REGION 10 ADMINISTRATOR

SEATTLE, WA 98101

Haines Borough
Wastewater Treatment Plant
Application for a Modified NPDES Permit
Under Section 301(h) of the Clean Water Act

Final Decision of the Regional Administrator
Pursuant to 40 CFR Part 125, Subpart G

I have reviewed the attached evaluation analyzing the merits of the Haines Borough's request and application for a variance from secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the Act for the Haines Borough wastewater treatment plant. It is my decision that the Haines Borough be granted a variance pursuant to Section 301(h) of the Act for the Haines Borough wastewater treatment plant in accordance with the terms, conditions, and limitations of the final 301(h)-modified NPDES permit AK0021385.

My decision is based on available information specific to the discharge from the Haines Borough wastewater treatment plant. It is not intended to assess the need for secondary treatment in general, nor does it reflect on the necessity for secondary treatment by other publicly owned treatment works discharging to the marine environment.

Under the procedures of permit regulations at 40 CFR Part 124, public notice and comment regarding the draft version of this decision and accompanying NPDES permit were made available to all interested persons.

This decision shall become effective on January 7, 2025, unless a request for review is filed. If a request for review is filed, this decision is stayed. Requests for review must be filed by January 6, 2025, and must meet the requirements of 40 CFR 124.19. All requests for review should be addressed to the Environmental Appeals Board. Those persons filing a request for review must have filed comments on the tentative decision. Requests for review from other persons must be limited to the extent of the changes made from the tentative decision to the final decision. EPA regulations regarding the effective date for the decision and requests for review procedures are set forth in 40 CFR 125.15, 125.19 and 125.20.

The Notice of Final Decision will also be posted on the EPA Region 10 website.

/signed/ 11-15-2024
Casey Sixkiller
Regional Administrator

Haines Borough Wastewater Treatment Plant

Application For A Modified NPDES Permit Under Section 301(h) Of

The Clean Water Act

Decision Document

December 2024

United States Environmental Protection Agency

Region 10

1200 6th Avenue

Seattle, WA 98101

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1) INTRODUCTION

The Haines Borough, Alaska, ("the applicant," "Haines," or "the permittee") has requested a renewal of its variance (sometimes informally called a "waiver" or "modification") under Section 301(h) of the Clean Water Act (the Act or CWA) from the secondary treatment requirements contained in Section 301(b)(1)(B) of the Act, 33 USC § 1311(b)(1)(B).

The United States Environmental Protection Agency, Region 10 (EPA) approved Haines' most recent National Pollutant Discharge Elimination System (NPDES) permit for the Haines Wastewater Treatment Plant ("WWTP" or "the facility") and issued a CWA Section 301(h)-modified permit on November 20, 2001 (AK0021385) (hereafter referred to as the 2001 permit). The 2001 permit became effective on December 24, 2001 and expired on December 26, 2006. A timely and complete NPDES application for permit reissuance was submitted by the permittee on July 13, 2006. Pursuant to 40 CFR 122.6, the permit has been administratively continued and remains fully effective and enforceable.

The 301(h) variance is being sought for the Haines WWTP, a publicly owned treatment works (POTW). The applicant is seeking a 301(h) variance to discharge wastewater receiving less-than-secondary treatment from a single outfall into Portage Cove. The effluent quality attainable by secondary treatment is defined in the regulations at 40 CFR Part 133 in terms of biochemical oxygen demand (BOD_5), total suspended solids (TSS), and pH. Pursuant to 40 CFR 133.102, secondary treatment requirements for TSS, BOD_5, and pH are as follows:

TSS: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

BOD_5: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

pH: The pH of the effluent shall be maintained within the limits of 6.0 to 9.0 pH standard units.

The City requested a modification for TSS and BOD_5, but not for pH.

This document presents EPA's findings and conclusions as to whether the applicant's proposed 301(h)-modified discharge (proposed discharge) will comply with the criteria set forth in Sections 301(h) of the Act, as implemented by regulations at 40 CFR Part 125, Subpart G, and Alaska Water Quality Standards (Alaska WQS), as amended.

2) DECISION CRITERIA

Under Section 301(b)(1)(B) of the Act, POTWs in existence on July 1, 1977, are required to meet effluent limits based on secondary treatment as defined by the Administrator of EPA ("the Administrator"). Secondary treatment is defined by the Administrator in terms of three parameters: TSS, BOD_5, and pH. Uniform national effluent limitations for these pollutants were promulgated and included in NPDES permits for POTWs issued under Section 402 of the CWA, POTWs were required to comply with these limitations by July 1, 1977.

Congress subsequently amended the Act, adding Section 301(h) which authorizes the Administrator, with State concurrence, to issue NPDES permits that modify the secondary treatment requirements of the Act with respect to certain discharges. P.L. 95-217, 91 Stat. 1566, as amended by P.L. 97-117, 95 Stat. 1623; and S303 of the Water Quality Act of 1987. Section 301(h) provides that:

> *[T]he Administrator, with the concurrence of the State, may issue a permit under section 402 [of the Act] which modifies the requirements of subsection (b)(1)(B) of this section [the secondary treatment requirements] with respect to the discharge of any pollutant from a publicly owned treatment works into marine waters, if the applicant demonstrates to the satisfaction of the Administrator that:*

(1) there is an applicable water quality standard specific to the pollutant for which the modification is requested, which has been identified under section 304(a)(6) of [the CWA];
(2) the discharge of pollutants in accordance with such modified requirements will not interfere, alone or in combination with pollutants from other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allows recreational activities, in and on the water;
(3) the applicant has established a system for monitoring the impact of such discharge on a representative sample of aquatic biota, to the extent practicable, and the scope of the monitoring is limited to include only those scientific investigations which are necessary to study the effects of the proposed discharge;
(4) such modified requirements will not result in any additional requirements on any other point or nonpoint source;
(5) all applicable pretreatment requirements for sources introducing waste into such treatment works will be enforced;
(6) in the case of any treatment works serving a population of 50,000 or more, with respect to any toxic pollutant introduced into such works by an industrial discharger for which pollutant there is no applicable pretreatment requirement in

effect, sources introducing waste into such works are in compliance with all applicable pretreatment requirements, the applicant has in effect a pretreatment program which, in combination with the treatment of discharges from such works, removes the same amount of such pollutant as would be removed if such works were to apply secondary treatment to discharges and if such works had no pretreatment program with respect to such pollutant;

(7) to the extent practicable, the applicant has established a schedule of activities designed to eliminate the entrance of toxic pollutants from nonindustrial sources into such treatment works;

(8) there will be no new or substantially increased discharges from the point source of the pollutant into which the modification applies above that volume of discharge specified in the permit; and

(9) the applicant at the time such modification becomes effective will be discharging effluent which has received at least primary or equivalent treatment and which meets the criteria established under [section 304(a)(1) of the CWA] after initial mixing in the waters surrounding or adjacent to the point at which such effluent is discharged.

For the purposes of this subsection the phrase "the discharge of any pollutant into marine waters" refers to a discharge into deep waters of the territorial sea or the waters of the contiguous zone, or into saline estuarine waters where there is strong tidal movement and other hydrological and geological characteristics which the Administrator determines necessary to allow compliance with paragraph (2) of this subsection, and [section 101(a)(2) of the Act]. For the purposes of paragraph (9), "primary or equivalent treatment" means treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biological oxygen demanding material and of the suspended solids in the treatment works influent, and disinfection, where appropriate. A municipality which applies secondary treatment shall be eligible to receive a permit pursuant to this subsection which modifies the requirements of subsection (b)(1)(B) of this section with respect to the discharge of any pollutant from any treatment works owned by such municipality into marine waters. No permit issued under this subsection shall authorize the discharge of sewage sludge into marine waters. In order for a permit to be issued under this subsection for the discharge of a pollutant into marine waters, such marine waters must exhibit characteristics assuring that water providing dilution does not contain significant amounts of previous discharged effluent from such treatment works. No permit issued under this subsection shall authorize the discharge of any pollutant into saline estuarine waters which at the time of application do not support a balanced, indigenous population of shellfish, fish and wildlife, or allow recreation in and on the waters or which exhibit ambient water quality below applicable

> *water quality standards adopted for the protection of public water supplies, shellfish, fish and wildlife or recreational activities or such other standards necessary to assure support and protection of such uses. The prohibition contained in the preceding sentence shall apply without regard to the presence or absence of a causal relationship between such characteristics and the applicant's current or proposed discharge. Notwithstanding any of the other provisions of this subsection, no permit may be issued under this subsection for discharge of a pollutant into the New York Bight Apex consisting of the ocean waters of the Atlantic Ocean westward of 73 degrees 30 minutes west longitude and westward of 40 degrees 10 minutes north latitude.*

On August 9, 1994, EPA promulgated final regulations implementing these statutory criteria at 40 CFR Part 125, Subpart G. The regulations provide that a Section 301(h)-modified NPDES permit may not be issued in violation of 40 CFR 125.59(b) which requires, among other things, compliance with provisions of the Coastal Zone Management Act, as amended, 16 USC 1451 *et seq.*, the Endangered Species Act, as amended, 16 USC 1531 *et seq.*, Title III of the Marine Protection Research and Sanctuaries Act, as amended, 16 USC 1431 *et seq.*, the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC 1801 *et seq.*, and any other applicable provisions of local, state, and federal laws or Executive Orders.

In accordance with 40 CFR 125.59(i), the decision to grant or deny a CWA Section 301(h) waiver shall be made by the Administrator[1] and shall be based on the applicant's demonstration that it has met all the requirements of 40 CFR 125.59 through 125.68, as described in this 301(h) Decision Document (301(h) DD). EPA has reviewed all data submitted by the applicant in the context of applicable statutory and regulatory criteria and has presented its findings and conclusions in this 301(h) DD.

3) SUMMARY OF FINDINGS

Based upon review of the data, references, and empirical evidence furnished by the applicant and other relevant sources, EPA Region 10 makes the following findings regarding the application with respect to the statutory and regulatory criteria:

1. The applicant's proposed discharge will comply with Alaska WQS for dissolved oxygen and turbidity. [CWA Section 301(h)(1), 40 CFR 125.61]
2. The applicant has demonstrated it can consistently achieve Alaska WQS and federal CWA Section 304(a)(1) water quality criteria at and beyond the zone of initial dilution (ZID). [CWA Section 301(h)(9), 40 CFR 125.62(a)]
3. The applicant's proposed discharge, alone or in combination with pollutants from other sources, will not adversely impact public water supplies or interfere with the protection

[1] The authority to make decisions on the eligibility of publicly owned treatment works for variances from the secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the CWA has been delegated to the Regional Administrators.

and propagation of a balanced, indigenous population (BIP) of shellfish, fish, and wildlife, and will allow for recreational activities in an on the water. [CWA Section 301(h)(2), 40 CFR 125.62(b), (c), (d)]

4. The applicant has a well-established and adequate program to monitor the impact of its proposed discharge on aquatic biota and has demonstrated it has adequate resources to continue the program. These monitoring requirements will remain enforceable terms of the permit. [CWA Section 301(h)(3), 40 CFR 125.63]
5. The applicant's proposed discharge will not result in any additional treatment requirements on any other point or nonpoint sources. [CWA Section 301(h)(4), 40 CFR 125.64]
6. The facility serves a population less than 50,000 people, so does not need to develop an urban area pretreatment program [CWA Section 301(h)(6), 40 CFR 125.65]
7. The applicant will continue to implement its nonindustrial source control program, consisting of public outreach and education designed to minimize the amount of toxic pollutants that enter the treatment system from nonindustrial sources. [CWA Section 301(h)(7), 40 CFR 125.66]
8. There will be no new or substantially increased discharges from the point source of the pollutants to which the 301(h) variance applies above those specified in the permit. [CWA Section 301(h)(8), 40 CFR 125.67]
9. The 301(h) modified permit contains the special conditions required regarding effluent limitations and mass loadings, schedules of compliance, and monitoring and reporting requirements [40 CFR 125.68]
10. The discharge is not expected to conflict with applicable provisions of State, local, or other Federal laws or Executive Orders, including compliance with the Coastal Zone Management Act of 1972, as amended, 16 USC1451 *et seq*.; the Endangered Species Act of 1973, as amended, 16 USC 1531 *et seq*.; Title III of the Marine Protection, Research and Sanctuaries Act, as amended, 16 USC 1431 *et seq*.; and the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC 1801 *et seq.* [40 CFR 125.59(b)(3)]
11. The applicant has demonstrated the proposed discharge will comply with federal primary treatment requirements. [CWA Section 301(h)(9), 40 CFR 125.60]

4) DECISION

Based on the findings in Section 3, above, EPA has concluded that the applicant's proposed discharge will comply with the requirements of CWA Section 301(h), and 40 CFR Part 125, Subpart G. Accordingly, EPA has decided to grant the applicant a CWA Section 301(h) variance and reissue their 301(h)-modified NPDES Permit AK0021385.

5) DESCRIPTION OF TREATMENT SYSTEM

The WWTP serves the community of Haines, Alaska, which has a population of approximately 1,800 people. According to the facility, the design flow is 1.9 mgd monthly average flow and 2.9 mgd maximum daily flow. In accordance with 40 CFR 125.58(c), the facility is a "small applicant." The collection system is a separate sanitary sewer system. The effluent is all domestic in origin, except for industrial flow from the local brewery and distillery of 1,700 gpd. The existing outfall (001) discharges to Portage Cove in Chilkoot Inlet approximately 1,830 feet (558 meters) offshore at a depth of 80 feet (24.4 meters) below mean lower low water (MLLW). The outfall location is at the following latitude and longitude: 59.23710 N, -135.43118 W.

Raw sewage enters the WWTP through two primary screens and then to the grit chamber where polymer is added. The influent is then routed to the clarifier. Primary sludge and skimmings from the clarifier are moved to the aerobic digestion chamber for thickening (by periodic gravity settling). This supernatant is decanted back into the system and eventually discharged through the outfall. The sludge is dewatered and disposed of at landfills.

See Appendix A for facility figures, area maps, and the treatment process flow diagram.

6) DESCRIPTION OF RECEIVING WATERS

A. General Features

The WWTP discharges into the saline estuarine waters of Portage Cove in Chilkoot Inlet, approximately 1,830 feet from the shore off the east side of Haines, Alaska. Portage Cove is a tidal estuary located on the western shoreline of the eastern branch of Chilkoot Inlet. Chilkoot Inlet is on the northern end of Lynn Canal.

Surface water densities near the outfall vary due to local freshwater inputs from nearby streams and rivers. Freshwater input north of Portage Cove comes from the combined flow of the Skagway, Taiya, Ferebee, and Chilkoot Rivers, as well as West Creek and other streams.

Portage Cove is classified in Alaska WQS as classes IIA(I)(ii)(iii), B(I)(ii), C and D, for use in aquaculture, seafood processing and industrial water supply, water contact and secondary recreation, growth and propagation of fish, shellfish, aquatic life and wildlife, and harvesting for consumption of raw mollusks or other raw aquatic life.

B. Currents and Flushing

According to the previous fact sheet, the mean tide range at Haines is 14.2 feet (4.3 m), and a mean tide level of 8.7 feet (2.7 m) above MLLW. At Battery Point, 3.15 miles south of Haines, tidal currents average 10 cm/sec on a flooding tide (to the north) and 23 cm/sec on an ebbing tide (to the south), with maximum flood- and ebb- tide velocities of 15.4 cm/sec and 36.0 cm/sec respectively. Measurements in Lynn Canal, south of Haines, indicate a strong average southerly flow on the surface and a weak average northerly flow below a depth of 50 feet (15.2 m). Due to freshwater supplied by runoff, the net transport is out of Chilkoot Inlet at a rate of 4.8 miles (2.9 km) to the south every 12.4 hours. The period of lowest net circulation is expected to be December through April, during times of minimum river flow.

7) PHYSICAL CHARACTERISTICS OF THE DISCHARGE

A. Outfall/Diffuser Design and Initial Dilution

Pursuant to 40 CFR 125.62(a)(1), the outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater to meet all applicable WQS at and beyond the boundary of the ZID during periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist.

The WWTP outfall and diffuser are made of a 16-inch diameter pipe. The outfall is 1,830 feet in length from MLLW, terminating in a diffuser 30 feet (9.1 m) in length. The effluent is directed horizontally through two ports in the diffuser, each with a diameter of 3 inches (7.6 cm). A third port on the diffuser was capped in 1986 and will not be used. The depth of the outfall is 80 feet at MLLW (i.e., on the bottom of Portage Cove).

<u>Zone of Initial Dilution (ZID)</u>

Section 301(h)(9) of the CWA, and 40 CFR 125.62 require 301(h) discharges to meet state WQS and federal CWA Section 304(a) criteria at the boundary of the ZID, which is the region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports. The ZID may not be larger than allowed by mixing zone restrictions in applicable WQS, as per 40 CFR 125.58(dd). The dilution ratio achieved at the completion of initial mixing at the edge of the ZID is used to determine compliance with these requirements. Dilution is defined as the ratio of the total volume of the sample (ambient water plus effluent) to the volume of effluent in the sample. The ZID is not intended to describe the area bounding the entire mixing process or the total area impacted. Rather, the ZID, or region of *initial mixing,* is the area of rapid, turbulent mixing of the effluent and receiving water and results from the interaction between the buoyancy and momentum of the discharge and the density and momentum of the receiving water. Initial dilution is normally complete within several minutes after discharge. In guidance, EPA has operationally delimited the ZID to include the bottom area within a horizontal distance equal to the water depth from any point on the diffuser and the water column above that area (Amended 301(h) Technical Support Document; 301(h) TSD). Beyond the ZID boundary (i.e., after initial mixing is complete), the effluent is diluted further by passive diffusion processes and far-field ambient receiving water conditions. The ZID is not inclusive of this far-field mixing process.

The 2001 permit used a dilution factor for the ZID of 52.9:1. EPA was unable to recreate this dilution factor using available effluent and receiving water data. Thus, EPA modeled the current discharge to determine the dilution achieved at the edge of the ZID using the discharge depth of the facility and tidal predictions from near the Haines facility, in combination with recent effluent and receiving water data provided by the nearby Skagway WWTP. At the time of dilution modeling, effluent and receiving water data from Haines were not available. Since Skagway is located nearby, 22 miles north in Chilkoot Inlet, EPA believes the dilution results are appropriate for Haines. In accordance with the 301(h) TSD, EPA used data reflecting critical discharge and receiving water conditions to determine dilution under critical conditions. The dilution modeling report is included in Appendix G.

According to the model, the discharge achieves initial mixing and a dilution of 100:1 within one water depth of the outfall in under four minutes of discharge under critical discharge and receiving water conditions. EPA used 100:1 dilution as the basis for determining compliance with CWA Section 301(h)(9) and 40 CFR 125.62. Consistent with the recommendations in the 301(h) TSD for setting spatial boundaries for the ZID, EPA has established the spatial dimensions of the ZID using a discharge depth of 80 feet (24.4 m) below MLLW, a mean tide level of 8.7 feet (2.65 m), and a port height above sea bottom of 0.7 feet (0.2m). Using the diffuser length of 30 feet (9.1 m), and a diameter of 16 in (1.33 feet; 0.41m), the ZID was calculated to be a rectangle of 209 feet (63.7 m) long (perpendicular to shore) and 180 feet (54.9 m) wide, centered on the diffuser and perpendicular to the shoreline.

The ZID dimension calculations are as follows:

Width (units in feet) = 1.33 + 2 x (80 + 8.7 + 0.7) = 180 ft

Length (units in feet) = 30 + 2 x (80 + 8.7 + 0.7) = 209 ft

8) APPLICATION OF STATUTORY AND REGULATORY CRITERIA

The sections below describe the statutory and regulatory requirements that are applicable to CWA Section 301(h) discharges and explains the basis for certain water quality effluent limits in the final permit.

A. Compliance with Primary or Equivalent Treatment Requirements [CWA Section 301(h)(9); 40 CFR 125.60]

Under CWA Section 301(h)(9) and 40 CFR 125.60, the applicant must demonstrate it will be discharging effluent that has received at least primary or equivalent treatment at the time the 301(h)-modified permit becomes effective. 40 CFR 125.58(r) defines primary or equivalent treatment as treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biochemical oxygen demanding material and other suspended solids in the treatment works influent, and disinfection, where appropriate. To ensure the effluent has received primary or equivalent treatment, 40 CFR 125.60 requires the applicant to perform monitoring of their influent and effluent and assess BOD_5 and TSS removal rates based on a monthly average.

Applicants for 301(h) waivers request concentration and loading (lb/day) limits for BOD_5 and TSS based on what the facility can achieve. Therefore, the technology-based requirements for POTWs with 301(h) waivers are established on a case-by-case basis taking into consideration facility performance and the federal primary treatment standards.

1. Total Suspended Solids

EPA reviewed influent and effluent monitoring data for TSS between 2016 and 2021. A summary table and graphical representation of the data is provided below.

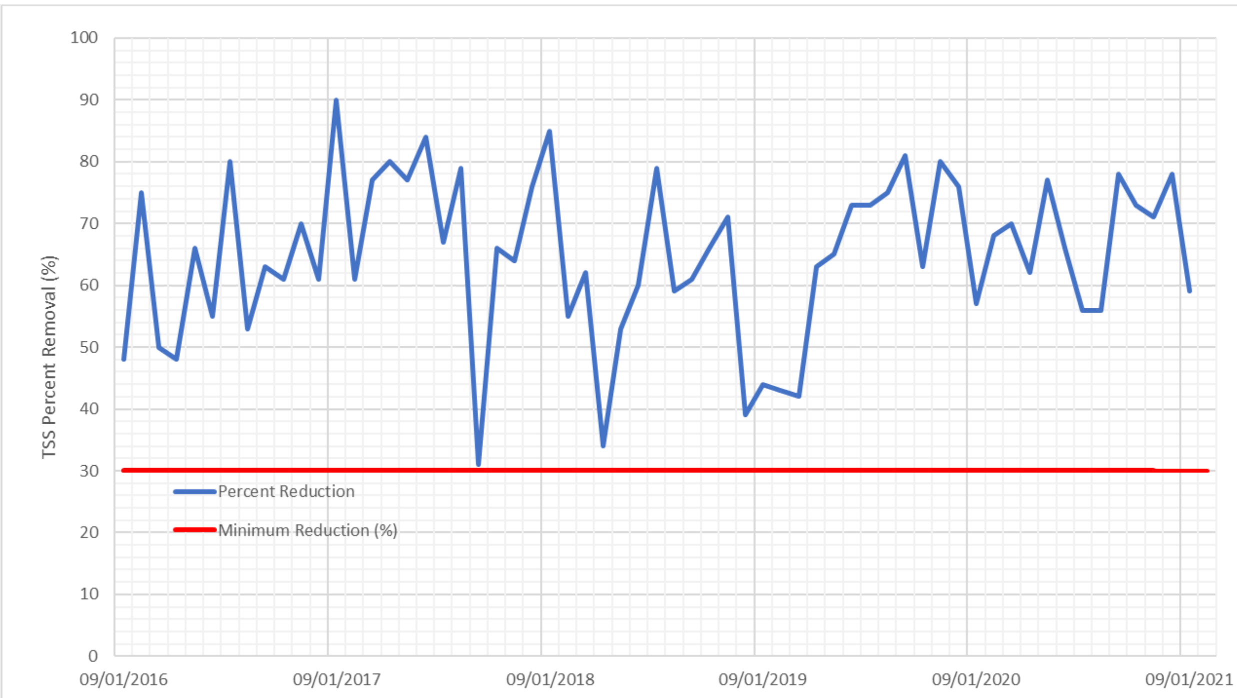


Figure 1. Minimum Monthly Percent TSS Removal (9/2016-9/2021)

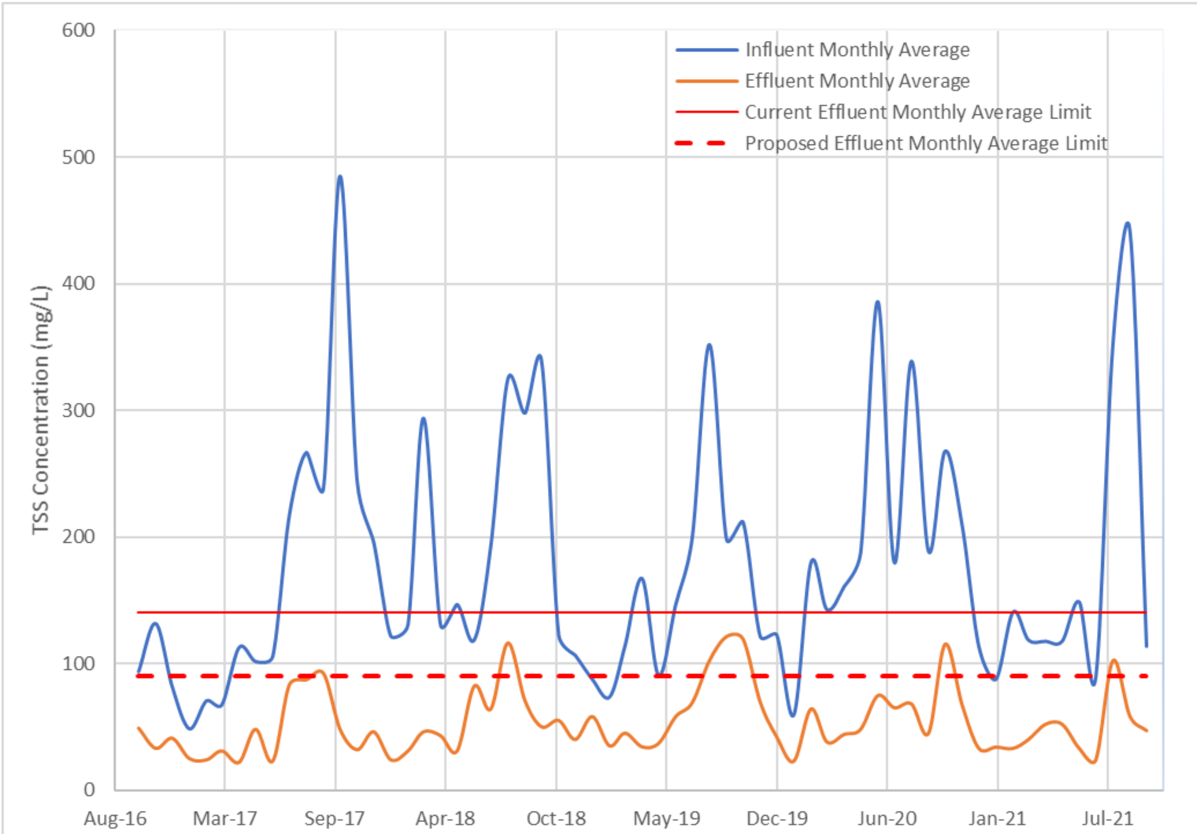


Figure 2. Average Monthly Influent and Effluent TSS Concentrations (9/2016-9/2021)

The facility achieved the minimum 30% removal requirement for TSS 100% of the time between 2016-2021, with the lowest monthly removal being 31%. Between 2016 and 2021 the facility achieved an average of nearly 65% removal of TSS, with maximum percent removal efficiencies as high as 90%.

Table 1. Influent and Effluent TSS Data (9/2016-9/2021)

Statistic	Influent, TSS, mg/L, Mo. Avg	Effluent, TSS, mg/L, Max Daily	Effluent, TSS, mg/L, Mo. Avg	Percent Removal
LIMIT	---	200	140	≥30%
COUNT	61	61	61	61
MEAN	178	88	54	65
MINIMUM	49	32	22	31
MAX	485	244	121	90
STDV	98	46	26	13
CV	0.55	0.521	0.478	0.20
5th	68	33	23	39
95th	383	200	116	84

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for TSS when the 301(h)-modified permit becomes effective. [CWA section 301(h)(9) and 40 CFR 125.60].

2. Biochemical Oxygen Demand

EPA reviewed influent and effluent data for BOD_5 between 2016 and 2021. A summary table and graphical representation of the data is provided below.

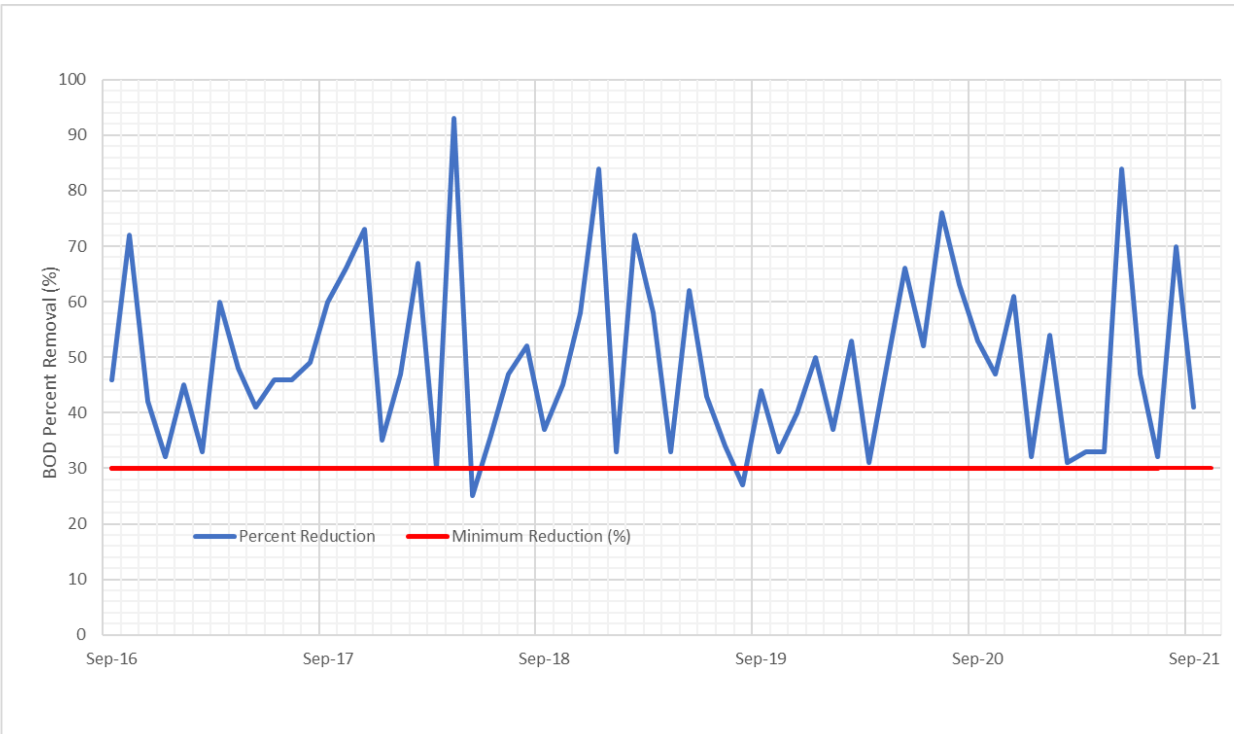


Figure 3. Minimum Monthly BOD_5 Removal (9/2016-9/2021)

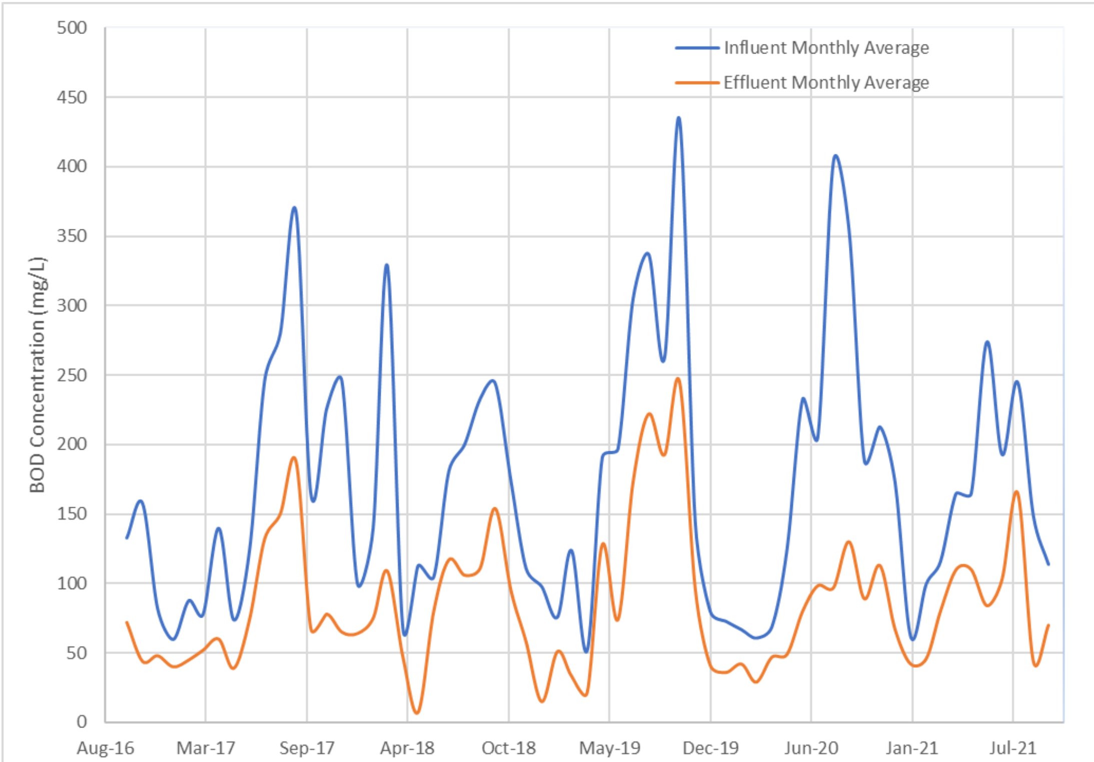


Figure 4. Monthly Influent and Effluent BOD_5 Concentrations (9/2016-9/2021)

The facility achieved the minimum 30% removal requirement for BOD_5 nearly 100% of the time, with two months below 30% removal (25%, May 2018 and 27%, August 2019). During these two months, the low percent removal was due to sampling error after equipment replacements. Between 2016 and 2021 the facility achieved an average of 48.8% removal of BOD_5, with maximum percent removal efficiencies as high as 93%.

Table 2. Influent and Effluent BOD Data (9/2016-9/2021)

Statistic	Influent, BOD_5, mg/L, Mo. Avg	Effluent, BOD_5, mg/L, Max Daily[1]	Effluent, BOD_5, mg/L, Mo. Avg[1]	Percent Removal
LIMIT	---	300	260	≥30%
COUNT	58	58	58	58
MEAN	174	87	87	49
MIN	52	7	7	25
MAX	434	245	245	93
STDV	95	51	51	16
CV	0.55	0.59	0.59	0.32
5th	62	28	28	31
95th	356	189	189	77
1) The 2001 permit required monthly influent/effluent BOD_5 monitoring, so reported values for maximum and average are identical				

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for BOD_5 when the 301(h)-modified permit becomes effective. [CWA Section 301(h)(9) and 40 CFR 125.60].

B. Attainment of Water Quality Standards Related to TSS AND BOD_5 [CWA 301(h)(1); 40 CFR 125.61]

Under 40 CFR 125.61, which implements CWA Section 301(h)(1), there must be WQS applicable to the pollutants for which the modification is requested, and the applicant must demonstrate that the proposed discharge will comply with these standards. The applicant has requested modified secondary treatment requirements for BOD_5, which affects dissolved oxygen (DO), and TSS, which affects the color or turbidity in the receiving water. The State of Alaska has water quality standards for DO and turbidity.

1. Turbidity and Light Transmittance/Attenuation

Alaska WQS applicable to the estuarine waters of Portage Cove provide that turbidity shall not exceed 25 nephelometric turbidity units (NTU), may not interfere with disinfection, may not cause detrimental effect on established levels of water supply treatment, and may not reduce the depth of the compensation point for photosynthetic activity by more than 10%. In addition, turbidity may not reduce the maximum secchi disc depth by more than 10%. Alaska WQS for turbidity can be found in Appendix E.

The applicant has been collecting annual receiving water data for turbidity and secchi depth. Sampling is conducted in August 2003, February 2004, and September 2005 at depth intervals of 5 meters at the following sites:

Site 1:1000m north-northeast of ZID

Site 2: North boundary of ZID

Site 3: South boundary of ZID

Site 4: 1000m south-southeast of ZID

Sites 1 and 4 are considered reference sites and sites 3 and 4 are ZID boundary sites. Monitoring results are presented in Table 3, Table 4, and Table 5 below.

Secchi depths were similar between reference sites 1 and 4 and ZID boundary sites 2 and 3, with minimum secchi depths of 4 feet observed in September 2005. The average of reference sites 1 and 4 was 13.6 feet, while the average for the ZID boundary sites was 13.3, approximately 2% lower.

Table 3. Secchi Depth Monitoring

Site	Secchi Depth (ft)					
	Aug 2003	Feb 2004	Sept 2005	Avg	Max	Min
Site 1: Ref. North	7	27	4	12.6	27	4
Site 2: North ZID	7	26	5	12.6	26	5
Site 3: South ZID	7	30	5	14.0	30	5
Site 4: Ref. South	7	32	5	14.6	32	5

Average receiving water turbidity values at reference sites 1 and 4 were 4.80, 3.37, 2.88, 1.90, 2.14, and 2.58 NTU for 0m, 5m, 10m, 15m, 20m, and 25m, respectively. Average values for ZID boundary sites 2 and 3 were 5.18, 3.44, 2.70. 2.02, and 1.77 NTU for 0 m, 5 m, 10 m, 15 m, 20 m, and 25 m, respectively. The maximum turbidity values of 8.77 NTU and 8.26 NTU were observed in surface samples taken at the ZID boundary and reference sites during September and August, respectively. The turbidity measured in all samples is below Alaska's water quality criteria for turbidity of 25 NTU.

Table 4. ZID Boundary Turbidity Monitoring (NTU)

Year	Site	0m	5m	10m	15m	20m	25m
Aug 2003	Site 2	7.74	4.36	2.64	1.88	1.24	2.03
	Site 3	8.26	8.26	3.59	2.31	1.43	-
Feb 2004	Site 2	1.09	1.11	1.45	1.4	1.06	1.22
	Site 3	1.09	0.98	0.98	1.09	0.83	2.74
Sept 2005	Site 2	6.98	2.91	4.15	2.59	3.03	-
	Site 3	5.92	3.03	3.39	2.83	3.03	-
Max	-	8.26	8.26	4.15	2.83	1.06	2.74
Min	-	1.09	0.98	0.98	1.09	3.03	1.22
Average	-	5.18	3.44	2.7	2.02	1.77	1.99

Table 5. Reference Site Turbidity Monitoring (NTU)

Year	Site	0m	5m	10m	15m	20m	25m	30m
Aug 2003	Site 1	5.49	6.38	2.45	2.32	2.4	2.9	-
	Site 4	6.37	2.43	2.3	1.83	1.71	2.05	-
Feb 2004	Site 1	1.13	1.11	1.21	1.21	1.19	1.29	-
	Site 4	1.15	0.93	1.05	0.75	2.49	-	-
Sept 2005	Site 1	8.77	5.81	7.71	2.76	2.15	1.58	2.16
	Site 4	5.92	3.57	2.54	2.54	2.88	5.07	-
Max	-	8.77	6.38	7.71	2.76	2.88	5.07	2.16
Min	-	1.13	0.93	1.05	0.75	1.19	1.29	2.16
Average	-	4.80	3.37	2.88	1.90	2.14	2.58	2.16

The turbidity results indicate that turbidity is generally higher at the surface and that there is a seasonal difference in turbidity levels. Portage Cove has elevated levels of sediment in the summer months due to freshwater and sediment inputs from nearby rivers.

The change in suspended solids in the water column is indirectly related to turbidity measurements. To further assess the potential for the discharge to cause or contribute to a violation of Alaska WQS for turbidity and light transmittance, EPA determined the maximum change in suspended solids concentration of TSS in the discharge at the edge of the ZID using formula B-32 from the 301(h) TSD. The results show a 1.9 mg/L increase in suspended solids in the receiving water after initial dilution, or 1%.

As discussed in the 301(h) TSD, an increase in TSS of less than 10% after initial dilution is not expected to have a substantial impact on water quality.

Based on the above analyses, the proposed discharge is expected to comply with Alaska WQS for turbidity and light transmittance/attenuation. See Appendix E for the full equations.

2. Dissolved Oxygen

The effect of the effluent on ambient DO can occur in the nearshore and far-field as effluent mixes with the receiving water and the oxygen demand of the effluent BOD_5 load is exerted. Pursuant to 40 CFR 125.61(b)(1) and 125.62(a)(1), the applicant must demonstrate that the proposed discharge will comply with WQS for DO and that the outfall and diffuser are located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed WQS at and beyond the ZID. Alaska WQS for DO applicable to the estuarine waters of Portage Cove provide that DO may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed, and in no case may DO levels exceed 17 mg/L [18 AAC 70.15(a)(i)]. Alaska WQS for DO are shown in in Appendix D.

In accordance with EPA's 301(h) TSD, EPA assessed attainment of the WQS for DO based on review of effluent (Sept 2016 - Sept 2021) and receiving water monitoring data (2003-2005).

The 301(h) TSD (USEPA 1994) provides several procedures for assessing whether a proposed discharge will meet WQS for DO at the edge of the ZID. Methods include calculating the final DO concentration of the effluent at the edge of the ZID using discharge and receiving water data and assessing the accumulation of suspended solids around the outfall.

DO Concentration at the Edge of the ZID

EPA calculated the DO concentration at the ZID boundary using receiving water data provided by the applicant and the procedures described in Equation B-5 of the 301(h) TSD.

The discharge results in a maximum near field DO depletion at the ZID of 0.12 mg/L (1.3%) reduction from ambient concentrations(Appendix E of this TDD). The minimum DO concentration of the receiving water immediately following initial dilution is between 5.15 mg/L and 8.9 mg/L and varies by water depth and location (reference or outfall), with a minimum DO concentration of 6.1 mg/L on the surface, and a maximum DO concentration on the edge of the ZID of 8.90 mg/L. These values meet Alaska WQS as described in Appendix D.

Far Field DO Impacts

To assess the potential for far field impacts to DO, the final BOD_5 concentration after initial mixing was determined using the simplified procedures described in Appendix B of the 301(h) TSD and outlined in Appendix E of this 301(h) DD. The calculation resulted in a final BOD_5 concentration of 4.38 mg/L after initial mixing, a concentration that is not anticipated to cause or contribute to any measurable far field DO impacts beyond the ZID.

Suspended Solids Accumulation

Impacts to DO concentrations resulting from the discharge of wastewater can also be assessed by examining the accumulation of suspended solids. 40 CFR 125.62 states that wastewater and particulates must be adequately dispersed following initial dilution so as not to adversely affect water use areas. The accumulation of suspended solids may lower DO in near-bottom waters and cause changes in the benthic communities. Accumulation of suspended solids in the vicinity of a discharge is influenced by the amount of solids discharged, the settling velocity distribution of the particles in the discharge, the plume height-of-rise, and current velocities. Hence, sedimentation of suspended solids is generally of little concern for small discharges into well-flushed receiving waters.

The applicant provided a certification on August 8, 2022, stating that there are no known water quality issues associated with the accumulation of suspended solids from the discharge in accordance with 40 CFR 125.66(d)(2).

To evaluate the potential impact of solids sedimentation, a simplified approach for small dischargers that are not likely to have sediment accumulation problems can be found in Figure B-2 of the 301(h) TSD. To use Figure B-2 of the 301(h) TSD to evaluate whether steady state solids accumulation will result in excess sediment accumulation to cause a 0.2 mg/L oxygen depression, the TSS mass emissions rate is needed, as well as plume height-of-rise. The mass emission or loading rate was calculated using the TSS concentration limit, facility design flow, and a conversion factor (Loading (lbs/day)) = 190 mg/L X 1.9 mgd X 8.34 = 3,011 lbs/day, or 1,366 kg/day). Plume height-of-rise was calculated to be 46.4 feet (14.1 meters) using the approach on page B-5 in the 301(h) TSD, which involves multiplying the water depth at the point of discharge (24.4 feet at MLLW) by the design flow of 1.9 mgd. When a height-of-rise of 14.1 meters and a loading rate of 1,366 kg/day are input in Figure B-2, steady state accumulation is well below the line at which greater than 0.2 mg/L oxygen depression is expected. Per the 301(h) TSD, no further analysis is needed to demonstrate that accumulating solids will not result in unacceptable DO depressions.

Based on the above analyses of DO depletion and suspended solids accumulation, the proposed discharge is expected to comply with AK WQS for DO. For the complete equations used in this analysis refer to Appendix E.

C. Attainment of Other Water Quality Standards and Impact of the Discharge on Shellfish, Fish And Wildlife; Public Water Supplies; And Recreation [CWA Section 301(h)(2), 40 CFR 125.62]

CWA Section 301(h)(2) requires that the proposed discharge not interfere, either alone or in combination with other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and allows recreational activities in and on the water. Pursuant to 40 CFR 125.62(a), the applicant's outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed, at and beyond the ZID, all applicable EPA-approved state WQS and, where no such standards exist, EPA's CWA Section 304(a)(1) aquatic life criteria for acute and chronic toxicity and human health criteria for carcinogens and noncarcinogens, after initial mixing in the waters surrounding or adjacent to the outfall. In addition, 40 CFR 125.59(b)(1) prohibits issuance of a 301(h)-modified permit that would not assure compliance with all applicable NPDES requirements of 40 CFR Part 122; under these requirements a permit must ensure compliance with all applicable WQS[2].

[2] ADEC authorized acute and chronic dilutions of 11:1 and 19:1, respectively, in its final 401 certification. Since these dilutions fall within the boundary of the ZID, these effluent limits also comply with CWA Section 301(h)(9) and 40 CFR 125.62.

Attainment of WQS for DO and turbidity was previously discussed. In accordance with 40 CFR 125.62(a), the applicant must also demonstrate that the proposed discharge will attain other WQS, including those for pH, temperature, toxic pollutants, and bacteria.

EPA used Alaska WQS and the processes described in the 301(h) TSD and the 1991 *Technical Support Document for Water Quality-based Toxics Control* to determine whether the proposed discharge has the reasonable potential to cause or contribute to an excursion above Alaska WQS, to calculate water quality-based effluent limits (WQBELs), and to assess compliance with CWA Section 301(h)(2) and 40 CFR 125.62.

To determine reasonable potential, EPA compares the maximum projected receiving water concentration after mixing to the WQS for that pollutant. If the projected receiving water concentration exceeds the WQS, there is reasonable potential for that pollutant to cause or contribute to an excursion above Alaska WQS, and a WQBEL must be included in the permit. If a permittee is unable to meet their WQBEL, it would fail to satisfy CWA Section 301(h)(9) and 40 CFR 125.62 and would be ineligible for a CWA Section 301(h) modification.

Pursuant to 40 CFR 125.62(a)(1)(iv), EPA's evaluation of compliance with WQS must be based upon conditions reflecting periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist, commonly referred to as critical conditions.

1. pH

The applicant did not request a CWA Section 301(h) modification for pH. But the proposed discharge must still meet the WQS for pH. Alaska's WQS provide that pH may not be less than 6.5 or greater than 8.5 and may not vary more than 0.2 pH unit outside of the naturally occurring range.

The effect of pH on the receiving water following initial dilution was estimated using Table 1 in the 301(h) TSD (*Estimated pH Values After Initial Dilution).*

EPA reviewed discharge monitoring report (DMR) data for pH between 2016 and 2021. The facility met the pH limits in the 2001 permit 100% of the time. The effluent pH ranged from 6.5 to 8.0, meeting the Alaska WQS for pH at the point of discharge (end of pipe). By utilizing the minimum measured effluent pH value of 6.5, an effluent alkalinity of 0.5 meq/L (suggested as reasonable for primary effluents with no industrial component on page 65 of the 301(h) TSD), a seawater temperature of 15^{o}C (95th percentile of trapping depth temperature was 12.5C), and an initial dilution of 100, the expected resulting pH range after initial dilution is 6.99 to 8.49 over an assumed seawater pH range of 7.00 to 8.50. This is within the range of 6.5 to 8.5, does not vary more than 0.2 pH units outside the naturally occuring range, and therefore meets the Alaska WQS for pH.

The proposed discharge is expected to comply with Alaska WQS for pH after initial mixing at the edge of the ZID.

2. Temperature

Alaska's WQS for temperature provide that the discharge may not cause the temperature of the receiving water to exceed 15°C and the discharge may not cause the weekly average temperature to increase more than 1°C. The maximum rate of change may not exceed 0.5°C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.

EPA reviewed surface water and DMR data from the facility to assess whether the modified discharge will comply with Alaska WQS for temperature. The maximum ocean temperature recorded at the trapping depth of the discharge during receiving water monitoring from 2003 to 2005 was 11.2°C, and the maximum recorded effluent temperature between 2016 and 2021 was 15.8°C. EPA conducted a mass balance analysis using these values and calculated a final receiving water temperature of 11.2°C after initial dilution. Based upon the above analysis the proposed discharge is expected to comply with Alaska WQS for temperature after initial mixing at the edge of the ZID.

3. Toxics

Alaska WQS for toxics for marine uses can be found in 18 AAC 70.020(b)(23) and the *Alaska Water Quality Criteria Manual for Toxics* (ADEC, 2008).

To assess whether the proposed discharge will comply with Alaska WQS for toxics after initial mixing, EPA reviewed DMR data collected between 2016 and 2021 and the results of two priority pollutant scans submitted with the 2006 permit application.

Several pollutants were reported above their respective detection limits. Using this data, EPA performed reasonable potential analyses using the numeric criteria in the *Alaska Water Quality Criteria Manual* (ADEC 2008) and the processes outlined in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991). No pollutants have the reasonable potential to cause or contribute to a violation of Alaska WQS at the edge of the ZID.

4. Bacteria

Alaska's WQS for bacteria are found at 18 AAC 17.020(b)(14).

Fecal Coliform
Alaska's most restrictive marine criterion for fecal coliform bacteria concentrations is in areas protected for the harvesting and use of raw mollusks and other aquatic life. The WQS specifies that the geometric mean of samples shall not exceed 14 MPN/100 mL, and that not more than 10 percent of the samples shall exceed:

- 43 MPN/100 mL for a five-tube decimal dilution test;
- 49 MPN/100 mL for a three-tube decimal dilution test;
- 28 MPN/100 mL for a twelve-tube single dilution test;
- 31 CFU/100 mL for a membrane filtration test.

This standard must be met at the edge of the ZID.

On June 21, 2001, the Alaska Department of Environmental Conservation (ADEC) provided a CWA Section 401 Certificate of Reasonable Assurance (401 Certification) that included a mixing zone defined as an arc of a circle with a 1600-meter radius, centered on the outfall going from one shoreline to the other extending on either side of the outfall line and over the diffuser, and extending from the marine bottom to the surface. In the 2001 permit, the number of fecal coliform bacteria in the primary treated effluent was not to exceed a 30-day average of 1.0 million FC per 100 mL and a daily limit of 1.5 million FC per 100 mL of sample. Outside this mixing zone, the fecal coliform concentrations were not to exceed a maximum of 14 FC/100 mL for a monthly average and 43 FC/100 mL for a daily maximum.

Haines WWTP DMR data from the past 5 years shows fecal coliform values ranges from 10,000—1,430,000 FC/100mL, with a 95th percentile of 1,140,500 FC/100mL and a geometric mean of 455,600 FC/100mL. Summary statistics of DMR data are provided in Table 6 below.

Table 6. Fecal Coliform DMR Summary Data (9/2016-9/2021)

	# of samples	Min	Max	95th Percentile	Average	Geomean
Fecal Coliform (FC/100mL)	40	10,000	1,430,000	1,140,500	596,925	455,600

The 2001 permit required the facility to conduct fecal coliform sampling at four receiving water locations and one shoreline sample within the mixing zone during January, May, August, and November for the life of the permit. The results of the facility's available fecal coliform sampling results are presented in Table 7 below.

Table 7. Fecal Coliform Statistics by Station (2016 - 2021)

	# of samples	Max (FC/100mL)	Average (FC/100mL)
Station 1	12	6	1.8
Station 2	12	11	1.3
Station 3	12	6	1.2
Station 4	12	117	14.3
Station 5	12	7	2
Station 1: Garbage Point, north edge of 1,600 m mixing zone Station 2: Hays Beach, 1600m south along shoreline from Station 1 Station 3: PC Beach, east edge of 1600m mixing zone, south from Station 2 Station 4: Last Hydrant, south edge of 1600m mixing zone Station 5: PC Dock, 300 meters from shoreline			

The maximum fecal coliform result of 117 FC/100mL occurred at Station 4 at the shoreline east of the diffuser at the east edge of the mixing zone. CWA Section 301(h)(9) requires 301(h) discharges to meet WQS and federal CWA Section 304(a) criteria at the edge of the ZID. The current 1,600 meter mixing zone for fecal coliform is inconsistent with the statutory or regulatory definition of a ZID: *the region of* *__initial mixing__* *surrounding or adjacent to the outfall.* ADEC will not reauthorize the 1,600 meter mixing zone for fecal coliform and the point of compliance for all bacteria limits is now the edge of the ZID. Consistent with CWA Section 301(h)(9) and 40 CFR 125.62, EPA used the 100:1 dilution achieved at the edge of the ZID to evaluate reasonable potential and assess compliance with CWA Section 301(h)(9) and 40 CFR 125.62.

Using effluent data from 2016 to 2021 and the same process and equations as those used for toxics, EPA conducted a reasonable potential analysis and determined fecal coliform has the reasonable potential to cause or contribute to a violation of Alaska WQS at the point of discharge.

The Alaska DEC included final fecal coliform limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit and has established interim fecal coliform limits based upon facility performance.

The interim and final effluent limits for fecal coliform will be protective of Alaska WQS after initial mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

__Enterococcus Bacteria__

Enterococci bacteria are indicator organisms of harmful pathogens recommended by EPA to protect primary contact recreation for marine waters. The EPA Beaches Environmental Assessment and Coastal Health Act (BEACH Act) requires states and territories with coastal recreation waters to adopt enterococci bacteria criteria into their WQS. EPA approved Alaska's WQS for enterococcus in 2017. The WQS at 18 AAC 70.020(b)(14)(B) for contact recreation specifies that the enterococci bacteria concentration shall not exceed 35 enterococci CFU/100mL, and not more than 10% of the samples may exceed a concentration of 130 enterococci CFU/100mL.

The 2001 permit does not contain an effluent limitation for enterococcus bacteria because there was no applicable enterococcus WQS in effect when the permit was issued in November 2001.

40 CFR 122.44(d)(1) requires EPA to account for existing controls on discharges when determining whether a discharge has the reasonable potential to cause or contribute to an excursion of state WQS. The WWTP does not currently disinfect its effluent, resulting in the high bacterial loads observed in the available fecal coliform data. The 2001 permit did not require enterococcus monitoring, but it reasons that the high fecal coliform loads observed are also indicative of high loads of other pathogens commonly found in WWTP effluents, including

enterococcus. With the available fecal coliform data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to a violation of Alaska WQS for enterococcus.

The Alaska DEC included final enterococcus limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit.

The final effluent limits for enterococcus will be protective of Alaska WQS after mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

D. Impact of the Discharge on Public Water Supplies [40 CFR 125.62(b)]

40 CFR 125.62(b) requires that the applicant's proposed discharge must allow for the attainment or maintenance of water quality that assures protection of public water supplies and must not interfere with the use of planned or existing public water supplies. According to the facility, there are no existing or planned public water supply intakes in the vicinity of the discharge.[3] Therefore, EPA concludes that the applicant's proposed discharge will have no effect on the protection of public water supplies and will not interfere with the use of planned or existing public water supplies.

E. Biological Impact of Discharge [40 CFR 125.62(c)]

40 CFR 125.62(c) requires that in addition to complying with applicable WQS, the proposed discharge must allow for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife. A BIP of shellfish, fish, and wildlife must exist immediately beyond the ZID and in all other areas beyond the ZID where marine life is actually or potentially affected by the applicant's discharge. In addition, conditions within or beyond the ZID must not cause or contribute to extreme adverse biological impacts, including, but not limited to, the destruction of distinctive habitats of limited distribution, the presence of disease epicenter, or the simulation of phytoplankton blooms which have adverse effects beyond the ZID, interfere with estuarine migratory pathways within the ZID, or result in the accumulation of toxic pollutants or pesticides at levels which exert adverse effects on the biota within the ZID. In accordance with the guidance for small dischargers in the 301(h) TSD, EPA has considered the following characteristics of the Haines WWTP discharge as indicators that there is a low potential for impact on the biota in the vicinity of the discharge: the location of the discharge is greater than 10m, the steady-state accumulation of suspended solids is less than 25 g/m^2, there are no distinctive habitats of limited distribution in the vicinity of the discharge, there is a low potential for impact on local fisheries, and less than 0.1% of the flow is from industrial users. Toxic conditions are not expected because the effluent achieves rapid

[3] Communication with Dennis Durr, March 2022

mixing within minutes of discharge, minimizing the potential exposure area. There is no evidence that the ZID is a disease epicenter, interfering with estuarine migratory pathways, or resulting in the accumulation of toxics at levels exerting adverse effects on biota within the ZID.

Further, EPA also considered the results of biological monitoring from the 2001 permit and other available information to evaluate the potential for the discharge to cause or contribute to significant biological impacts. Biological monitoring required in the 2001 permit consisted of a benthic survey and sediment analysis for total volatile solids (TVS) within the ZID, at a reference location, and within 5m beyond the ZID boundary. Based on the results of the TVS analysis of sediment presented in Appendix F, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID boundary and reference sites. The results of the TVS analysis are presented in Appendix F. Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the Haines WWTP discharge is causing significant changes in the benthic community structure.

Additionally, there have been no known cases of mass mortalities of fish or invertebrates, no increased incidence of disease in marine organisms, and no other known cases of adverse biological impacts. Portage Cove provides shelter for molting crabs and schooling juvenile salmonoids, but there is no indication that these are affected by the discharge. The small volume of the discharge, the small area of the ZID relative to the width of Lynn Canal, the mobility of juvenile salmonids, and the results of the biological monitoring indicate that the discharge will have not cause or contribute to significant biological impacts.

Considering the above evidence, EPA has concluded that the discharge allows for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife, and will not cause or contribute to adverse biological impacts.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit. For additional information refer to Part 8.G.3.

F. Impact of Discharge on Recreational Activities [40 CFR 125.62(d)]

Under 40 CFR 125.62(d), the applicant's discharge must allow for the attainment or maintenance of water quality that allows for recreational activities beyond the ZID, including, without limitation, swimming, diving, boating, fishing, and picnicking, and sports activities along shorelines and beaches. There must be no federal, state, or local restrictions on recreational activities within the vicinity of the applicant's outfall unless such restrictions are routinely imposed around sewage outfalls.

The applicant stated that no impacts on recreational activities were expected due to the proposed discharge.[4] Swimming is not common in Portage Cove due to the cold water

[4] Communication with Dennis Durr, May 4 2022

temperatures and diving is expected to be rare due to the turbid nature of the receiving water. The permittee also stated that sport fishing, kayaking, and boating occur in the receiving water. No adverse effects have been reported.

The 2001 permit required signs to be placed on the shoreline near the 1600-meter fecal coliform mixing zone and the outfall line that state primary treated domestic wastewater is being discharged, mixing zones exist, and certain activities such as the harvesting of shellfish for raw consumption and bathing should not take place within the mixing zone. EPA has retained the requirement to place these signs on the shoreline and outfall line in the final permit until the final fecal coliform and enterococcus limits are maintained.

The applicant has demonstrated that the proposed discharge meets the requirements to allow for the attainment or maintenance of water quality which allows for recreational activities beyond the ZID.

G. Establishment of Monitoring Programs [CWA 301(h)(3), 40 CFR 125.63]

Under 40 CFR 125.63, which implements Section 301(h)(3) of the Act, the applicant must have a monitoring program designed to provide data to evaluate the impact of the proposed discharge on the marine biota, demonstrate compliance with applicable WQS, and measure toxic substances in the discharge. The applicant must demonstrate the capability to implement these programs upon issuance of a 301(h)-modified NPDES permit. In accordance with 40 CFR 125.63(a)(2), the applicant's monitoring programs are subject to revision as may be required by EPA.

1. Influent/Effluent Monitoring Program [40 CFR 125.63(d)]

40 CFR 125.63(d) requires an effluent monitoring program and the applicant proposes continuation of the current monitoring program. In addition to the 301(h) specific monitoring requirements, Section 308 of the CWA, and 40 CFR 122.44(i) require monitoring in permits to determine compliance with effluent limitations. Monitoring may also be required to gather effluent and surface water data to determine if additional effluent limitations are required and/or to monitor effluent impacts on receiving water quality. Throughout the previous permit term (and the administratively continued period), the applicant submitted effluent monitoring data as required by the 2001 permit.

Summary statistics of the effluent data submitted by the permittee between 2016 and 2021 is presented in Appendix C.

The final permit retains largely the same effluent and influent monitoring requirements and includes the new requirement to monitor the effluent for enterococcus and per-and polyfluoroalkyl substances, and increases monitoring frequency for BOD_5, fecal coliform, and copper. Consistent with 40 CFR 125.66, the final permit also includes a new requirement for the permittee to perform an analysis of their effluent for all toxics and pesticides, identified in 40

CFR 401.15, twice during the term of the permit, once during the wet season and once during the dry season. The final permit also includes new ammonia monitoring.

2. Receiving Water Quality Monitoring Program [40 CFR 125.63(c)]

40 CFR 125.63(c) requires that the receiving water quality monitoring program must provide data adequate to evaluate compliance with applicable WQS. The applicant proposes continuation of the current receiving water monitoring program. As is the case of effluent monitoring, NPDES permits include receiving water monitoring requirements to allow for compliance assessment, and to determine if additional effluent limitations and/or monitoring requirements are necessary in future permitting actions.

EPA is retaining most of the receiving water monitoring program from the 2001 permit in the final permit. Changes to the receiving water monitoring program include the addition of enterococcus to the suite of parameters analyzed and the movement of the ZID boundary sites from the edge of the 2001 mixing zone at 1,600 m to the edge of the ZID in the final permit at 50 feet. Sampling at the edge of the 1,600 m mixing zone is no longer required because the 1,600 m mixing zone is not being reauthorized by ADEC and the point of compliance for all parameters is now the edge of the ZID, which is 50 feet from the outfall.

In addition, the EPA has determined that once the facility is able to consistently achieve compliance with the final fecal coliform and enterococcus limits in the permit and has demonstrated ongoing compliance with Alaska WQS at the boundary of the ZID, continued sampling for bacteria in the receiving water is no longer warranted to satisfy the requirements of 40 CFR 125.62(a). By achieving compliance with the final fecal coliform and enterococcus limits the EPA expects that the facility will be able to meet Alaska's WQS for fecal coliform and enterococcus at the edge of the ZID after initial mixing. For additional information refer to the final permit.

3. Biological Monitoring Program [40 CFR 125.63(b)]

40 CFR 125.63(b) requires a permittee to implement a biological monitoring program that provides data adequate to evaluate the impact of the applicant's discharge on the marine biota. Such a program should, at a minimum, allow for evaluation of any ecosystems impacts; any changes in the amount of organic material in the seafloor sediment; any changes to benthic communities; and the effectiveness/bases for permit conditions.

The Biological Monitoring Program in the 2001 permit consisted of a benthic survey and sediment analysis TVS within the ZID, at a reference location, and within 5 meters beyond the ZID boundary. Based on the results of the TVS analysis of sediment, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID Boundary and reference sites. Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the Haines outfall discharge is causing significant changes in the benthic community structure.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit.

The 301(h) regulations at 40 CFR 125.63(b)(2) provide that small 301(h) applicants are not subject to sediment analysis requirements if they discharge at depths greater than 10 meters and can demonstrate through a suspended solids deposition analysis that there will be negligible seabed accumulation in the vicinity of the modified discharge. The Haines WWTP discharges at depths greater than 10 meters and the suspended solids deposition analysis provided below demonstrates there will be negligible seabed accumulation in the vicinity of the discharge.

Figure B-2 in Appendix B of the 1994 Amended Section 301(h) Technical Support Document provides a simplified graphical method for small estuarine dischargers to assess the potential for suspended solids deposition around their outfall using the reported daily solids mass emission rate (y-axis in Fig. B-2) and the height-of-rise of the discharge (x-axis in Fig. B-2). For the discharge height-of-rise, also known as the plume trapping depth, the height-of-rise from dilution modeling should be used, or 0.6 times the water depth, whichever is larger. The height-of-rise for the Haines discharge is approximately 20 meters and the discharge depth is 24.4 meters; 20 meters was selected for the x-axis in Figure B-2.

The guidance recommends calculating the suspended solids daily mass emission rate using the average flow rate and an average suspended solids concentration. The maximum reported monthly average flow rate from the Haines WWTP between 2016 and 2021 was 0.66 million gallons per day and the maximum monthly average total suspended solids (TSS) concentration was 121 mg/L. To determine the daily loading of solids the monthly average concentration of TSS was multiplied by the reported average monthly flow and the loading conversion factor of 8.34 (see Footnote 1 in Table 1 of the final permit for more information on mass loading calculations).

121 mg/L X 0.66 million gallons per day X 8.34 = 666.03 lbs/day. Using this loading rate along the y-axis and 20 meters along the x-axis in Figure B-2, the projected steady state sediment accumulation is expected to be well below 25g/m2. The EPA considers this to be a negligible accumulation of sediment. Therefore, the applicant has satisfied the requirement of 40 CFR 125.63(b)(2) and the EPA has removed the requirement to conduct sediment TVS analysis from the final permit.

H. Effect of Discharge on Other Point and Nonpoint Sources [CWA 301(h)(4), 40 CFR 125.64]

Under 40 CFR 125.64, which implements Section 301(h)(4) of the Act, the applicant's proposed discharge must not result in the imposition of additional treatment requirements on any other point or nonpoint source. The applicant reports that the proposed discharge would not place any additional treatment requirements on point or nonpoint sources. Pursuant to 40 CFR 125.64(b), the applicant is required to submit a determination signed by the State of Alaska indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The State determination must include a discussion of the basis for its conclusion.

The State of Alaska provided the determination required under 125.64 in its final 401 certification. For additional information refer to Part M – State Determination and Concurrence.

I. Urban Area Pretreatment Program [CWA 301(h)(6), 40 CFR 125.65]

Under 40 CFR 125.65, dischargers serving a population greater than 50,000 are required to have a pretreatment program. As previously discussed, the Haines WWTP serves a population of approximately 1,800 people, so this provision is not applicable to this analysis.

J. Industrial and Nonindustrial Sources and Toxics Control [CWA 301(h)(7), 40 CFR 125.66]

1. Chemical Analysis and Toxic Pollutant Source Identification [40 CFR 125.66(a) and (b)]

Under 40 125.66(a) and (b), applicants are required to perform chemical testing for toxic pollutants and pesticides and identify the source of any parameters detected.

As previously discussed, the permittee conducted two toxics pollutant scans in 2006, the results of which EPA used in development of the final permit. In 2022, the permittee provided an updated certification that there are no known sources of toxic pollutants and no known industrial sources of toxics into the treatment system.

Pursuant to 40 CFR 125.66, the final permit requires submittal of two updated toxics and pesticides scans and an industrial user survey at the time of permit reapplication.

2. Industrial Pretreatment Program [40 CFR 125.66(c)]

40 CFR 125.66(c) requires that applicants that have known or suspected industrial sources of toxic pollutants shall have an approved pretreatment program in accordance with the requirements of 40 CFR Part 403 (Pretreatment Regulations). This requirement shall not apply to any applicant which has no known or suspected industrial sources of toxic pollutants or pesticides and so certifies to EPA. Because the facility certified that there are no known

industrial sources of toxic pollutants on April 8, 2022, under 40 CFR 125.66(c)(2), the facility is not required to have an approved pretreatment program.

Pursuant to 40 CFR 126.66, the final permit requires submittal of an updated industrial user survey at the time of permit reapplication.

3. Nonindustrial Source Control Program [40 CFR 125.66(d)]

40 CFR 125.66(d), which implements Section 301(h)(6) of the Act, requires the applicant to submit a proposed public education program designed to minimize the entrance of non-industrial toxic pollutants and pesticides into its POTW. The applicant must also develop and implement additional nonindustrial source control programs on the earliest possible schedule. The requirement to develop and implement additional nonindustrial source control programs does not apply to a small Section 301(h) applicant that certifies there are no known or suspected water quality, sediment accumulation, or biological problems related to toxic pollutants or pesticides in its discharge.

The applicant provided this certification to EPA on April 8, 2022, as well as documentation that a public education program meeting the requirements of 40 CFR 125.66(d)(1) has been developed and implemented. The applicant publishes a biannual Citizens Advisory notice in the local newspaper and an annual Household Hazardous Waste bulletin in the newspaper and online. Therefore, EPA concludes that Haines has satisfied the requirements for nonindustrial source control.

K. Effluent Volume and Amount of Pollutants Discharged [40 CFR 125.67]

Under 40 CFR 125.67, which implements Section 301(h)(7) of the Act, the applicant's proposed discharge may not result in any new or substantially increased discharges of the pollutant to which the modification applies above the discharge specified in the 301(h)-modified permit. The applicant has applied on the basis of the current discharge and does not propose any new or substantially increased discharges of TSS or BOD_5, the two parameters for which the facility has requested a waiver.

L. Compliance with other Applicable Laws [40 CFR 125.59]

Under 40 CFR 125.59(b)(3), a 301(h)-modified permit may not be issued if such issuance would conflict with applicable provisions of state, local, or other federal laws or executive orders. As part of the application renewal, the applicant must demonstrate compliance with all applicable Alaska and federal laws and regulations, and executive orders, including the Coastal Zone Management Act, Marine Protection Research and Sanctuaries Act, the Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act.

1. Coastal Zone Management Act

Alaska withdrew from the voluntary National Coastal Zone Management Program on July 1, 2011 (NOAA 2019c); therefore, this requirement is not applicable.

2. Marine Protection, Research, and Sanctuaries Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA), 16 USC 1431 *et seq.*, which authorizes the Secretary of Commerce (i.e., NOAA) to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries. In the U.S., there are 14 national marine sanctuaries and two marine national monuments, none of which are in Alaska (NOAA 2019d).

The final permit is therefore expected to comply with Title III of the MPRSA.

3. Endangered Species Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with the Endangered Species Act (ESA), 16 USC 1531 *et seq.* The ESA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) and/or the U.S. Fish and Wildlife Service (USFWS) (collectively, "the Services") if any activity proposed to be permitted, funded, or undertaken could beneficially or adversely affect any threatened or endangered species (ESA-listed species) or such species designated critical habitat.

Pursuant to ESA Section 7, on August 30, 2024, the EPA requested concurrence from the NMFS that renewal of the 301(h)-modified NPDES permit to the Haines WWTP is not likely to adversely affect the following threatened, endangered, or candidate species or their designated critical habitats:

- Western Distinct Population Segment (Western DPS or WDPS) Steller sea lions, and
- Mexico DPS humpback whales
- Sunflower sea star

On October 15, 2024, the NMFS concurred with EPA's determination that renewal of AK0021385 is not likely to adversely affect any ESA-listed species or designated critical habits under their jurisdiction.

No ESA-listed species or designated critical habitat under the jurisdiction of USFWS were identified.

4. Magnuson-Stevens Fishery Conservation and Management Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), 16 USC 1801 *et seq*., which protects against adverse impacts to Essential Fish Habitat (EFH).The MSFCMA requires federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken by a federal agency may have an adverse effect on designated EFH as defined by the MSFCMA. The EFH regulations define an *adverse effect* as any impact that reduces quality and/or quantity of EFH and may include direct (e.g. contamination or physical disruption), indirect (e.g. loss of prey, reduction in species' fecundity), site-specific, or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

EPA has prepared an EFH Assessment and determined that renewal of AK0021385 will not have an adverse effect on EFH for any managed species.

M. State Determination and Concurrence [40 CFR 125.61(b)(2); 40 CFR 125.64(d)]

Under 40 CFR 125.61(b)(2), the applicant must provide a determination signed by the state or interstate agency(s) authorized to provide certification under 40 CFR 124.53 and 124.54 that the proposed discharge will comply with applicable provisions of state law, including WQS. This determination must include a discussion of the basis for the conclusion reached. Furthermore, pursuant to 40 CFR 124.53 and 124.54, the state must either grant a certification pursuant to Section 401(a)(1) of the CWA or waive this certification before EPA may issue a 301(h)-modified permit. The applicant did not provide this certification at the time of application.

40 CFR 125.64(d) requires applicants to provide a determination from the state or interstate agency(s) having authority to establish wasteload allocations indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The state determination shall include a discussion of the basis for its conclusion. The applicant did not submit this determination with their application.

The EPA requested that ADEC provide final 401 certification and the determinations under 40 CFR 125.61(b)(2) and 125.64(b) during the public notice period of the draft permit and tentative 301(h) decision. ADEC provided final 401 certification and the requested determinations on December 4, 2023.

9) REFERENCES

ADEC. 2003. *18 AAC 70, Water Quality Standards, As Amended Through June 26, 2003.* Approved by the EPA in 2004. Available at: https://www.epa.gov/wqs-tech/water-quality-standards-regulations-alaska.

ADEC. 2008. *Alaska Water Quality Criteria Manual for Toxic and other Deleterious Organic and Inorganic Substances*. Available at: https://dec.alaska.gov/water/water-quality/standards/

USEPA. 1991. *Technical Support Document for Water Quality-based Toxics Control.* EPA/505/2-90-001.

USEPA. 1994. *Amended Section 301(h) Technical Support Document*. EPA-842-B-94-007.

NOAA. 2019a. High and Low Water Predictions West Coast of North and South America Including the Hawaiian Islands. Retrieved at https://tidesandcurrents.noaa.gov/tide_predictions.html

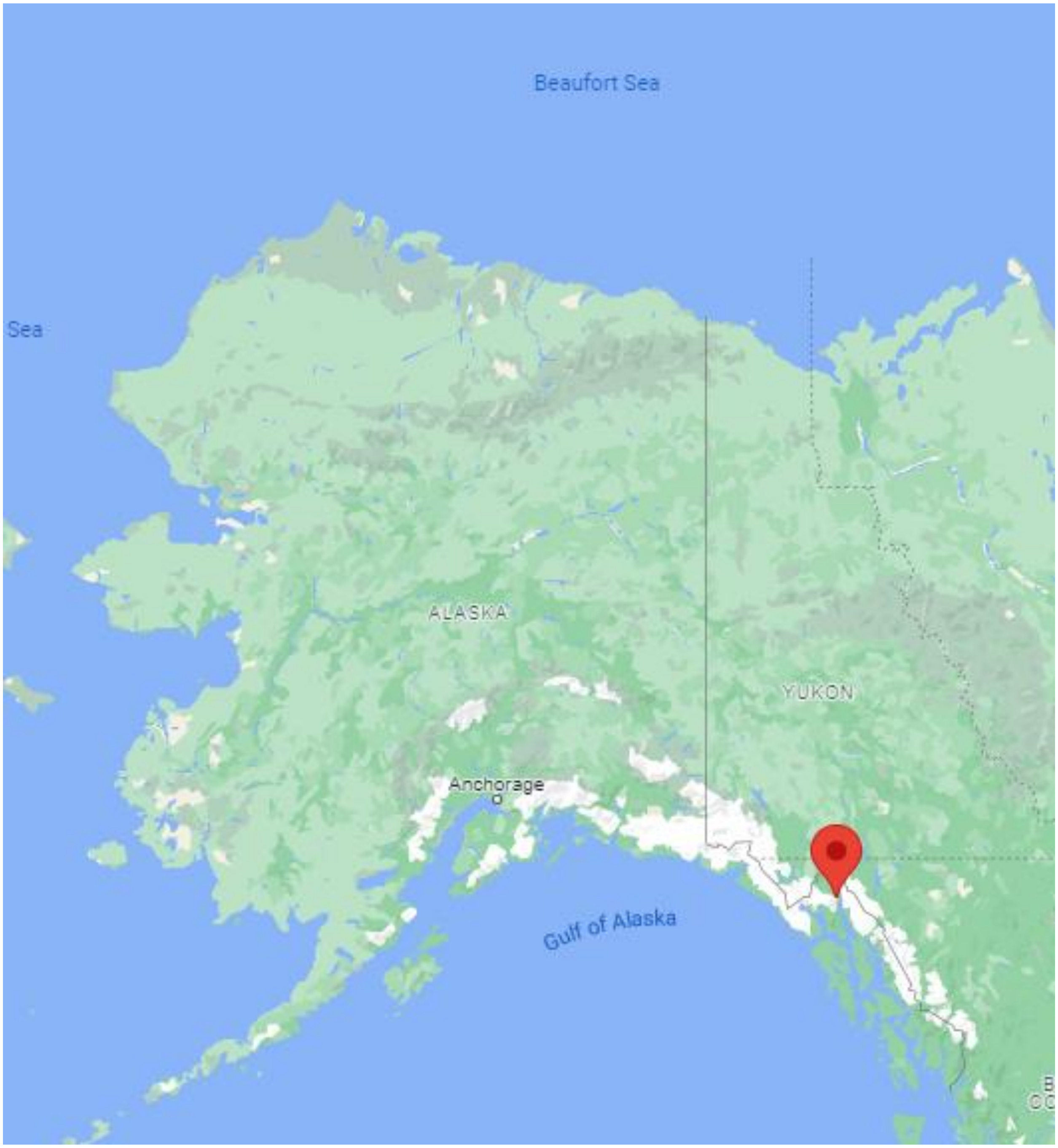
NOAA. 2019b. Tidal Current Tables 2020 Pacific Coast of North America and Asia. Retrieved at https://tidesandcurrents.noaa.gov/historic_tide_tables.html.

NOAA. 2019c. *Coastal Zone Management Programs*. Web. https://coast.noaa.gov/czm/mystate/.

NOAA. 2019d. *National Marine Sanctuaries*. Web. https://sanctuaries.noaa.gov/.

APPENDICES

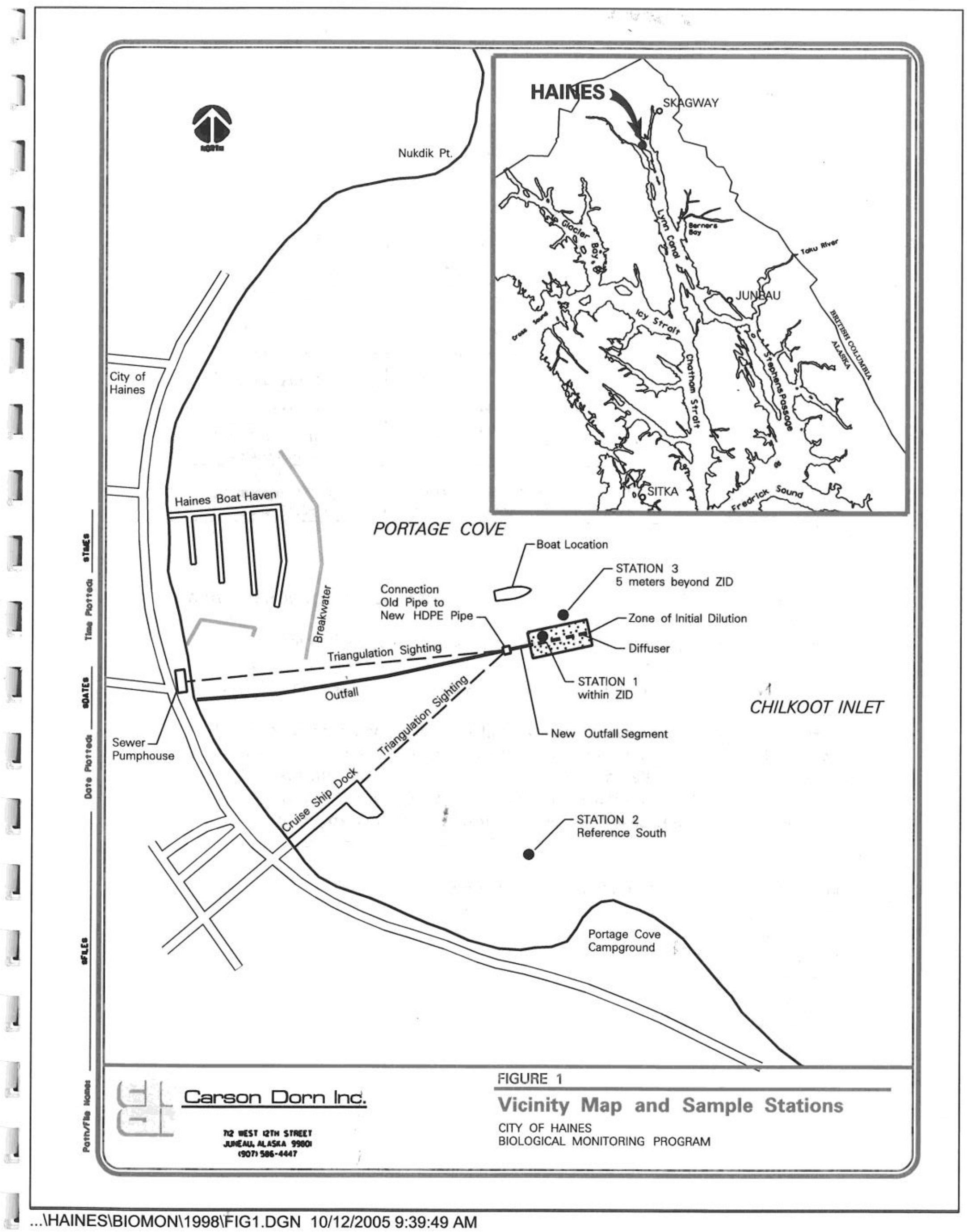
A. Facility and Outfall Locations



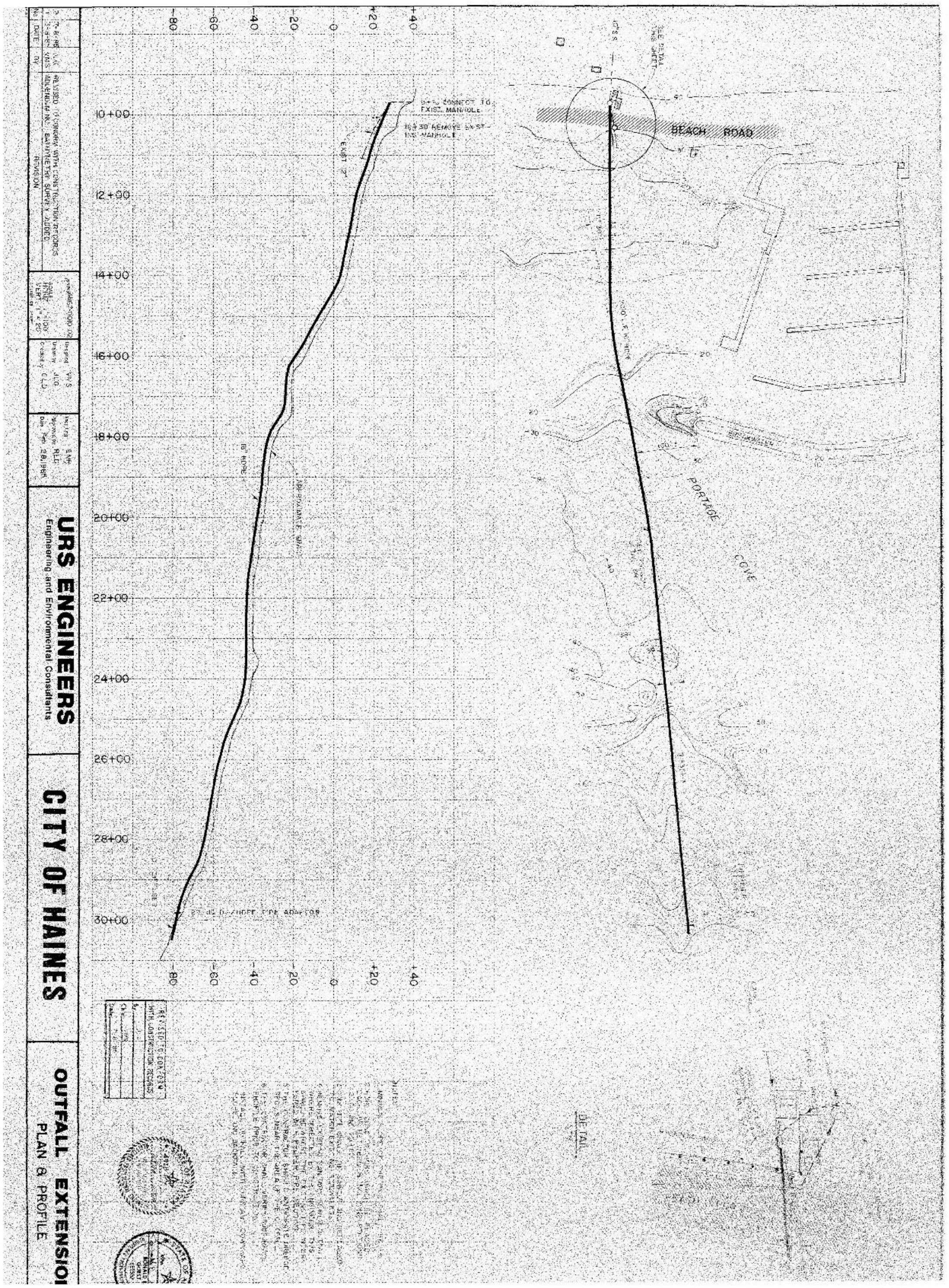
Facility Location in Alaska

Facility Location Small Scale

B. Facility Figures and Process Flow Diagram

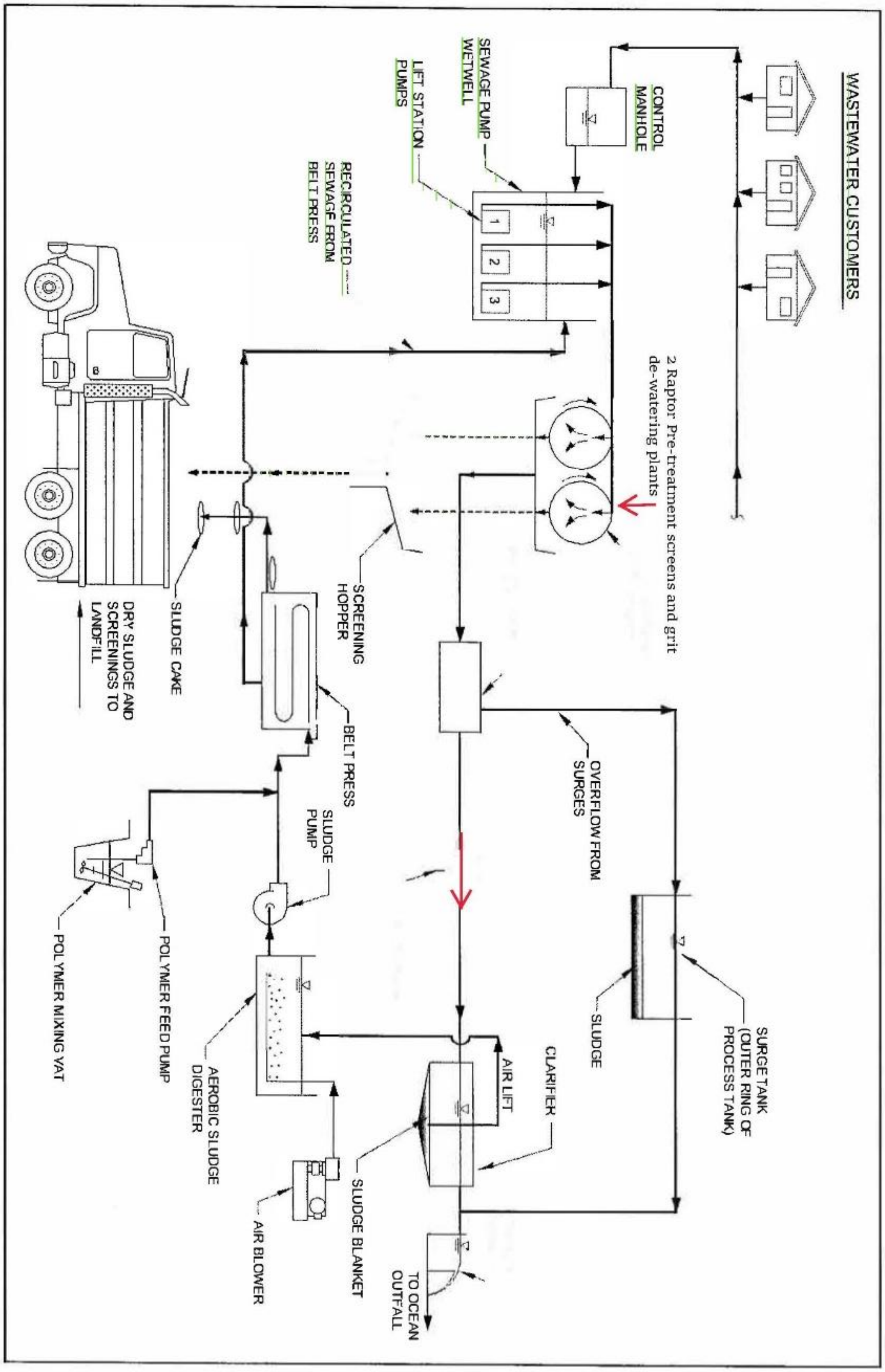


Haines WWTP Map and Sample Stations



Haines Borough Sewer Outfall Plan View and Cross Section

267 Cubic Yards of native sand and gravel in a 4-foot deep by 4-foot wide by 450 linear foot ditch covering 0.04 acres was removed and replaced after installation of sewer outfall pipe. The project was completed in 1985.



Primary Settling Process Schematic

C. Discharge Monitoring Data (2016-2021)

Discharge Monitoring Data (2016-2021)

Parameter	Flow		BOD, 5 day, 20 deg C (mg/L)	BOD, 5 day, 20 deg C (mg/L)		BOD, 5 day, 20 deg C (lbs/day)		BOD % removal	TSS (mg/L)	TSS (lbs/day)		TSS % removal
Statistical Base	MX DAY	MO AVE	Influent	MO AVE	MX DAY	MO AVE	MX DAY	MO AVE	Influent	MO AVE	MX DAY	MO AVE
Sep-16	0.72	0.3857	133	72	72	231	432	46	81	157	260	48
Oct-16	0.45	0.229	158	44	44	84	165	72	56	63	210	75
Nov-16	0.762	0.326	82	48	48	130	305	42	77	111	489	50
Dec-16	0.618	0.326	60	40	40	109	109	32	32	68	87	48
Jan-17	1.2	0.456	88	45	45	170	450	45	32	83	320	66
Feb-17	1.101	0.3	78	52	52	130	477	33	35	77	321	55
Mar-17	0.408	0.218	140	60	60	109	204	60	35	40	119	80
Apr-17	0.45	0.255	74	39	39	83	146	48	93	102	198	53
May-17	0.501	0.219	124	74	74	135	309	41	58	42	242	63
Jun-17	0.405	0.202	246	132	132	225	445	46	106	153	566	61
Jul-17	0.447	0.2	280	150	150	250	559	46	124	145	462	70
Aug-17	0.318	0.199	368	188	188	312	528	49	148	153	392	61
Sep-17	0.669	0.302	164	67	67	169	374	60	59	121	329	90
Oct-17	0.45	0.262	226	78	78	170	189	66	118	70	443	61
Nov-17	0.453	0.192	246	65	65	104	246	73	59	74	223	77
Dec-17	0.825	0.391	100	64	64	209	440	35	33	78	227	80
Jan-18	0.486	0.288	140	75	75	180	304	47	46	74	186	77
Feb-18	0.369	0.184	329	109	109	167	335	67	60	70	185	84
Mar-18	0.552	0.266	68	47	47	104	216	30	55	97	187	67
Apr-18	0.424	0.263	113	7.3	7.3	16	23	93	54	68	167	79
May-18	0.437	0.257	105	80	87	171	313	25	135	176	260	31
Jun-18	0.258	0.202	181	117	117	197	251	36	79	108	170	66
Jul-18	0.238	0.182	200	106	106	161	209	47	203	176	403	64
Aug-18	0.287	0.187	233	111	111	172	266	52	81	172	194	76
Sep-18	0.213	0.167	244	154	154	214	274	37	82	70	146	85
Oct-18	0.77	0.313	174	95	95	248	610	45	92	144	591	55
Nov-18	0.67	0.253	111	58	58	122	292	58	55	84	277	62
Dec-18	0.762	0.342	98	15	15	43	95	84	128	165	813	34
Jan-19	0.698	0.307	76	51	51	131	297	33	87	90	506	53
Feb-19	0.435	0.195	124	33.4	33.4	55	121	72	76	74	276	60
Mar-19	0.952	0.319	52	21.5	21.5	57.2	166	58	52	86	423	79
Apr-19	0.449	0.269	191	128	128	287	479	33	41	83	153	59
May-19	0.36	0.204	197	74	74	126	222	62	82	99	174	61
Jun-19	0.266	0.192	305	173	173	277	383	43	106	110	318	66
Jul-19	0.25	0.184	337	222	222	340	462	34	126	157	263	71
Aug-19	0.237	0.171	262	192.5	192.5	275	294	27	208	173	328	39
Sep-19	0.322	0.192	434	245	245	345	345	44	244	175	350	44
Oct-19	0.61	0.272	145	96.5	96.5	213	213	33	122	148	255	43
Nov-19	0.771	0.376	80	41	45	125	137	40	108	180	287	42
Dec-19	0.986	0.414	73	36	36	74	74	50	36	91	92	63
Jan-20	0.789	0.328	67	42	42	118	118	37	76	160	232	65
Feb-20	0.724	0.401	61	29	29	96	96	53	52	125	185	73
Mar-20	0.68	0.359	69	47	47	218	218	31	54	142	159	73
Apr-20	0.507	0.357	125	49	49	120	120	49	59	129	162	75
May-20	0.39	0.222	232.9	80.1	80.1	148	148	66	172	123	261	81
Jun-20	0.231	0.17	205.7	98.4	98.4	136	136	52	128	91	178	63
Jul-20	0.275	0.178	404	97	97	123	123	76	104	96	132	80
Aug-20	0.283	0.211	354	130	130	162	162	63	64	67	80	76
Sep-20	0.405	0.174	189	89	89	116	116	53	140	157	207	57
Oct-20	0.413	0.231	213	113	113	175	175	47	108	110	185	68
Nov-20	0.547	0.234	173	67	67	108	108	61	66	72	109	70
Dec-20	1.65	0.658	62	42	42	157	157	32	59	124	165	62
Jan-21	1.07	0.458	100	46	46	171	171	54	35	131	214	77
Feb-21	0.3	0.236	116	80	80	159	159	31	52	83	102	66
Mar-21	0.486	0.265	165	110	110	258	258	33	105	52	173	56
Apr-21	0.486	0.265	165	110	110	257	257	33	105	122	173	56
May-21	0.449	0.233	274	84	84	138	138	84	67	61	123	78
Jun-21	0.253	0.22	193	103	103	155	155	47	49	40	74	73
Jul-21	0.222	0.163	245	165	165	263	263	32	126	140	162	71
Aug-21	0.286	0.174	149	44	44	58	58	70	156	96	200	78
Sep-21	0.578	0.25	114	70	70	96	96	41	63	117	117	59
Average	0.5327627	0.264983	174.8724138	86.86	87.05	163.917	242.91	48.7759	88.2542	108.898	251.102	64.949153
Minimum	0.213	0.163	52	7.3	7.3	16	23	25	32	40	74	31
Maximum	1.65	0.658	434	245	245	345	610	93	244	180	813	90
Count	59	59	58	58	58	58	58	58	59	59	59	59
Std Dev	0.2809443	0.091609	94.73749104	51.11	51.04	73.9836	136.96	15.8037	46.609	39.3476	143.284	13.011167
CV	0.5273348	0.345717	0.541752064	0.588	0.586	0.45135	0.5638	0.32401	0.52812	0.36132	0.57062	0.2003285
95th Percentile	1.0731	0.4182	356.1	188.7	188.7	290.75	486.35	77.2	175.1	175.1	512	81.3
5th Percentile	0.2364	0.1709	61.85	27.88	27.88	56.87	91.85	30.85	34.8	51	91.5	41.7
90th percentile	0.8504	0.379	312.2	157.3	157.3	266.6	453.6	70.6	141.6	166.4	446.8	80
50th percentile	0.45	0.25	164.5	76.5	76.5	158	214.5	47	77	102	200	66

Parameter	pH (s.u.)		Fecal Coliform (#100/mL)		Copper (ug/L)		Dissolved Oxygen (mg/L)		Temperature (deg C)
Statistical Base	max	min	DAILY MAX	MO GEO	DAILY MAX	MO AVG	MAX	MIN	MO AVG
Sep-16	7.58	6.99	470,000.00	470,000.00	3	3.00	4.04	2.55	13.6
Oct-16	7.72	6.98					6.78	5.23	11.8
Nov-16	7.9	7.1	270,000.00	243,721.00			9.9	6.7	9.45
Dec-16	7.8	7.4			4	4.00	10.7	6.7	7.6
Jan-17	7.96	7.34	270,000.00	270,000.00			11.33	8.08	5.85
Feb-17	7.36	6.88					11.47	9.47	5.95
Mar-17	7.9	7	660,000.00	544,977.00	2	2.00	9.3	8.9	5.6
Apr-17	7.9	7.14					9.4	8	6.7
May-17	7.37	7.31	340,000.00	314,006.00			8.61	3.77	10.5
Jun-17	7.4	7.2	1,030,000.00	836,899.00	3	3.00	9.1	2.7	11.6
Jul-17	7.38	7.28	1,150,000.00	976,985.00			2.93	2.32	12.6
Aug-17	7.39	7.19	600,000.00	579,655.00			3.72	2.95	14
Sep-17	7.2	7.1	270,000.00	270,000.00	4	4.00	4.31	2.08	13.9
Oct-17	7.1	7					5.62	2.13	12.4
Nov-17	7.14	7.06	180,000.00	179,722.00			5.28	2.31	10.4
Dec-17	7.13	7.02			4	4.00	9.72	8.05	8.3
Jan-18	7.2	7.3	790,000.00	540,648.00			9.3	7.7	7.3
Feb-18	7.32	7.19					9.66	6.94	7.9
Mar-18	7.28	7.04	300,000.00	256,905.00	3	3.00	9.45	7.11	7.5
Apr-18	7.24	7.14					9.32	7.2	7.1
May-18	7.1	7	210,000.00	177,482.00			6.6	5.3	8.2
Jun-18	7.22	7.13	530,000.00	519,903.00	2	2.00	3.9	3.51	12.1
Jul-18	7.32	6.89	920,000.00	830,662.00			2.2	2.1	14.8
Aug-18	7.45	7.08	1,100,000.00	932,201.00			4.62	2.07	14.8
Sep-18	7.33	7.19	210,000.00	210,000.00	4	4.00	3.9	2.9	14
Oct-18	7.52	7.17					9.6	3.68	13.5
Nov-18	7.5	6.7	960,000.00	924,337.00			16.5	9.8	11
Dec-18	7.19	7.07			3	3.00	13.2	8.4	9
Jan-19	7.2	7.1	345,000.00	321,714.00			9.17	7.47	8.5
Feb-19	7.32	7.1					14.6	7.8	7.9
Mar-19	7.1	6.8	360,000.00	344,674.00	0	0.00	11.4	7.3	8.15
Apr-19	7.5	6.9					9.6	9.3	8.1
May-19	7.2	6.83	590,000.00	590,000.00			6.58	3.98	11.125
Jun-19	7.22	6.74	790,000.00	519,904.00	23	23.00	4.33	4.16	9.175
Jul-19	7.19	6.94	980,000.00	980,000.00			4.4	2.45	15.35
Aug-19	7.25	6.78	850,000.00	819,451.00			4.62	2.83	15.6
Sep-19	6.97	6.91	610,000.00	610,000.00	0	0.00	6.91	2.12	15.8
Oct-19	7.17	6.85					8.24	4.27	12.92
Nov-19	7.15	6.83	520,000.00	420,476.00			10.25	8.33	11.3
Dec-19	7.12	6.56			0	0.00	12.13	7.64	8.85
Jan-20	7.44	7.02	10,000.00	14,142.00			10.02	8.72	8.13
Feb-20	7.37	6.51					10.39	9.43	8.34
Mar-20	7.31	7.11	750,000.00	739,932.00	0	0.00	11.4	9.05	8.95
Apr-20	7.31	7.08					10.9	8.88	7.3
May-20	7.21	7.09	42,000.00	388,844.00			9.55	6.52	11.13
Jun-20	7.23	7.02	980,000.00	980,000.00	0	0.00	4.02	3.62	14
Jul-20	7.17	7.02	710,000.00	604,618.00			4.1	2.15	14.55
Aug-20	7.22	7.08	760,000.00	616,441.00			5.02	2.53	14.4
Sep-20	7.16	7.09	670,000.00	542,955.00			8.71	2.96	13.7
Oct-20	7.22	7.11					7.7	3.6	12.15
Nov-20	7.45	7.14	170,000.00	92,195.00			8.66	7.23	10.8
Dec-20	7.16	6.98			0	0.00	13.33	11.18	7
Jan-21	7.15	6.74	360,000.00	317,490.00			11.92	10.43	8.1
Feb-21	7.04	6.86					10.64	10.39	9.2
Mar-21	7.14	6.86	500,000.00	374,166.00	0	0.00	11.2	8.51	7.05
Apr-21	7.14	6.86					11.2	8.51	7.05
May-21	7.23	6.98	510,000.00	468,295.00			8.68	5.33	7.09
Jun-21	7.39	7.05	810,000.00	661,362.00	30	30.00	7.33	4.31	13
Jul-21	7.34	7.05	1,140,000.00	900,000.00			4.4	3.03	14.5
Aug-21	7.28	7	1,430,000.00	770,324.00			6.69	2.42	14.52
Sep-21	6.99	6.89	200,000.00	200,000.00	0	0.00	9.25	3.48	13
Average	7.3041	7.014	596,925.00	522,127.15	4.32	4.32	8.42	5.78	10.49
Minimum	6.97	6.51	10,000.00	14,142.00	0.00	0.00	2.20	2.07	5.60
Maximum	7.96	7.4	1,430,000.00	980,000.00	30.00	30.00	16.50	11.18	15.80
Count	59	59	40.00	40.00	19.00	19.00	59.00	59.00	59.00
Std Dev	0.2186	0.178	345,851.26	273,040.15	8.08	8.08	3.15	2.82	3.01
CV	0.0299	0.025	0.58	0.52	1.87	1.87	0.37	0.49	0.29
95th Percentile	7.9	7.301	1,140,500.00	977,135.75	23.70	23.70	13.21	9.86	14.86
5th Percentile	7.094	6.736	163,600.00	173,217.65	0.00	0.00	3.88	2.12	6.63
90th percentile	7.504	7.192	1,037,000.00	925,123.40	7.80	7.80	11.56	9.33	14.53
50th percentile	7.23	7.04	595,000.00	530,276.00	2.00	2.00	9.25	6.52	10.40

D. Alaska WQS

Alaska WQS for Turbidity for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(24) TURBIDITY, FOR MARINE WATER USES	
(A) Water Supply (i) aquaculture	May not exceed 25 nephelometric turbidity units (NTU).
(A) Water Supply (ii) seafood processing	May not interfere with disinfection.
(A) Water Supply (iii) industrial	May not cause detrimental effects on established levels of water supply treatment.
(B) Water Recreation (i) contact recreation	Same as (24)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (24)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	May not reduce the depth of the compensation pointfor photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (24)(C).

Alaska WQS for Dissolved Gas for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(15) DISSOLVED GAS, FOR MARINE WATER USES	
(B) Water Supply (i) aquaculture	Surface dissolved oxygen (D.O.) concentration in coastal water may not be less than 6.0 mg/l for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/l at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/l except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
(A) Water Supply (ii) seafood processing	Not applicable.
(A) Water Supply (iii) industrial	Not applicable.
(C) Water Recreation (i) contact recreation	Same as (15)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (15)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (15)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (15)(A)(i).

Alaska WQS for pH for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(18) pH, for marine water uses (variation of pH for waters naturally outside the specified range must be toward the range)	
(A) Water Supply (i) Aquaculture	May not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range.
(A) Water Supply (ii) seafood processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (iii) industrial	May not be less than 5.0 or greater than 9.0
(D) Water Recreation (i) contact recreation	May not be less than 6.0 or greater than 8.5. If the natural pH condition is outside this range, substances may not be added that cause any increase in buffering capacity of the water.
(B) Water Recreation (ii) secondary recreation	Same as (18)(A)(iii).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (18)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (18)(A)(ii).

Alaska WQS for Temperature for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(22) TEMPERATURE, FOR MARINE WATER USES	
(C) Water Supply (i) aquaculture	May not cause the weekly average temperature toincrease more than 1° C. The maximum rate of change may not exceed 0.5° C per hour. Normal daily temperature cycles may not be altered inamplitude or frequency.
(A) Water Supply (ii) seafood processing	May not exceed 15° C.
(A) Water Supply (iii) industrial	May not exceed 25° C.
(E) Water Recreation (i) contact recreation	Not applicable.
(B) Water Recreation (ii) secondary recreation	Not applicable.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (22)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (22)(A)(i).

Alaska WQS for Toxics for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(23) TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES, FOR MARINE WATER USES	
(D) Water Supply (i) aquaculture	Same as (23)(C).
(A) Water Supply (ii) seafood processing	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marinewater shown in the *Alaska Water Quality Criteria Manual* (see note 5). Substances may not be introduced that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(A) Water Supply (iii) industrial	Concentrations of substances that pose hazards to worker contact may not be present.
(F) Water Recreation (i) contact recreation	There may be no concentrations of substances in water, that alone or in combination with other substances, make the water unfit or unsafe for theuse.
(B) Water Recreation (ii) secondary recreation	Concentrations of substances that pose hazards to incidental human contact may not be present.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water and human health for consumption of aquatic organisms only shown in the *Alaska Water Quality Criteria Manual* (see note 5), or any chronic and acute criteria established in this chapter, for a toxic pollutant of concern, to protect sensitive and biologically important life stages of resident species of this state. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects onaquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable

	odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (23)(C).

Alaska WQS for Bacteria for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(14) BACTERIA, FOR MARINE WATER USES, (see note 1)	
(E) Water Supply (i) aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (ii) seafood processing	In a 30-day period, the geometric mean of samples may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (iii) industrial	Where worker contact is present, the geometric meanof samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml.
(G) Water Recreation (i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 35 enterococci CFU/100 ml, and notmore than 10% of the samples may exceed a statistical threshold value (STV) of 130 enterococci CFU/100 ml.
(B) Water Recreation (ii) secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100ml, and not more than 10% of the samples may exceed 400 fecal coliform/100ml.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Not applicable.

(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	The geometric mean of samples may not exceed 14 fecal coliform/100 ml; and not more than 10% of the samples may exceed; - 43 MPN per 100 ml for a five-tube decimal dilution test; - 49 MPN per 100 ml for a three-tube decimal dilution test; - 28 MPN per 100 ml for a twelve-tube single dilution test; - 31 CFU per 100 ml for a membrane filtration test (see note 14).

E. Equations and Analysis

1. Section 8.B.1: Attainment of TSS Standard

EPA calculated the maximum change in the concentration of TSS at the edge of the ZID using formula B-32 from the 301(h) TSD. The average weekly TSS limitation of 190 mg/L and the modeled critical initial dilution of 100:1 were used in the equation. The results show a 1.9 mg/L increase in suspended solids in the receiving water after initial dilution, or 1%.

<u>Formula B-2</u>

$SS = SS_e/S_a$

where,

SS = change in suspended solids concentration following initial dilution

SS_e = effluent suspended solids concentration (45 mg/L)

S_a = critical initial dilution (100:1)

45/100 = 0.45 mg/L

2. Section 8.B.2: Attainment of DO Standard

EPA calculated the final concentration of DO at the boundary of the ZID and at the edge of the chronic mixing zone using equation B-5 from the 301(h) TSD. The analysis is presented in Table 14 below.

Dissolved Oxygen Analysis

Dissolved Oxygen in mg/L	Surface	Mid[1]	Bottom	Notes
Ambient DO concentration (DO_a) = (reference sites)	6.2	5.8	5.23	minimum observed at two reference sites
Ambient DO concentration (DO_a) = (ZID boundary sites)	7.05	8.91	9.02	minimum observed at two outfall sites
Effluent DO concentration (DO_e) =	2.1	2.1	2.1	5th Percentile
Immediate DO demand (IDOD) =	5.0	5.0	5.0	Table B-3 301(h) TSD[2]
Initial dilution (S_a) =	100	100	100	Dilution modeling results
Chronic mixing zone (S_a) =	19	19	19	ADEC Preliminary Comments
Final DO at ZID boundary using reference site ambient DO $DO_f = DO_a + (DO_e - IDOD - DO_a)/S_a$ = (using reference site ambient DO)	6.11	5.71	5.15	Equation B-5 from 301(h) TSD, using reference site ambient DO and 100:1 ZID dilution
Final DO at ZID boundary assuming 0 mg/L effluent (worst-case) $DO_f = DO_a + (DO_e - IDOD – DO_a)/S_a$ =	>6.09	>5.69	>5.13	Worst-Case
FINAL DO at ZID Boundary using outfall site ambient DO $DO_f = DO_a + (DO_e + IDOD – DO_a)/S_a$ = (using ZID boundary ambient DO)	6.95	8.79	8.90	Equation B-5 from 301(h) TSD, using outfall site ambient DO and 100:1 ZID dilution
Final DO at chronic MZ boundary using outfall site ambient DO $DO_f = DO_a + (DO_e + IDOD – DO_a)/S_a$ =	6.53	8.29	8.39	Equation B-5 from 301(h) TSD, using outfall site ambient DO and 19:1 chronic mixing zone dilution
Depletion at Refence Sites (Reference Site DO – Final DO at ZID using reference site ambient DO)	-0.09 (1.5%)	-0.09 (1.5%)	-0.08 (1.6%)	
Depletion at ZID Boundary Sites (Outfall site DO – Final DO at ZID	-0.10 (1.4%)	-0.12 (1.3%)	-0.12 (1.3%)	

boundary using outfall site ambient DO)				
Depletion at Chronic Mixing Zone (Outfall site DO – Final DO at chronic MZ boundary using outfall site ambient DO)	-0.52 (7.4%)	-0.62 (7.0%)	-0.63 (7.0%)	
[1]DO sampled at 5m intervals between surface and bottom depths. [2] Primary facility, effluent BOD_5 150-200 mg/L, travel time 0-100 minutes.				

The final BOD_5 after initial dilution was also calculated to assess the potential for far field DO using a simplified procedure from Appendix B of the 301(h) TSD. The maximum reported average monthly BOD_5 value is first converted to ultimate BOD_5 by multiplying it by the constant 1.46. The ultimate BOD_5 is then divided by the initial dilution factor (100) to determine the final BOD_5 after initial dilution.

Max BOD_5: 300 mg/L

Ultimate BOD_5: 300 mg/L x 1.46 = 438 mg/L

Final BOD_5: 438 mg/L ÷ 100 = 4.38 mg/L BOD_5

A final BOD_5 concentration of 4.38 mg/L after initial dilution is not expected to cause or contribute to any measurable far field DO impacts.

3. Section 8.C.3. Toxics Analysis

The following mass-balance equation was used to determine whether the discharge has reasonable potential to cause or contribute to an excursion above Alaska WQS:

$$Cd = \frac{Ce + [\, Cu\, (Sa - 1)\,]}{Sa}$$ where

Cd = Resultant magnitude or predicted concentration at edge of mixing zone, µg/L

Ce = Maximum projected effluent concentration, µg/L

Cu = Background receiving water concentration, µg/L

Sa = dilution factor

The maximum projected effluent concentration (Ce) in the mass balance equation is represented by the highest reported concentration measured in the effluent multiplied by a reasonable potential multiplier. The reasonable potential multiplier accounts for uncertainty in the data. The multiplier decreases as the number of data points increases and variability of the data decreases. Variability is measured by the coefficient of variation (CV) of the data. When there is not enough data to reliably determine a CV (n<10), the TSD recommends using 0.6 as a default value. A partial listing of reasonable potential multipliers can be found in Table 3-1 of the TSD. The resulting maximum projected effluent concentration is then divided by the minimum critical dilution. This product represents the maximum effluent concentration at the edge of the ZID. The maximum effluent concentration at the edge of the ZID is then added to the background concentration, Cu, which is represented by the 95th percentile value from the background data set (the 5th percentile value is used for DO). The sum Cd represents the projected maximum receiving water concentration at the edge of the ZID. This concentration is compared to the water quality criterion to determine whether a water-quality based effluent limitation is needed. If the receiving water concentration at the edge of the ZID exceeds the water-quality criteria a water-quality based effluent limitation is developed. If a permittee is unable to meet their WQBEL they would fail to satisfy CWA 301(h)(9) and 40 CFR 125.62 and would be ineligible for a 301(h)-modified permit.

No pollutants have reasonable potential at the edge of the ZID. A summary of the reasonable potential analyses used to develop WQBELs is located in Appendix C of the Fact Sheet.

F. TVS Survey Results

Total Volatile Solids Results

Sample Location	Date	Method	Result (% Volatile Solids)
Station 1-TVS #1 within ZID	9/4/05	SM 2540G	0.43
Station 1-TVS #2 within ZID	9/4/05	SM 2540G	1.29
Station 1-TVS #3 within ZID	9/4/05	SM 2540G	0.97
Station 2-TVS #1 5m outside ZID	9/3/05	SM 2540G	4.95
Station 2-TVS #2 5m outside ZID	9/3/05	SM 2540G	5.52
Station 2-TVS #3 5m outside ZID	9/3/05	SM 2540G	9.62
Station 3-TVS #1 Reference Station	9/4/05	SM 2540G	0.90
Station 3-TVS #2 Reference Station	9/4/05	SM 2540G	0.96
Station 3-TVS #2 Reference Station	9/4/05	SM 2540G	1.26

G. Dilution Modeling Report

The dilution model is attached to the end of this document.

FINAL

Mixing Zone Dilution Modeling for Six Alaska POTWs

Prepared for:

United States Environmental Protection Agency
Cincinnati Procurement Operations Division
Cincinnati, Ohio 45268

USEPA OW Contract: 68HERC20D0010; Task Order: 68HERV21F0114

Technical Support for National Pollutant Discharge
Elimination System (NPDES), Clean Water Act Section 301(h),
and Endangered Species Act Section 7 Implementation
in EPA Region 10 NPDES Permits Section

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MIXING ZONE DILUTION MODELING FOR SIX ALASKA POTWS

For each of the six POTWs of interest in southeast Alaska (Haines, Ketchikan, Petersburgh, Sitka, Skagway, and Wrangell) mixing zone dilution models were developed and applied to predict the steady-state dilution of effluent being discharged into the marine coastal receiving waters. Because of the nature of the discharges and receiving waters, initial dilution models within the EPA-approved Visual Plumes software (EPA 2003) were selected for use. From a modeling perspective, each of the receiving water mixing zones share several important characteristics that led to the selection of Visual Plumes, as opposed to the alternative EPA-approved modeling framework, CORMIX:

- Discharge of buoyant effluent into a deep (20-30 meter), stratified marine water body;
- No shoreline boundaries within 100 meters of the outfalls;
- Relatively small discharge flow rates (0.6-7 MGD); and
- No obstructions in the receiving waters to impede circulation near the outfalls, making tidal build-up of pollutants unlikely.

For each site, appropriate models were applied to predict average dilution at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point, as well as the geometry (depth, width, etc.) of the plume itself. Aquatic life-based mixing zone analyses involve the concept of determining reasonable worst-case values for various parameters because the durations established for these water quality criteria vary for both acute and chronic toxicities (Washington DoE, 2018). The term *reasonable worst-case* refers to the value selected for a specific effluent or receiving water parameter. *Critical conditions* refer to a scenario involving reasonable worst-case parameters, which has been set up to run in a mixing zone model. For this work, steady-state mixing zone models were applied using a combination of parameters (e.g., effluent flow, current speed, density profile) to simulate critical conditions. The predictions were based on input data representing critical conditions demonstrated to minimize the dilution of effluent pollutants. It should be understood that each critical condition (by itself) has a low probability of occurrence.

It should also be understood that mixing zone modeling is not an exact science (Reese et al., 2021). With limited data and numerous variables, mixing zone sizes may be considered best estimates to ± 50%. Sensitivity analysis and comparison of alternative models were used to develop confidence in the dilution model predictions. All simulations explicitly included fecal coliform (FC) as a pollutant, which required the models to simulate bacterial decay in the receiving waters. Maximum effluent (end-of-pipe) FC concentrations were estimated for modeling by applying the EPA (1991) reasonable potential procedure to maximum monthly concentrations reported over the past five years in Discharge Monitoring Reports (DMRs) provided by EPA Region 10. The maximum effluent FC concentrations for each discharge are presented in Table 1 along with the dilution factors required to meet the Alaska marine water quality standards for harvesting for consumption of raw mollusks or other raw aquatic life (18 AAC 70 Water Quality Standards, amended as of March 5, 2020):

The geometric mean of samples may not exceed 14 fecal coliform/100 ml, and not more than 10% of the samples may exceed 43 MPN per 100 mL for a five-tube decimal dilution test.

Table 1. Maximum Effluent FC Concentrations Based on EPA (1991) Reasonable Potential Procedure (Maximum Monthly Concentrations Reported in DMRs Over the Past 5 Years)

City	Haines	Kechikan	Petersburg	Sitka	Skagway	Wrangell
Maximum expected effluent FC (daily max, 99%; n/100 mL)	2,100,000	2,900,000	2,000,000	3,700,000	2,600,00	190,000
Dilution factor[1] required to meet 14/100 mL FC criterion	150,000	210,000	140,000	270,000	190,000	14,000
Dilution factor required to meet 43/100 mL FC criterion	50,000	67,000	47,000	87,000	60,000	4,400

Model predictions of the size of the mixing zones required to attain these dilution factors are presented in the summary of this report.

Most mixing zone simulations required the combination of initial dilution and far-field models. Initial dilution models simulate the “initial mixing region” or “hydrodynamic mixing zone” defined to end where the self-induced turbulence of the discharge collapses under the influence of ambient stratification and initial dilution reaches its limiting value (EPA, 1994). At the end of this region/zone the waste field is established and then drifts with the ocean currents and is diffused by oceanic turbulence.

The initial dilution models included UM3, DKHW and NRFIELD, all contained within the Visual Plumes (VP) framework. Although the three initial dilution models run under the same VP interface, they differ in terms of origin and development, underlying assumptions, empirical datasets, solution techniques and coding. UM3 is a three-dimensional Updated Merge (UM) model for simulating single and multiport submerged diffusers. DKHW is an acronym for the Davis, Kannberg and Hirst model, a three-dimensional model for submerged single or multi-port diffusers. DKHW is limited to positively buoyant plumes and considers either single or multiport discharges at an arbitrary horizontal angle into a stratified, flowing current. NRFIELD is based on the Roberts, Snyder and Baumgartner (RSB) model, an empirical model for multiport diffusers (T-risers, each having two ports for a total of 4-ports) in stratified currents. A shortcoming of each of these initial dilution models in VP is their inability to recognize and address lateral boundary constraints, although that is not a major issue for these Alaskan mixing zone sites. Although the original 2001 version of VP is still available from EPA’s CEAM site, it is currently unsupported and known to contain a number of errors (Frick et al. 2010; Frick and Roberts, 2019). We instead used the updated VP version 20, maintained and distributed by the California State Water Resources Control Board, Ocean Standards Unit (https://ftp.waterboards.ca.gov).

The Brooks far-field model was used to extend dilution simulations beyond the spatial bounds of initial dilution. Although this model is incorporated in VP, we also used a stand-alone spreadsheet version of the

[1] Dilution Factor, DF = (end of pipe) concentration/mixed concentration.

Brooks model, FARFIELD, that is contained in the Washington Department of Ecology (DoE), *Permit Calculation workbook* (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Water-quality-permits-guidance). FARFIELD calculates dilution using the method of Brooks (1960) and is recommended by Frick et al. (2010) in lieu of using far-field predictions within VP, since the latter does not allow for the use of linear diffusivity as recommended in estuaries. FARFIELD was used to double-check the far-field results in VP, and in some instances to replace them.

The initial dilution models relied upon a variety of data to characterize the effluent, discharge outfall and receiving water. These data are summarized in Table 2. The data were gathered from a number of sources including EPA Region 10 and the State of Alaska; from the permittees as documented in permit files, as-built drawings and charts, etc.; tidal current predictions made by the National Oceanic and Atmospheric Administration (NOAA); and other literature sources found by Internet search.

All six of the POTWs discharge effluent using deeply-submerged outfalls with diffusers and multiple ports (Table 2). Haines and Petersburg both use two-diffuser ports, while the others use multiport diffusers with 6 to 16 ports. Modeling initial dilution from the four sites using multiport diffusers required additional considerations, because these diffusers have opposing ports (ports on both sides of the diffuser pipe that discharge effluent into opposite directions), creating co-flowing and counter-flowing plumes. Counter-flowing plumes are discharged opposing the ambient current and will generally rise and bend back into the direction from whence they came, eventually merging with the co-flowing plumes that are discharged on the opposite side of the pipe in the direction of the current. This is called cross-diffuser merging (EPA, 2003). Two alternative modeling approaches were applied to simulate initial mixing from opposing ports in the UM3 and DKHW models (NRFIELD models cross-diffuser merging directly). The first approach ("half spacing") treated the diffuser as if all ports are on one side with half the spacing. In the context of merging plumes, this approach works well when the distances of interest are somewhat beyond the point of merging.

The second approach ("downstream only") involves simulating only downstream ports. This necessitates doubling the flow per port (assuming there is an even number of ports in the diffuser) and increasing the diameter of the ports to maintain approximately the same densimetric Froude number. With this approach only the downstream ports would be used when determining spacing and number of ports. The Washington DoE Permit Writer's Manual, Appendix C (2018) discusses the merits of these approaches. When possible, we applied both approaches to modeling cross-diffuser merging and compared the results.

We assumed that all ports on a multiport diffuser discharged effluent flow equally and at the same depth. The multiport diffuser at Ketchikan was unique because it was the only diffuser that combined ports of different sizes. Five 6-inch opposing ports were spaced along a 12-inch manifold, and a sixth 12-inch port was located at the manifold's end. The CORMIX hydraulic module CorHyd (MixZone, 2020) was used to determine the flow distribution between the 6-inch ports and the 12-inch port. At a nominal flow rate of 5.35 MGD, CorHyd calculated that the 6-inch ports would discharge 52% of the flow, and the remaining 48% would be discharged from the 12-inch port. These same percentages were applied to other flow rates at Ketchikan. Initial model simulations suggested that the plumes emanating from the 12-inch port would not merge with the plume from the other ports, due to the 90° difference in port orientations. Therefore, these plumes were modeled separately.

The diffuser port orifice contraction coefficient is an initial dilution model hydraulic parameter that is specified according to how ports are machined in the diffuser pipe wall (EPA, 2003). For all of the outfalls except Sitka, sharp-edged ports were assumed, and contraction coefficients of 0.61 were specified. For Sitka, the port orifices were bell-shaped, so a contraction coefficient of 1.0 was applied.

Tidal current predictions were used to calculate 10^{th} percentile and average current velocities at each site. The tidal prediction location nearest each discharge site was identified and tidal velocity predictions for 2021 were downloaded from the NOAA Tides & Currents web site (http://tidesandcurrents.noaa.gov). These data were imported into a spreadsheet and the predictions for the month in which the critical ambient conditions fell were selected. For Haines, Ketchikan and Skagway, 6-minute tidal velocity predictions were available. The tenth percentile of the absolute value of these velocities were calculated and used as the critical ambient velocity input for mixing zone dilution modeling. For the other locations, only times and velocities for ebb, slack and flood tides were available. The Excel FORECAST function was then used to interpolate hourly values from the tidal velocity predictions, and the tenth percentile of the absolute value of these interpolated hourly values was calculated and used for modeling[2]. These velocities, ranging from 1.4 to 5.9 cm/s, are presented in Table 2. The compass directions of tidal currents (also presented in Table 2) were based on the tidal current predictions, the orientation of the nearest shoreline (presuming currents to flow parallel to the shoreline), and other information from the permit files. The average hourly ebb and flood tidal velocities were calculated similarly and are also presented in Table 2 and were used in the model sensitivity analysis.

The decay of fecal coliform was included in the initial dilution and far-field models by using the Mancini (1978) bacteria model that incorporates four variables (salinity, temperature, solar insolation, and water column absorption) to determine the rate of first-order decay. Summertime solar insolation in southeast Alaska was based upon the models and measurements of Dissing and Wendler (1998). Summertime solar radiation flux, that takes into account both latitude and fractional cloud cover, averaged 190 Watts/m^2 (16.3 Langleys/hr) in the Alexander Archipelago. The bacterial decay model used ambient water temperature and salinity, and a default light absorption coefficient of 0.16, to calculate decay rates of ~0.0002/d. Decay of fecal coliform was found to be insignificant in comparison to physical dilution at the time and space scales of interest for mixing zone analysis.

[2] Comparison between linear interpolation and cubic spline interpolation of the tidal velocity predictions suggests that linear interpolation may yield average velocities that could be low by a factor of 1.6 to 2.3. The impact of this discrepancy on DF predictions will be demonstrated via sensitivity analysis.

Table 2. Summary of Data Used for Mixing Zone Dilution Modeling

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
Permit	*AK0021385*	*AK0021440*	*AK0021458*	*AK0021474*	*AK0020010*	*AK0021466*
DMR data available	2011-2020	2013-18	2015-2019	2015-20	2007-19	2007-19
DMR data used	2016-2020	2013-2018	2015-2019	2015-2020	2014-2019	2015-2019
Permit Maximum Flow Rate (MGD[3])	2.9	7.2	3.6	5.3	0.63	3.0
monthly[4] average effluent temperature	12.0	14.6[5]	13.2	14.0	14.7	17.3
monthly maximum effluent temperature	15.8	20.5	14.6	15.0	17.3	18.4
Outfall						
distance from shore (m)	549	221	366	114	125	457
depth at LWWD (m)	21.3	29.9	18.3	24.4	18.3	30.5
number of diffuser ports	2 (3rd is capped)	6	2 (3 others capped)	16 bell-shaped	8	16
diffuser length (ft)	30	190	45.9	195	25	240
port diameter (in)	3	5@6", 1@12"	4	4	3	3
Elevation of ports above bottom (in)	8	12	9	18	6	6
Port spacing (ft)	15-30[6]	40 (20’ apart on alternating sides of pipe)	10-34[6]	26 (13’ apart on alternating sides of pipe)	7	32 (16’ apart on alternating sides of pipe)
Port orientation	horizontal	horizontal (opposing/ alternating) + diffuser end	horizontal	horizontal opposing/ alternating	horizontal opposing	horizontal opposing/ alternating

[3] Million gallons per day.
[4] Average effluent temperature for month of limited dilution
[5] Average of maximum monthly effluent temperatures (no monthly averages in DMR)
[6] Port spacing is uncertain given information in permit fact sheet.

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
VP discharge angle[7] (degrees)	90	115 (5x6" ports), 205 (1x12" port)	115	300	350	90
Receiving Water						
Water body	Portage Cove, Chinook Inlet	Tongass Narrows, Charcoal Point	Frederick Sound	Sitka Sound, Middle Channel	Tiaya Inlet	Zimovia Strait
tidal range (ft)	14.2	13	15	7.7	14.1	13
data source/file[8] name for ambient data	NA; used Skagway data	AK0021440_Ketchikan_temp_salinity	Petersburg_Receiving Water Data	Sitka Receiving Water Monitoring	Table 2-5_v2	Wrangell FC and RW Monitoring
Ambient salinity/temp profile limiting dilution	Skagway site 1, June 2005	Ketchikan site 3, July 1997	Petersburg site 1, August 2005	Sitka site C, July 2010	Skagway site 1, June 2005	Wrangell site 4, August 2016
NOAA tides & current predictions	Battery Point, Chinook Inlet (SEA0826)	East of Airport (SEA0711)	Cosmos Point (PCT3811)	Sitka Harbor, Channel off Harbor Island (PCT4166)	Tiaya Inlet (SEA0825)	Wrangell Harbor (PCT3131)
Tidal current 10th percentile (cm/s)	June: 2.1 @ 35', 2.8 @ 133'; 2.3 (interpolated to discharge depth)	July: 5.9 @87'	August: 1.6	July: 1.7	June: 1.4 @37'	August: 4.0
Tidal current average (Ebb/Flood, cm/s)	June: 10.2/10.7 @ 35', 11.3/16.1 @ 133'; 10.5/12.6 (interpolated to discharge depth)	July: 49.2/20.1 @87'	August: 10.4/7.8	July: 10.3/8.0	June: 6.9/12.2 @37'	August: 20.8/23.5
VP current angle[7] (degrees)	90	140	120	225	350	90

[7] Zero degrees is eastward.
[8] Names of electronic files provided by EPA Region 10 on March 31, 2021.

In the following sections, the modeling of effluent dilution in mixing zones at each site is presented and results are displayed in both tables and graphs. Text output from the VP and FARFIELD model simulations at each location are provided in an appendix to this report.

HAINES

The wastewater treated at Haines is discharged 549 m offshore in Portage Cove, Chinook Inlet (Figure 1), from a 2-port diffuser at a depth of 21.3 m (MLLW[9]). The permitted maximum flow rate is 2.9 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The diffuser port spacing at Haines is uncertain (somewhere in the range of 15 to 30 ft.) due to one of three ports being closed. The models predicted lower DFs for the narrowest port spacing (15 ft.), so that spacing was used for all model simulations.

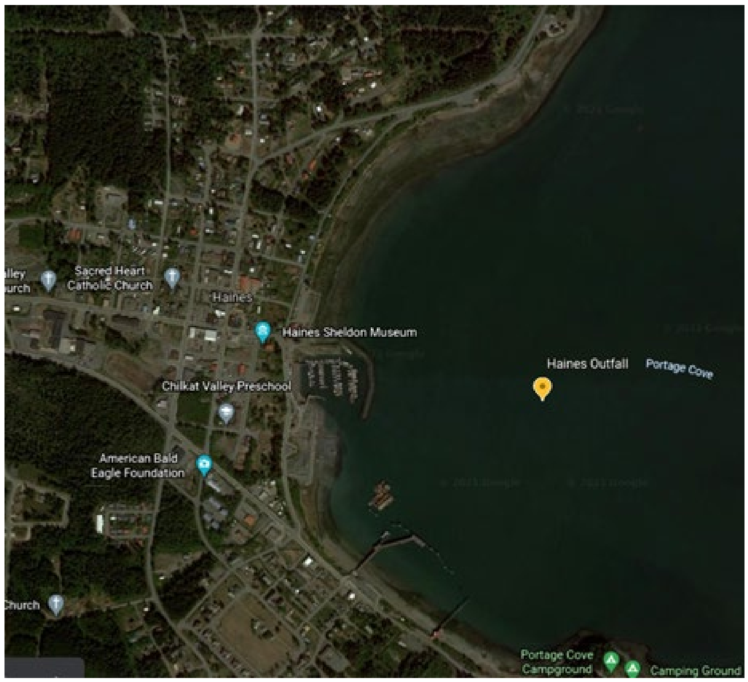

Figure 1. Aerial View of the POTW Outfall Location at Haines

According to the permit fact sheet, the circulation patterns within Portage Cove are not known. The effluent discharged by the Haines WWTP is subject to a net transport of water out of Chinook Inlet due to fresh water supplied by runoff. The period of low net circulation is expected to be December through April, during times of minimum river flow. NOAA 6-minute tidal current predictions from Battery Point, Chinook Inlet (SEA0826) were used to calculate the 10th percentile and average tidal current velocities at 35 and 133 ft. (10.7 and 40.5 m; Table 2), that were then interpolated to the discharge depth of 21.1 m. The resulting 10th percentile current velocity used for modeling was 2.3 cm/s, while the average ebb and flood tidal velocities were 10.5 and 12.6 cm/s.

No specific data were available for vertical profiles of temperature and salinity in Portage Cove or Chinook Inlet. Such data are used to calculate the density profile and define the vertical stratification that limits vertical mixing of the buoyant discharge plume. Instead, we used vertical profiles of temperature and salinity measured in Tiaya Inlet, an adjoining waterway that is also the receiving water body for Skagway's discharge. Vertical profile data were available for five locations that were sampled in October

[9] Mean lower low water.

2002, July and August 2004, and June 2005. Preliminary initial dilution simulations made with UM3 for profiles measured at four of the locations (the fifth was excluded because it was influenced by freshwater input from a tributary near Skagway), determined that the June 2005 vertical profile from site 1 (shown in Figure 2) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Haines.

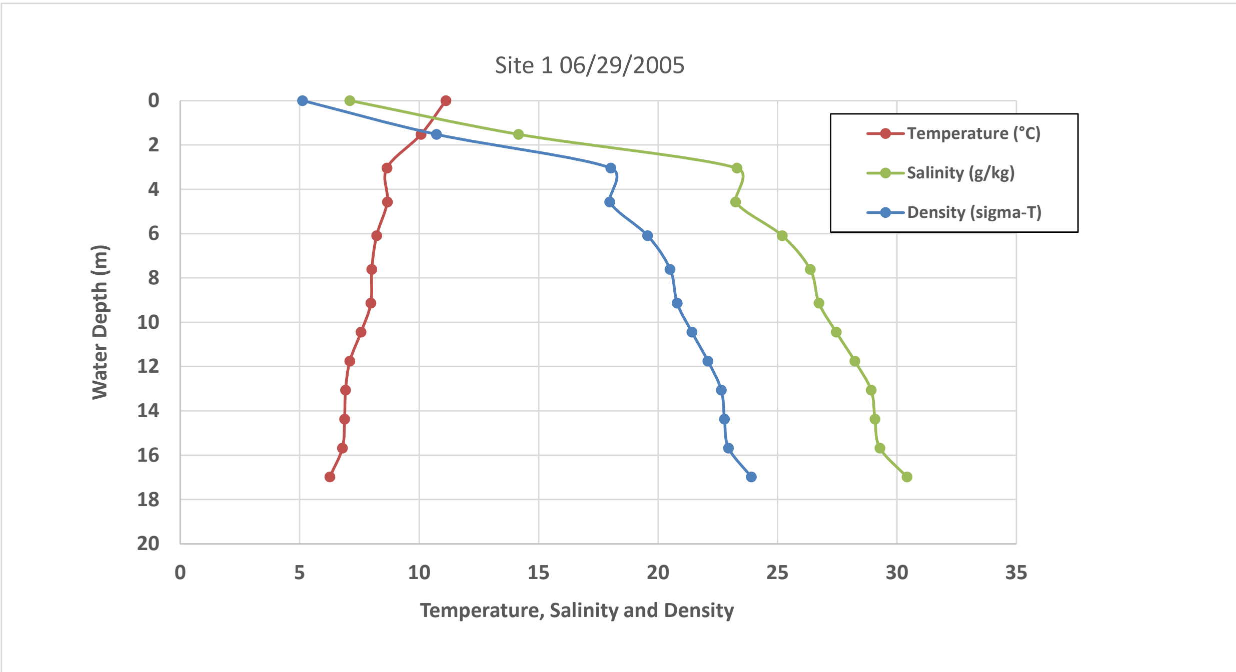

Figure 2. Vertical Ambient Profile of Temperature, Salinity and Density in Haines Mixing Zones Resulting in Least Mixing

Mixing zone dilution modeling results for Haines are summarized in Table 3. The two applicable initial mixing models, UM3 and DKHW, gave nearly identical results for dilution at a distance of 1*depth (Table 3, simulations 10 vs. 11). UM3 was selected for further analysis at Haines. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 100 to 766 (Table 3, simulations 15-18); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 3 (plan view from above of the discharge plume boundary), 4 (profile view from the side of the discharge plume centerline and boundary) and 5 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 3, the plume was trapped at a depth of 20 m by the ambient density stratification, the initial mixing region extended 16 m from the outfall, and the travel time to the mixing zone boundaries ranged from 4 minutes (MZ=1*depth) to 143 minutes (MZ=10*depth). A dilution factor of 99 was predicted for the boundary of the initial mixing region and at the distance to the shore (549 m) the DF was 2770.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[10], current velocity and direction, and discharge flow rate) is demonstrated in simulations 20-28 (Table 3). Of these

[10] The alternative effluent temperature used for sensitivity analysis was the monthly average effluent temperature for the month found to have the most limited dilution.

parameters, DFs were most sensitive to variation in effluent flow rate (Q), with dilution increasing with greater flow. DFs were relatively insensitive to variation in ambient velocity. Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity (see Washington DoE, 2018 for explanation).

Table 3. Haines mixing zone dilution modeling results

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
1. MZ=1*depth	Skagway site 1 Oct. 2002	UM3	21.3	190	117	118	17	>21.3	
2. " "	Skagway site 2 Oct. 2002	UM3	" "	191	118	118	17	>21.3	
3. " "	Skagway site 4 Oct. 2002	UM3	" "	190	117	118	17	>21.3	
4. " "	Skagway site 1 Jul. 2004	UM3	" "	189	117	118	17	>21.3	
5. " "	Skagway site 2 Jul. 2004	UM3/FF	" "	185	110	113	19	20	2
6. " "	Skagway site 4 Jul. 2004	UM3/FF	" "	181	113	116	19	21	0.5
7. " "	Skagway site 1 Aug. 2004	UM3	" "	188	118	118	17	>21.3	
8. " "	Skagway site 2 Aug. 2004	UM3	" "	186	117	117	17	>21.3	
9. " "	Skagway site 4 Aug. 2004	UM3/FF	" "	181	114	117	19	21	0.2
10. " "	Skagway site 1 June 2005	UM3/FF	" "	179	99	104	20	16	5
11. " "	Skagway site 1 June 2005	DKHW/FF	" "	179	99	99	20	16	4
12. " "	Skagway site 2 June 2005	UM3/FF	" "	183	105	109	20	18	2
13. " "	Skagway site 4 June 2005	UM3	" "	185	117	117	17	>21.3	

[11] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Different mixing zone distances:									
14. MZ= initial mixing region	Skagway site 1 June 2005	UM3	16	179	**99**	100	20		1
15. MZ=1*depth	“ “	UM3/FF	21.3	179	**100**	100	20	16	4
16. MZ=2*depth	“ “	UM3/FF	42.6	179	**136**	137	20	16	19
17. MZ=5*depth	“ “	UM3/FF	106.5	179	**330**	331	20	16	65
18. MZ=10*depth	“ “	UM3/FF	213	179	**766**	768	20	16	143
19. MZ=distance to nearest shore	“ “	UM3/FF	549	179	**2770**	2780	20	16	386
Model sensitivity:									
20. avg. effluent T=11.975° C	Skagway site 1 June 2005	UM3/FF	21.3	181	100	100	20	16	4
21. ½*current v=1.15 cm/s	“ “	UM3/FF	“ “	178	101	101	20	16	8
22. ¼ *current v=0.575 cm/s		UM3/FF	“ “	179	120	120	20	16	16
23. 2*current v=4.6 cm/s	“ “	UM3/FF	“ “	179	105	105	20	17	2
24. average current v=12.6 cm/s	“ “	UM3/FF	“ “	179	126	126	20	19	4
25. reverse current direction=270°	“ “	UM3/FF	“ “	179	92	92	20	15	4
26. average Q=0.27 MGD	“ “	UM3/FF	“ “	17	63	63	18	5	12
27. Q/2=1.45 MGD	“ “	UM3/FF	“ “	89	87	87	20	11	7
28. 2*Q=5.8 MGD	“ “	UM3	“ “	358	111	111	20	21	0.5

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Far-field model sensitivity to diffusion parameter:									
29. alpha=0.0001	Skagway site 1 June 2005	UM3/FF	213	178	248	249	20	16	143
30. alpha=0.000453	" "	UM3/FF	" "	178	1280	1280	20	16	143
31. Linear eddy diffusivity	" "	UM3/FF	" "	178	486	488	20	16	143

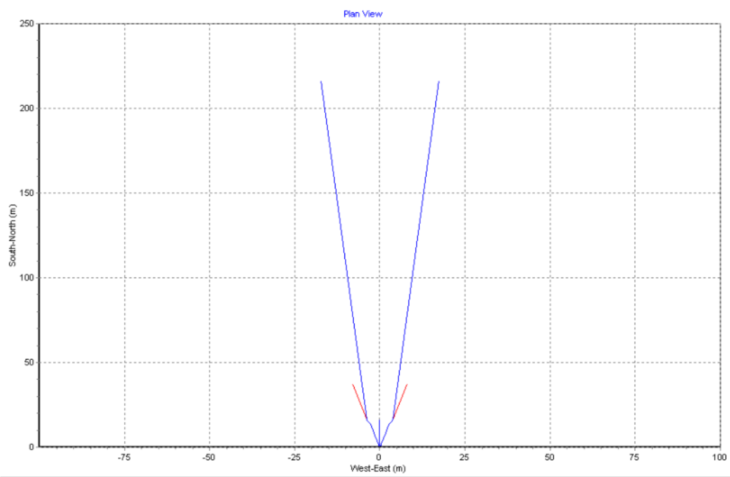

Figure 3. Haines Discharge Plume Boundary Plan View from Above

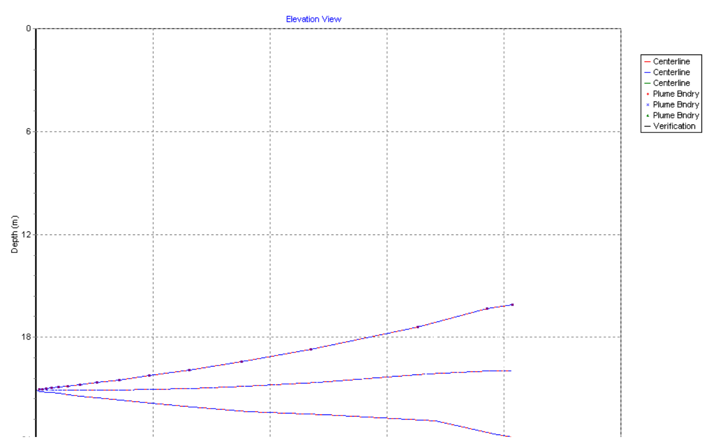

Figure 4. Haines Discharge Plume Centerline and Boundary Profile View from Side

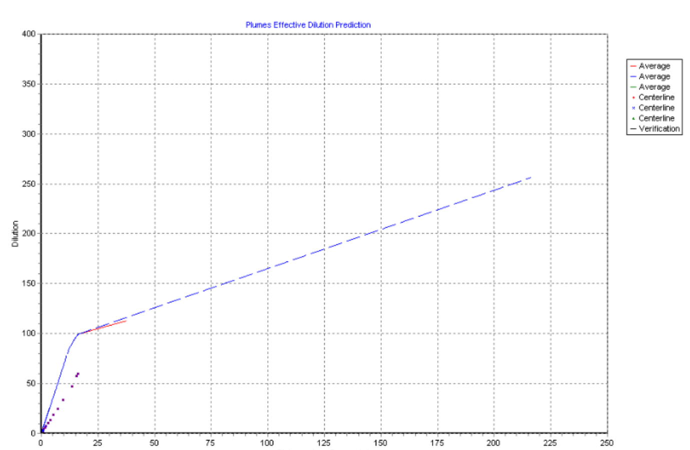

Figure 5. Haines Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

KETCHIKAN

The wastewater treated at Ketchikan is discharged 221 m offshore of Charcoal Point in the Tongass Narrows (Figure 6), at a depth of 29.9 m (MLLW). Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2.

Figure 6. Aerial View of the POTW Outfall Location at Ketchikan

Charcoal Point is at the narrowest width of the Narrows and is approximately 400 m wide and 34 m deep. According to the 2000 Permit application, the Tongass Narrows has a net northwest seaward exchange (away from the City and Pennock Island) with the Gulf of Alaska. Strong currents (that do not vary seasonally) provide vertical mixing in Tongass Narrows, minimizing the vertical density gradient and preventing stratification. Ambient tidal current data were collected with a current meter deployed near shore in December 1988 to verify published Tidal Current Table predictions. The data collected indicate that the flood tide current velocity was 34 cm/s, while the ebb tide currents was 1 cm/s in both directions. NOAA 6-minute tidal current predictions from East of Airport (SEA0711) were used to calculate the 10th percentile and average tidal current velocities at a depth of 87 ft. (26.5 m; Table 2). The 10th percentile current velocity used for modeling was 5.9 cm/s, while the average ebb and flood tidal velocities were 49.2 and 20.1 cm/s.

Preliminary initial dilution simulations made with UM3 for five available ambient profiles, determined that the July 1997 vertical profile from Site 3 (Figure 7) was limiting in terms of minimizing effluent dilution. As noted previously, the diffuser at Ketchikan was a hybrid, consisting of five 6-inch ports on a manifold and a single 12-inch port. These were modeled separately, and initial simulations with both UM3 and DKHW demonstrated that effluent dilution from the single 12-inch port was lower than from the five, 6-inch ports. UM3 gave more conservative dilution predictions (see Table 4, simulations 5 vs. 6), so that initial mixing model was selected for further analysis at Ketchikan.

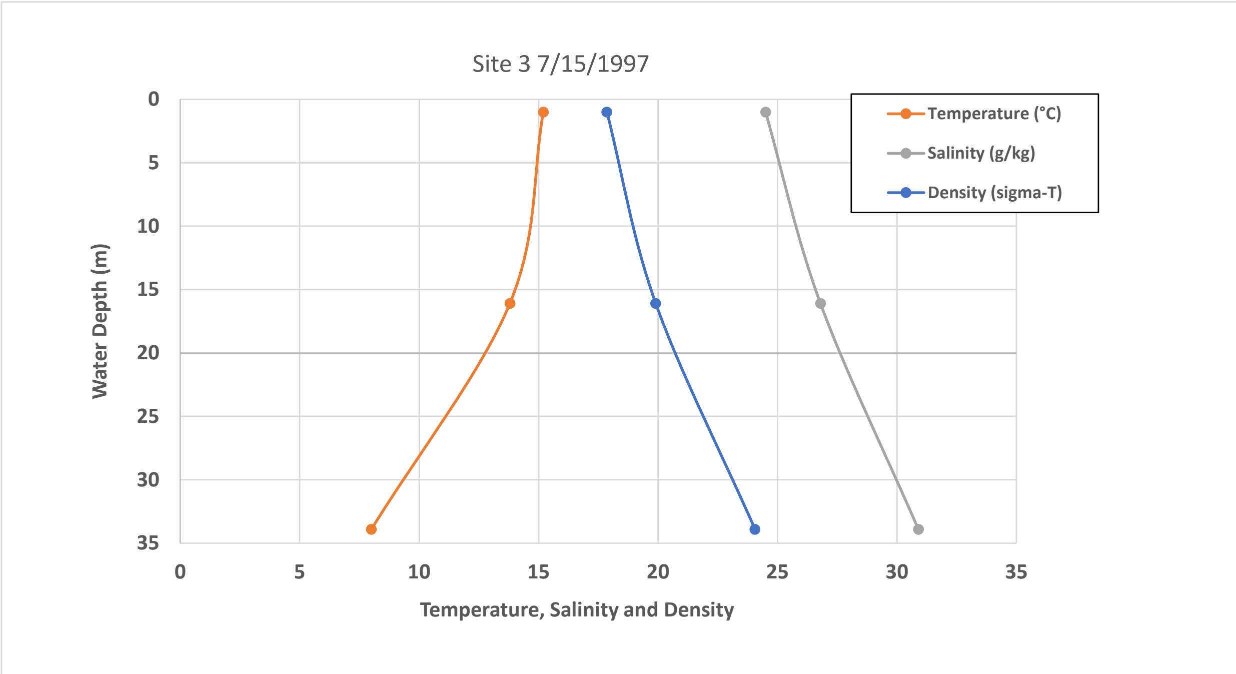

Figure 7. Vertical Ambient Profile of Temperature, Salinity and Density in Ketchikan Mixing Zone Resulting in Least Mixing.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Ketchikan on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 4 (simulations 20 vs. 31 and 32).

Dilution factors at distances of 1*depth to 10*depth range from 52 to 179 (Table 4, simulations 17-20). It should be noted that the 10*depth distance (299 m) is greater than the distance from the diffuser to shore (221 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 8 (plan view from above of the discharge plume boundary), 9 (profile view from the side of the discharge plume centerline and boundary) and 10 (discharge plume average and centerline dilution vs. distance from the outfall). Note that these figures include dilution model predictions for both the single 12-inch port and the five 6-inch ports. As shown in Table 4, the plume was trapped at a depth of 22 m by the ambient density stratification, the initial mixing region extended 13 m from the outfall. The travel time to the mixing zone boundaries ranged from 5 minutes (MZ=1*depth) to 81 minutes (MZ=10*depth). A dilution factor of 51 was predicted for the boundary of the initial mixing region and at the distance to the shore (221 m) the DF was 141.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[12], current velocity and direction, and discharge flow rate) is demonstrated in simulations 22-30 (Table 4). Of these parameters, DFs were most sensitive to variation in ambient velocity (simulations 23-26).

[12] The alternative effluent temperature used for sensitivity analysis was the average of maximum monthly effluent temperatures (no monthly averages in DMR).

Table 4. Ketchikan Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Ketchikan 2000	UM3/FF	29.9	12" port	14	73	75	19	15	4
2. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	117	123	22	12	5
3. " "	Ketchikan Pier 12/1988	UM3/FF	" "	12" port	14	158	168	7	17	4
4. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	305	324	8	18	3
5. " "	Ketchikan site 3 7/1997	UM3/FF	" "	12" port; limiting	14	52	54	22	13	5
6. " "	" "	DKHW/FF	" "	12" port	14	79	79	24	12	5
7. " "	" "	UM3(DS only, 3 ports x7.35")/FF	" "	5x6" ports	17	60	62	23	12	5
8. " "	Ketchikan site 3 9/1997	UM3/FF	" "	12" port	14	99	104	14	15	4
9. " "	Ketchikan site 3 8/1997	UM3/FF	" "	12" port	13	106	112	12	14	4
10. " "	Ketchikan site 3 7/1996	UM3/FF	" "	12" port	13	99	104	14	15	4
11. " "	Ketchikan site 3 8/1996	UM3/FF	" "	12" port	14	79	83	18	15	4

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
12. " "	Ketchikan site 3 9/1996	UM3/FF	" "	12" port	14	101	106	15	16	4
13. " "	Ketchikan site 3 7/1998	UM3/FF	" "	12" port	14	89	93	16	6	4
14. " "	Ketchikan site 3 8/1998	UM3/FF	" "	12" port	13	112	118	13	17	4
15. " "	Ketchikan site 3 9/1998	UM3/FF	" "	12" port	14	92	97	16	16	4
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:										
16. MZ= initial mixing region	Ketchikan 3 7/1997	UM3	13	12" port	14	**51**	52	22		1
17. MZ=1*depth	Ketchikan 3 7/1997	UM3/FF-LED	29.9	" "	14	**52**	52	22	13	5
18. MZ=2*depth	" "	" "	59.8	" "	14	**62**	63	22	13	13
19. MZ=5*depth	" "	" "	149.5	" "	14	**105**	106	22	13	39
20. MZ=10*depth	" "	" "	299[13]	" "	14	**179**	180	22	13	81
21. MZ=distance to nearest shore	" "	" "	221	" "	14	**141**	141	22	13	59
Model sensitivity:										
22. avg. effluent T=14.6° C	Ketchikan 3 7/1997	UM3/FF-LED	29.9	12" port	14	52	52	22	13	5

[13] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
23. ½*current v=2.95 cm/s	" "	" "	" "	" "	14	54	54	20	13	10
24. ¼ *current v=1.475 cm/s	" "	" "	" "	" "	14	67	67	20	13	19
25. 2*current v=11.8 cm/s	" "	" "	" "	" "	14	88	88	24	14	2
26. average current v=49.2 cm/s	" "	UM3	" "	" "	14	179	180	27	30	1
27. reverse current direction=320°	" "	UM3/FF-LED	" "	" "	14	47	47	22	10	6
28. Q/4=0.864 MGD	" "	" "	" "	" "	4	72	72	22	6	7
29. Q/2=1.728 MGD	" "	" "	" "	" "	7	58	59	22	8	6
30. 2*Q=6.912 MGD	" "	" "	" "	" "	28	56	57	23	20	3
Far-field model sensitivity to diffusion parameter:										
31. alpha=0.0001	Ketchikan 3 7/1997	UM3/FF	299	12" port	14	94	94	22	13	81
32. alpha=0.000453	" "	" "	" "	" "	14	396	398	22	13	81

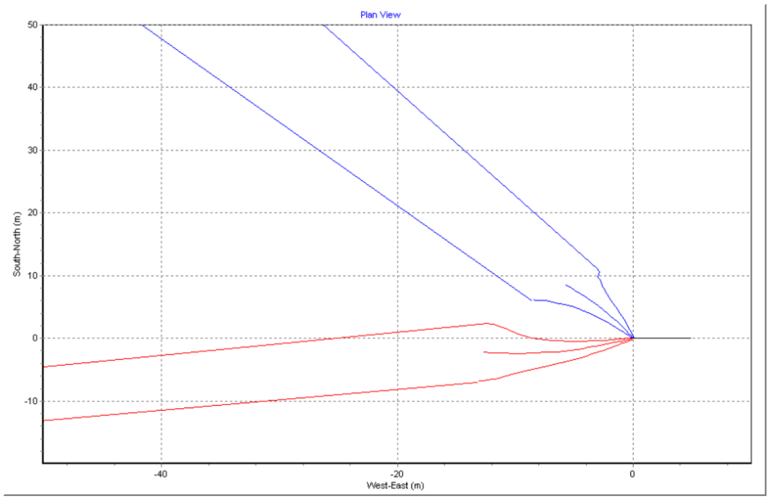

Figure 8. Ketchikan Discharge Plume Boundary Plan View from Above
(plume from 12-inch port is red; plume from five 6-inch ports is blue)

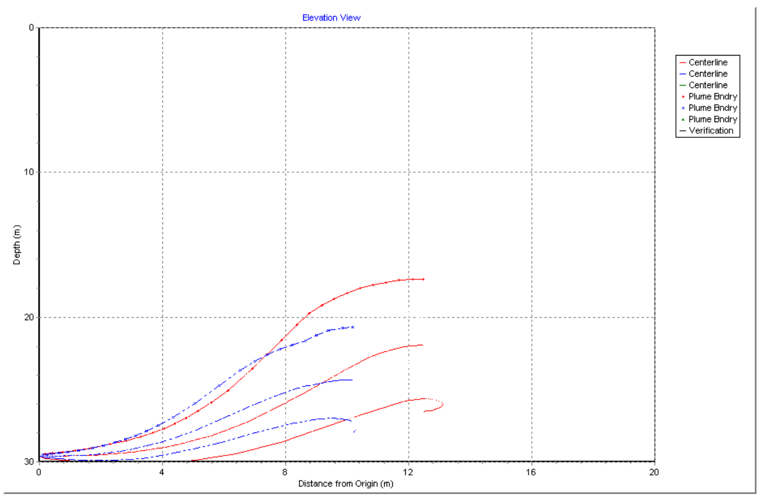

Figure 9. Ketchikan Discharge Plume Centerline and Boundary Profile View from Side

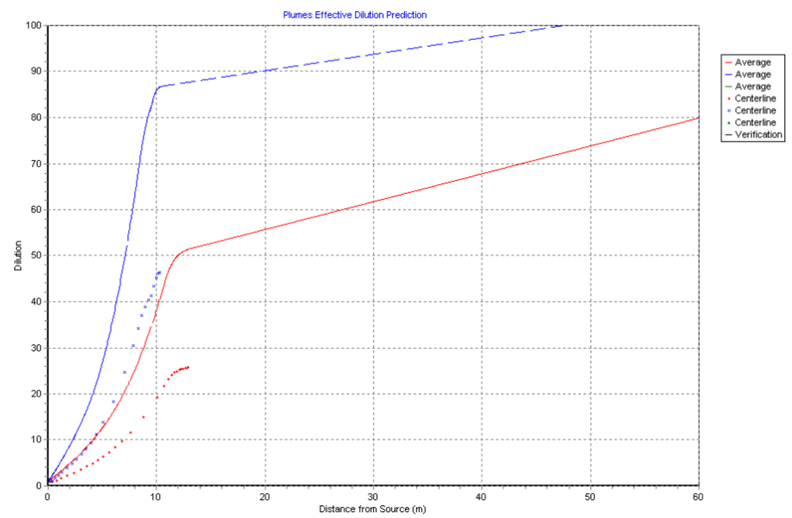

Figure 10. Ketchikan discharge plume average and centerline dilution vs. distance from outfall
Figure is based on graphic output by VP; DFs in far field (beyond 13 m for the 12-inch port) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity.

PETERSBURG

Wastewater treated at Petersburg is discharged 366 m offshore in Frederick Sound (Figure 11), from a two-port diffuser at a depth of 18.3 m (MLLW). The permitted maximum flow is 3.6 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The port spacing at Petersburg is uncertain (somewhere in the range of 10 to 34 ft.) due to only two of five diffuser ports being open. The models predicted lower DFs for the narrowest port spacing (10 ft.), so that spacing was used for all model simulations.

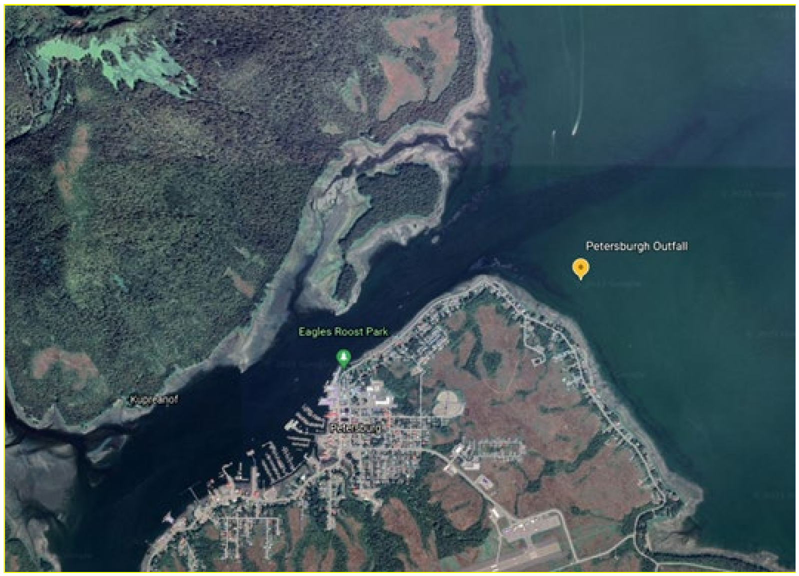

Figure 11. Aerial View of the POTW Outfall Location at Petersburg

Frederick Sound is connected to the Pacific Ocean via Chatham Strait to the northwest and Dry Strait/Sumner Strait to the southeast. According to the 1990 permit questionnaire, surface water densities near the outfall vary due to freshwater inputs from nearby streams. Maximum freshwater input to Frederick Sound occurs in summer (June or July) and minimum freshwater input occurs in March. The freshwater input is due primarily to the combined flows of the Stikine and Iskut Rivers. Currents generally flow northwestward in Frederick Sound with southwestward flows during large tides. NOAA tidal current predictions for nearby Cosmos Point (PCT3811) were used to calculate the 10th percentile current velocity used for modeling, 1.6 cm/s, and the average ebb and flood tidal velocities, 10.4 and 7.8 cm/s. According to the questionnaire, current velocities in the area are reportedly in the range of two to five knots (100 to 260 cm/s), 10 to 100 times larger than the velocities calculated from NOAA tidal current predictions and used for modeling. This discrepancy in the magnitude of ambient velocities could not be resolved given the information available, but may warrant further inquiry.

Preliminary initial dilution simulations made with UM3 for eight available ambient profiles sampled at two ZID boundary monitoring locations in January of 2002 and 2004, and August 2003 and 2005, determined that the August 2005 vertical profile from Site 1 (Figure 12) was limiting in terms of minimizing effluent dilution.

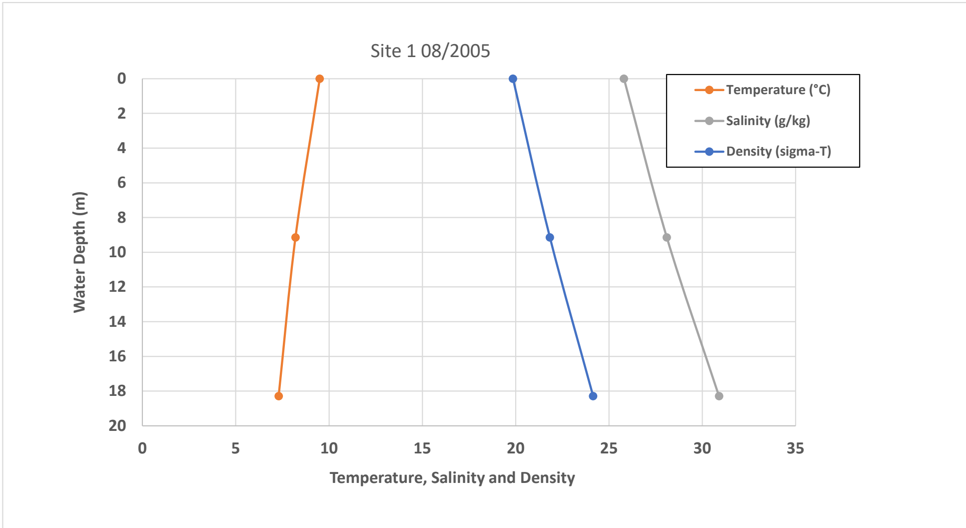

Figure 12. Vertical Ambient Profile of Temperature, Salinity and Density in Petersburg Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Petersburg are summarized in Table 5. The two applicable initial mixing models, UM3 and DKHW, gave very similar results for dilution at a distance of 1*depth (67 vs. 70). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Petersburg. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 67 to 647 (Table 5, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 13 (plan view from above of the discharge plume boundary), 14 (profile view from the side of the discharge plume centerline and boundary) and 15 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 5, the plume was trapped at a depth of 14 m by the ambient density stratification, the initial mixing region extended 23 m from the outfall, and the travel time to the mixing zone boundaries ranged from 1 minute (MZ=1*depth) to 167 minutes (MZ=10*depth). A dilution factor of 74 was predicted for the boundary of the initial mixing region and at the distance to the shore (366 m) the DF was 1720.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 5). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 21-24). Sensitivity of the far-field model to bounding values of the diffusion parameter ɑ (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Table 5. Petersburg Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
1. MZ=1*depth	Petersburg 1 8/2005	UM3	18.3	114	67	67	15	>18.3	
2. " "	" "	DKHW	18.3	114	70	70	14	>18.3	
3. " "	Petersburg 1 8/2003	UM3	18.3	95	72	73	12	>18.3	
4. " "	Petersburg 1 1/2002	UM3	18.3	114	69	69	14	>18.3	
5. " "	Petersburg 2 1/2002	UM3	18.3	113	69	69	14	>18.3	
6. " "	Petersburg 1 1/2004	UM3	18.3	114	69	69	14	>18.3	
7. " "	Petersburg 2 1/2004	UM3	18.3	114	69	69	14	>18.3	
8. " "	Petersburg 2 8/2003	UM3	18.3	94	72	72	12	>18.3	
9. " "	Petersburg 2 8/2005	UM3	18.3	116	68	68	15	>18.3	
Dilution at different distances:									
10. MZ= initial mixing region	Petersburg 1 8/2005	UM3	23	115	**74**	75	14		1
11. MZ=1*depth	" "	UM3	18.3	115	**67**	67	15	>18.3	1
12. MZ=2*depth	" "	UM3/FF	36.6	115	**90**	90	14	23	15
13. MZ=5*depth	" "	UM3/FF	91.5	115	**256**	257	14	23	72
14. MZ=10*depth	" "	UM3/FF	183	115	**647**	650	14	23	167
15. MZ=distance to nearest shore	" "	UM3/FF	366	115	**1720**	1730	14	23	358

[14] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
Model sensitivity:									
16. avg. effluent T=13.2° C	Petersburg 1 8/2005	UM3	18.3	115	67	68	15	>18.3	
17. ½*current v=0.8 cm/s	" "	UM3	18.3	115	66	66	15	>18.3	
18. 2*current v=3.2 cm/s	" "	UM3	18.3	115	70	70	15	>18.3	
19. average current v=10.4 cm/s	" "	UM3	18.3	115	80	81	16	>18.3	
20. reverse current direction=300°	" "	UM3	18.3	115	66	66	15	>18.3	
21. average Q=0.43 MGD	" "	UM3/FF	18.3	14	81	82	12	6	13
22. Q/4=0.9 MGD	" "	UM3/FF	18.3	29	68	69	13	9	9
23. Q/2=1.8 MGD	" "	UM3/FF	18.3	57	65	65	14	15	4
24. 2*Q=7.2 MGD	" "	UM3	18.3	229	65	65	17	>18.3	
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Petersburg 1 8/2005	UM3/FF	183	114	202	203	14	23	167
26. alpha=0.000453	" "	UM3/FF	183	114	1090	1091	14	23	167
27. Linear eddy diffusivity	" "	UM3/FF	183	114	397	399	14	23	167

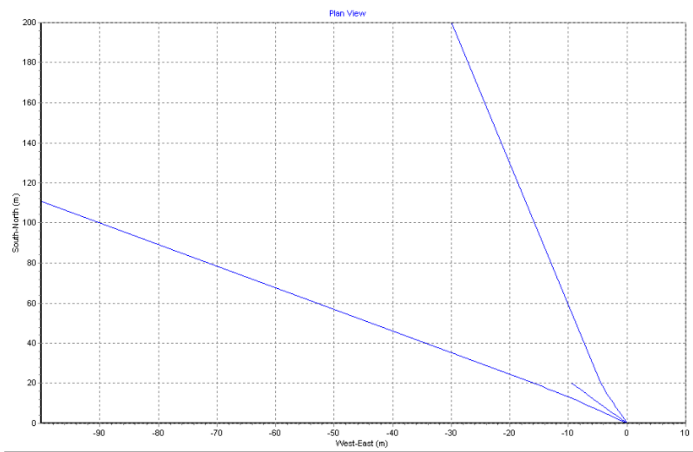

Figure 13. Petersburg Discharge Plume Boundary Plan View from Above

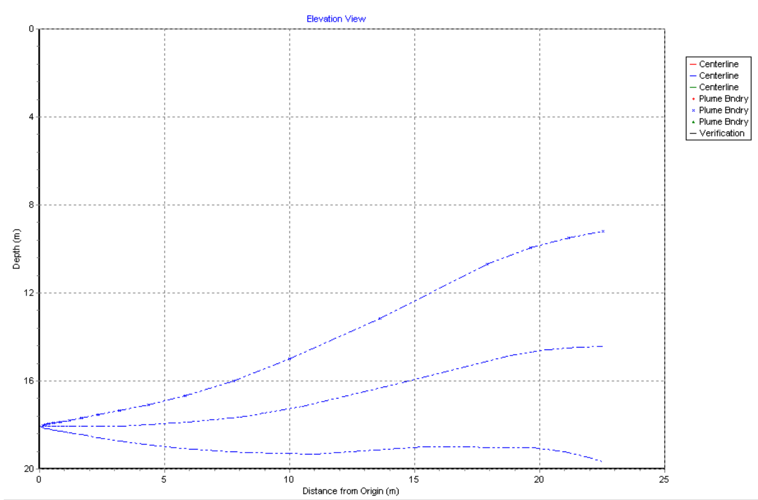

Figure 14. Petersburg Discharge Plume Centerline and Boundary Profile View from Side

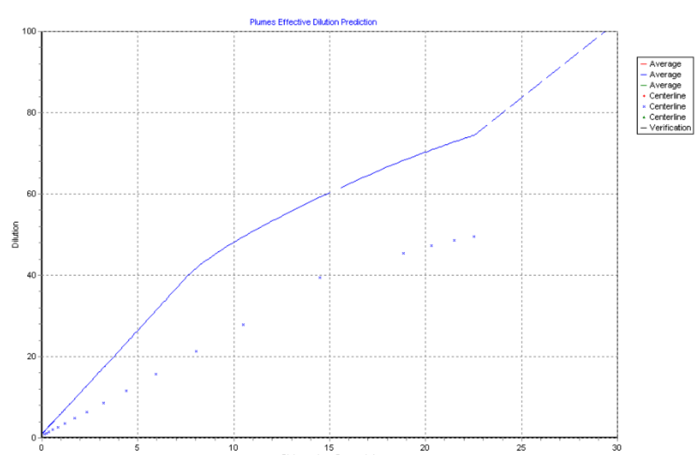

Figure 15. Petersburg Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SITKA

The wastewater treated at Sitka is discharged 114 m offshore in the Middle Channel of Sitka Sound (Figure 16), from a 16-port diffuser at a depth of 24.4 m (MLLW). The permitted maximum flow is 5.3 MGD.

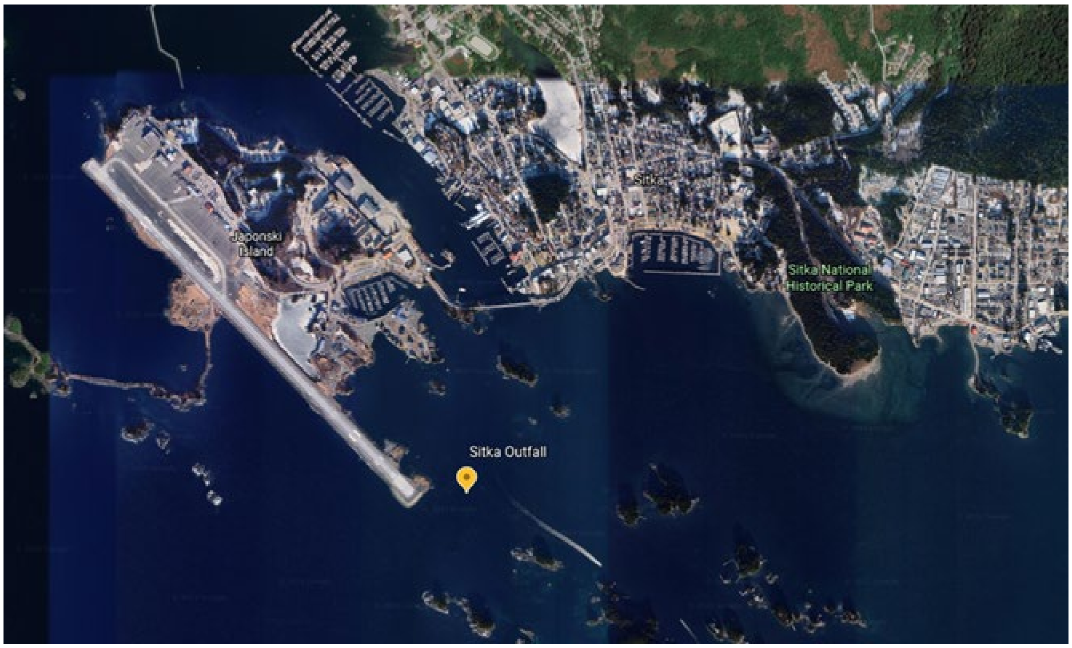

Figure 16. Aerial View of the POTW Outfall Location at Sitka

According to the permit fact sheet, the Middle Channel has relatively weak tidal currents, rotating in a clockwise pattern, which are superimposed on the seaward flow of fresh water in Sitka Sound. The net current is toward the southeast and included an easterly wind-driven component. The direction of transport of effluent from the outfall varies, depending upon the tidal stage and direction of prevailing winds. NOAA tidal current predictions for Sitka Harbor, Channel off Harbor Island (PCT4166) were used to calculate the 10^{th} percentile current velocity used for modeling, 1.7 cm/s, and the average ebb and flood tidal velocities, 10.3 and 8.0 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Detailed vertical ambient profiles were only available for one location (Site C, a reference station west of the outfall) that was in sampled in the months of April and July in 2010 and 2015. Preliminary initial dilution simulations made with UM3 for these four available ambient profiles, determined that the July 2010 vertical profile from Site C (Figure 17) was limiting in terms of minimizing effluent dilution (Table 6, simulations 1, 2, 8 and 9).

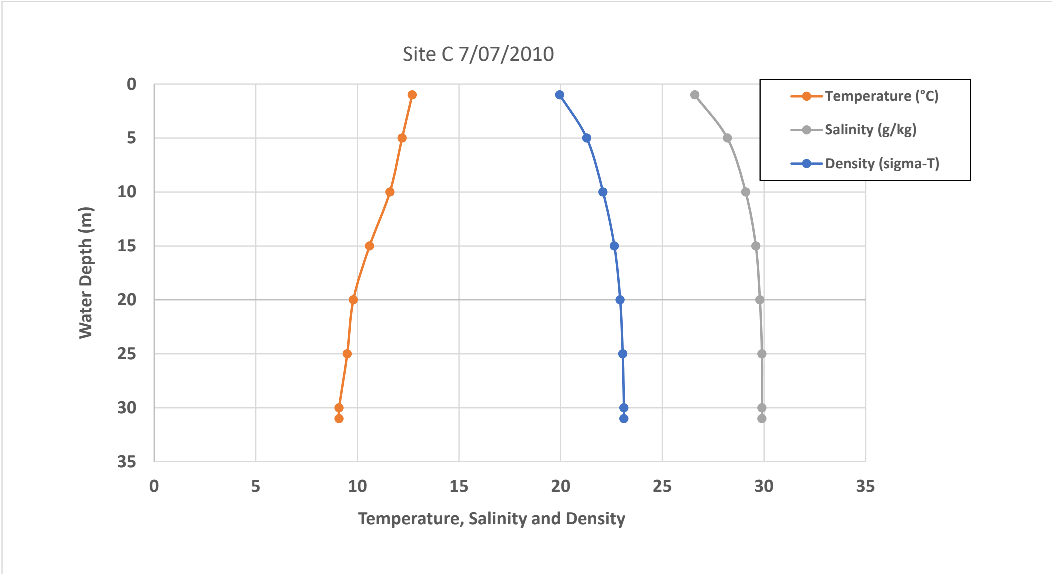

Figure 17. Vertical Ambient Profile of Temperature, Salinity and Density in Sitka Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Sitka are summarized in Table 6. The two initial mixing models, DKHW and UM3, combined with the Brooks far-field model gave similar results for dilution at a distance of 1*depth (sims. 2 and 5); simulation results for the downstream-only cross-diffuser merging approach and the third initial mixing model, NRFIELD, also fell within this range of DFs. DKHW gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Sitka.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Sitka on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 6 (simulations 14 vs. 25 and 26).

Dilution factors at distances of 1*depth to 10*depth range from 87 to 227 (Table 6, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 5*depth and 10*depth distances (122 and 244 m) are greater than the distance from the diffuser to shore (114 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 18 (plan view from above of the discharge plume boundary), 19 (profile view from the side of the discharge plume centerline and boundary) and 20 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 6, the plume was trapped at a depth of 10 m by the ambient density stratification, the initial mixing region extended 6.9 m from the outfall, and the travel time to the mixing zone boundaries ranged from 17 minutes (MZ=1*depth) to 232 minutes (MZ=10*depth). A dilution factor of 86 was predicted for the boundary of the initial mixing region and at the distance to the shore (114 m) the DF was 138.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 6). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 22-24).

Table 6. Sitka Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
1. MZ=1*depth	Sitka C 7/2015	UM3(half spacing)/FF	24.4	11	131	133	9	7	17
2. " "	Sitka C 7/2010	" "	24.4	12	118	119	12	6	18
3. " "	Sitka C 7/2010	" "	16.0	12	113	114	12	6	10
4. " "	Sitka C 7/2010	NRFIELD	16.0	12	89		10		
5. " "	Sitka C 7/2010	DKHW(half spacing)/FF	24.4	12	87	87	10	7	17
6. " "	" ";	UM3(DS-only, 8 portsx5.3")/FF	24.4	11	109	110	11	7	17
7. " "	" "	DKHW(DS-only, 8 portsx5.3")/FF	24.4	11	90	90	10	8	16
8. " "	Sitka C 4/2010	UM3(half-spacing)/FF	24.4	12	179	181	4	7	17
9. " "	Sitka C 4/2015	" "	24.4	11	172	174	5	7	17
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
10. MZ= initial mixing region	Sitka C 7/2010	DKHW(half-spacing)	6.9	12	**86**	86			1
11. MZ=1*depth	" "	DKHW(half-spacing)/FF-LED	24.4	12	**87**	87	10	7	17
12. MZ=2*depth	" "	" "	48.8	12	**97**	97	10	7	41
13. MZ=5*depth	" "	" "	122[16]	12	**143**	143	10	7	113
14. MZ=10*depth	" "	" "	244[16]	12	**227**	227	10	7	232

[15] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.
[16] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
15. MZ=distance to nearest shore	" "	" "	114	12	**138**	138	10	7	105
Model sensitivity:									
16. avg. effluent T=14° C	Sitka C 7/2010	DKHW(half-spacing)/FF-LED	24.4	12	87	87	10	7	17
17. ½*current v=0.85 cm/s	" "	" "	" "	12	79	79	9	7	35
18. 2*current v=3.4 cm/s	" "	" "	" "	12	119	119	11	9	8
19. average current v=10.3cm/s	" "	" "	" "	12	187	187	15	22	0.5
20. reverse current direction=45°	" "	" "	" "	12	87	87	10	7	17
21. current dir +30°	" "	" "	" "	12	131	131	12	7	17
22. average Q=0.98 MGD	" "	" "	" "	2	208	208	15	4	20
23. Q/2=2.65 MGD	" "	" "	" "	6	121	121	12	5	19
24. 2*Q=10.6 MGD	" "	" "	" "	23	66	66	8	12	12
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Sitka C 7/2010	DKHW(half-spacing)/FF	244	12	126	126	10	7	233
26. alpha=0.000453	" "	" "	" "	12	426	426	10	7	233

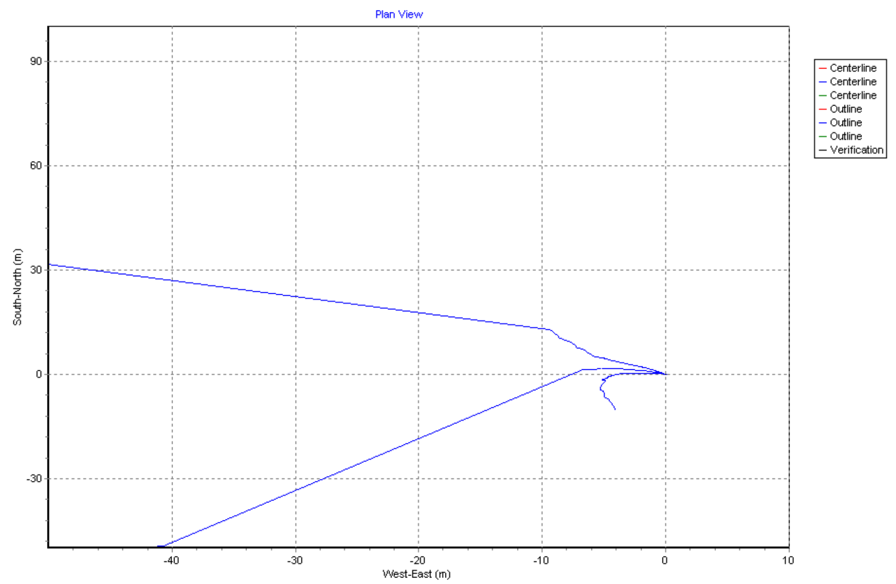

Figure 18. Sitka Discharge Plume Boundary Plan View from Above

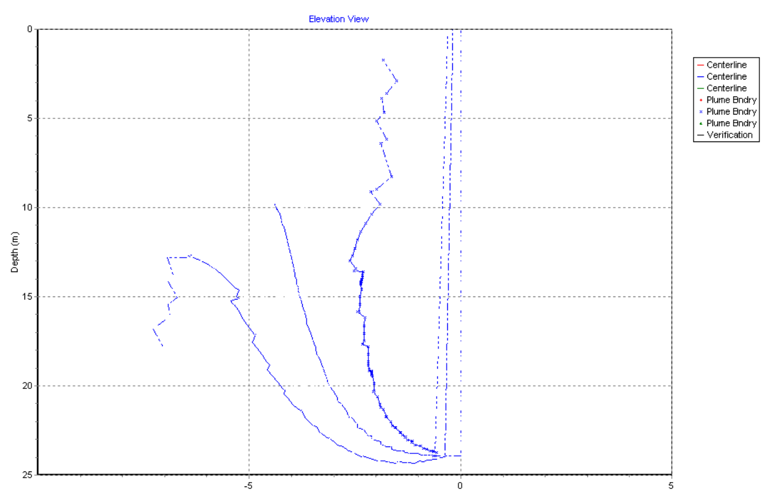

Figure 19. Sitka Discharge Plume Centerline and Boundary Profile View from Side

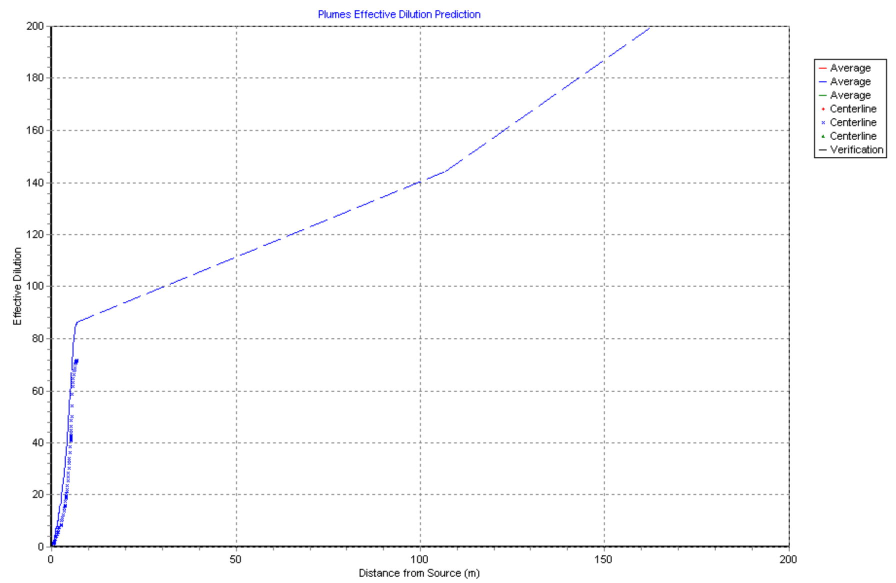

Figure 20. Sitka Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 7 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity).

SKAGWAY

Wastewater treated at Skagway is discharged 125 m offshore in Tiaya Inlet (Figure 21), at a depth of 18.3 m (MLLW), from an 8-port diffuser. The permitted maximum flow rate is 0.63 MGD.

Figure 21. Aerial View of the POTW Outfall Location at Skagway

According to the permit fact sheet, Taiya Inlet is a deep fjord with a 457 m average depth. Taiya Inlet supports a classic fjord-type, two-layer circulation, with a large saline lower layer and a very thin upper brackish layer. The circulation of the inlet is dependent on tides and freshwater flow into the inlet. There are no obstructions to impede circulation near the outfall. Stratification in Taiya Inlet is dependent on freshwater inflows from the Taiya and Skagway Rivers with the highest stratification typically occurs during the high runoff summer period from June through August. As noted in the 2007 permit reapplication, a small cross-current (2 cm/s) was present under stratified condition in a June 1999 temperature/salinity data set.

NOAA 6-minute tidal current predictions from Tiaya Inlet (SEA0825) were used to calculate the 10th percentile and average tidal current velocities (Table 2). The 10th percentile current velocity used for modeling was 1.4 cm/s, while the average ebb and flood tidal velocities were 6.9 and 12.2 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Tiaya Inlet were available for five locations that were sampled in October 2002, July and August 2004 and June 2005. Preliminary initial dilution simulations made with UM3 for all available profiles, determined that the June 2005 vertical profile measured at site 1 (shown in Figure 22) was limiting in terms of minimizing effluent dilution[17]. That profile was used for all subsequent dilution modeling at Skagway.

[17] A different vertical profile measured in June 2005 at site 5 (a site in the cruise ship terminal harbor nearest to freshwater inflow from the Skagway River) actually produced smaller DF predictions. However, the unusually low

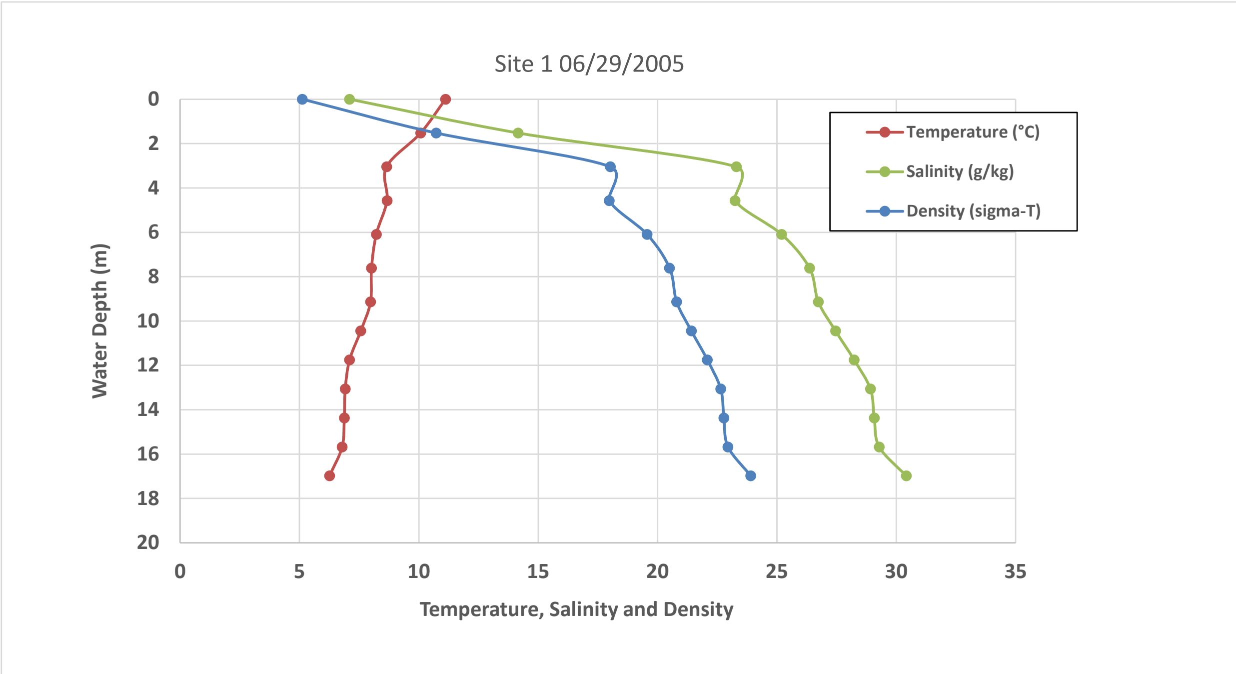

Figure 22. Vertical Ambient Profile of Temperature, Salinity and Density in Skagway Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Skagway are summarized in Table 7. Two of the applicable initial mixing models, UM3 and DKHW, gave similar results for dilution at a distance of 1*depth, for both cross-diffuser merging approaches (simulations 11-13). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Skagway. We also applied the third initial mixing model, NRFIELD, that predicted DFs reasonably comparable to UM3 (simulations 14 vs. 15) at a distance shorter than 1*depth (5.9 m).

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Skagway on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 7 (simulations 23 vs. 33 and 34).

Dilution factors at distances of 1*depth to 10*depth range from 56 to 330 (Table 7, simulations 20-23); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 10*depth distance (183 m) is greater than the distance from the diffuser to shore (125 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 23 (plan view from above of the discharge plume boundary), 24

salinity of the upper 3-4 m of that profile led to difficulties in modeling dilution over the range of parameters and conditions of interest, so the site 1 June 2005 profile (that was the next most conservative in terms of limiting DFs) was used instead.

(profile view from the side of the discharge plume centerline and boundary) and 25 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 7, the plume was trapped at a depth of 15 m by the ambient density stratification, the initial mixing region extended 3.5 m from the outfall, and the travel time to the mixing zone boundaries ranged from 18 minutes (MZ=1*depth) to 214 minutes (MZ=10*depth). A dilution factor of 42 was predicted for the boundary of the initial mixing region and at the distance to the shore (125 m) the DF was 233.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 25-32 (Table 7). DFs were moderately sensitive to variation in ambient velocity (minimum DFs at velocities near 2 cm/s, simulations 26-28) and effluent flow rate (DFs decrease with Q, simulations 30-32).

Table 7. Skagway Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Skagway site 1 10/02	UM3 (half spacing) /FF	18.3	10	129	130	9	4	17
2. " "	Skagway site 2 10/02	" "	18.3	10	145	147	7	5	16
3. " "	Skagway site 4 10/02	" "	18.3	10	127	128	9	4	17
4. " "	Skagway site 1 7/2004	" "	18.3	10	94	95	12	4	18
5. " "	Skagway site 2 7/2004	" "	18.3	10	97	97	12	4	17
6. " "	Skagway site 4 7/2004	" "	18.3	10	79	79	13	4	17
7. " "	Skagway site 1 8/2004	" "	18.3	10	130	131	9	4	17
8. " "	Skagway site 2 8/2004	" "	18.3	10	113	114	10	4	17
9. " "	Skagway site 4 8/2004	" "	18.3	10	82	83	13	4	17
10. " "	Skagway site 1 6/2005	" "	18.3	10	59	59	15	3	18
11. " "	" "	UM3(DS-only, 4x3.95")/FF	18.3	10	59	59	14	5	16
12. " "	" "	DKHW(half spacing)/FF	18.3	10	62	63	16	3	18
13. " "	" "	DKHW(DS-only, 4x3.95")/FF	18.3	10	66	66	15	4	17
14. " "	" "	NRFIELD	5.9	10	39		14		
15. " "	" "	UM3(half spacing) /FF	5.9	10	42	42	15	3	3
16. " "	Skagway site 2 6/2005	" "	18.3	10	80	80	13	4	17
17. " "	Skagway site 4 6/2005	" "	18.3	10	100	100	12	4	17
18. " "	Skagway site 5 6/2005	" "	18.3	9	39	39	16	2	19
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
19. MZ= initial mixing region	Skagway site 1 6/2005	UM3(half spacing)	3.5	10	**42**	42	15		0.7

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
20. MZ=1*depth	" "	UM3(half spacing) /FF-LED	18.3	10	**56**	56	15	3	18
21. MZ=2*depth	" "	" "	36.6	10	**86**	86	15	3	39
22. MZ=5*depth	" "	" "	91.5	10	**177**	178	15	3	105
23. MZ=10*depth	" "	" "	183[18]	10	**330**	331	15	3	214
24. MZ=distance to nearest shore	" "	" "	125	10	**233**	234	15	3	145
Model sensitivity:									
25. avg. effluent T=14.7° C	Skagway site 1 6/2005	UM3(half spacing) /FF-LED	18.3	10	56	56	15	3	18
26. ½*current v=0.7 cm/s	" "	" "	" "	10	76	76	15	3	36
27. 2*current v=2.8 cm/s	" "	" "	" "	10	52	52	15	4	9
28. average current v=12.2 cm/s	" "	" "	" "	10	101	101	17	6	2
29. reverse current direction=170°	" "	" "	" "	10	56	56	14	5	19
30. average Q=0.27 MGD				4	73	73	15	2	19
31. Q=0.5 MGD	" "	" "	" "	8	60	60	15	3	18

[18] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
32. 2*Q=1.26 MGD	" "	" "	" "	20	49	49	15	5	16
Far-field model sensitivity to diffusion parameter:									
33. alpha=0.0001	Skagway site 1 6/2005	UM3(half spacing) /FF	183	10	173	174	15	3	214
34. alpha=0.000453	" "	" "	183	10	1100	1103	15	3	214

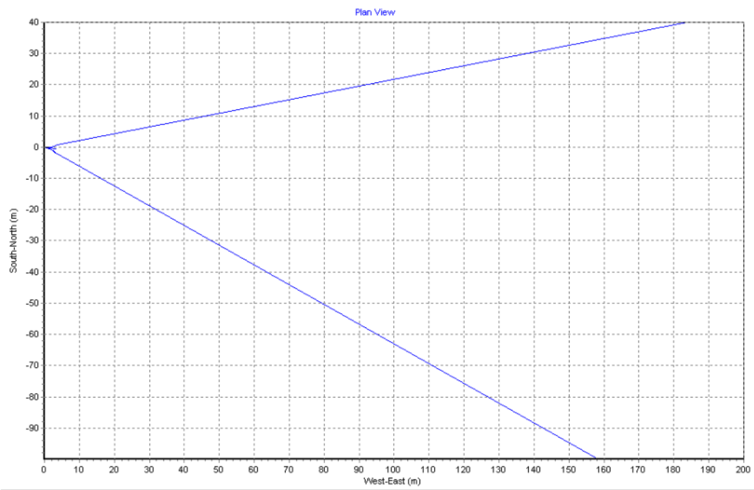

Figure 23. Skagway Discharge Plume Boundary Plan View from Above

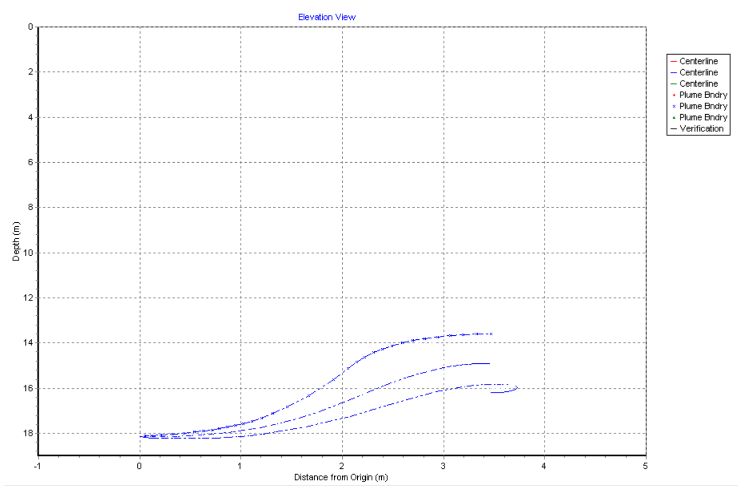

Figure 24. Skagway Discharge Plume Centerline and Boundary Profile View from Side

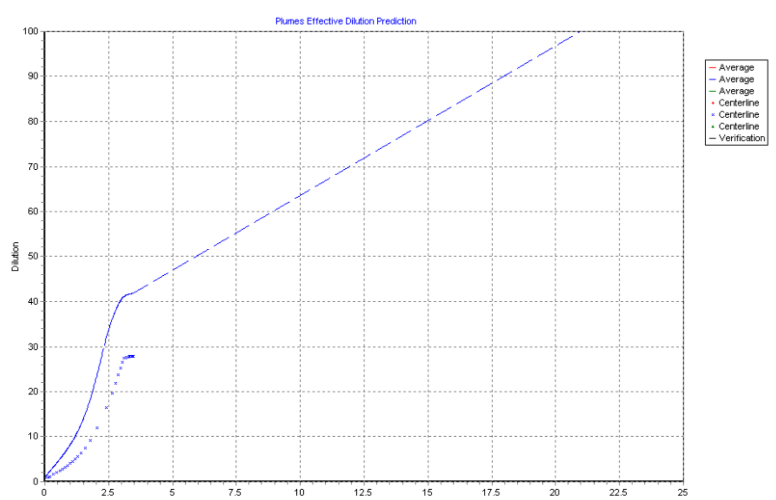

Figure 25. Skagway Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 3 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity)

WRANGELL

The wastewater treated at Wrangell is discharged 457 m offshore in the Zimovia Strait (Figure 26), at a depth of 30.5 m (MLLW), from a 16-port diffuser. The permitted maximum flow rate is 3.0 MGD.

Figure 26. Aerial View of the POTW Outfall Location at Wrangell

According to the permit fact sheet, Zimovia Strait has a net northwest seaward exchange with the Gulf of Alaska. The maximum current velocity is around 51.4 cm/sec (1.0 knot) and the water circulation patterns do not vary seasonally. Strong currents provide vertical mixing, minimize the vertical density gradient, and prevent stratification. Also, according to the permit fact sheet, prior dilution modeling in Zimovia Strait used a conservative current speed of 2.35 cm/sec and no stratification. NOAA tidal current predictions for Wrangell Harbor (PCT3131) were used to calculate the 10th percentile current velocity used for modeling, 4.0 cm/s, and the average ebb and flood tidal velocities, 20.8 and 23.5 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Zimovia strait at the ZID boundaries were available for two mixing zone locations that were sampled in August of 2015, 2016 and 2017. Preliminary initial dilution simulations made with UM3 for all profiles, determined that the vertical profile measured at station 4 in August of 2016 (shown in Figure 27) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Wrangell.

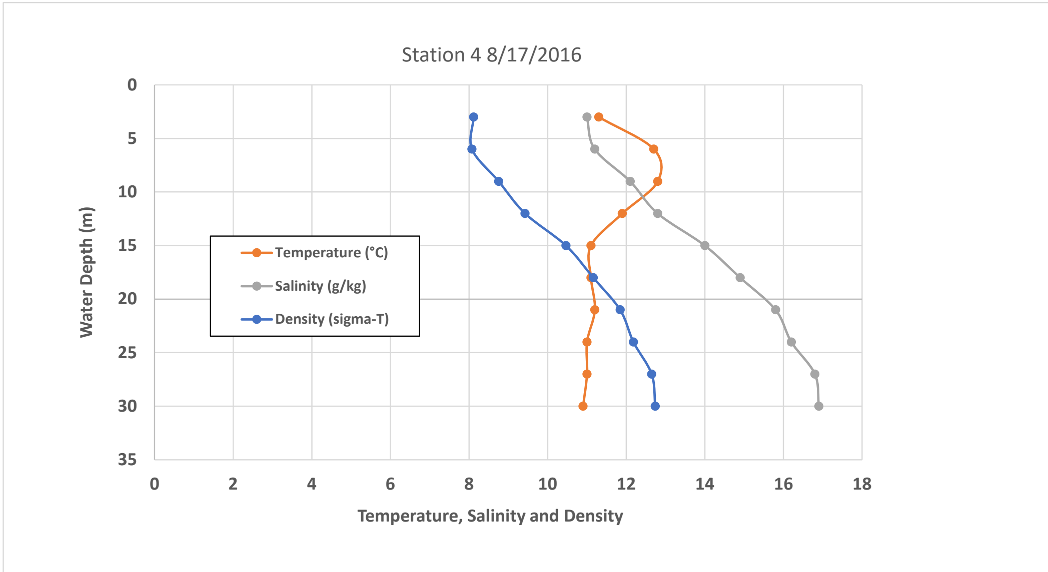

Figure 27. Vertical Ambient Profile of Temperature, Salinity and Density in Wrangell Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Wrangell are summarized in Table 8. Two of the applicable initial mixing models, UM and DKHW, gave different results for dilution at a distance of 1*depth (30.5 m; simulations 3 vs. 4). The third initial mixing model, NRFIELD, predicted a lower DF at a distance shorter than 1*depth (16.8 m; simulations 5 vs. 6). UM3 gave more conservative DF results (simulation 7) when run using the downstream-only cross-diffuser merging, so we selected this approach for further analysis at Wrangell. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Sensitivity of the far-field model to bounding values of the diffusion parameter α was found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Dilution factors at distances of 1*depth to 10*depth range from 112 to 229 (Table 8, simulations 10-13); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 28 (plan view from above of the discharge plume boundary), 29 (profile view from the side of the discharge plume centerline and boundary) and 30 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 8, the plume was trapped at a depth of 24 m by the ambient density stratification, the initial mixing region extended 12 m from the outfall, and the travel time to the mixing zone boundaries ranged from 8 minutes (MZ=1*depth) to 122 minutes (MZ=10*depth). A dilution factor of 112 was predicted for the boundary of the initial mixing region and at the distance to the shore (457 m) the DF was 323.

The initial mixing model was moderately sensitive to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 8). DFs were sensitive to variation in ambient velocity (dilution increasing with velocity, simulations 17-19) and effluent flow rate (dilution decreases with Q, simulations 21-24).

Table 8. Wrangell Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
1. MZ=1*depth	Wrangell station 4 8/2015	UM3(half spacing)/FF	30.5	34	262	274	23	15	7
2. " "	Wrangell station 3 8/2016	" "	" "	33	232	243	23	13	8
3. " "	Wrangell station 4 8/2016	" "	" "	32	153	160	25	10	8
4. " "	" "	DKHW(half spacing)/FF	" "	32	228	228	26	11	8
5. " "	" "	UM3 (half spacing)/FF	16.8	32	153	157	25	10	3
6. " "	" "	NRFIELD	16.8	33	75		25		
7. " "	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	112	117	24	12	8
8. " "	Wrangell station 3 8/2017	UM3(half-spacing)/FF	" "	39	494	516	17	25	2
9. " "	Wrangell station 4 8/2017	" "	" "	40	743	791	6	21	4
Dilution at different distances:									
10. MZ= initial mixing region	Wrangell station 4 8/2016	UM3 (DS-only, 8x3.95")	12	33	**112**	113	24		2
11. MZ=1*depth	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	**112**	113	24	12	8
12. MZ=2*depth	" "	" "	61	33	**115**	115	24	12	20
13. MZ=5*depth	" "	" "	152.5	33	**149**	149	24	12	59
14. MZ=10*depth	" "	" "	305	33	**229**	230	24	12	122

[19] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
15. MZ=distance to nearest shore	" "	" "	457	33	**323**	325	24	12	185
Model sensitivity:									
16. avg. effluent T=17.3° C	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	30.5	33	112	112	24	12	8
17. ½*current v=2 cm/s	" "	" "	" "	33	86	86	24	11	16
18. 2*current v=8 cm/s	" "	" "	" "	33	198	199	25	15	3
19. ave. current v=23.5 cm/s	" "	UM3 (DS-only, 8x3.95")	" "	33	412	412	27	31	2
20. reverse current direction=270°	" "	UM3(DS-only, 8x3.95")/FF	" "	33	112	113	24	12	8
21. ave. Q=0.36 MGD	" "	" "	" "	3.9	243	244	26	5	11
22. Q/4=0.75 MGD	" "	" "	" "	8.1	161	161	25	6	10
23. Q/2=1.5 MGD	" "	" "	" "	16	125	126	25	8	9
24. 2*Q=6.0 MGD	" "	" "	" "	65	119	120	25	18	5
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	305	33	130	131	24	12	122
26. alpha=0.000453	" "	" "	" "	33	321	323	24	12	122
27. Linear eddy diffusivity	" "	" "	" "	33	203	204	24	12	122

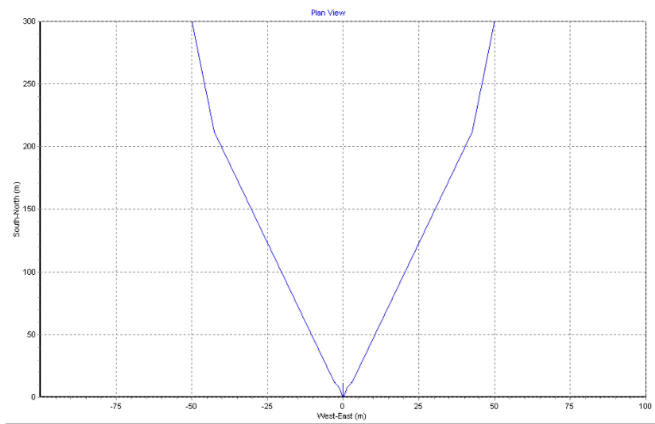

Figure 28. Wrangell Discharge Plume Boundary Plan View from Above

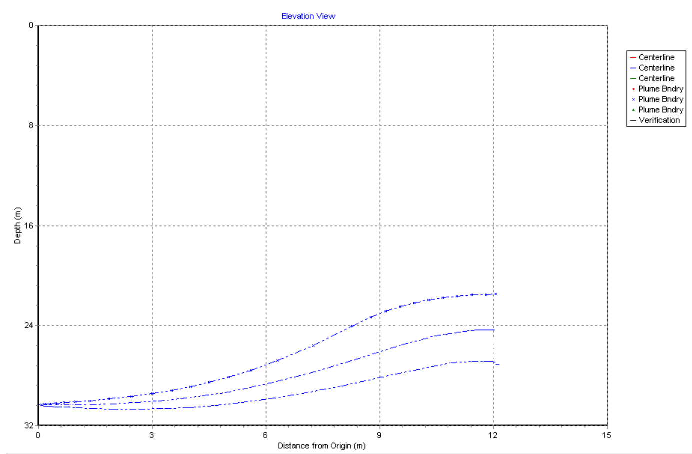

Figure 29. Wrangell Discharge Plume Centerline and Boundary Profile View from Side

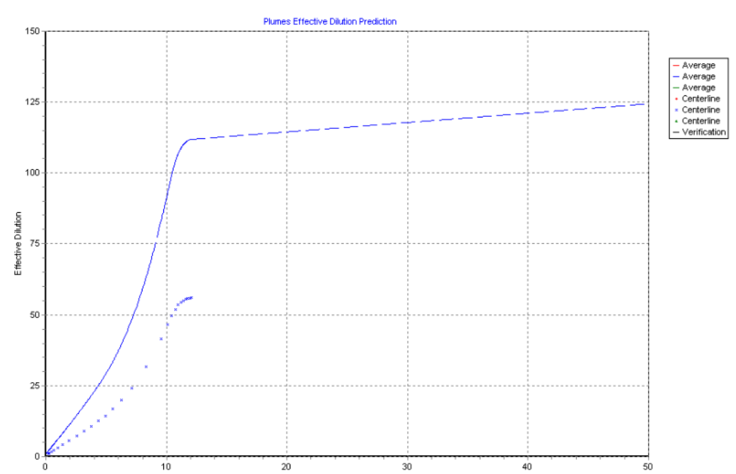

Figure 30. Wrangell Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SUMMARY

A summary of the average dilution predictions at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point at each Alaskan mixing zone location is presented in Table 9. As indicated in this table, some of the distances exceed the distance from the outfall to the nearest shore. Under some conditions the tidal currents could direct the discharge plume towards the shore and, upon reaching this boundary, further mixing would likely not occur. The distance from the outfall to nearest shore at each location and the predicted DFs and travel times for these distances are presented in Table 10. The dilution predictions are also graphed as a function of distance from the outfall (Figure 31). In this figure, DFs for Ketchikan, Sitka and Skagway have been truncated at the distance to shore.

Table 9. Average Dilution Factor Predictions at Distances from the Discharge Point Corresponding to 1-10 Times the Depth of Discharge

Location	1*depth			2*depth			5*depth			10*depth		
	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)
Haines	21.3	100	4	43	136	19	107	330	65	213	766	143
Ketchikan	29.9	52	5	60	62	13	150	105	39	299*	179	81
Petersburg	18.3	67	1	37	90	15	92	256	72	183	647	167
Sitka	24.4	87	17	49	97	41	122*	143	113	244*	227	232
Skagway	18.3	56	18	37	86	39	92	177	105	183*	330	214
Wrangell	30.5	112	8	61	115	20	153	149	59	305	229	122

* Distance greater than the distance from the outfall to shore.

Table 10. Average Dilution Factor Predictions at the Distance from the Outfall to Shore

Location	Distance from outfall to shore (m)	DF at distance from outfall to shore	Travel time to shore (min)
Haines	549	2770	386
Ketchikan	221	141	59
Petersburg	366	1720	358
Sitka	114	138	105
Skagway	125	233	145
Wrangell	457	323	185

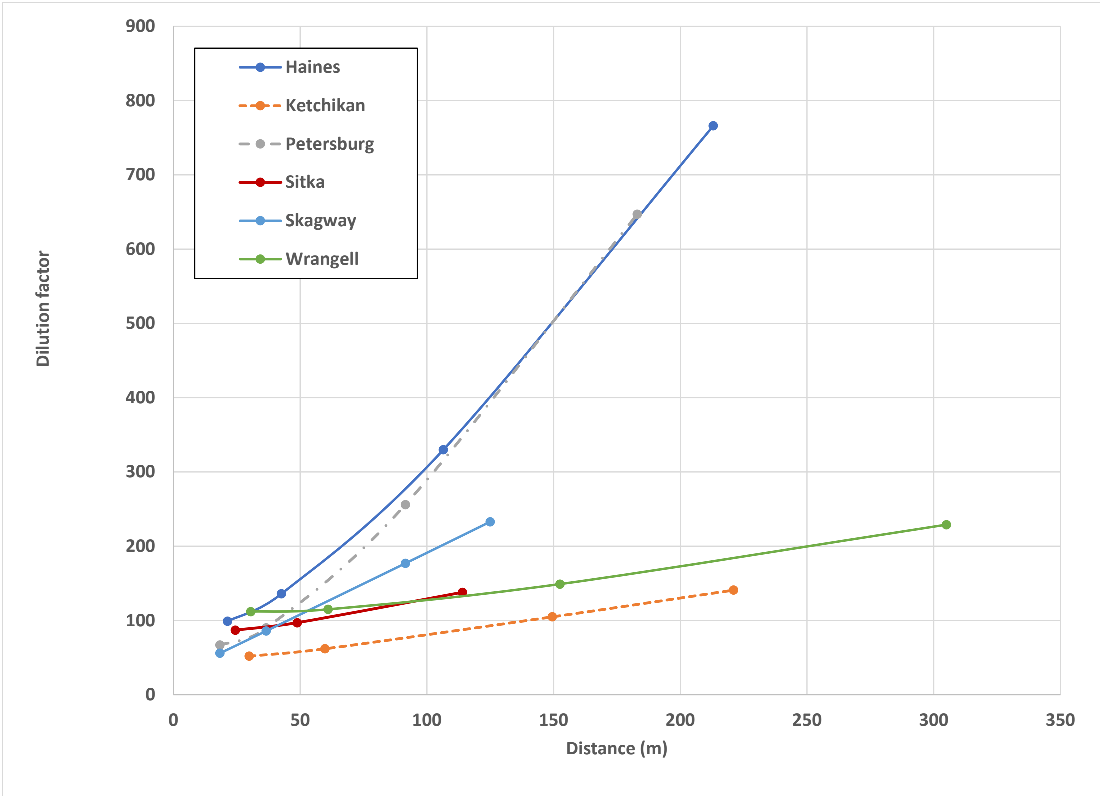

Figure 31. DF Predictions Graphed as a Function of Distance from the Outfall
(predictions are DFs for distances corresponding to 1-10 times the depth of discharge; in the cases of Ketchikan, Sitka and Skagway, DFs have been truncated at the distances to the shore)

A summary of the dilution factors predicted at the initial mixing region boundaries is presented in Table 11. For each location this table includes the distance to this boundary, the predicted DF and the travel times to the boundary. Compared to the depth-based distances in Table 9, the initial mixing region boundary distances are quite short, although the DFs at a distance of 1*depth are comparable (within 25%) of the initial mixing region dilution factors.

Table 11. Dilution Factor Predictions at Distances Equal to Initial Mixing Region Boundaries

Location	Initial Mixing Region Boundary (m)	DF	Travel Time to Boundary (min)
Haines	16	99	1
Ketchikan	13	51	1
Petersburg	23	74	1
Sitka	6.9	86	1
Skagway	3.5	42	0.7
Wrangell	12	112	2

The far-field model was also used to calculate the distances required to attain the FC criteria (i.e., the DFs in Table 1). These distances, presented in Table 11, range from 3.4 to 135 km to attain the 43/100 mL FC criterion and 7.2 to 420 km to attain the 14/100 mL FC criterion. These distances greatly exceed the mixing zone sizes certified by the state in the current wastewater discharge permits for the six POTW facilities.

Table 12. Dilution Factors and Mixing Zone Distances Required to Attain FC Criteria

Location	DF required to attain the 43/100 mL FC criterion	Distance to attain the 43/100 mL FC criterion (km)	DF required to attain the 14/100 mL FC criterion	Distance to attain the 14/100 mL FC criterion (km)
Haines	50,000	4.0	150,000	8.3
Ketchikan	67,000	135	210,000	420
Petersburg	47,000	3.4	140,000	7.2
Sitka	87,000	126	270,000	390
Skagway	60,000	36	190,000	114
Wrangell	4,400	3.9	14,000	8.9

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APPENDIX: VP AND FARFIELD[20] OUTPUT FOR EACH LOCATION

Haines (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Haines" memo4

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:19:37 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000192	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000194	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000193	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000193	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000193	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000193	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000193	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000193	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000193	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000193	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000192	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000192	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000192	0.023	90.00	0.0003	23.93584

[20] If required.

22.00 0.023 90.00 34.78 4.213 0.0 0.000192 0.023 90.00 0.0003 27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 21.300 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Iso dia (m)
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.0; 10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058; 10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614; bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261; 10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599; trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475; merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425; local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
21392.8	99.34	12.34	16.27	2.78E-4	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
20539.8	99.48	14.21	21.30	0.061	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
18354.2	113.1	20.80	37.57	0.258	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5

count: 1
;
5:19:40 AM. amb fills: 4
/ UM3. 6/23/2021 5:20:06 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192

11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 42.600 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (m)
0 21.10 2.300 2.343 2.130E+6 1.000 0.0 0.0 0.05935; 10.68 T-90hr,
100 21.10 2.300 23.86 208749.0 10.20 0.000 1.346 0.6058; 10.68 T-90hr,
160 21.03 2.300 77.28 63725.7 33.42 0.000 4.775 1.9614; bottom hit; 10.65 T-90hr,
200 20.49 2.300 166.7 28847.1 73.76 0.000 10.62 4.2261; 10.42 T-90hr,
204 20.37 2.300 179.9 26645.8 79.84 0.000 11.48 4.5599; trap level; 10.37 T-90hr,
205 20.34 2.300 183.3 26122.1 81.44 0.000 11.71 4.6475; merging; 10.36 T-90hr,
232 19.97 2.300 305.7 21392.8 99.34 0.000 16.27 7.7425; local maximum rise or fall; 10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
21392.8 99.34 12.34 16.27 2.78E-4 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
19386.1 118.7 23.00 42.60 0.318 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
15243.7 136.7 30.62 58.87 0.515 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:20:07 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	42.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.317995169	26.33	42.6	1.36E+02	1.56E+04	137

```
/ UM3. 6/23/2021 5:20:24 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------
--------------------

Ambient Table:
   Depth  Amb-cur  Amb-dir  Amb-sal  Amb-tem  Amb-pol Solar rad  Far-spd  Far-dir  Disprsn
Density
       m      m/s      deg      psu       C     kg/kg      s-1       m/s      deg  m0.67/s2  sigma-T
     0.0    0.023    90.00    7.100    11.12      0.0  0.000194    0.023    90.00   0.0003  5.180276
   1.523    0.023    90.00    14.16    10.08      0.0  0.000198    0.023    90.00   0.0003  10.78304
   3.047    0.023    90.00    23.30    8.650      0.0  0.000197    0.023    90.00   0.0003  18.06627
   4.570    0.023    90.00    23.25    8.670      0.0  0.000196    0.023    90.00   0.0003  18.02474
   6.090    0.023    90.00    25.20    8.220      0.0  0.000196    0.023    90.00   0.0003  19.60292
   7.617    0.023    90.00    26.37    8.020      0.0  0.000196    0.023    90.00   0.0003  20.54204
   9.140    0.023    90.00    26.74    7.980      0.0  0.000196    0.023    90.00   0.0003  20.83621
   10.45    0.023    90.00    27.46    7.570      0.0  0.000196    0.023    90.00   0.0003  21.45192
   11.75    0.023    90.00    28.24    7.100      0.0  0.000196    0.023    90.00   0.0003  22.12180
   13.06    0.023    90.00    28.92    6.920      0.0  0.000195    0.023    90.00   0.0003  22.67724
   14.37    0.023    90.00    29.08    6.880      0.0  0.000195    0.023    90.00   0.0003  22.80770
   15.68    0.023    90.00    29.29    6.790      0.0  0.000195    0.023    90.00   0.0003  22.98359
   16.98    0.023    90.00    30.42    6.260      0.0  0.000195    0.023    90.00   0.0003  23.93584
   22.00    0.023    90.00    34.78    4.213      0.0  0.000195    0.023    90.00   0.0003  27.61629

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)     (m)     (m)     ()   (ft)     (m)(concent)    (m)  (MGD)   (psu)    (C)(col/dl)
  3.0000     0.0  90.000     0.0     0.0  2.0000  15.000  106.50  200.00  21.100  2.9000     0.0  15.800
2.13E+6

Simulation:
Froude No:     178.8; Strat No: 2.20E-3; Spcg No:   76.82; k:   992.9; eff den (sigmaT) -0.960860; eff vel
22.84(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (m)
   0    21.10    2.300    2.343 2.130E+6    1.000      0.0      0.0  0.05935;  10.68 T-90hr,
 100    21.10    2.300    23.86 208749.0    10.20    0.000    1.346   0.6058;  10.68 T-90hr,
 160    21.03    2.300    77.28  63725.7    33.42    0.000    4.775   1.9614; bottom hit;  10.65 T-90hr,
 200    20.49    2.300    166.7  28847.1    73.76    0.000    10.62   4.2261;  10.42 T-90hr,
 204    20.37    2.300    179.9  26645.8    79.84    0.000    11.48   4.5599; trap level;  10.37 T-90hr,
 205    20.34    2.300    183.3  26122.1    81.44    0.000    11.71   4.6475; merging;  10.36 T-90hr,
 232    19.97    2.300    305.7  21392.8    99.34    0.000    16.27   7.7425; local maximum rise or fall;
10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   16.274
Lmz(m):   16.274
forced entrain      1   1.873   1.132   7.764   1.000
Rate sec-1   0.00019515 dy-1      16.8607  kt:  0.000062421 Amb Sal      33.0175
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of      12.34 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)      (m)     (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
```

21392.8	99.34	12.34	16.27	2.78E-4	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
16299.5	181.1	56.68	106.5	1.090	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
10795.8	194.1	66.75	122.8	1.287	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5

count: 1
;
5:20:24 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	106.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	8.5548E-03	m^2/s
Beta =	3.6170E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.0897343	90.23	106.5	3.30E+02	6.43E+03	331

/ UM3. 6/23/2021 5:20:41 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	90.000	0.0	0.0	2.0000	15.000	213.00	200.00	21.100	2.9000	0.0	15.800	2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(m)	
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.05935;	10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058;	10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614;	bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261;	10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599;	trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475;	merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425;	local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
21392.8	99.34	12.34	16.27	2.78E-4	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5

12646.5 246.9 121.4 200.0 2.219 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
8191.65 256.7 134.2 216.3 2.416 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:20:41 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	213	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

				Eo =	8.5548E-03	m^2/s
				Beta =	3.6170E-01	unitless
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.375966184	196.73	213	7.66E+02	2.77E+03	768

Ketchikan (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Ketchikan_1port" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:27:49 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000196	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	29.900	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2374;	13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410;	13.32 T-90hr,

200 27.61 5.900 135.6 1142.4 17.50 -6.017 -2.060 14.40 3.3681; 12.62 T-90hr,
249 24.16 5.900 233.0 562.5 35.49 -9.308 -2.435 34.83 5.6507; trap level; 11.26 T-90hr,
276 22.92 5.900 300.9 445.7 44.77 -10.56 -2.414 45.33 7.2032; begin overlap; 10.77 T-90hr,
300 22.48 5.900 333.7 414.4 48.13 -11.13 -2.377 50.59 7.9496; 10.60 T-90hr,
400 21.94 5.900 383.7 388.9 51.25 -12.54 -2.254 64.07 9.1014; 10.40 T-90hr,
417 21.94 5.900 385.5 387.6 51.42 -12.73 -2.235 65.91 9.1403; local maximum rise or fall; 10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
387.592 51.42 9.799 12.92 2.78E-4 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
372.140 52.31 12.10 29.90 0.0802 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
346.023 56.38 13.95 42.82 0.141 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
count: 1
;
5:27:49 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	29.9	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	7.99E-02	16.98	29.90	5.22E+01	3.82E+02	52

/ UM3. 6/23/2021 5:28:05 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	59.800	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222;	13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410;	13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681;	12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507;	trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032;	begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496;	10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014;	10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403;	local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
361.000	64.47	16.52	59.80	0.221	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
273.501	71.65	18.57	72.72	0.282	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 1
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	59.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.21E-01	46.88	59.80	6.24E+01	3.19E+02	63

5:28:05 AM. amb fills: 4
/ UM3. 6/23/2021 5:28:34 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	149.50	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222; 13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410; 13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681; 12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507; trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032; begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496; 10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014; 10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403; local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4 5.9972E-5
329.541	122.8	32.26	149.5	0.643	0.0	16.00	5.900	140.0	3.00E-4 5.9972E-5
149.151	132.4	34.81	162.4	0.704	0.0	16.00	5.900	140.0	3.00E-4 5.9972E-5

count: 1
;
5:28:34 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
		Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	149.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.43E-01	136.58	149.50	1.05E+02	1.89E+02	106

/ UM3. 6/23/2021 5:28:46 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: -------------------
----

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn
Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.059 140.0 24.50 15.20 0.0 0.000195 0.059 140.0 0.0003 17.89918
1.000 0.059 140.0 24.50 15.20 0.0 0.0002 0.059 140.0 0.0003 17.89918
16.10 0.059 140.0 26.80 13.80 0.0 0.0002 0.059 140.0 0.0003 19.93814
33.90 0.059 140.0 30.90 8.000 0.0 0.000199 0.059 140.0 0.0003 24.08526

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp
Polutnt
(in) (deg) (deg) (m) (m) () (m)(concent) (m) (MGD) (psu) (C)(col/dl)
12.000 0.0 205.00 0.0 0.0 1.0000 299.00 100.00 29.600 3.4560 0.0 20.500 20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff
vel 3.402(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 29.60 5.900 9.372 20000.0 1.000 0.0 0.0 0.0 0.2222; 13.41 T-90hr,
100 29.37 5.900 61.18 2975.1 6.722 -2.606 -1.081 3.096 1.5410; 13.32 T-90hr,
200 27.61 5.900 135.6 1142.4 17.50 -6.017 -2.060 14.40 3.3681; 12.62 T-90hr,
249 24.16 5.900 233.0 562.5 35.49 -9.308 -2.435 34.83 5.6507; trap level; 11.26 T-90hr,
276 22.92 5.900 300.9 445.7 44.77 -10.56 -2.414 45.33 7.2032; begin overlap; 10.77 T-
90hr,
300 22.48 5.900 333.7 414.4 48.13 -11.13 -2.377 50.59 7.9496; 10.60 T-90hr,
400 21.94 5.900 383.7 388.9 51.25 -12.54 -2.254 64.07 9.1014; 10.40 T-90hr,
417 21.94 5.900 385.5 387.6 51.42 -12.73 -2.235 65.91 9.1403; local maximum rise or
fall; 10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
387.592 51.42 9.799 12.92 2.78E-4 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
313.051 161.8 42.56 200.0 0.881 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
94.9421 348.2 91.63 400.0 1.823 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
54.9006 361.8 95.21 412.9 1.884 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
count: 2
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	299	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	6.2830E-03	m^2/s
Beta =	1.3053E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.35E+00	286.08	299.00	1.79E+02	1.11E+02	180

Petersburg (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Petersburg" me

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:40:38 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------
----

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	18.300	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.0746;	9.342 T-90hr,

100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
221 14.97 1.600 323.8 29956.8 67.21 -7.796 16.57 45.91 8.2053; MZ dis; 8.143 T-90hr,
forced entrain 1 1.914 3.095 8.224 0.970
Rate sec-1 0.00019604 dy-1 16.9376 kt: 0.000077955 Amb Sal 29.8950
Mixing Zone reached in near-field, no far-field calculation attempted
;
5:40:38 AM. amb fills: 4
/ UM3. 6/23/2021 5:40:52 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	36.600	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.07918; 9.342 T-90hr,
100	18.07	1.600	27.00	233103.2	8.665	-0.637	1.364	0.470	0.6855; 9.340 T-90hr,
177	17.70	1.600	121.5	50815.2	39.73	-3.202	6.837	9.667	3.0831; merging; 9.198 T-90hr,
200	16.92	1.600	192.0	38804.9	51.98	-4.867	10.37	20.86	4.8693; 8.895 T-90hr,
212	15.74	1.600	258.0	32719.8	61.58	-6.629	14.10	35.23	6.5408; trap level; 8.436 T-90hr,
269	14.43	1.600	412.1	27015.9	74.42	-9.596	20.37	63.81	10.443; local maximum rise or fall; 7.935 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)

27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
24577.8 89.58 21.72 36.60 0.245 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
13316.6 149.2 37.30 59.12 0.636 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
;
5:40:52 AM. amb fills: 4
/ UM3. 6/23/2021 5:41:05 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------------------

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.016 120.0 25.80 9.500 0.0 0.000195 0.016 120.0 0.0003 19.89413
9.150 0.016 120.0 28.10 8.200 0.0 0.000196 0.016 120.0 0.0003 21.86897
18.29 0.016 120.0 30.90 7.300 0.0 0.000196 0.016 120.0 0.0003 24.18118
20.00 0.016 120.0 31.42 7.132 0.0 0.000195 0.016 120.0 0.0003 24.61448

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
4.0000 0.0 115.00 0.0 0.0 2.0000 10.000 91.500 200.00 18.070 3.6000 0.0 14.600 2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 18.07 1.600 3.124 2.020E+6 1.000 0.0 0.0 0.0 0.07916; 9.342 T-90hr,
100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
269 14.43 1.600 412.1 27015.9 74.42 -9.596 20.37 63.81 10.443; local maximum rise or fall; 7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
18670.4 255.8 64.12 91.50 1.198 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
5869.71 340.7 85.44 114.0 1.589 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
; 5:41:06 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	9.6530E-03	m^2/s
Beta =	5.3588E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.197569444	68.98	91.5	2.56E+02	7.86E+03	257

/ UM3. 6/23/2021 5:41:17 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.016 120.0 25.80 9.500 0.0 0.000195 0.016 120.0 0.0003 19.89413
9.150 0.016 120.0 28.10 8.200 0.0 0.000196 0.016 120.0 0.0003 21.86897
18.29 0.016 120.0 30.90 7.300 0.0 0.000196 0.016 120.0 0.0003 24.18118
20.00 0.016 120.0 31.42 7.132 0.0 0.000195 0.016 120.0 0.0003 24.61448

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
4.0000 0.0 115.00 0.0 0.0 2.0000 10.000 183.00 200.00 18.070 3.6000 0.0 14.600 2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 18.07 1.600 3.124 2.020E+6 1.000 0.0 0.0 0.0 0.07916; 9.342 T-90hr,
100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
269 14.43 1.600 412.1 27015.9 74.42 -9.596 20.37 63.81 10.443; local maximum rise or fall; 7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
11807.9 646.9 162.2 183.0 2.786 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
2638.61 760.1 190.6 205.5 3.177 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
;
5:41:17 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.786111111	160.48	183	6.47E+02	3.11E+03	650

Sitka (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Sitka" memo

Model configuration items checked: Brooks far-field solution; Report effective dilution; ;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 1
Light absorption coefficient 0.16
Farfield increment (m) 100
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	24.400	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:

Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	23.94	1.700	4.000	3.740E+6	0.0	0.0	0.0	0.0	0.1014; 11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016; 11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780; 11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632; 11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372; 11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162; 11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883; 11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405; 11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165; merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498; 11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298; 10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616; 10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416; 9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811; 9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450; 8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048; 7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008; 6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4 5.5441E-5
3.53E+6	87.12	100.3	24.40	0.287	0.0	8.000	1.700	225.0	3.00E-4 5.5441E-5
9.94E+5	89.08	107.1	31.25	0.399	0.0	8.000	1.700	225.0	3.00E-4 5.5441E-5

count: 1

;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	24.4	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.87E-01	17.549	24.40	8.70E+01	4.30E+04	87

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	48.800	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
43327.2 86.32 83.51 6.851 2.78E-4 0.0 8.000 1.700 225.0 3.00E-4 5.5441E-5

```
 3.26E+6  98.22  125.2  48.80  0.686   0.0  8.000  1.700  225.0 3.00E-4 5.5441E-5
 2.14E+5  102.8  132.5  55.65  0.798   0.0  8.000  1.700  225.0 3.00E-4 5.5441E-5
count: 1
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	48.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.85E-01	41.949	48.80	9.65E+01	3.87E+04	97

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	122.00	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.76E+6	138.1	183.2	100.0	1.522	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

```
 46877.1   236.4   315.8   200.0   3.156     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 23592.2   243.8   325.7   206.9   3.268     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 2
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	122	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	1.0947E-01	m^2/s	
			Beta =	9.2555E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.88E+00	115.149	122.00	1.43E+02	2.61E+04	143

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	244.00	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014; 11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016; 11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780; 11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632; 11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372; 11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162; 11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883; 11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405; 11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165; merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498; 11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298; 10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616; 10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416; 9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811; 9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450; 8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048; 7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008; 6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.76E+6	138.1	183.2	100.0	1.522	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

46877.1	236.4	315.8	200.0	3.156	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
17411.5	352.0	470.5	300.0	4.790	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
13591.4	360.5	481.8	306.9	4.902	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 3

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	244	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.87E+00	237.149	244.00	2.27E+02	1.65E+04	227

Skagway (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Skagway" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:51:09 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000195	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt

```
   (in)   (deg)   (deg)     (m)     (m)     ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
  3.0000     0.0  350.00     0.0     0.0  8.0000  3.5000  18.300  200.00  18.150  0.6300     0.0  17.300
2.59E+6

Simulation:
Froude No:     10.06; Strat No: 2.47E-3; Spcg No:   17.93; k:   88.59; eff den (sigmaT) -1.214163; eff vel
1.240(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)      ()      (m)      (m)      (s)      (m)
   0    18.15    1.400    2.343 2.590E+6    1.000      0.0      0.0      0.0    0.0594;  9.458 T-90hr,
 100    18.07    1.400    12.32 471750.7    5.490    0.639   -0.113    1.673    0.3130;  9.424 T-90hr,
 200    17.61    1.400    21.87 219905.3    11.77    1.318   -0.232    6.056    0.5554;  9.240 T-90hr,
 267    16.05    1.400    42.65  85238.4    30.34    2.296   -0.405    19.44    1.0826; trap level, merging;
8.615 T-90hr,
 300    15.34    1.400    63.27  67833.1    38.10    2.732   -0.482    28.58    1.6057;  8.339 T-90hr,
 318    15.20    1.400    71.39  65187.4    39.64    2.853   -0.503    31.31    1.8117; begin overlap;  8.285
T-90hr,
 400    14.95    1.400    94.95  62151.2    41.55    3.192   -0.563    39.26    2.4091;  8.187 T-90hr,
 480    14.90    1.400    102.6  61721.1    41.83    3.409   -0.601    44.43    2.6036; local maximum rise or
fall;  8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m):   0.0000; CL(m):   3.4620
Lmz(m):   3.4620
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal      29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.07 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 55457.0   59.02   19.36   18.30  0.295     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 38485.5   66.05   21.80   21.76  0.363     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:09 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	18.3	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.94E-01	14.838	18.30	5.61E+01	4.60E+04	56

/ UM3. 6/23/2021 5:51:23 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	36.600	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620

forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
61721.1 41.83 10.08 3.462 2.78E-4 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
50071.9 100.1 33.29 36.60 0.658 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
23499.3 108.8 36.19 40.06 0.726 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
count: 1
;
5:51:23 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	36.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.58E-01	33.138	36.60	8.58E+01	3.01E+04	86

/ UM3. 6/23/2021 5:51:35 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	91.500	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 36855.9   263.9   87.83   91.50   1.747    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 9323.75   275.8   91.82   94.96   1.816    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:35 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.75E+00	88.038	91.50	1.77E+02	1.46E+04	178

/ UM3. 6/23/2021 5:51:47 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	183.00	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
61721.1	41.83	10.08	3.462	2.78E-4	0.0	16.30	1.400	350.0	3.00E-4	7.8146E-5
22115.3	634.0	211.0	183.0	3.563	0.0	16.30	1.400	350.0	3.00E-4	7.8146E-5
3965.60	649.9	216.3	186.5	3.631	0.0	16.30	1.400	350.0	3.00E-4	7.8146E-5

count: 1
;
5:51:47 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.56E+00	179.538	183.00	3.30E+02	7.82E+03	331

Wrangell (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Wrangell" memoQ=

Model configuration items checked: Brooks far-field solution; Report effective dilution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 8/3/2021 9:23:16 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000194	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000194	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000194	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000194	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000194	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000194	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000194	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000194	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000194	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000194	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)

3.9500 0.0 90.000 0.0 0.0 8.0000 32.000 30.500 200.00 30.350 3.0000 0.0 18.400
1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

```
      Depth  Amb-cur   P-dia  Polutnt  net Dil  x-posn  y-posn   Time   Iso dia
Step   (m)   (cm/s)    (in)  (col/dl)    ()      (m)     (m)     (s)     (m)
  0   30.35   4.000   3.085 191000.0   1.000     0.0     0.0     0.0     0.0;  14.06 T-90hr,
 100  30.32   4.000   21.88  25869.1   7.383   0.000   1.223   1.461  0.5546;  14.05 T-90hr,
 200  29.23   4.000   75.55   6306.8   30.29   0.000   5.127   18.85  1.9038;  13.64 T-90hr,
 265  25.85   4.000   147.1   2462.3   77.57   0.000   9.228   57.16  3.6599; trap level;  12.34 T-90hr,
 300  24.85   4.000   191.4   1914.4   99.77   0.000   10.45   72.89  4.7344;  11.95 T-90hr,
 301  24.84   4.000   192.3   1907.0   100.2   0.000   10.47   73.16  4.7551; begin overlap;  11.95 T-90hr,
 400  24.32   4.000   227.5   1702.3   112.2   0.000   11.88   93.03  5.6075;  11.75 T-90hr,
 415  24.32   4.000   228.3   1697.3   112.5   0.000   12.05   95.47  5.6269; local maximum rise or fall;  11.75 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn  width distnce   time bckgrnd   decay current cur-dir eddydif
(col/dl)          (m)     (m)   (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4   0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1632.35   112.0   81.17   30.50  0.128    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1668.65   112.4   85.91   42.55  0.212    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
```

count: 1
;
9:23:18 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT

4/3 Power Law
Eo=(alpha)*(width)$^{4/3}$
(Grace/Brooks equation 7-66)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	30.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.128125	18.45	30.5	1.12E+02	1697	113

/ UM3. 8/3/2021 9:24:14 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	61.000	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603; 14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546; 14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038; 13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599; trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344; 11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551; begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075; 11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269; local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1565.88   114.7   93.35   61.00   0.340    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1596.09   117.5   98.31   73.05   0.424    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:24:14 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	61	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.339930556	48.95	61	1.15E+02	1657	115

/ UM3. 8/3/2021 9:24:33 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	152.50	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603;	14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546;	14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038;	13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599;	trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344;	11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551;	begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075;	11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269;	local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1382.28 148.5 133.1 152.5 0.976 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1220.33 154.2 138.7 164.5 1.059 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 1
;
9:24:33 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	152.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	9.3337E-02	m^2/s	
			Beta =	3.7799E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	0.975347222	140.45	152.5	1.49E+02	1280	149

/ UM3. 8/3/2021 9:24:50 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	305.00	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603; 14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546; 14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038; 13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599; trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344; 11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551; begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075; 11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269; local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1295.62 171.8 155.5 200.0 1.306 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
819.357 286.6 261.7 400.0 2.694 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
642.616 294.2 268.7 412.0 2.778 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 2
;
9:24:50 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	305	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.034375	292.95	305	2.29E+02	829	230