Final Report

Outfall Mixing Zone Study
Woodburn WWTP Outfalls

Prepared for

City of Woodburn

October 2009

CH2MHILL

Contents

SECTION 1

Introduction

This report presents the objectives, methodology, and results of the Outfall Mixing Study of the City of Woodburn's Wastewater Treatment Plant (WWTP) outfalls (Outfalls 001a & 001b) that discharge to the Pudding River (Figure 1-1). This study has included study plan development with agency review, extensive field measurements under summer river flow conditions, analysis for field measurements of dilution, dilution modeling, and reporting. The information developed in this study will be submitted to Oregon's Department of Environmental Quality (DEQ) for use in the NPDES permit renewal.

Background

Wastewater Treatment & Discharge Limits

The Woodburn WWTP provides secondary treatment and disinfection (ultra-violet disinfection) with an average dry weather design flow of 5.0 mgd. The Woodburn WWTP discharges to the Pudding River via Outfall 001a, and since 1999 has used an 84 acre poplar tree plantation to accept up to 0.9 mgd of reuse effluent during the months of July and August.

Oregon DEQ completed a TMDL to address dissolved oxygen impairment in the Pudding River in 1993. DEQ assigned wasteload allocations for biochemical oxygen demand (BOD), ammonia, and total suspended solids to two facilities discharging to the Pudding River, including the Woodburn WWTP. DEQ incorporated the resulting wasteload allocations into the wastewater permit for the City of Woodburn WWTP. The existing NPDES Permit for the Woodburn WWTP has limits on effluent ammonia discharges to the Pudding River during June through October, and the existing limits are based on available flow in the Pudding River.

In December 2008, Oregon DEQ published the Mollala-Pudding Subbasin TMDL (Oregon DEQ, December 2008), and this TMDL addresses temperature, nitrate, metals, bacteria, and pesticides in the Mollala and Pudding River subbasin of the Willamette River basin. The 1993 TMDL was not reviewed or changed as part of the 2008 TMDL and the allocations established in that TMDL and incorporated into Woodburn's permit remain in effect.

The 2009 Facilities Plan for the Woodburn WWTP (CH2M HILL, 2009) evaluated and selected facilities improvements to implement in Phase 2 plant expansion that will meet the temperature waste load allocations specified in the 2008 Mollala-Pudding Subbasin TMDL and continue to meet the wasteload allocations in the 1993 TMDL. In Phase 2, the significant improvements will be completed to increase dry and wet weather design flows, increase treatment effectiveness and disinfection capacity, expand poplar tree acreage for irrigation of reuse effluent, add a 10 acre wetland lagoon and 14 acres of floodplain wetlands for effluent cooling, and add a new outfall to discharge flows from the new wetland system to the Pudding River (downstream of the Highway 211 bridge).

This mixing zone study uses the wastewater flows for the Woodburn WWTP, both existing plant conditions and future (Phase 2) conditions that reflect the improvements that are defined in the 2009 Woodburn WWTP Facilities Plan. The primary limitations for the Woodburn WWTP discharge to the Pudding River are effluent ammonia load during July and August, and excess thermal load during July through September. The implementation of wetlands systems for thermal reductions and the changes in effluent flows discharged to the river by 2015 are represented in this study. Exhibit 1-1 presents a schematic diagram of the effluent flow alternatives that will be implemented based on the 2009 Facilities Plan. During July and August, as much as 2 mgd will be discharged via Outfall 001a either directly from the WWTP or after passing through the new wetland lagoon for effluent cooling, and flows above 2.0 mgd would be used for poplar tree irrigation. During September, all effluent flow will be routed through the new lagoon wetland and the floodplain lagoon system before discharging via the new downstream outfall into the Pudding River.

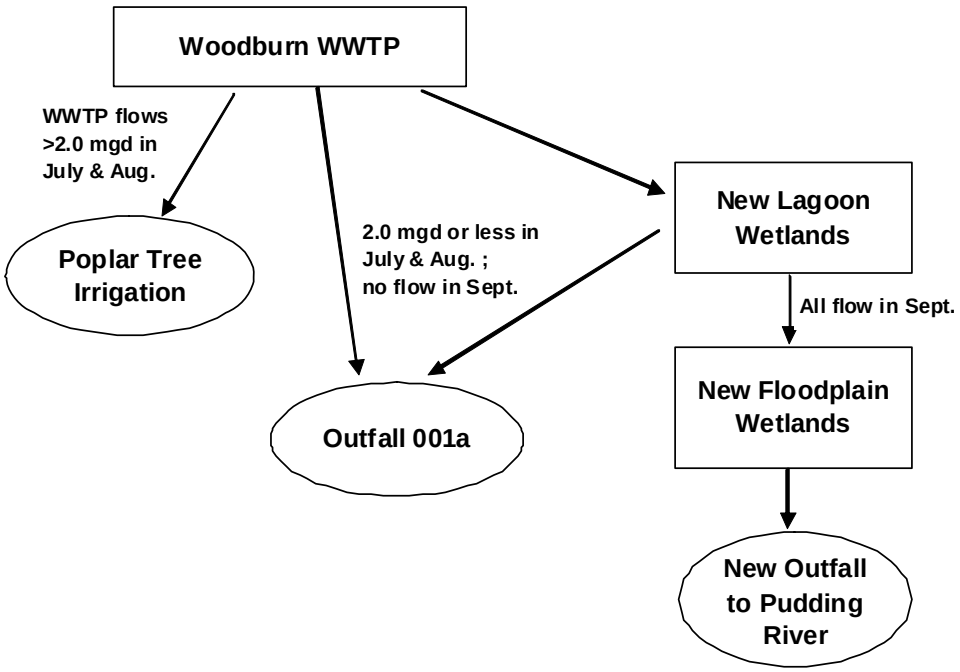

Exhibit 1-1. Dry Season Effluent Flow Path Alternatives based on the 2009 Facilities Plan

Outfalls 001A and 001B

The Woodburn WWTP discharges secondary effluent into the Pudding River through a single-port outfall (001a) at River Mile 21.5. Outfall 001A originates following the Parshall flume at the WWTP and consists of 2,120 feet of buried 24″ concrete cylinder pipe to the manhole at the top of the river bank (MH-2). From MH-2 at the top of the river bank slope the outfall pipe is 18″ steel pipe with a 30-foot section of corrugated 20″ steel pipe inserted for effluent re-aeration followed by 18″ steel pipe to MH-3 on the river bank slope (80-foot length). The last 40 feet of buried outfall pipe consists of 24″ steel pipe from MH-3 to outfall terminus. The outfall terminates with a 24″ single port directed downstream (co-flowing)

Figure 1-1. Location of Woodburn WWTP and Outfalls 001a and 001b on the Pudding River

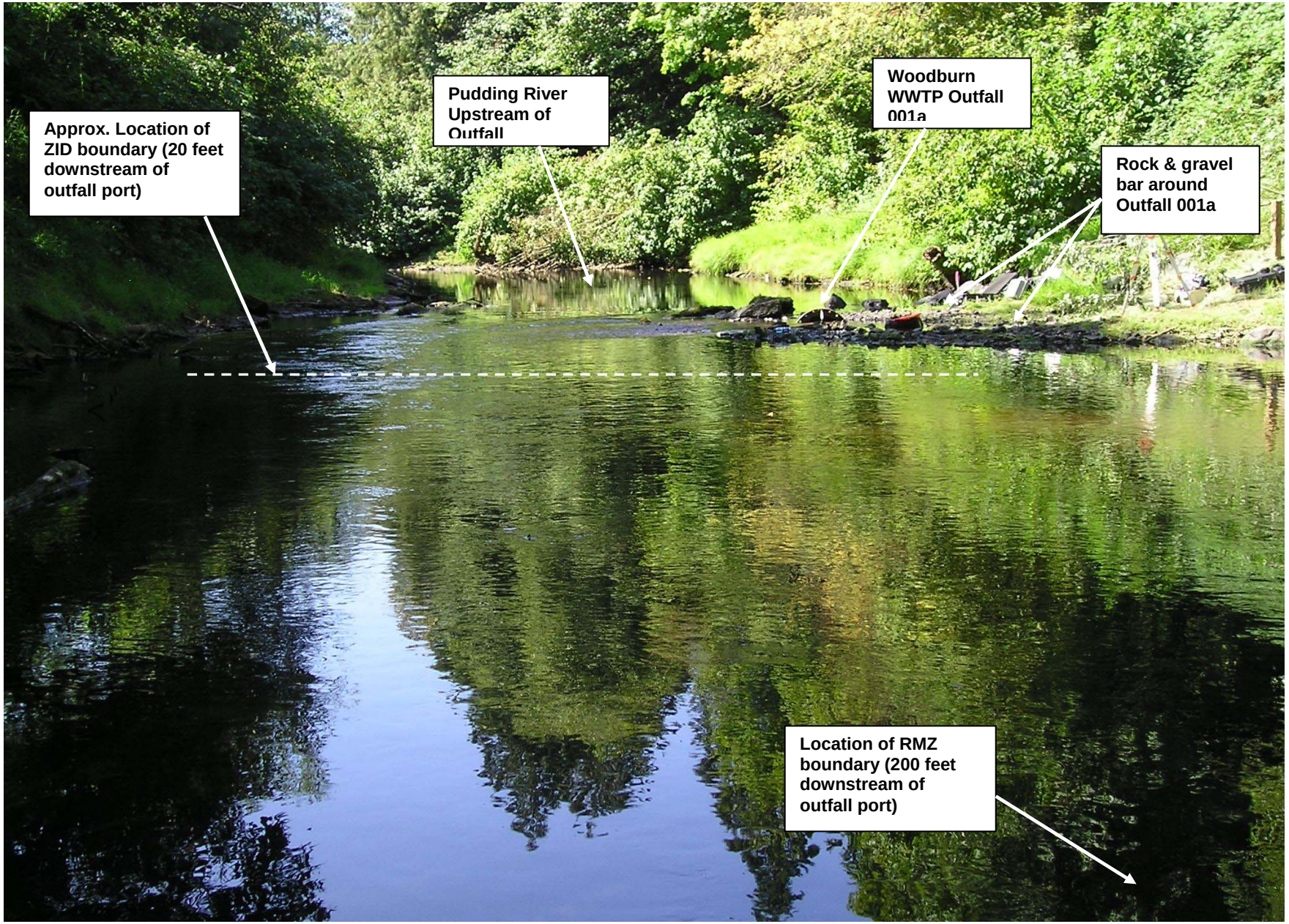

Figure 1-2. View of the Site of the Woodburn WWTP Outfall 001a on the Pudding River (from 75 feet downstream of the outfall)

and offshore of the left river bank a distance or approximately one-third of the entire Pudding River channel width. Appendix A provides the available drawings of the Woodburn WWTP Outfall 001a. Figure 1-2 shows the site of Outfall 001a on the Pudding River at RM 21.5.

In addition to Outfall 001a, there is a separate bank-side discharge outfall (001b) that is located 250 feet downstream of Outfall 001a on the left river bank. The outfall invert is approximately 5 feet above the water surface at low river flow condition. Outfall 001b is designed to discharge only during periods of high effluent flow volumes (greater than 12 million gallons per day, mgd) and high river stage. When effluent flows at the WWTP exceed 12 mgd, secondary-treated wastewater overflows an effluent flow diversion weir immediately prior to the Parshall flume and begins to discharge from both outfalls. Woodburn WWTP effluent flows only exceed 12 mgd under prolonged and extreme wet weather condition, when the Pudding River is at flood stages. According to the Woodburn WWTP records, Outfall 001b has not discharged in the past five years.

Woodburn's NPDES Permit specifies mixing zone distances downstream of the outfall and stream flow restrictions for the mixing zones. The NPDES Permit for Woodburn defines the mixing zones as follows: "the allowable mixing zone is that portion of the Pudding River where the effluent mixes with 25 percent of the stream flow but in no case shall it extend farther than ten (10) feet upstream of the outfall or to a point two hundred (200) feet downstream from each outfall. The Zone of Immediate Dilution (ZID) shall be defined as that portion of the allowable mixing zone that is within twenty (20) feet of the point of each discharge." Figure 1-2 shows Outfall 001a in the Pudding River channel and the approximate location of the ZID and RMZ, where field dilution and water quality measurements were conducted during the field tracer study in September 2008.

New Wetlands Outfall

As part of the Phase 2 facilities improvement the Woodburn WWTP will add a 10 acre wetland lagoon and 14 acres of floodplain wetlands for effluent cooling, and a new outfall to discharge flows from the new wetland system to the Pudding River. The new outfall will be located downstream of the Highway 211 bridge (approximately 3/4 mile downstream of Outfalls 001a and 001b). Figure 1-3 shows the site of the new wetlands outfall on the Pudding River.

The new wetlands outfall will consist of a buried 20"or 24" pipe with a diffuser located in the deepest channel region of the Pudding River. The new outfall diffuser concept includes 3-9" ports (or equivalent Tideflex ports) at 5-foot spacing. The design, permitting, and construction of the new outfall will be completed during the Phase 2 facilities improvements in 2010-2012. The mixing zone for this new wetlands outfall is assumed to be the same dimensions as Woodburn WWTP Outfall 001a.

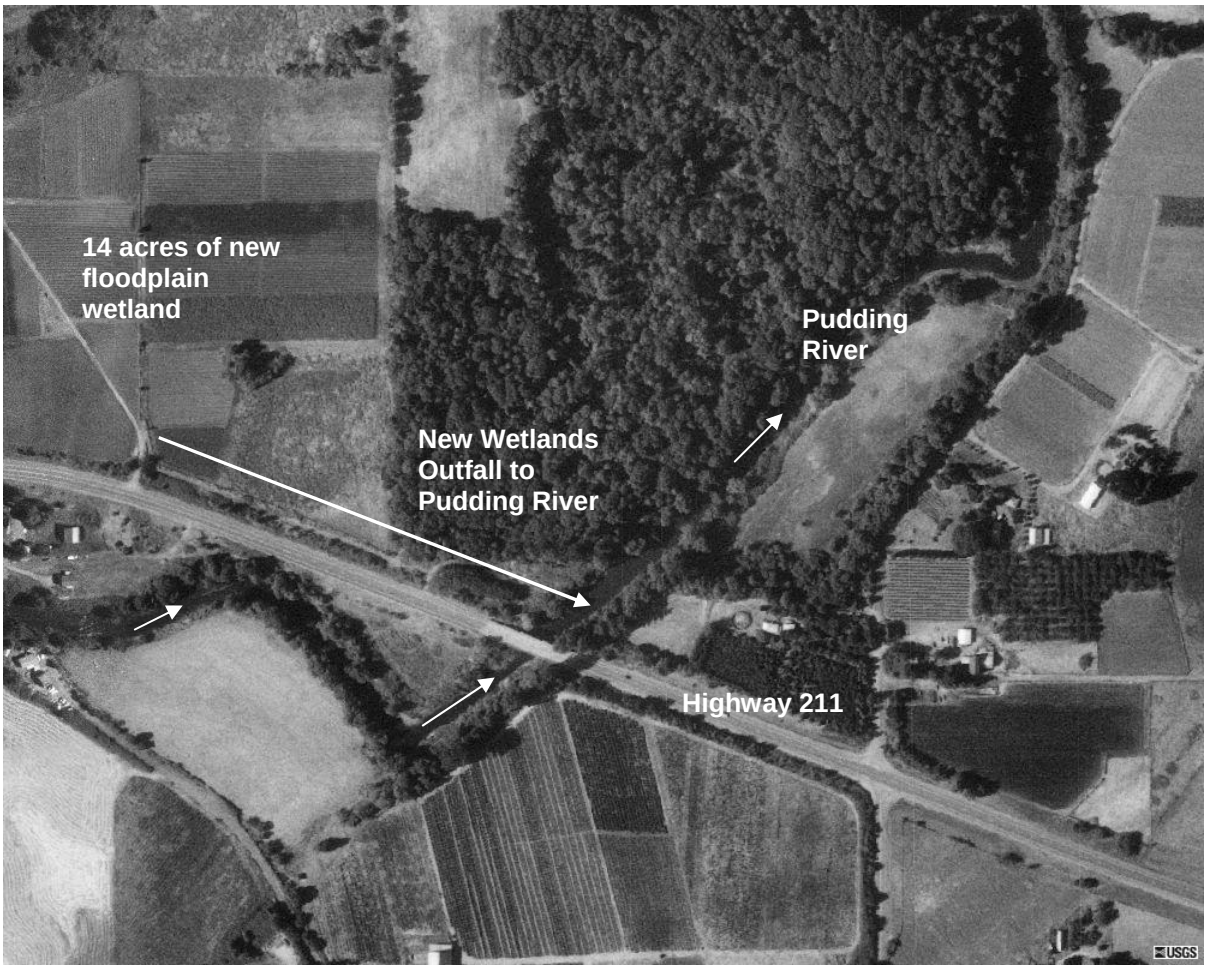

Figure 1-3. Location of New Wetlands Outfall on the Pudding River

Project Basis & Objectives

The objective of this study were to use well-planned procedures to produce a technically-defensible study that documents the dilution performance of the Woodburn WWTP outfall and meets the requirements of DEQ's Level 3 mixing zone study, as defined in the RMZ-IMD (DEQ, December 2007). The specific requirements of the RMZ-IMD for this Level 3 mixing zone study and the specific application to the Woodburn WWTP outfall are outlined as follows:

Outfall and Mixing Zone Characteristics: Provide plan view or diagram of each discharge including the location of the mixing zone and zone of initial dilution (ZID) boundaries. Diagram will include average water depth, water depth at outfall, distance from outfall to river bank, outfall elevation above the bottom, outfall and port dimensions and configuration, outfall length, number of ports (functioning and closed), and port orientation angles. The document includes the description of the mixing zone and the ZID (per NPDES permit), latitude and longitude for Outfall 001a and 001b, and photographs of the area upstream and downstream of the discharges.

Discharge Characteristics: Provide effluent flow statistics for defined effluent critical flows, and effluent temperature data. The RMZ-IMD specifies critical design conditions for low river flow periods and requires the discharger to define the off-design condition based on in-stream biological uses and other considerations. Based on a review of salmonid uses of the Pudding River, salmon migration periods will define the period to represent the off-design condition (March-April). Effluent chemistry data developed by the City of Woodburn are used for the Reasonable Potential analysis (RPA).

Ambient Receiving Water Characteristics: Provide river flow and stage statistics for critical low-flow and off-design conditions, stream cross-sectional profile at outfall site, receiving water velocities, temperatures, and densities for low-flow and off-design conditions (based on site-specific measurements during low flow field study). Background river water chemistry data for the Pudding River will be used for the RPA.

Environmental Mapping: Provide an environmental map of the region near the outfall outfall, including estimates of fish spawning/rearing habitat (if present); the presence, habitat, and migration pathways of threatened and endangered species; cold water refugia; presence of physical structures; drinking water intakes; and locations of other NPDES discharges within a half mile.

Mixing Zone Modeling Analyses: Provide the basis for model selection, modeling input and output, and field measurements for input data. This Level 3 assessment will provide a documented basis for model selection and calibration, based on the field tracer study measurements of outfall dilution performance under seasonal low flow conditions. Modeling analyses will be performed for the critical flow conditions defined in Table 4-2 of Part 2 of the RMZ-IMD, as well as the selected "off-design" condition.

The specific objectives of the Outfall Mixing Zone Study of the Woodburn WWTP outfalls are to develop site-specific field measurements at Outfall 001a under dry season low river flow conditions, develop environmental mapping information at both Outfalls 001A and 001b discharge sites, develop river flow and stage statistics for critical discharge conditions, apply field-measured dilutions for Outfall 001a and ambient conditions in dilution modeling, develop dilution modeling results for the defined critical river flow conditions, and evaluate the discharge compliance with the Oregon water quality standards including the thermal plume provisions.

To meet these project objectives, this project was performed to develop accurate and defensible field measurements of the outfall, mixing zone region, and river physical conditions for dilution modeling, and to document the selection and application of an appropriate dilution model to represent the outfalls. A study plan was developed specifically to define the field measurements necessary for this mixing zone study to provide the elements defined in the RMZ-IMD, as well provide the field data needed for accurate dilution modeling. Table 1-1 summarizes the alignment of this study with DEQ's RMZ-IMD objectives and identifies the specific sections of this report that provide the results.

TABLE 1-1
Woodburn WWTP Outfall Mixing Zone Study Alignment with DEQ IMD Objectives

DEQ IMD Objectives	Report Sections that Address	IMD Study Level Data Provided in Report
Outfall and Mixing Zone Descriptions	Section 3	All elements required for Level 3
Environmental Mapping	Section 3	All elements required for Level 3
Ambient and Receiving Water Conditions	Section 2	All elements required for Level 3
Discharge Characteristics	Sections 2 & 3	All elements required for Level 3
Mixing Zone Modeling	Section 4	All elements required for Level 3

Study Approach

The approach for this study involves collection of site-specific field measurements and direct field-measured dilutions during dry season low flow river conditions in September 2008. These field data are used along with effluent data to develop model predictions of discharge dilutions for critical seasonal river flow conditions. The field-measured dilutions are also used to compare and select the correct dilution model for application with the range of discharge conditions. Since the Pudding River flows under critical dry season conditions are very low and the Woodburn outfalls mixing zones are defined by a volume restriction of 25 percent of the river volume, then most dilution modeling results are superseded by the volume-restricted dilutions.

Prior to the field study, an Outfall Mixing Zone Study Plan document (CH2M HILL, 2008) was developed specifically to define the field measurements that are necessary for the mixing zone study to provide the elements defined in the RMZ-IMD, as well provide the field data needed for accurate dilution modeling. The Outfall Mixing Study Plan has been included in Appendix B of this report. The study plan was submitted to DEQ for review and approval on September 8th, and DEQ provided specific comments on September 9th, 2008. DEQ's review comments were addressed in a response to DEQ on September 9th.

CH2M HILL conducted the field data collection work during a two-day period in September 2008 using an experienced three person field team. The field study activities included site-specific field measurements of the Pudding River in the mixing zone region including river channel characteristics (water depth and cross-section profiles), ambient current velocity and temperature, dilution (dye tracer) measurements, and assessment of riverbed sediment characteristics.

Using the field measurements, dilution models were tested and then selected to represent the dilutions at the Zone of Immediate Dilution (ZID) and the Regulatory Mixing Zone (RMZ) under the field study river flow conditions. Once the dilution model was selected and calibrated to the field study conditions, then it was applied to the critical 7Q10 river flow condition and the off-design condition. The evaluation of "off-design conditions" focused on the seasonal period when adult steelhead salmon and spring Chinook salmon in-

migration occurs in the Pudding River. Available salmon migration data document that the appropriate critical period for adult salmon migration in the Pudding River occurs in the early fall period, and in March and April. The period of adult salmon migration(s) selected was used to evaluate if there is any potential for Woodburn's discharge to create thermal barriers or blockage of adult salmon migration (as defined in OAR 340-041-0053(2)(d) Temperature Thermal Plume Limitations).

This study describes the wastewater characteristics for the Woodburn WWTP, both existing plant conditions and future conditions with the implementation of improvements that are defined in the 2009 Woodburn WWTP Facilities Plan (CH2M HILL, 2009). The 2009 Facilities Plan evaluated and selected facilities improvements to meet the nutrient and temperature waste load allocations that are specified in the 1993 and 2008 Mollala-Pudding Subbasin TMDLs. The primary limits for the Woodburn WWTP discharge to the Pudding River are effluent ammonia load during July and August, and excess thermal load during July through September. The implementation of wetlands systems for thermal reductions and the changes in effluent flows discharged to the river by 2015 are represented in this study.

This Outfall Mixing Study Report has been prepared to document the receiving water, wastewater, outfall, and mixing zone characteristics, field measurements, modeling results, environmental mapping, and an assessment of the discharge compliance with water quality standards.

SECTION 6

Conclusions

This Outfall Mixing Study of the Woodburn WWTP outfall discharge to the Pudding River was designed and conducted to: 1) provide site-specific field measurements of the dilution performance of the Woodburn WWTP outfall under low river flow conditions, 2) provide accurate field measurements of dilution that can be used to calibrate and compare with dilution modeling results, 3) provide dilution modeling results for Woodburn WWTP effluent flows at critical low and off-design river flow conditions, and 4) provide dilution results that can be used to assess the discharge dilution performance relative to meeting water quality standards. This dilution study was conducted in accordance with the Study Plan approved by Oregon DEQ in September 2008. The findings of the study are summarized below:

1. September 10th through 12th , 2008, CH2M HILL conducted field measurements and a dye tracer study to measure the dilution performance of the Woodburn WWTP outfall under low river flow conditions. Cross-section surveys of the Pudding River channels were recorded at three site in the river. Stream flows in the river channel were gaged and currents were measured.

2. The Woodburn WWTP Outfall 001A consists of 2,240 feet of buried pipe to the single discharge port in the river. The outfall terminates with a 24" single port directed downstream (co-flowing) and located approximately one-third of the Pudding River channel width. Woodburn has a separate bank-side discharge outfall (001B) that is located 250 feet downstream of Outfall 001A on the left river bank. Outfall 001B is designed to discharge only during periods of high effluent flow volumes (greater than 12 million gallons per day, mgd) and high river stage. According to the Woodburn WWTP records, Outfall 001B has not discharged in the past five years and no modeling was conducted of this outfall for this reason.

3. Dye injection and in-river tracer monitoring were conducted on September 12th. Over 5,000 dye concentration measurements were recorded during the test to characterize the dilution and dispersion of the plume at the ZID and RMZ boundaries. The Pudding River flow on September 12th was 18 cfs. The study was conducted under low river flow however the river flow was still above the 7Q10 low flow condition at RM 21.5.

4. Ambient current measurements recorded near the outfall ranged between 0.9 and 1.7 fps. The river channel of the Pudding River was typically 40 to 50 feet wide in the mixing zone region, except at the outfall site where a large gravel and rock bar constricted the river flow and accelerated stream velocities and mixing.

5. The field-measured minimum average plume dilutions at the ZID and RMZ, based on the dye study measurements in the plume, are summarized below. At the ZID the plume occupied approximately 70 percent of the channel width, the plume was attached

to the left channel bank, and the minimum centerline dilutions were measured at 20 feet off the left bank. The plume was mixed in the water column at the RMZ, however the center of the plume was still adjacent to the left bank in the river thalweg region.

	Measurement Period	Centerline Minimum Dilution at ZID	Lowest Average Dilution at RMZ
2008 Field Study Condition Stream Flow = 18 cfs Effluent = 1.8-2.5 MGD	0825 to 1330 PDT	**2** **(Range 2 – 5)**	**6.5** **(Range 4 - 19)**

6. Three dilution models were evaluated for application with this shallow outfall in a confined channel, and the model CORMIX3 was selected to perform the dilution modeling, based on modeling requirements and a comparison with the field-measure dilutions at the ZID and RMZ. Dilution modeling was conducted to predict dilutions at the ZID and RMZ boundaries at the river flow conditions of the dye study, and seasonal critical low and off-design flow conditions. Model-predicted dilutions were compared with field-measured dilutions for the Sept. 12th river flow condition. Model-predicted dilutions were compared and verified with the field-measured dilutions at critical low river flow (see model-predicted dilutions below).

Discharge Scenarios	Case	Minimum Dilution at ZID	Minimum Dilution at RMZ
2008 Field Study Condition Stream Flow = 18 cfs Current Speed = 1.3 fps Effluent = 2.1 MGD	**Field- Measured**	**2:1**	**6.5**
	Modeled (CORMIX3)	**1.2**	**4.3**

7. Dilution modeling was performed using current and projected (2015) Woodburn effluent flows and seasonal 1Q10 and 7Q10 low flow, annual 30Q5 and harmonic mean flow, and off-design season (March-April) river flow conditions. Based on a range of seasonal river and effluent flow conditions, the minimum dilutions for the current Woodburn effluent flows are listed below. The NPDES Permit for Woodburn restricts the allowable dilution within the mixing zones to "that portion of the Pudding River where the effluent mixes with *25 percent of the stream flow* but in no case shall it extend farther than ten (10) feet upstream of the outfall or to a point two hundred (200) feet downstream from each outfall. The Zone of Immediate Dilution (ZID) shall be defined as that portion of the allowable mixing zone that is within twenty (20) feet of the point of each discharge." This volume restriction of effluent mixing proves to be the limiting dilution under most of the discharge scenarios that were modeled. These dilutions are provided for use in the NPDES permit renewal and the reasonable potential analysis.

Discharge Conditions	Case	Minimum Dilution at ZID	Minimum Dilution at RMZ
1Q10 Low Flow (Summer)	2008 (3.34 mgd) 2015 (5.56 mgd)	1.2 1.2	n/a n/a
7Q10 Low Flow (Summer)	2008 (2.1 mgd) 2015 (4.09 mgd)	n/a n/a	1.7 1.4
30Q5 Annual Flow Condition	2008 (2.13 mgd) 2015 (3.56 mgd)	n/a n/a	2.2 1.7
Harmonic Mean Flow Condition	2008 (2.13 mgd) 2015 (3.56 mgd)	n/a n/a	7.5 3.7
Off-Design Flow Condition (March- April)	2008 (2.69 mgd) 2015 (7.11 mgd)	n/a n/a	45 15

8. Discharge compliance with Oregon's temperature criteria, thermal plume provisions, and chemical criteria in the state water quality standards was evaluated. Based on the minimum dilution factor at the RMZ boundary under 7Q10 low river flow conditions, the Woodburn WWTP discharge will comply with all of the thermal plume provisions of the Oregon water quality standards, including the migration blockage with the use of new wetland systems. For the biologically-based temperature criteria (seasonal uses), the Woodburn WWTP discharge will not cause a measurable temperature increase (<0.2 deg. C) at the RMZ during the winter (off-design period) when native salmon and steelhead migration peaks (March-April).

9. The Woodburn NPDES permit already includes an Excess Thermal Load limit that was developed prior to the establishment of a TMDL for temperatures on the Pudding River. The existing Excess Thermal Load limits is 9.2 million Kcals/day, implemented as a weekly average. The Mollala--Pudding River Basin TMDL for Temperature was published in December 2008 and has been approved by EPA. The 2008 Mollala--Pudding River Basin TMDL for Temperature establishes a matrix table of Excess Thermal Load limits that are based on the combination of Woodburn effluent flow rate and Pudding River flows at the Woodburn gage. A Mutual Agreement and Order issued in June 2007 by the Environmental Quality Commission specifies a timeline for meeting the Excess Thermal Load limits specified within the Temperature TMDL.

10. More than four years of effluent ammonia and metals data were used to represent the maximum probable concentrations discharged, in accordance with the Oregon DEQ *Reasonable Potential Analysis for Toxic Pollutants – Internal Management Directive* (Oregon DEQ, Sept. 2005). The RPA shows that the Woodburn effluent does not have a reasonable potential to exceed acute or chronic aquatic life criteria for ammonia, except the chronic criteria during low river flow. The RPA for effluent metals shows that the discharge does not have a reasonable potential to exceed aquatic life acute or chronic chemical criteria, with the exception of copper and zinc. One copper and one zinc value

triggered the RPA, and clean sampling methods at the Woodburn WWTP are being implemented to provide reliable data.