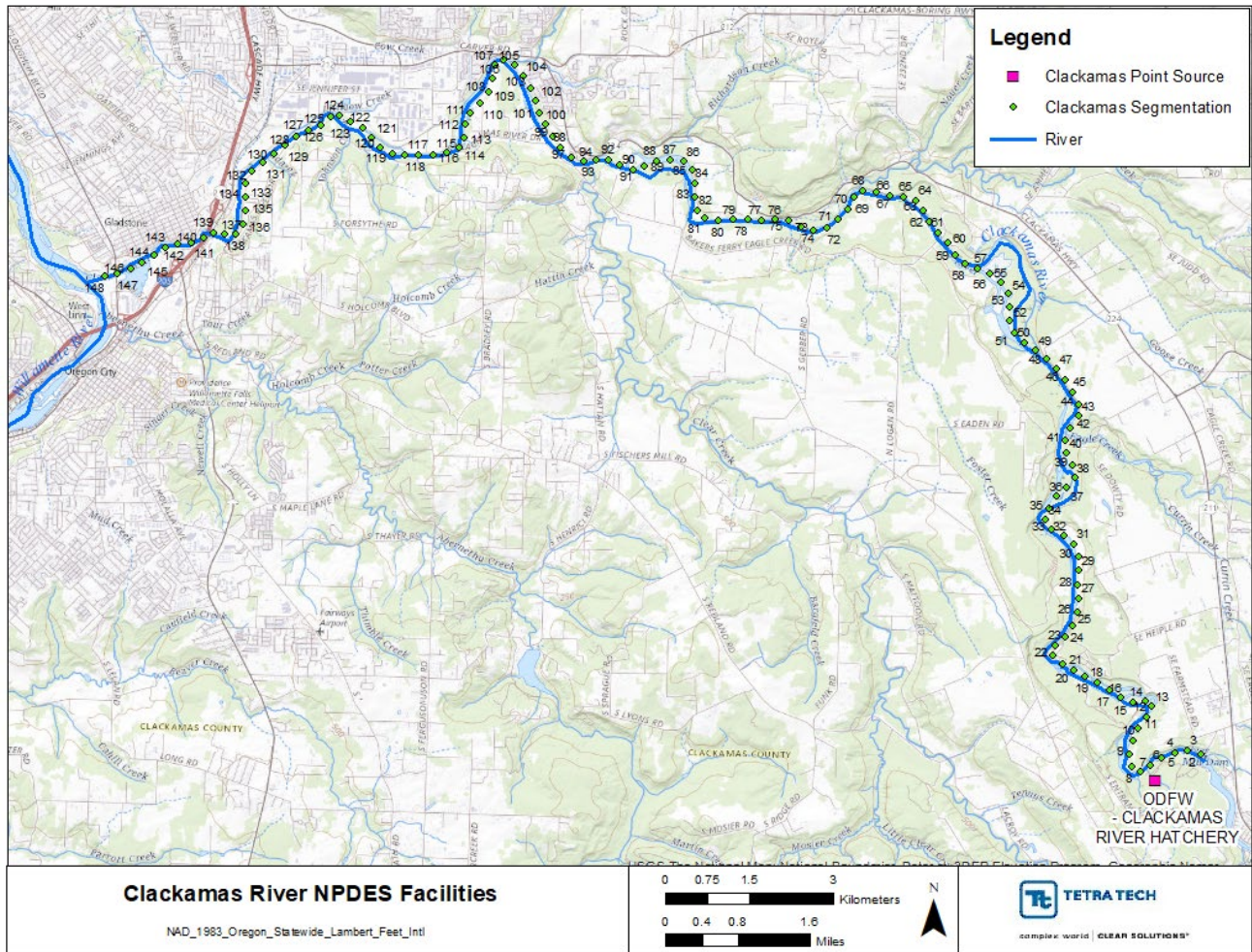


Figure 3-27. Clackamas River point source facility locations.

4.0 CALIBRATED CURRENT CONDITION SCENARIO

This scenario is based on the 2015 calibrated current condition (CCC), with the model boundaries and existing point sources configured for the modeling period from approximately late March through October. The CCC scenario includes updated current conditions reflected in the point source updates discussed in Section 3. These revisions are minor and are not expected to impact the model calibration.

Daily maximum water temperatures were calculated from the hourly time series output from the model at each segment, and then the 7DADM was calculated by averaging the daily maximum instream water temperatures for 7 consecutive days as a rolling average. For each of the models, the modeled maximum 7DADM at each segment for the modeling period from March 21, 2015, to November 1, 2015, are presented below in Figure 4-1 through Figure 4-9. The longitudinal 7DADM temperature profile shows the variation in temperature from upstream to downstream as it is influenced by the various point sources and tributaries along the system.

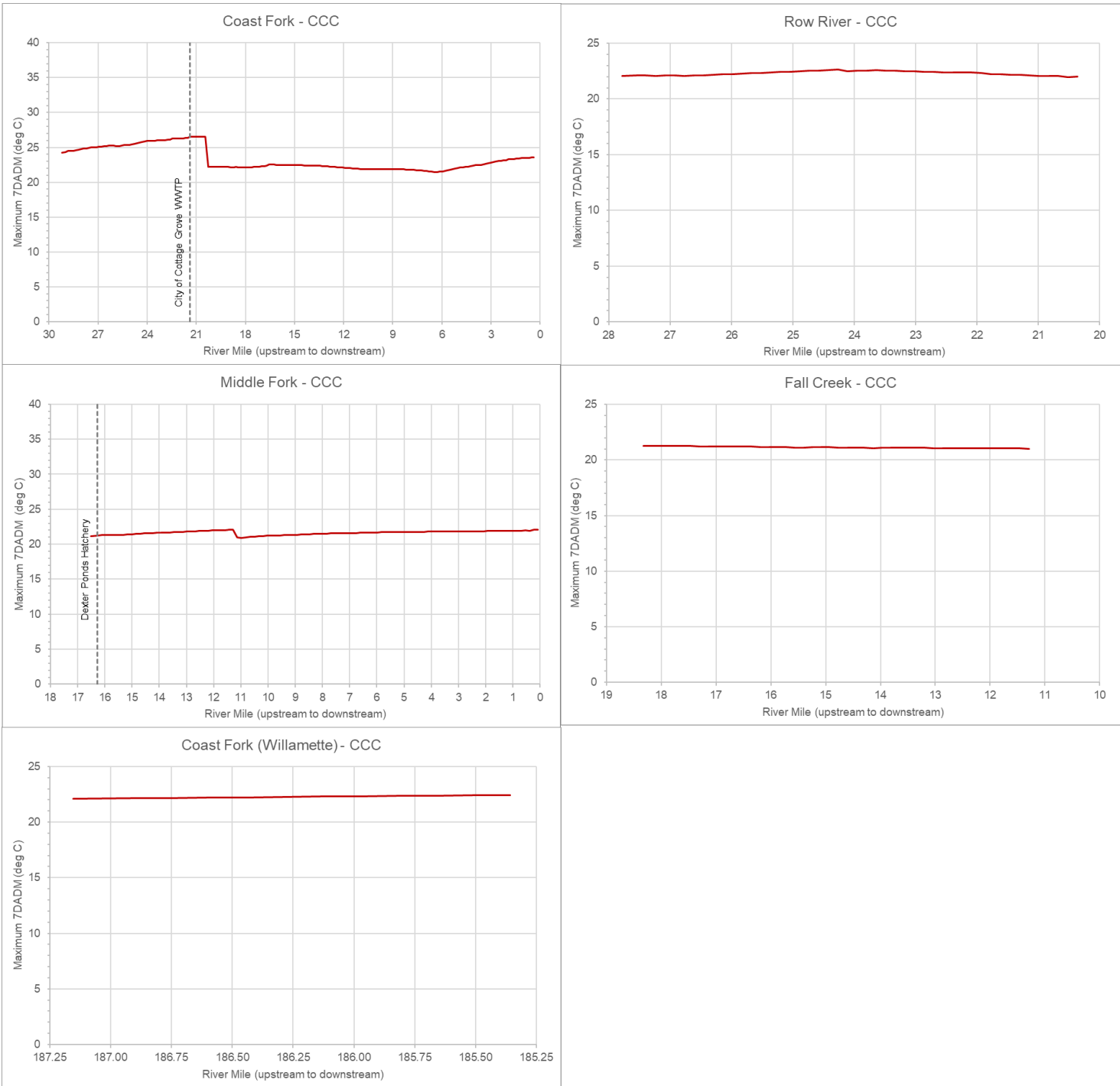


Figure 4-1. CCC Maximum 7DADM water temperature along Coast Fork Middle Fork River (March 21 to November 1, 2015).

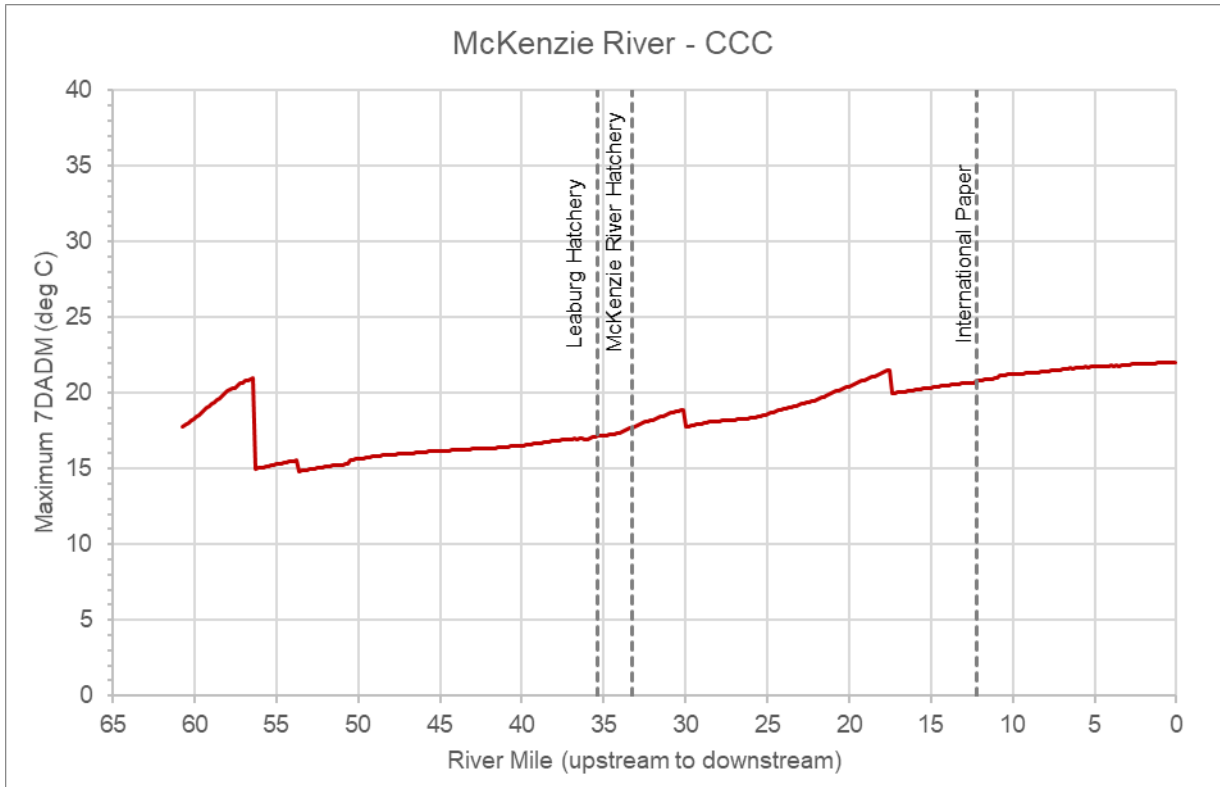


Figure 4-2. CCC Maximum 7DADM water temperature along McKenzie River (March 21 to November 1, 2015).

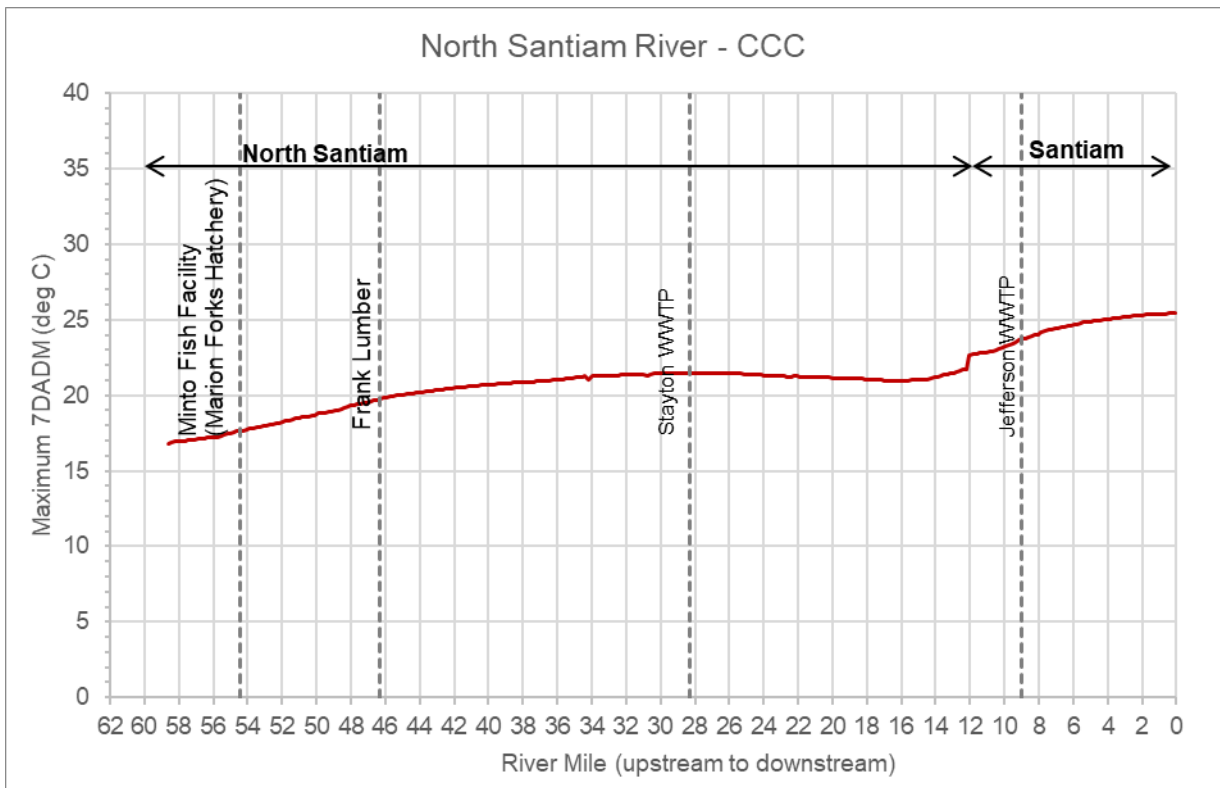


Figure 4-3. CCC Maximum 7DADM water temperature along North Santiam River (March 21 to November 1, 2015).

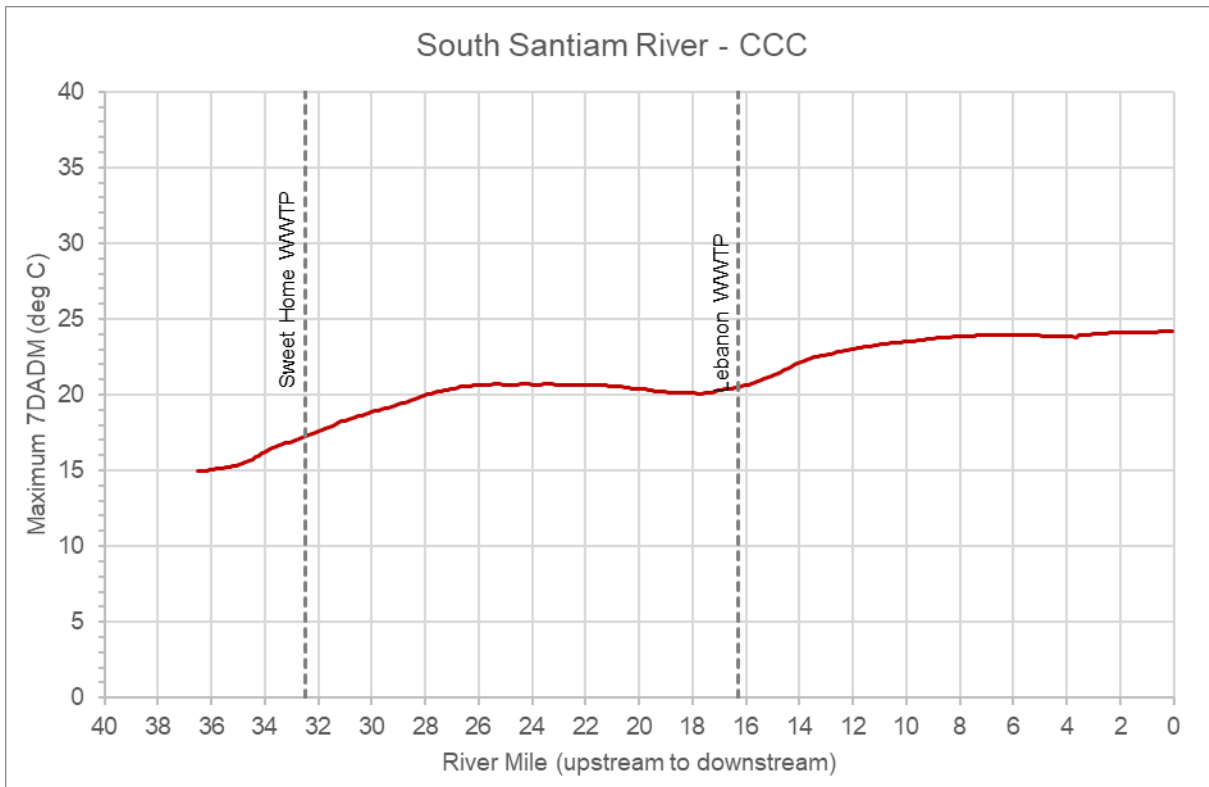


Figure 4-4. CCC Maximum 7DADM water temperature along South Santiam River (March 21 to November 1, 2015).

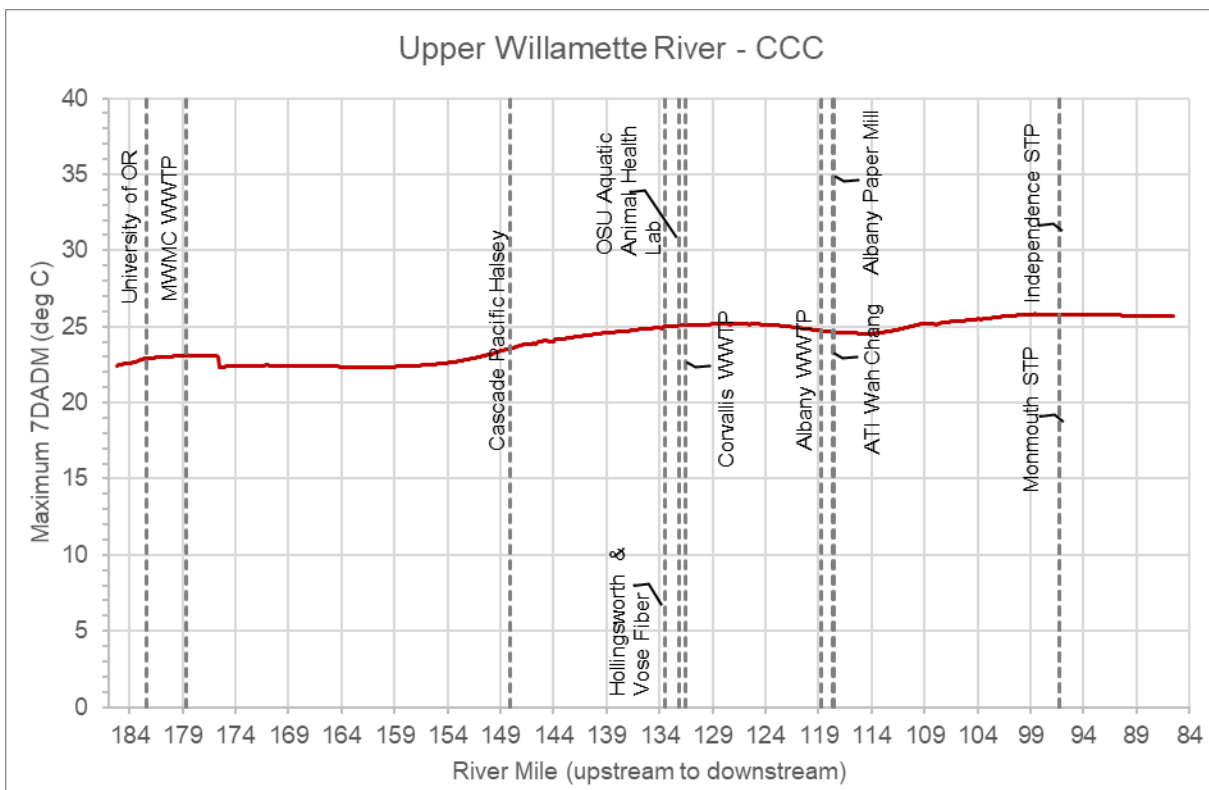


Figure 4-5. CCC Maximum 7DADM water temperature along Upper Willamette River (March 21 to November 1, 2015).

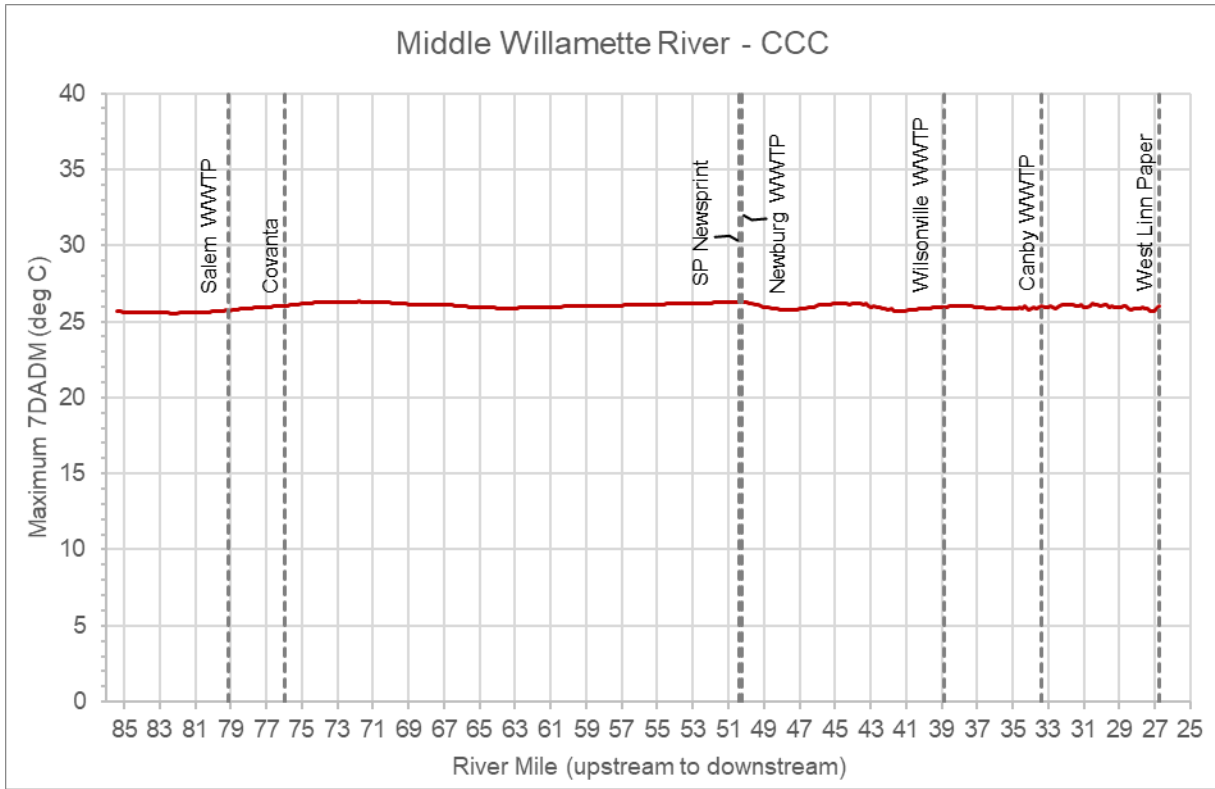


Figure 4-6. CCC Maximum 7DADM water temperature along Middle Willamette River (March 21 to November 1, 2015).

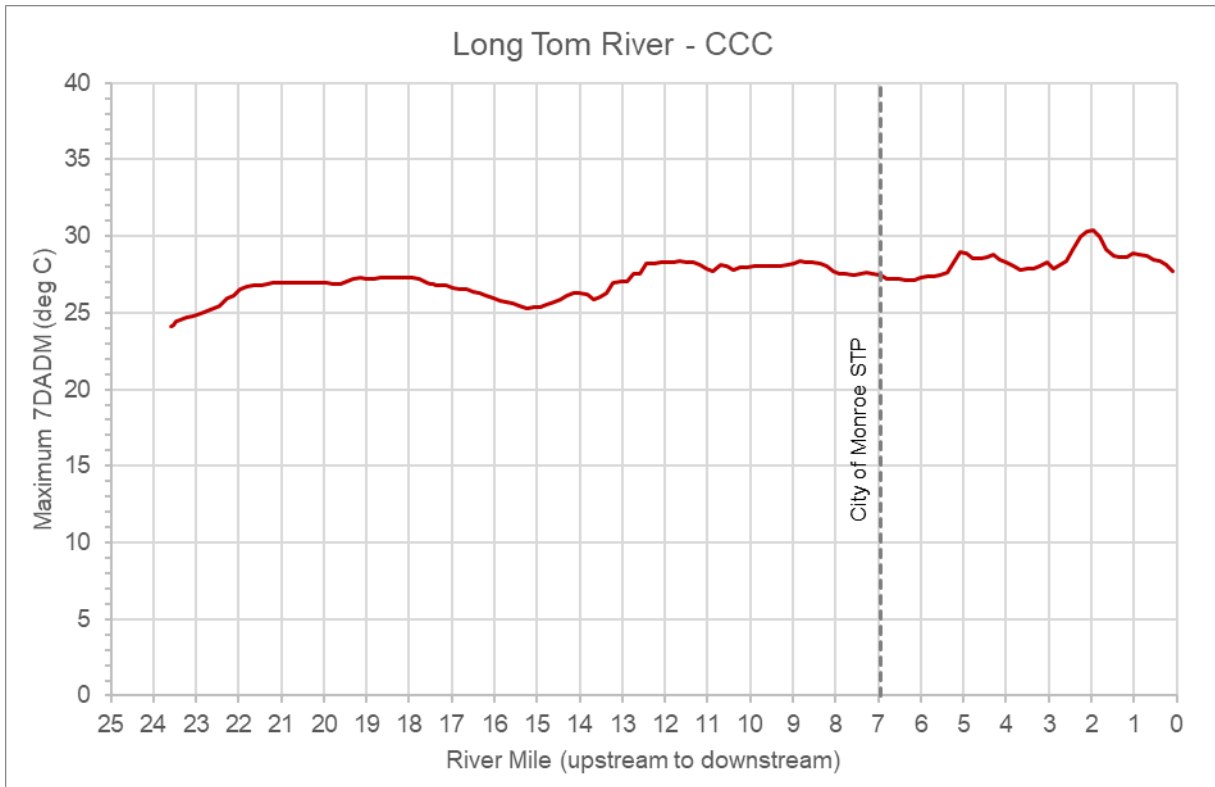


Figure 4-7. CCC Maximum 7DADM water temperature along Long Tom River (March 21 to November 1, 2015).

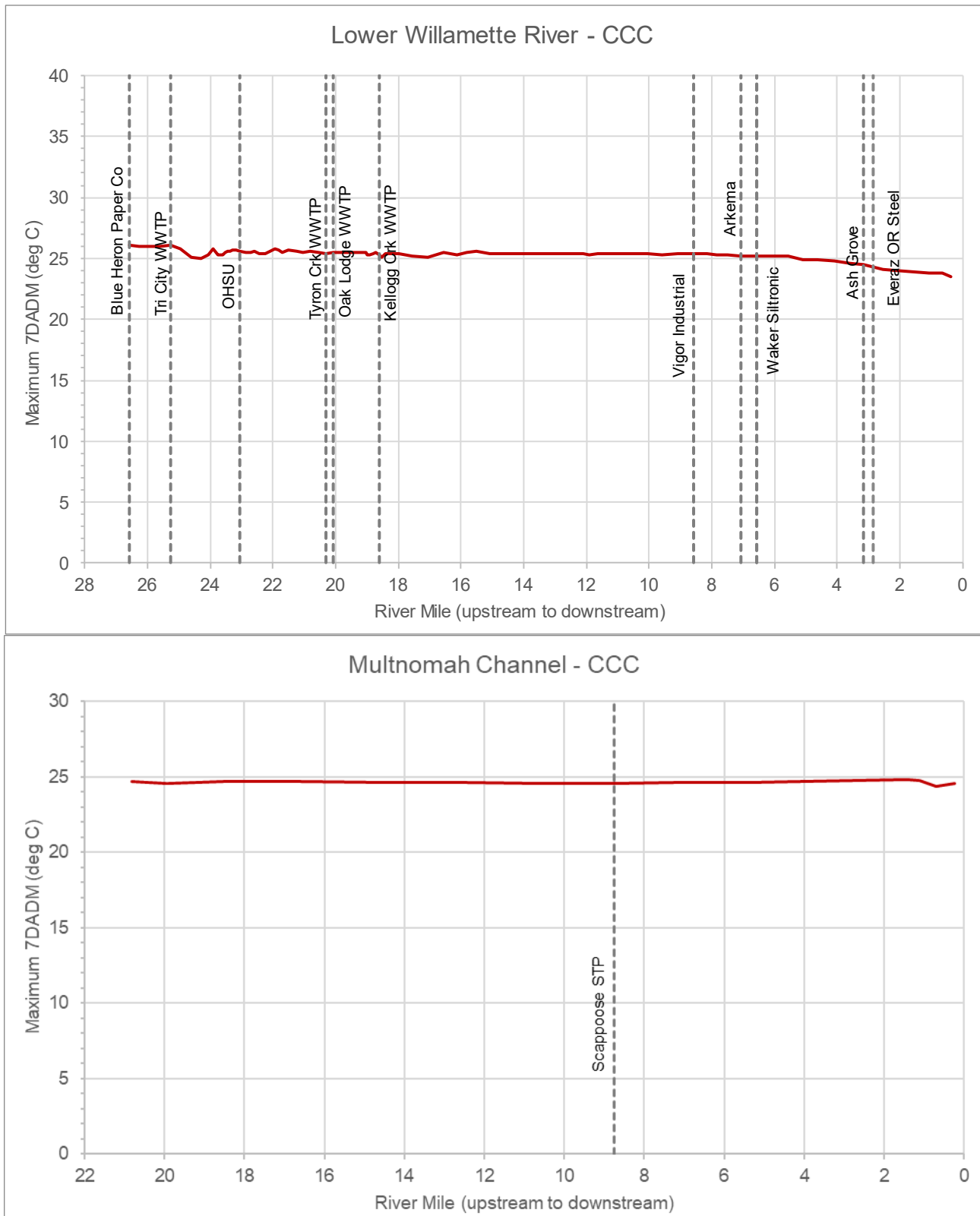


Figure 4-8. CCC Maximum 7DADM water temperature along Lower Willamette mainstem and Multnomah Channel (March 21 to November 1, 2015).

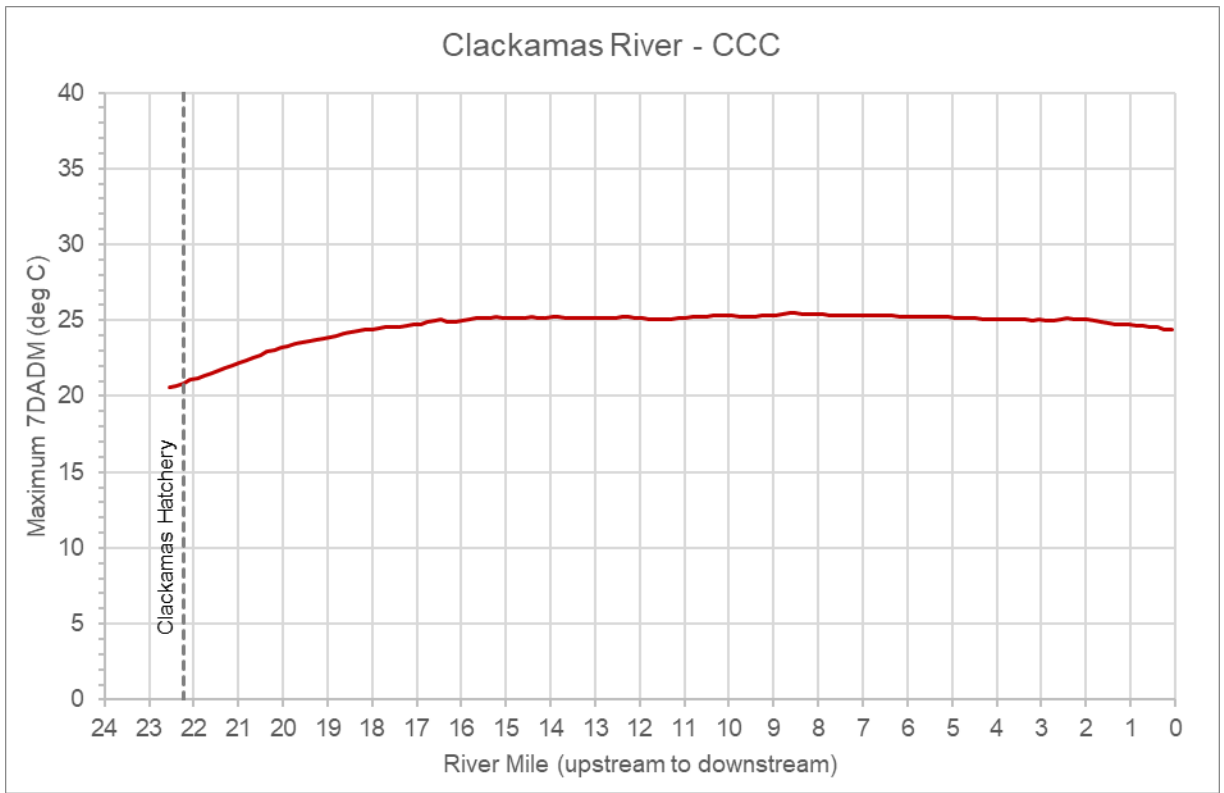


Figure 4-9. CCC Maximum 7DADM water temperature along Clackamas River (March 21 to November 1, 2015).

5.0 NO POINT SOURCES SCENARIO

This scenario was configured to assess the impact of the point sources to the various waterbodies. The settings for this scenario were set to be identical to the CCC scenario model, except that all point source discharges were removed. The maximum 7DADM change (warming) from permitted NPDES point sources was determined by computing the difference in 7DADM temperature between the point source scenario conditions and the no point sources model scenarios. Maximum 7DADM deltas were calculated when either the current condition with point sources or the no point sources scenario temperatures exceeded the BBNC. For each of the models, the modeled maximum 7DADM difference at each segment for the modeling period from March 21, 2015, to November 1, 2015, are presented below in Figure 5-1 through Figure 5-9. The figures show the impact of the point sources at their discharge locations and downstream of the discharge location. The locations where the maximum impact and when the maximum impact due to the point sources were observed were also calculated. Table 5-1 shows the maximum 7DADM delta summary for the entire modeling time period. Table 5-2 and Table 5-3 show the maximum 7DADM delta for the spawning and non-spawning periods. For each table, the date when the maximum 7DADM delta occurred and where the delta occurred are also included. Note that since the spawning and non-spawning criteria vary along some of the waterbodies, the maximum 7DADM deltas are reported individually for each reach portion where the spawning or non-spawning criteria applies.

Table 5-1. Maximum 7DADM delta observed across the entire model domain for the various waterbodies for (3/21/2015 to 11/1/2015)

Model	Waterbody	Segment ID	RM	Max 7DADM delta (deg C)	Date when Max 7DADM delta occurs
Coast Fork Middle Fork	Coast Fork Main	53	21.22	0.12	4/16/2015
Coast Fork Middle Fork	Row River	196	27.79	0.00	NA
Coast Fork Middle Fork	Middle Fork	358	0.23	0.01	6/15/2015
Coast Fork Middle Fork	Fall Creek	362	18.32	0.00	NA
Clackamas	Clackamas River	58	13.81	0.02	6/18/2015
Long Tom	Long Tom River	178	0.55	0.007	4/23/2015
McKenzie	McKenzie River	356	6.77	0.14	10/9/2015
North Santiam	North Santiam River	227	17.14	0.04	10/24/2015
North Santiam	Santiam River	258	12	0.00	NA
South Santiam	South Santiam River	199	14.45	0.03	10/31/2015
Upper Willamette	Upper Willamette River	47	178.43	0.12	4/1/2015
Middle Willamette	Middle Willamette River	258	49.32	0.09	9/13/2015
Lower Willamette River	Lower Willamette River	3	26.27	0.06	9/6/2015

Note: NA refers to not applicable

Table 5-2. Maximum 7DADM delta observed during the spawning period

Model	Waterbody	Segment ID	RM	Max 7DADM (deg C)	Date when Max 7DADM delta occurs	Applicable Period for Spawning	Applicable Location for Spawning (Segment)	Applicable Location for Spawning (RM)
Coast Fork Middle Fork	Coast Fork Main	53	21.22	0.12	4/16/2015	1/1 to 5/15	2 to 193	29.2 to 0
Coast Fork Middle Fork	Row River	196	27.79	0.00	NA	10/15 to 5/15	196 to 205	27.8 to 26.6
Coast Fork Middle Fork	Row River	206	26.46	0.00	NA	1/1 to 5/15	206 to 249	26.5 to 20.4
Coast Fork Middle Fork	Middle Fork	268	13.94	0.00	6/12/2015	9/15 to 6/15	252 to 299	16.5 to 9.4
Coast Fork Middle Fork	Middle Fork	359	0.08	0.01	6/15/2015	9/1 to 6/15	300 to 359	9.3 to 0
Coast Fork Middle Fork	Fall Creek	362	18.32	0.00	NA	9/1 to 6/15	362 to 406	18.3 to 11.3
Clackamas	Clackamas River	56	14.12	0.02	6/13/2015	9/15 to 6/15	2 to 93	22.54 to 8.35
Clackamas	Clackamas River	101	7.41	0.01	6/15/2015	9/1 to 6/15	94 to 148	8.19 to 0
Long Tom	Long Tom River	178	0.55	0.007	4/23/2015	12/1 to 5/31	2 to 181	23.6 to 0
McKenzie	McKenzie River	323	11.91	0.14	10/9/2015	9/1 to 6/15	2 to 151; 167 to 328	60.7 to 37.8; 35.6 to 11.1
McKenzie	McKenzie River	356	6.77	0.14	10/9/2015	9/1 to 5/15	152 to 164; 329 to 399	37.6 to 35.7; 10.98 to 0
North Santiam	North Santiam River	227	17.14	0.04	10/24/2015	9/1 to 6/15	2 to 255	58.6 to 12.2
North Santiam	Santiam River	258	12.03	0.00	NA	10/15 to 5/15	258 to 321	12 to 0
South Santiam	South Santiam River	101	25.82	0.01	7/15/2015	9/1 to 6/15	2 to 151	36.5 to 19.9
South Santiam	South Santiam River	199	14.45	0.03	10/31/2015	10/15 to 5/15	152 to 315	19.8 to 0
Upper Willamette	Upper Willamette River	47	178.43	0.12	4/1/2015	10/15 to 5/15	2 to 666	185.2 to 85.5
Middle Willamette	Middle Willamette River	43	78.95	0.09	10/31/2015	10/15 to 5/15	2 to 212; 228 to 396	85.4 to 53.2; 53.1 to 26.8
Lower Willamette River	Lower Willamette River	NA	NA	NA	NA	NA	NA	NA

Model	Waterbody	Segment ID	RM	Max 7DADM (deg C)	Date when Max 7DADM delta occurs	Applicable Period for Spawning	Applicable Location for Spawning (Segment)	Applicable Location for Spawning (RM)
Lower Willamette River	Multnomah Channel	NA	NA	NA	NA	NA	NA	NA

Note: NA refers to not applicable

Table 5-3. Maximum 7DADM delta observed during the non-spawning period

Model	Waterbody	Segment ID	RM	Max 7DADM (deg C)	Date when Max 7DADM delta occurs	Applicable Non-Spawning Period	Applicable Non-Spawning Location (Segment)	Applicable Non-Spawning Location (RM)
Coast Fork Middle Fork	Coast Fork Main	50	21.68	0.06	6/29/2015	Applies outside spawning period	2 to 193	29.2 to 0
Coast Fork Middle Fork	Row River	196	27.79	0.00	NA	Applies outside spawning period	196 to 249	27.8 to 20.4
Coast Fork Middle Fork	Middle Fork	358	0.23	0.01	6/15/2015	Applies outside spawning period	252 to 359	16.5 to 0
Coast Fork Middle Fork	Fall Creek	362	18.32	0.00	NA	Applies outside spawning period	362 to 406	18.3 to 11.3
Clackamas	Clackamas River	58	13.81	0.02	6/18/2015	Applies outside spawning period	2 to 93	22.54 to 8.35
Clackamas	Clackamas River	114	5.38	0.01	6/23/2015	Applies outside spawning period	94 to 148	8.19 to 0
Long Tom	Long Tom River	115	9.77	0.00	NA	Applies outside spawning period	2 to 181	23.6 to 0
McKenzie	McKenzie River	324	11.75	0.12	8/8/2015	Applies outside spawning period	2 to 151; 167 to 328	60.7 to 37.8; 35.6 to 11.1
McKenzie	McKenzie River	399	0.08	0.13	8/9/2015	Applies outside spawning period	152 to 164; 329 to 399	37.6 to 35.7; 10.98 to 0
North Santiam	North Santiam River	223	18.09	0.02	8/31/2015	Applies outside spawning period	2 to 255	58.6 to 12.2
North Santiam	Santiam River	258	12.03	0.00	NA	Applies outside spawning period	258 to 321	12 to 0

Model	Waterbody	Segment ID	RM	Max 7DADM (deg C)	Date when Max 7DADM delta occurs	Applicable Non-Spawning Period	Applicable Non-Spawning Location (Segment)	Applicable Non-Spawning Location (RM)
South Santiam	South Santiam River	146	20.50	0.01	8/13/2015	Applies outside spawning period	2 to 151	36.5 to 19.9
South Santiam	South Santiam River	226	11	0.02	9/10/2015	Applies outside spawning period	152 to 315	19.8 to 0
Upper Willamette	Upper Willamette River	266	145.89	0.10	6/6/2015	Applies outside spawning period	2 to 666	185.2 to 85.5
Middle Willamette	Middle Willamette River	252	49.32	0.09	9/13/2015	Applies outside spawning period	2 to 212; 228 to 396	85.4 to 53.2; 53.1 to 26.8
Lower Willamette River	Lower Willamette River	3	26.27	0.06	9/6/2015	Non-spawning only	2 to 101	26.6 to 0
Lower Willamette River	Multnomah Channel	113	1.12	0.04	6/10/2015	Non-spawning only	102 to 115	19.5 to 0.25

Note: NA refers to not applicable

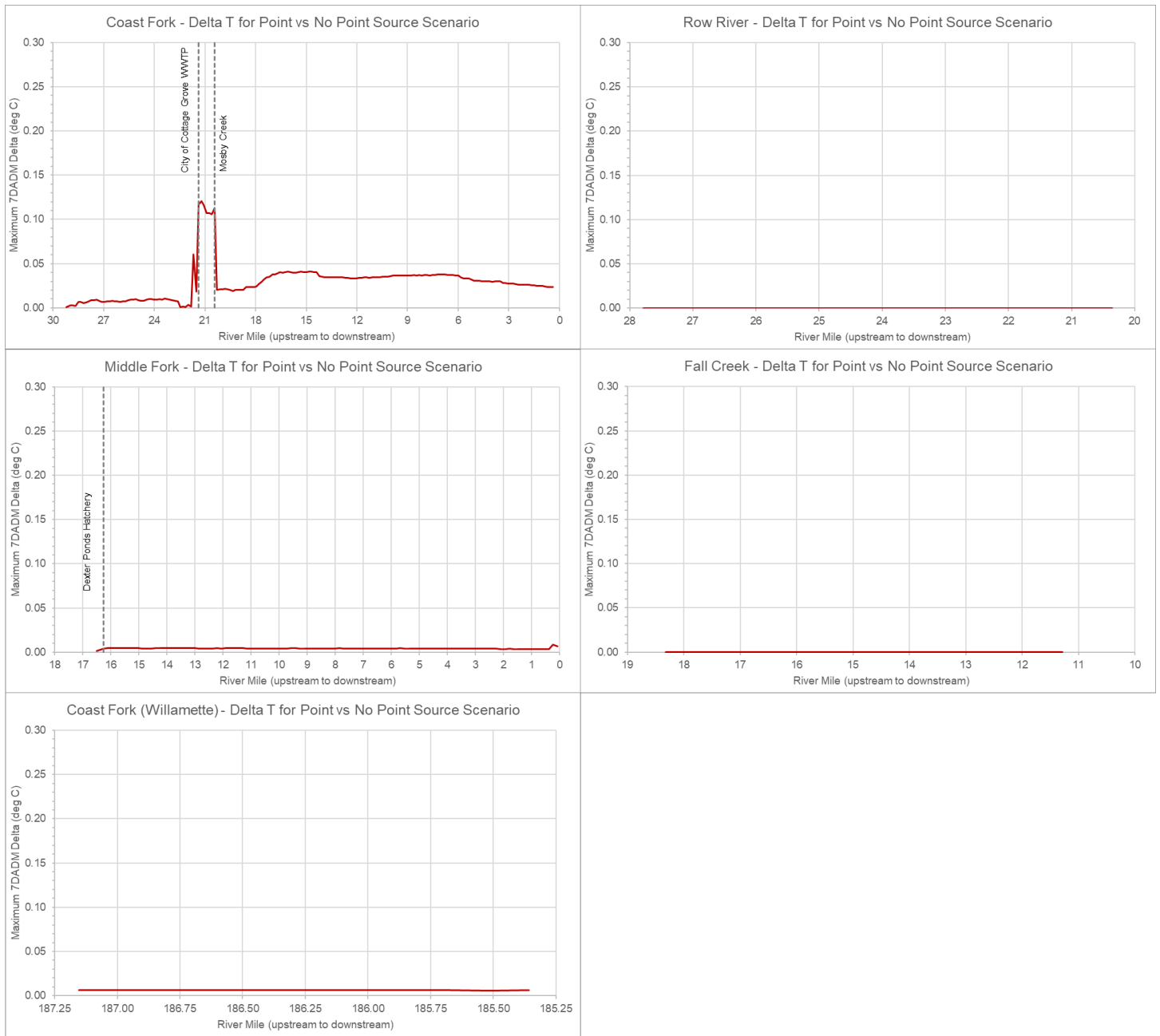


Figure 5-1. Maximum estimated warming (7DADM delta) due to point sources along the Coast Fork Middle Fork. Note: Delta at the start of the Coast Fork (Willamette) is due to delta carried from upstream

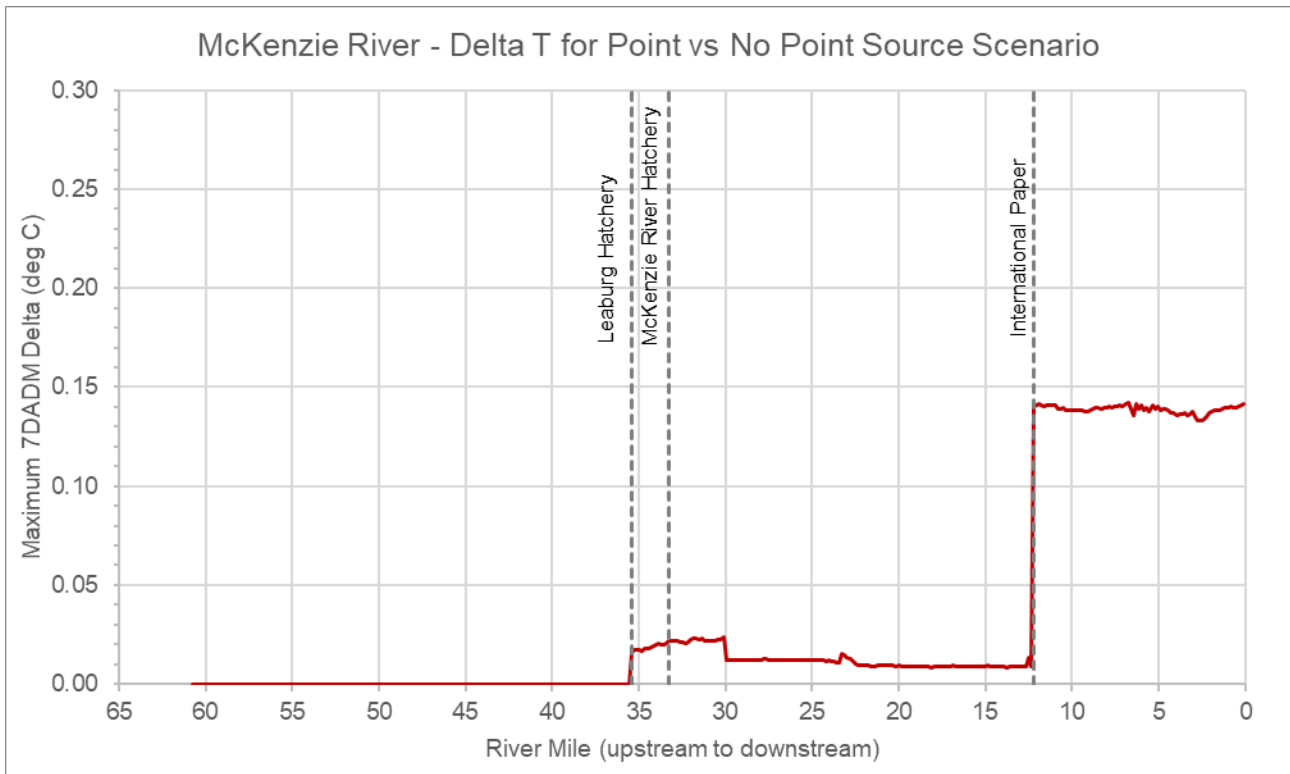


Figure 5-2. Maximum estimated warming (7DADM delta) due to point sources along the McKenzie River

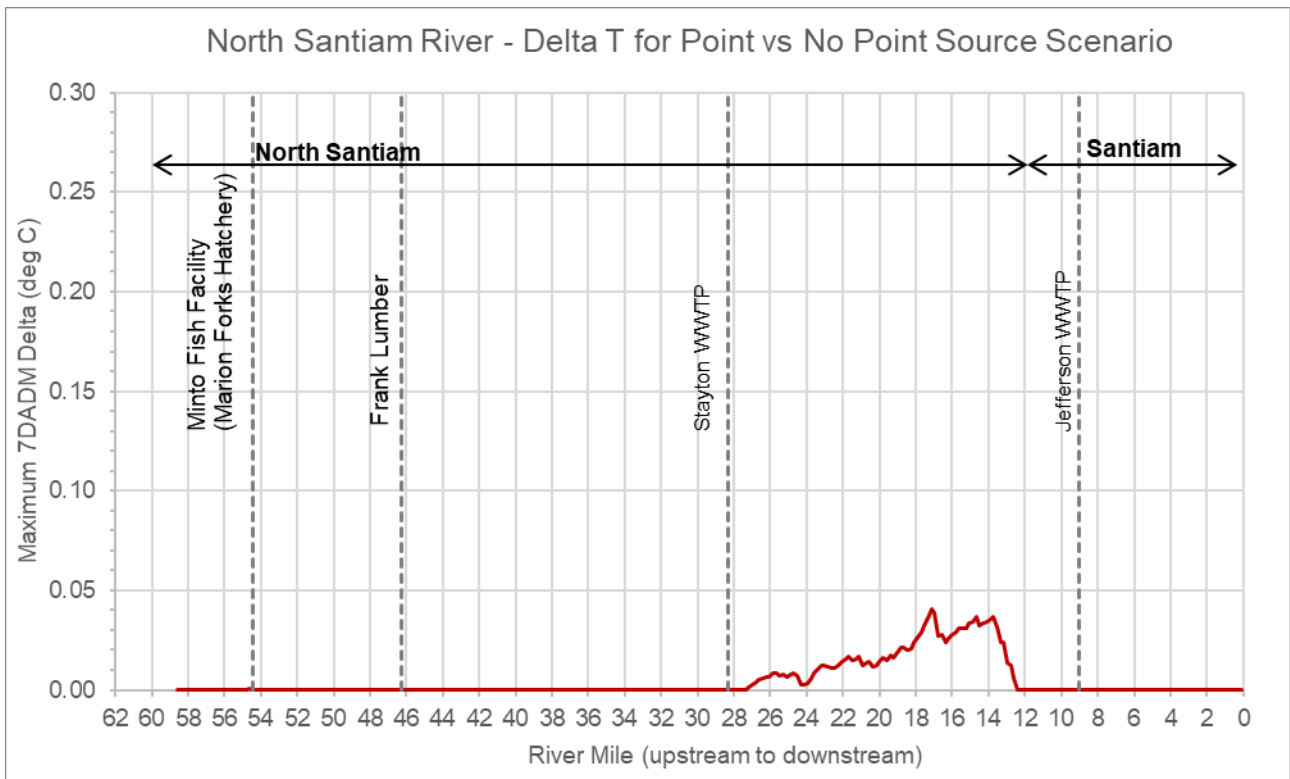


Figure 5-3. Maximum estimated warming (7DADM delta) due to point sources along the North Santiam River

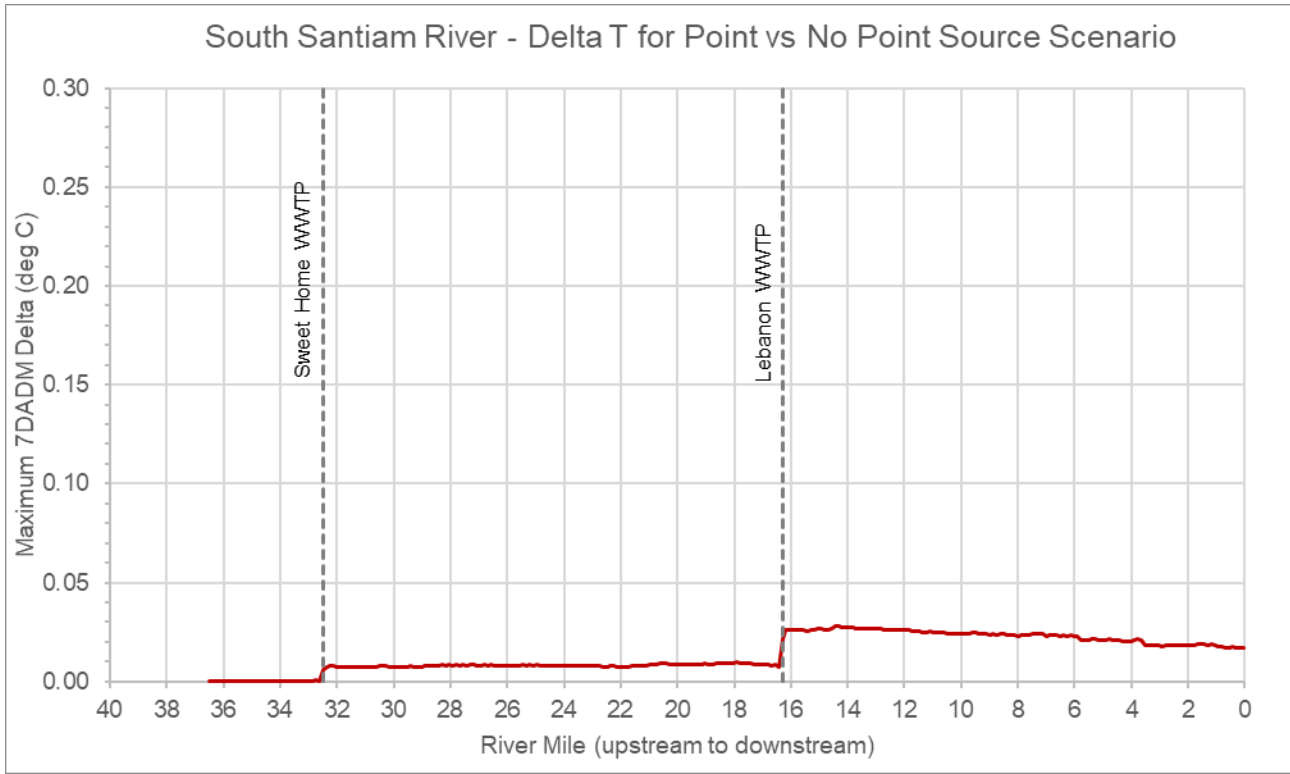


Figure 5-4. Maximum estimated warming (7DADM delta) due to point sources along the South Santiam River

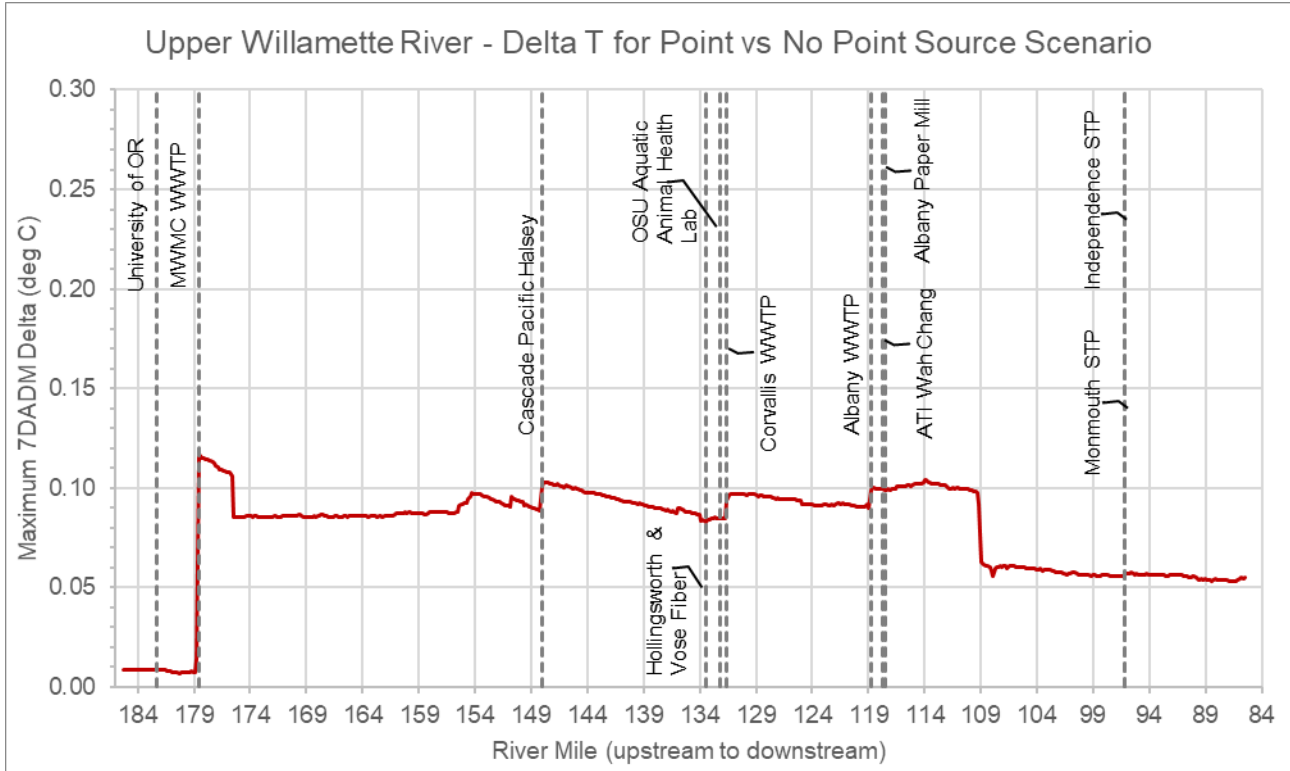


Figure 5-5. Maximum estimated warming (7DADM delta) due to point sources along the Upper Willamette River. Note: Delta at the start of the waterbody is due to delta carried from upstream

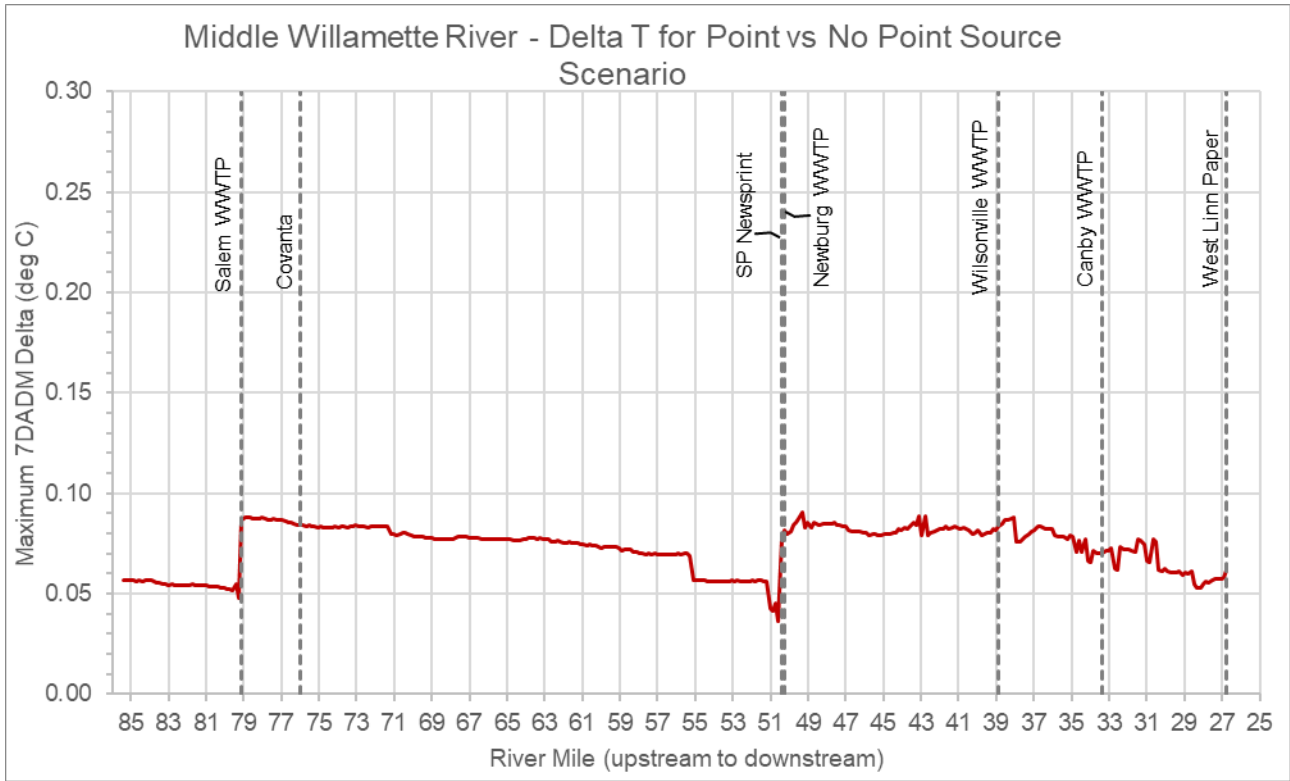


Figure 5-6. Maximum estimated warming (7DADM delta) due to point sources along the Middle Willamette River. Note: Delta at the start of the waterbody is due to delta carried from upstream

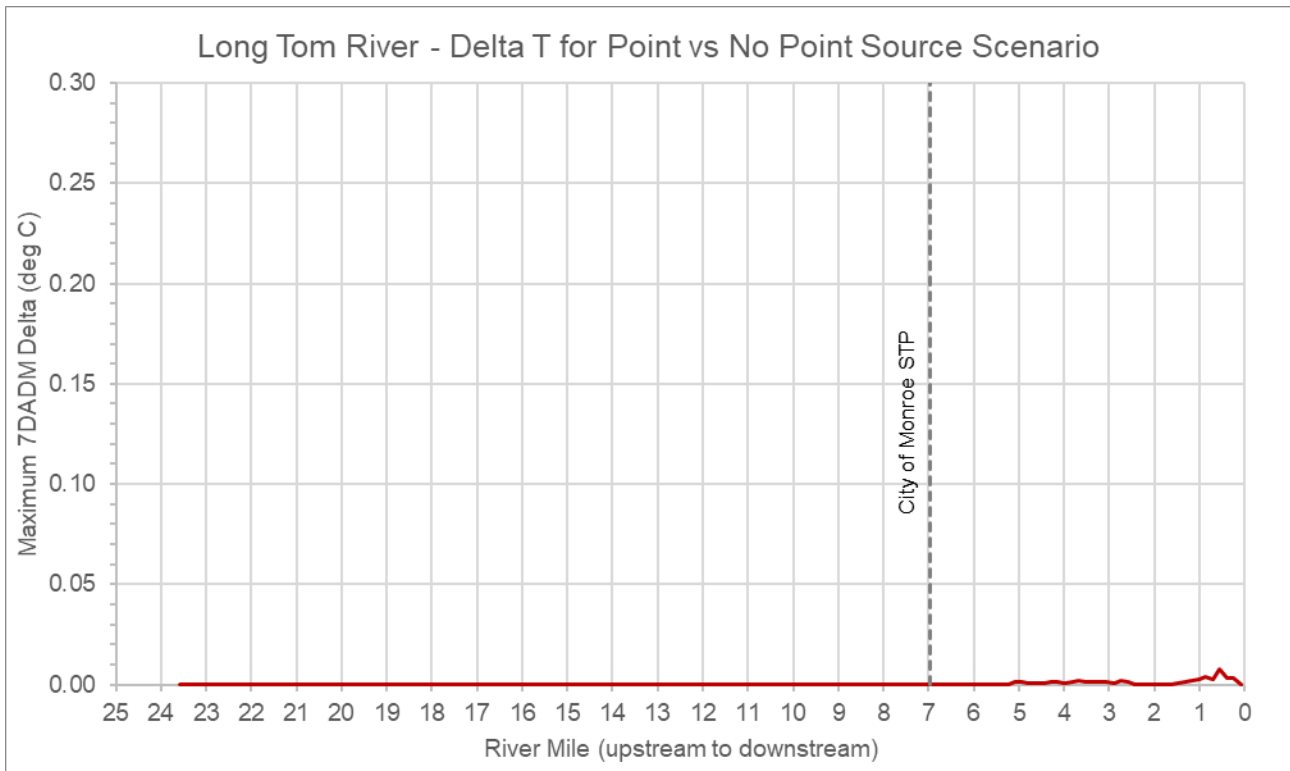


Figure 5-7. Maximum estimated warming (7DADM delta) due to point sources along the Long Tom River

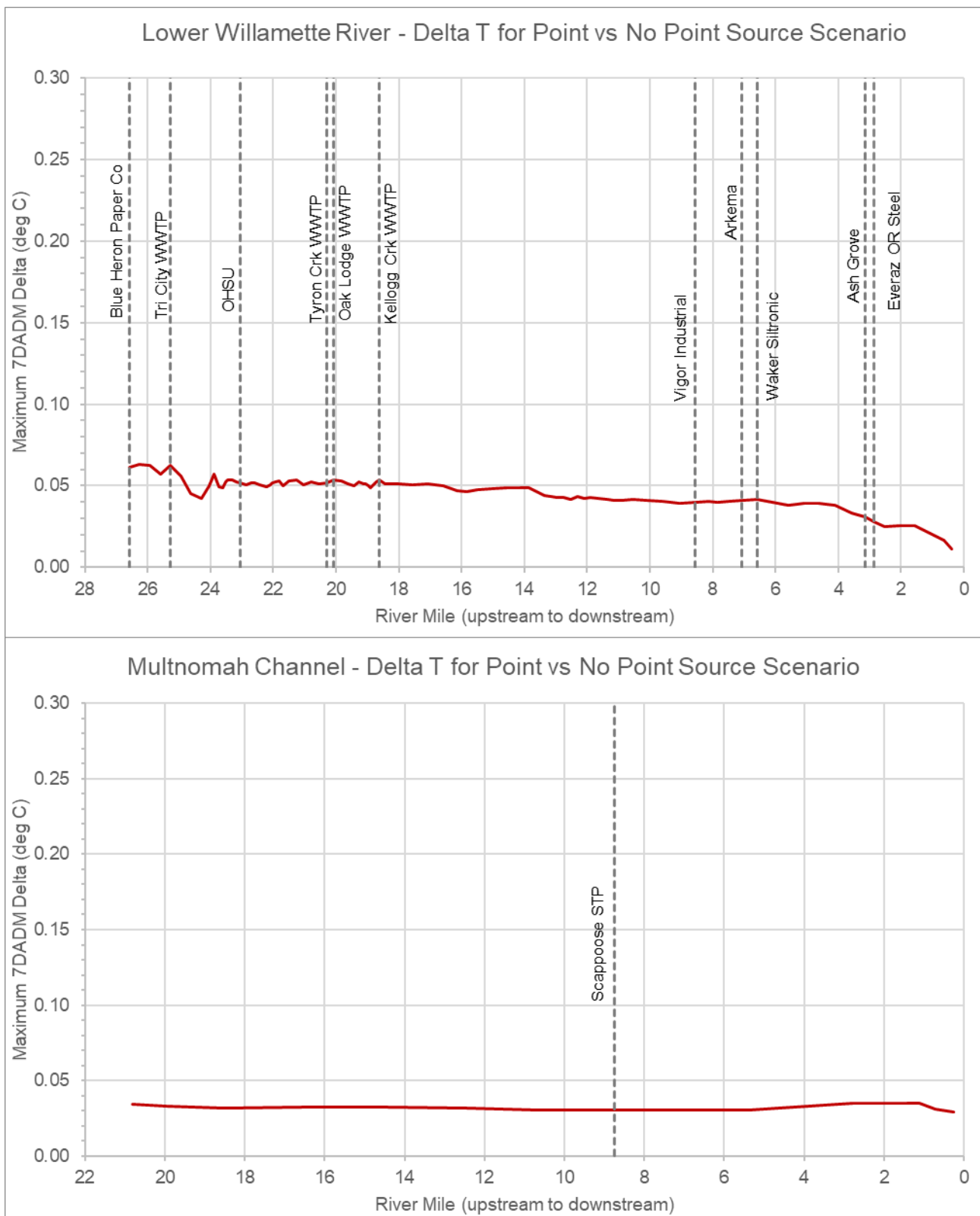


Figure 5-8. Maximum estimated warming (7DADM delta) due to point sources along the Lower Willamette and Multnomah Channel. Note: Delta at the start of the waterbody is due to delta carried from upstream.

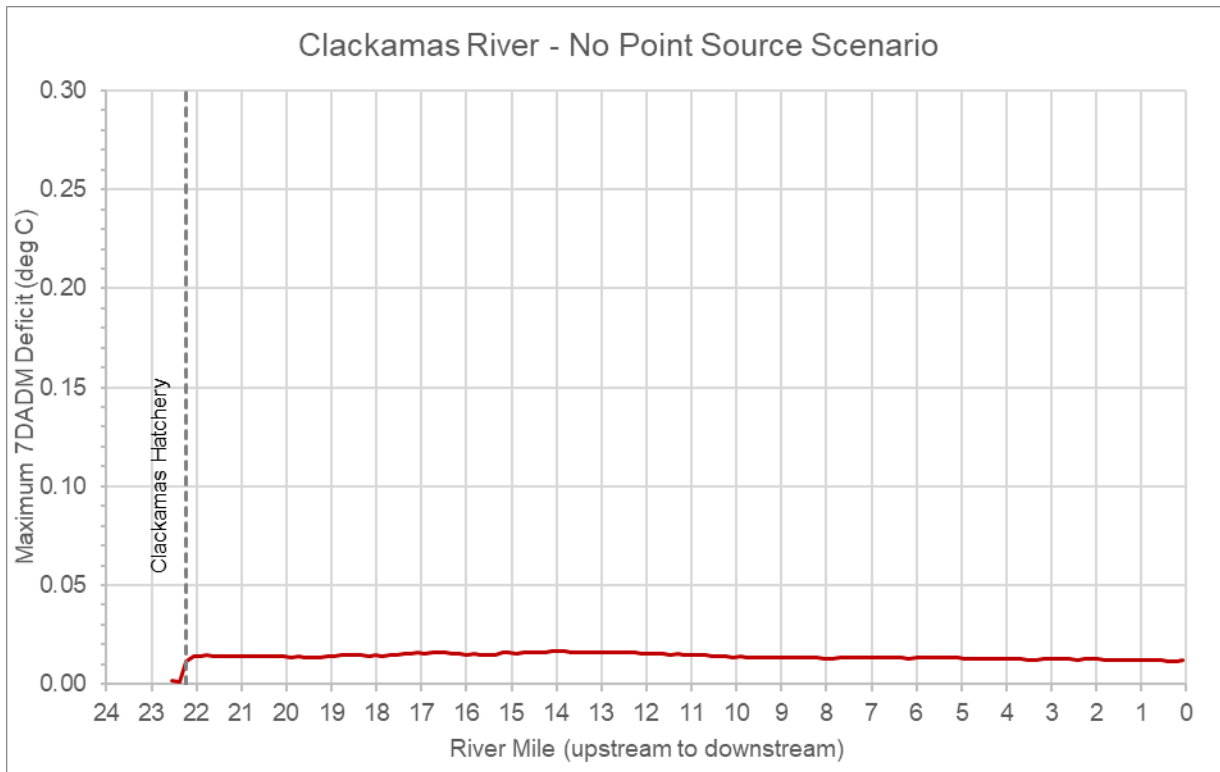


Figure 5-9. Maximum estimated warming (7DADM delta) due to point sources along the Clackamas River

6.0 REFERENCES

- DEQ (Oregon Department of Environmental Quality). 2008. Temperature water quality standard implementation— A DEQ internal management directive, Oregon. Oregon Department of Environmental. Quality. Portland, OR. <https://www.oregon.gov/deq/Filtered%20Library/IMDTemperature.pdf>
- DEQ. 2013. Internal Management Directive - The Use of Significant Figures and Rounding Conventions in Water Quality Permitting. Water Quality Division, Surface Water Management Section, Headquarters. Portland, OR. <https://www.oregon.gov/deq/Filtered%20Library/SigFigsIMD.pdf>.
- Stratton Garvin, L.E., S.A. Rounds, and N.L. Buccola. 2022. Updates to models of streamflow and water temperature for 2011, 2015, and 2016 in rivers of the Willamette River Basin, Oregon: U.S. Geological Survey Open-File Report 2022–1017, 73 p., <https://doi.org/10.3133/ofr20221017>
- Tetra Tech. 2023. Lower Willamette River, Clackamas River, and Long Tom River Temperature Model Configuration and Calibration Report – Final. Presented to US Environmental Protection Agency, Region 10 and Oregon Department of Environmental Quality. April 17, 2023.

APPENDIX A – TEMPERATURE BBNC

