**FINAL**

# Mixing Zone Dilution Modeling for Six Alaska POTWs

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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.

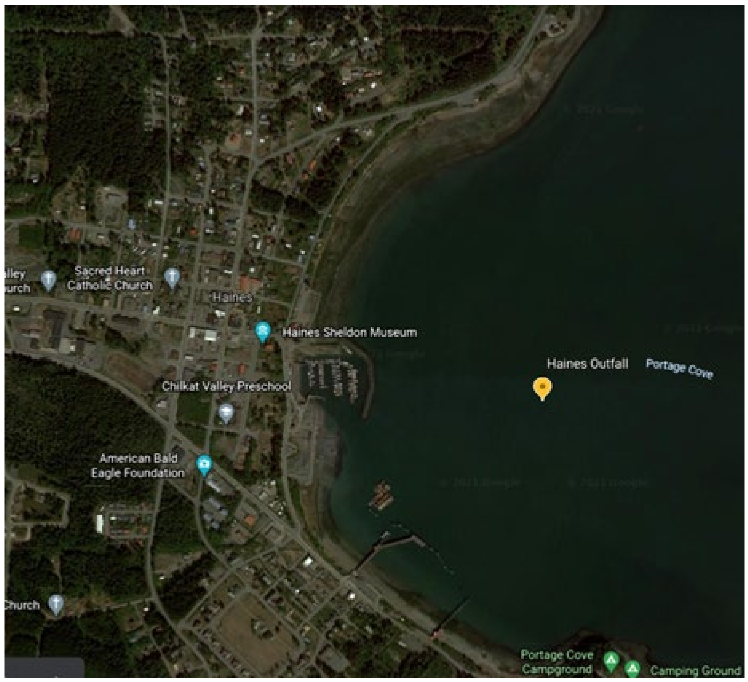


**Figure 1. Aerial View of the POTW Outfall Location at Haines**

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.

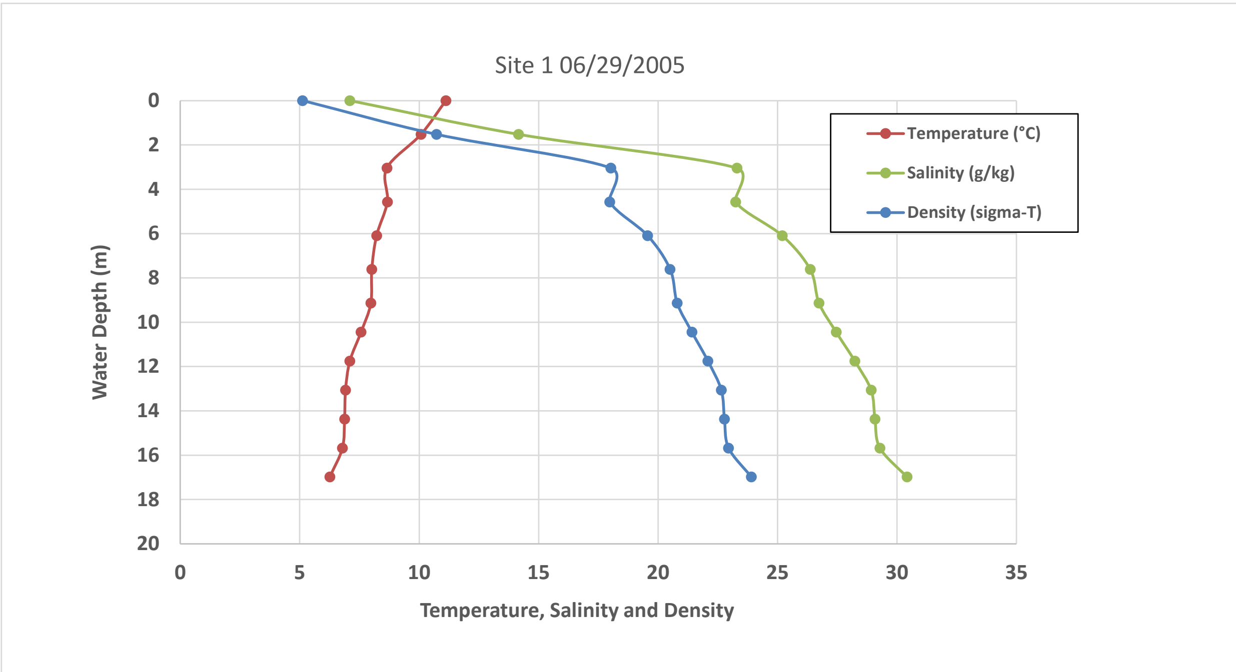


**Figure 2. Vertical Ambient Profile of Temperature, Salinity and Density in Haines Mixing Zones Resulting in Least Mixing**

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 |

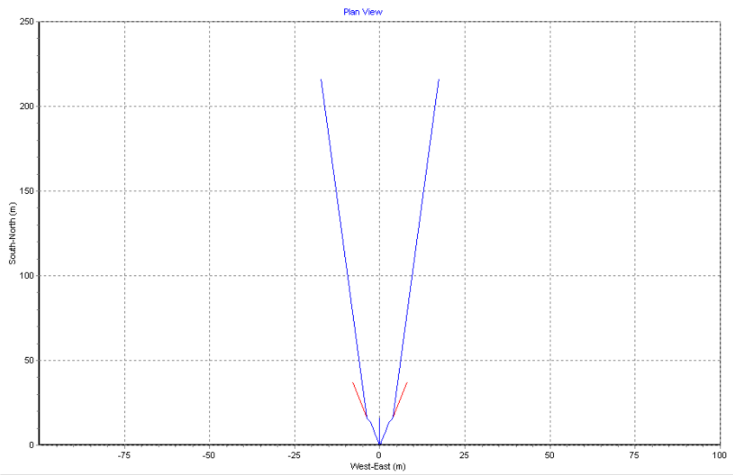


**Figure 3. Haines Discharge Plume Boundary Plan View from Above**

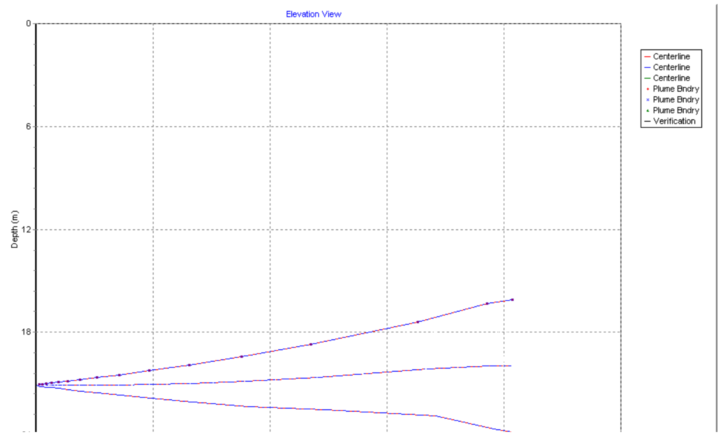


**Figure 4. Haines Discharge Plume Centerline and Boundary Profile View from Side**

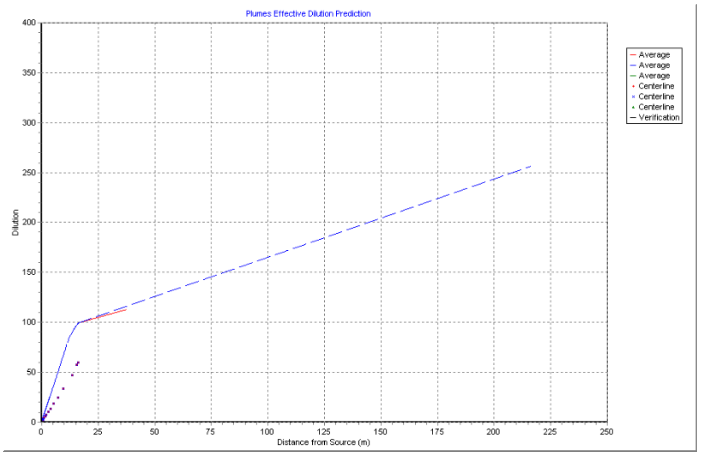


**Figure 5. Haines Discharge Plume Average and Centerline Dilution vs. Distance from Outfall**

## 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 10$^{th}$ percentile and average tidal current velocities at a depth of 87 ft. (26.5 m; Table 2). The 10$^{th}$ 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.

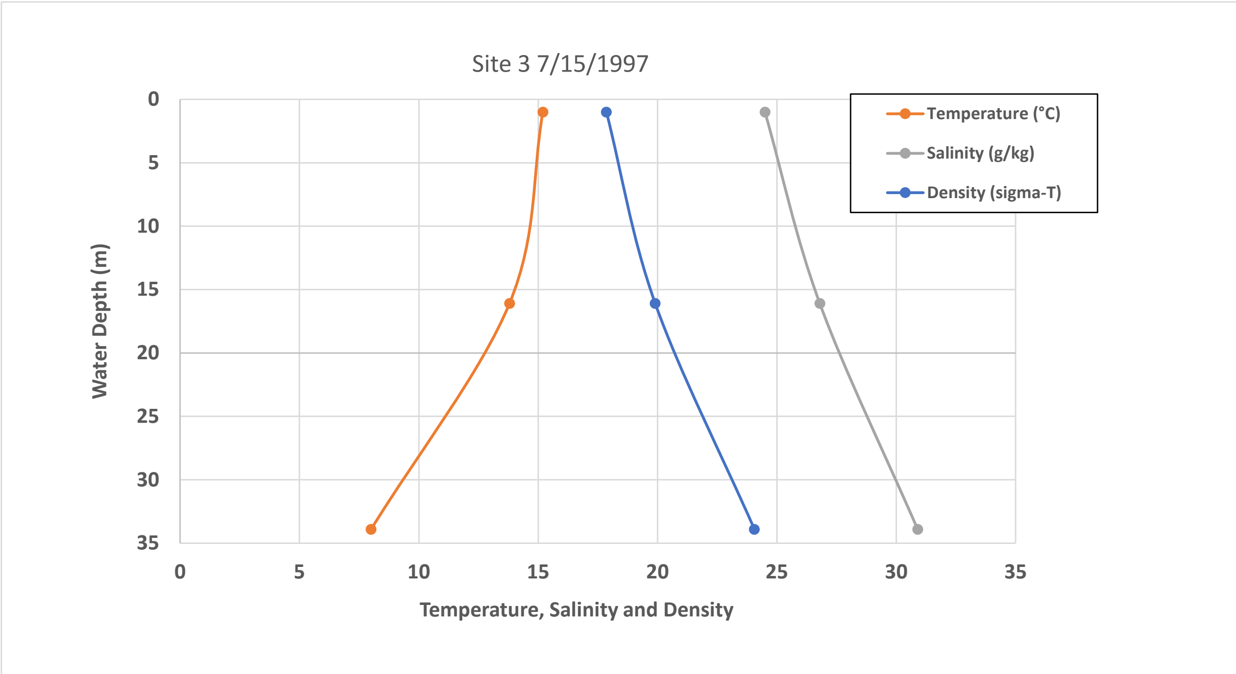


**Figure 7. Vertical Ambient Profile of Temperature, Salinity and Density in Ketchikan Mixing Zone Resulting in Least Mixing.**

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 |

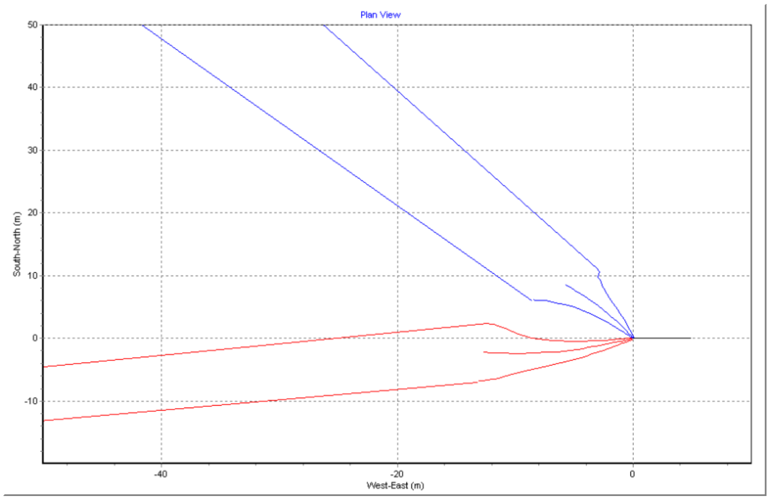


**Figure 8. Ketchikan Discharge Plume Boundary Plan View from Above**
(plume from 12-inch port is red; plume from five 6-inch ports is blue)

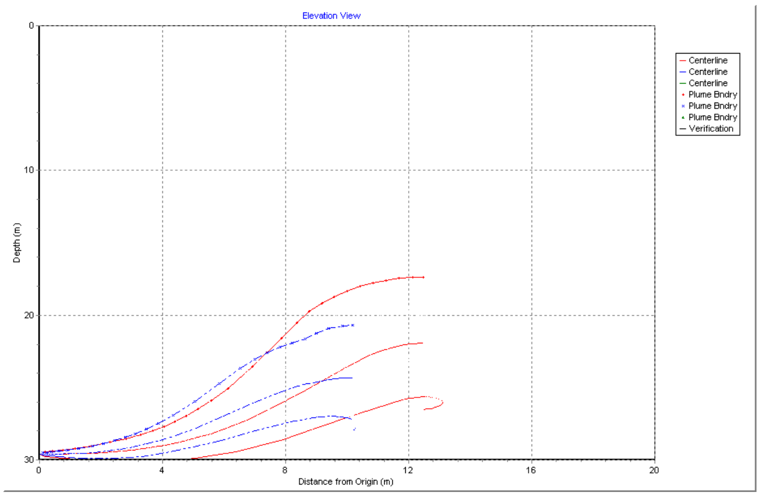


**Figure 9. Ketchikan Discharge Plume Centerline and Boundary Profile View from Side**

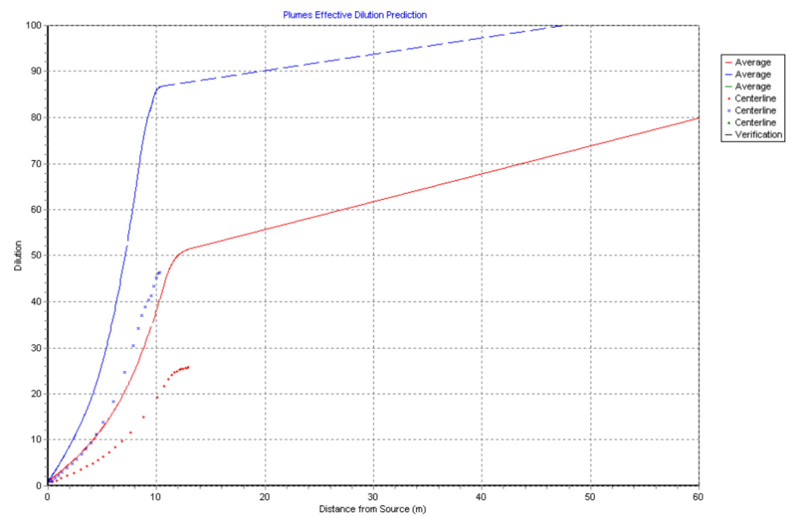


**Figure 10. Ketchikan discharge plume average and centerline dilution vs. distance from outfall**
Figure is based on graphic output by VP; DFs in far field (beyond 13 m for the 12-inch port) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity.

## 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.

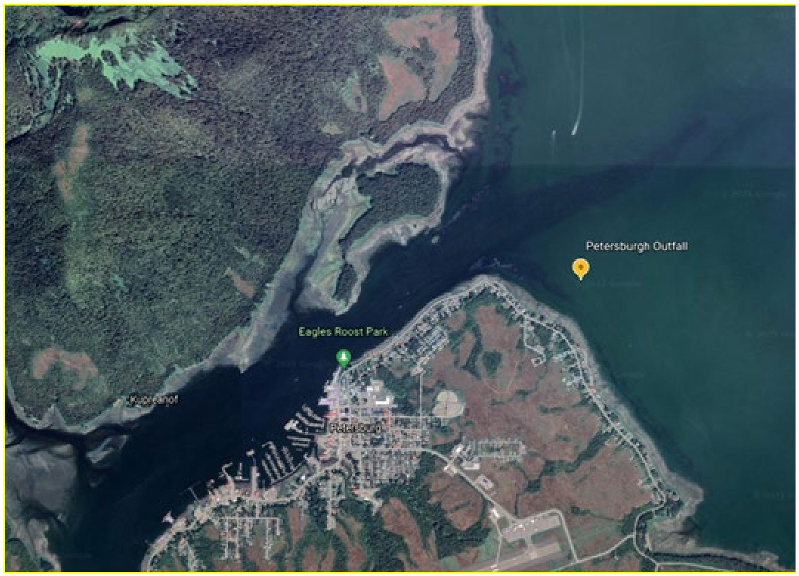


**Figure 11. Aerial View of the POTW Outfall Location at Petersburg**

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 10$^{th}$ 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.

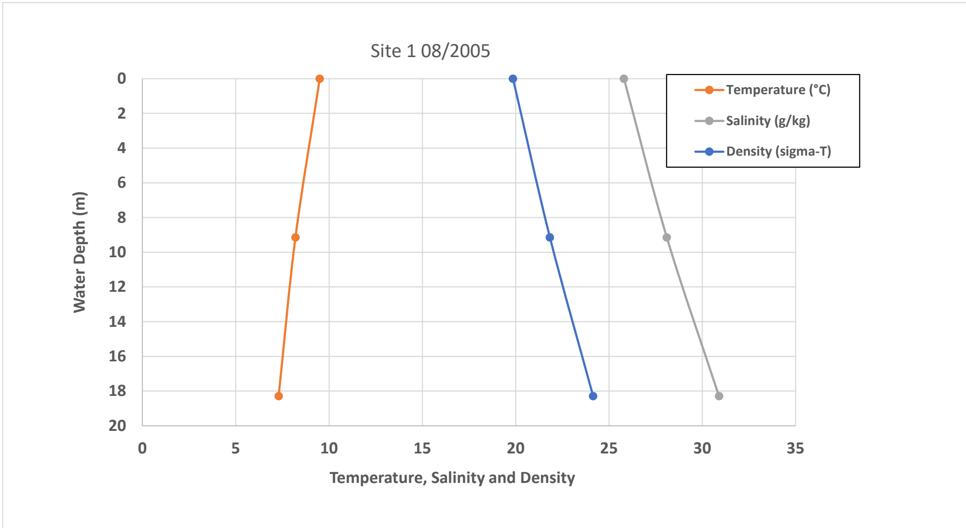


**Figure 12. Vertical Ambient Profile of Temperature, Salinity and Density in Petersburg Mixing Zone Resulting in Least Mixing**

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 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.

**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 |

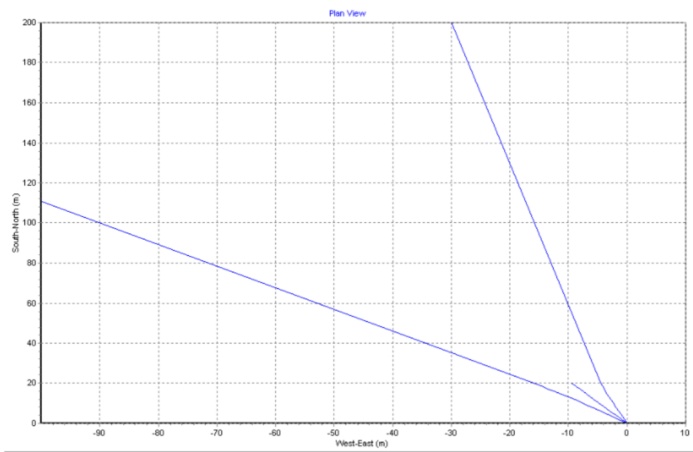


**Figure 13. Petersburg Discharge Plume Boundary Plan View from Above**

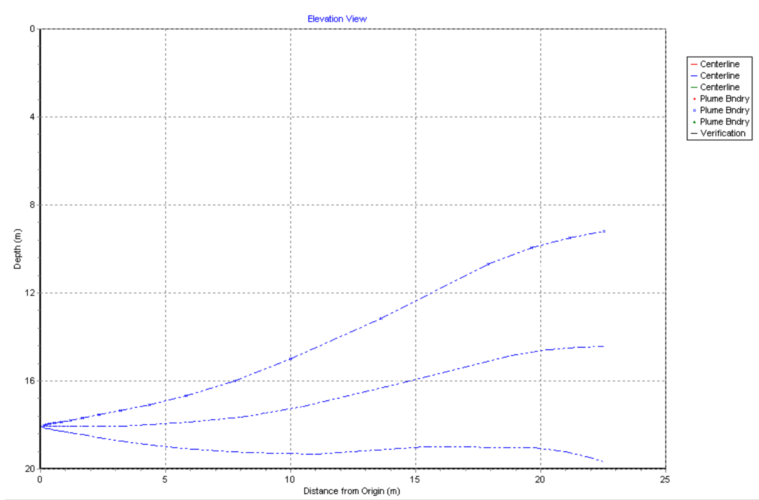


**Figure 14. Petersburg Discharge Plume Centerline and Boundary Profile View from Side**

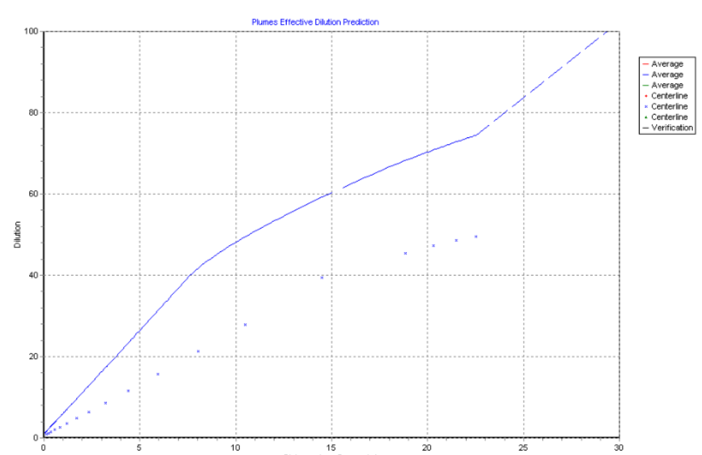


**Figure 15. Petersburg Discharge Plume Average and Centerline Dilution vs. Distance from Outfall**

## 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.

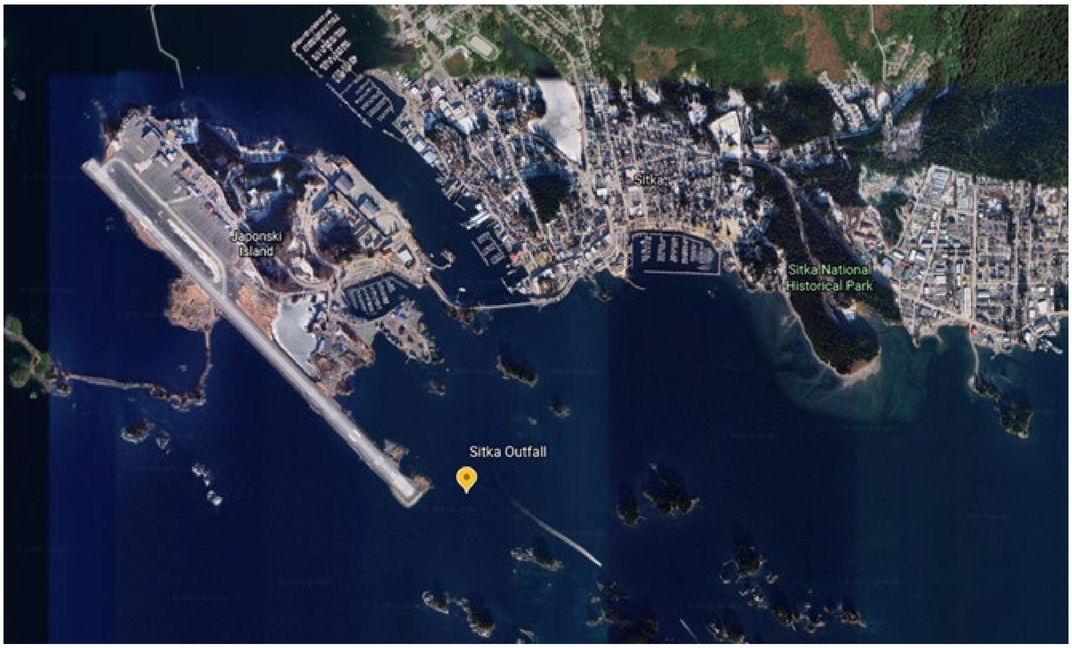


**Figure 16. Aerial View of the POTW Outfall Location at Sitka**

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).

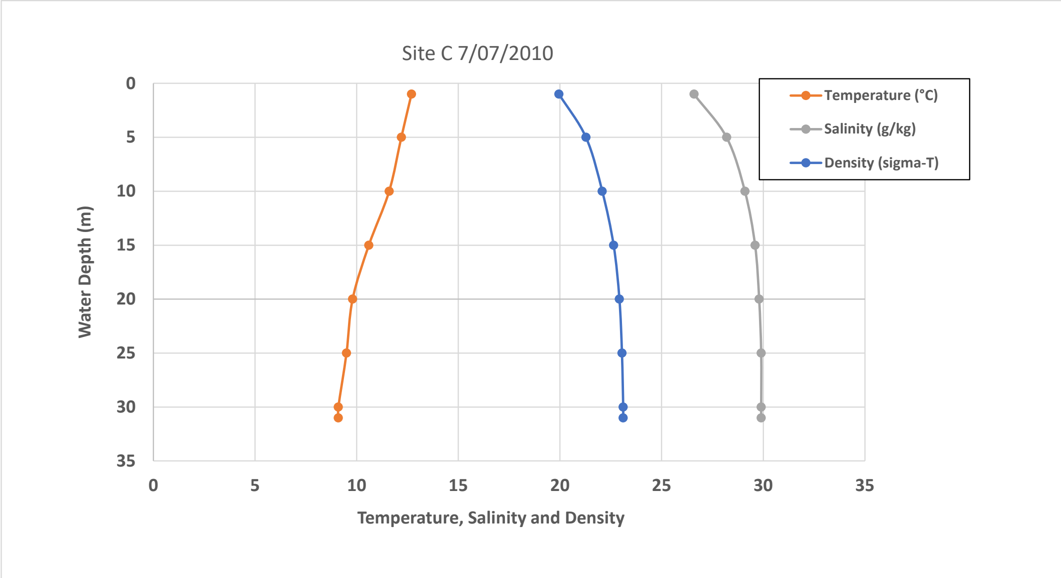


**Figure 17. Vertical Ambient Profile of Temperature, Salinity and Density in Sitka Mixing Zone Resulting in Least Mixing**

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 |

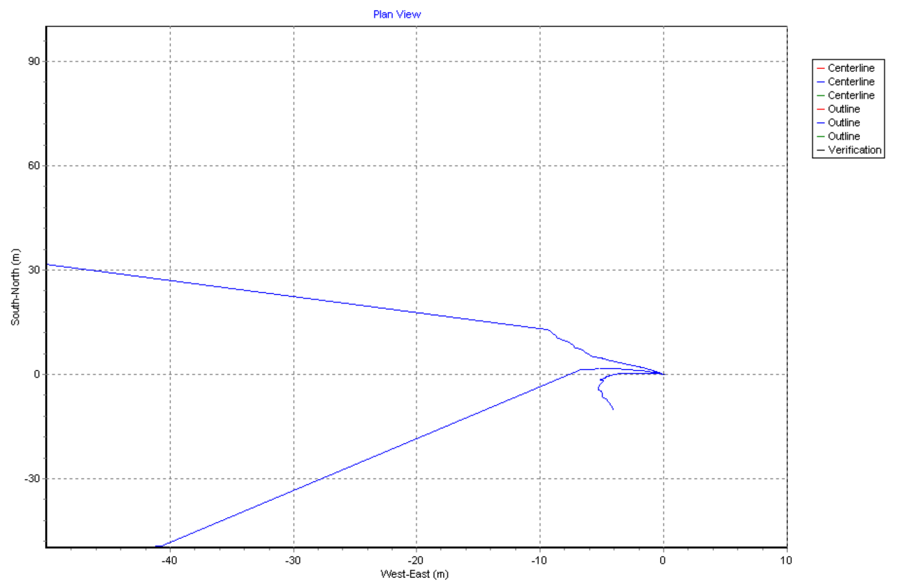


**Figure 18. Sitka Discharge Plume Boundary Plan View from Above**

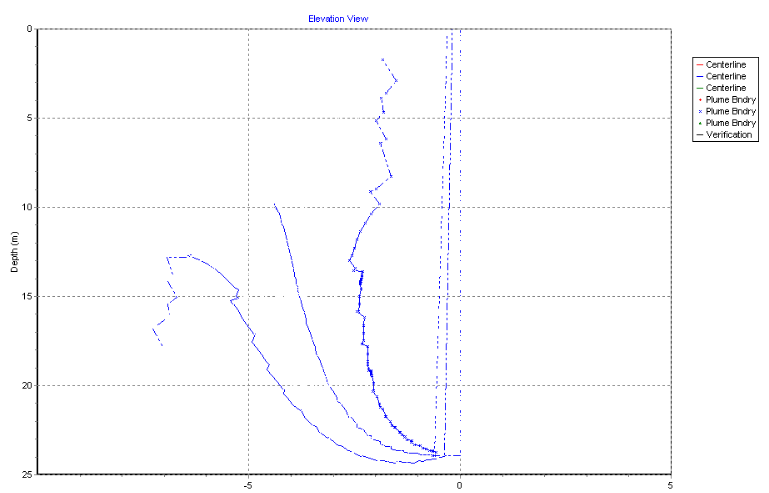


**Figure 19. Sitka Discharge Plume Centerline and Boundary Profile View from Side**

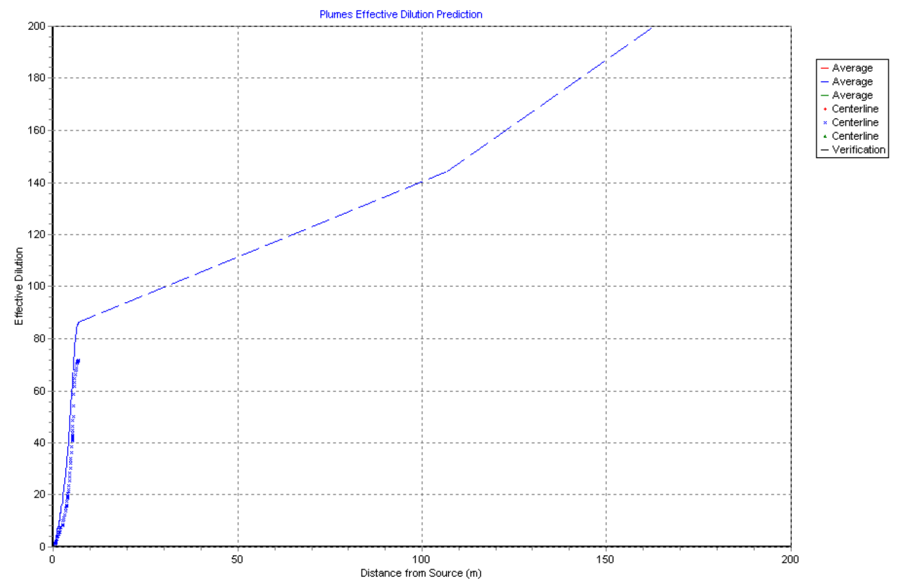


**Figure 20. Sitka Discharge Plume Average and Centerline Dilution vs. Distance from Outfall** (Figure is based on graphic output by VP; DFs in far field (beyond 7 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity).

## 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 10$^{th}$ percentile and average tidal current velocities (Table 2). The 10$^{th}$ 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

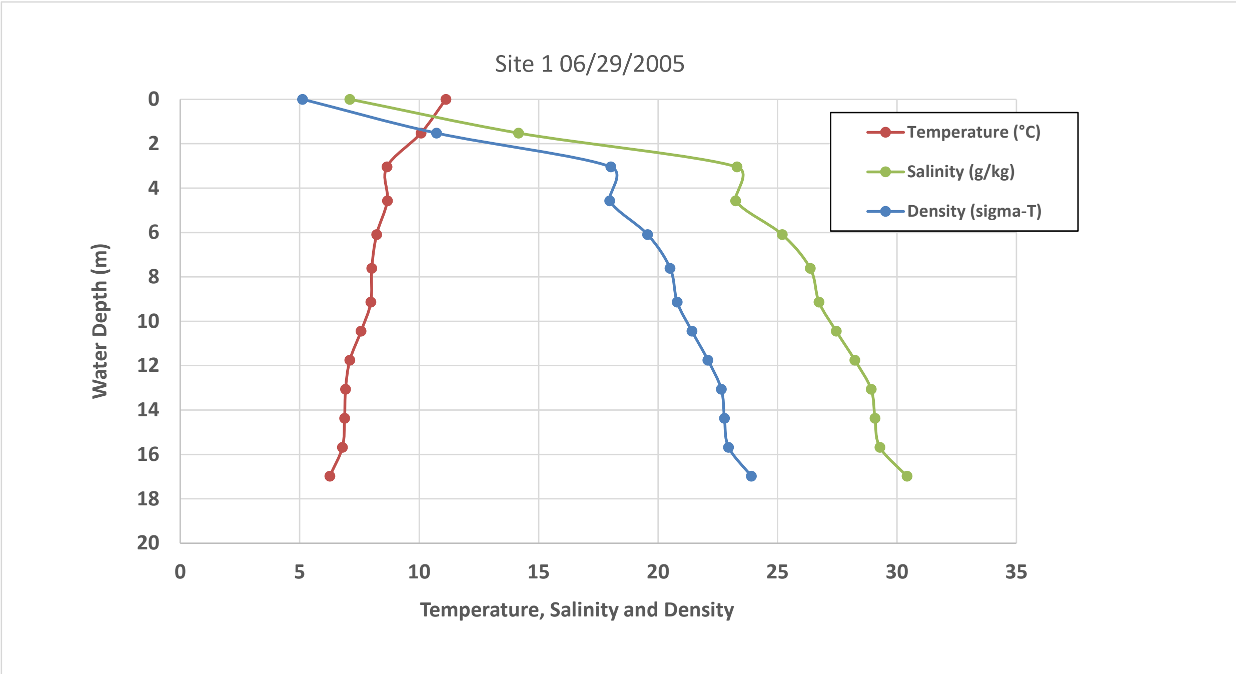


**Figure 22. Vertical Ambient Profile of Temperature, Salinity and Density in Skagway Mixing Zone Resulting in Least Mixing**

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

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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 |

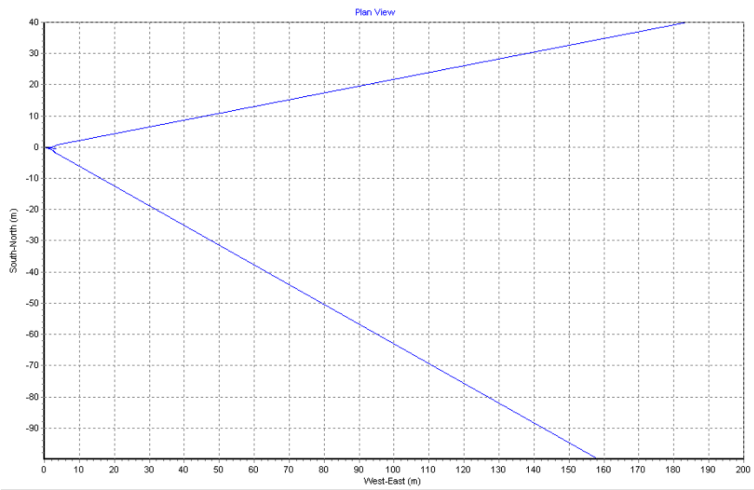


**Figure 23. Skagway Discharge Plume Boundary Plan View from Above**

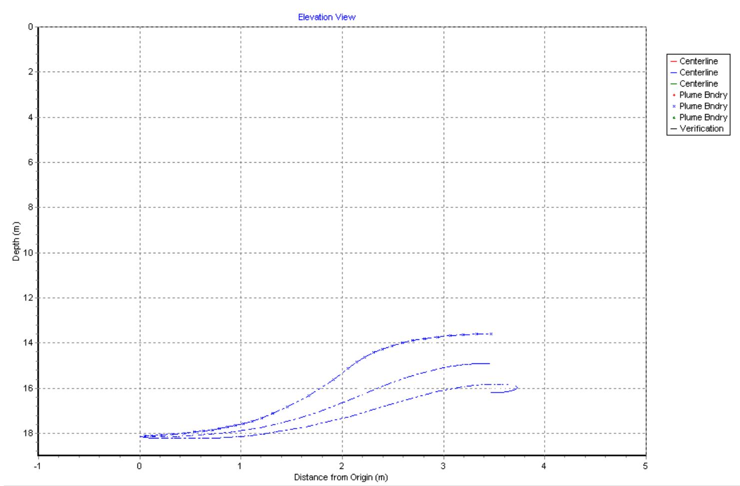


**Figure 24. Skagway Discharge Plume Centerline and Boundary Profile View from Side**

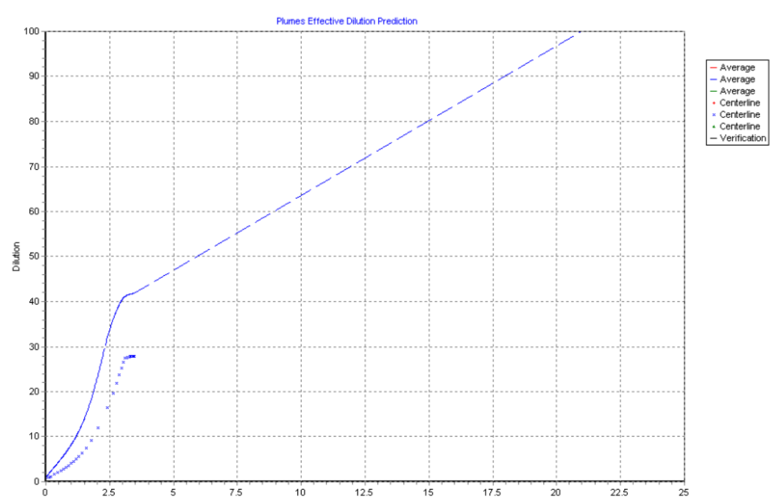


**Figure 25. Skagway Discharge Plume Average and Centerline Dilution vs. Distance from Outfall** (Figure is based on graphic output by VP; DFs in far field (beyond 3 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity)

## 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 10$^{th}$ 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.

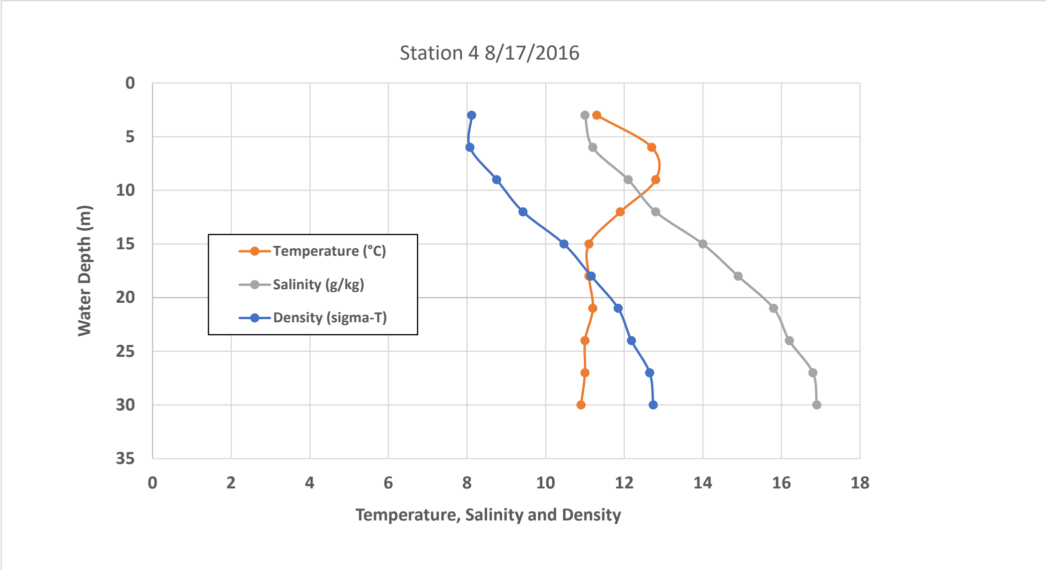


**Figure 27. Vertical Ambient Profile of Temperature, Salinity and Density in Wrangell Mixing Zone Resulting in Least Mixing**

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 |

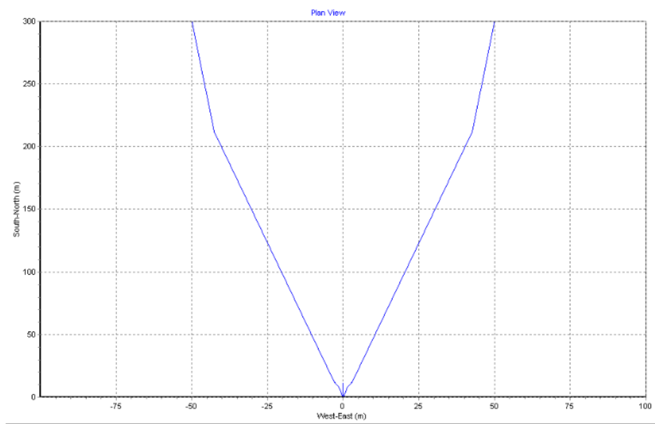


**Figure 28. Wrangell Discharge Plume Boundary Plan View from Above**

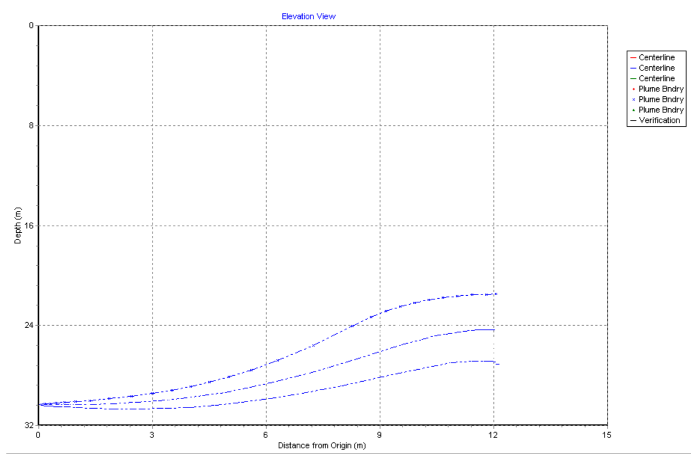


**Figure 29. Wrangell Discharge Plume Centerline and Boundary Profile View from Side**

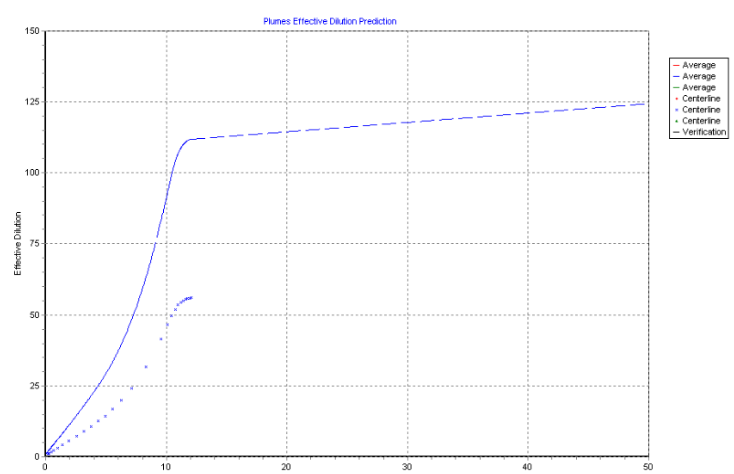


**Figure 30. Wrangell Discharge Plume Average and Centerline Dilution vs. Distance from Outfall**

# 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 |

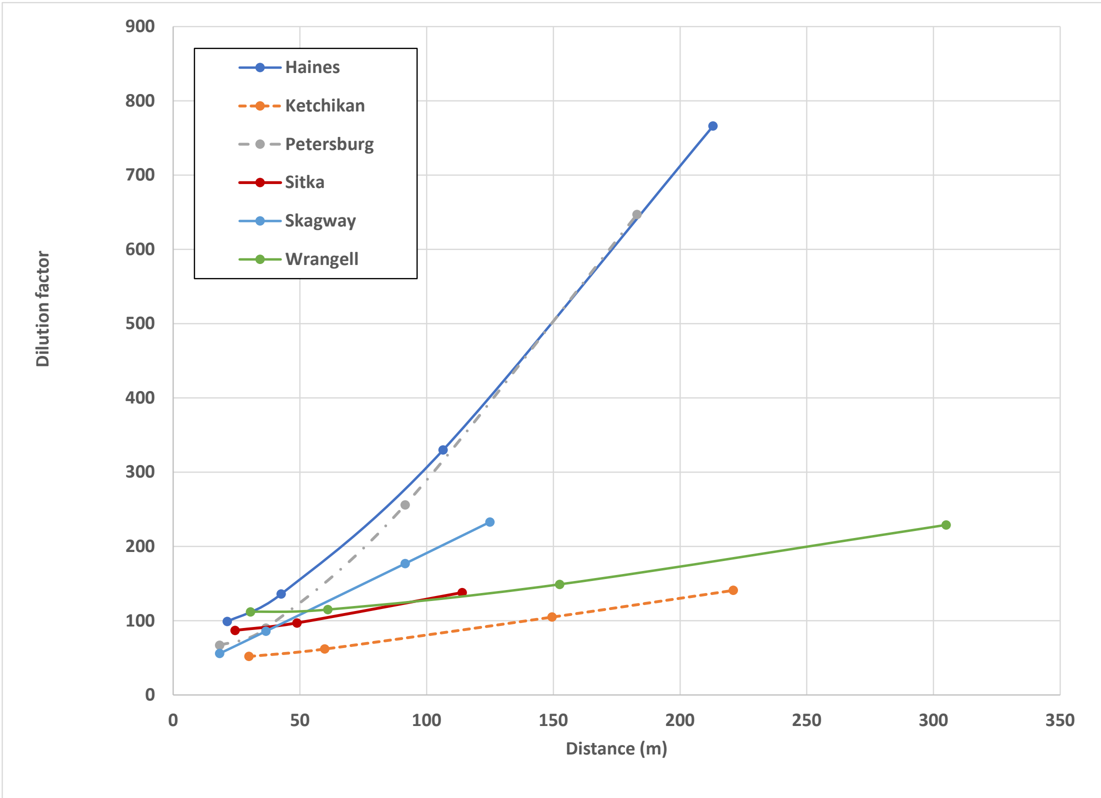


**Figure 31. DF Predictions Graphed as a Function of Distance from the Outfall**
(predictions are DFs for distances corresponding to 1-10 times the depth of discharge; in the cases of Ketchikan, Sitka and Skagway, DFs have been truncated at the distances to the shore)

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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MixZone Inc. 2020. CorHyd Internal Diffuser Hydraulics Model User Manual. December 15, 2020.

Reese, C., George, K. and Gerry Brown. 2021. Mixing zones 101 (PowerPoint presentation). Alaska Department of Environmental Conservation (https://dec.alaska.gov/media/16267/mixing-zones.pdf, accessed April 21, 2021).

Washington Department of Ecology (DoE). 2018. Permit Writer's Manual (Revised January 2015/ Updated September 2018). Publication no. 92-109 Part 1. Appendix C. Water Quality Program, Washington State Department of Ecology. Olympia, Washington (https://fortress.wa.gov/ecy/publications/SummaryPages/92109part1.html).

# 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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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-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 | 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);

| 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 |
| 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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 (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 | 0.05935; | 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 (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 |

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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 |

**<u>Ketchikan (model output for 1*depth, 2*depth, 5*depth and 10*depth)</u>**

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 (m) | Amb-cur (cm/s) | P-dia (in) | Polutnt (col/dl) | Dilutn () | x-posn (m) | y-posn (m) | Time (s) | Iso dia (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 (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) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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**<br>Eo=(alpha)(width)<br>(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);
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
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);

| Step | Depth (m) | Amb-cur (cm/s) | P-dia (in) | Polutnt (col/dl) | Dilutn () | x-posn (m) | y-posn (m) | Time (s) | Iso dia (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 (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) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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**<br>Eo=(alpha)(width)<br>(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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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-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 | 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);

| Step | Depth (m) | Amb-cur (cm/s) | P-dia (in) | Polutnt (col/dl) | Dilutn () | x-posn (m) | y-posn (m) | Time (s) | Iso dia (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 (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) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 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 |
| 3.53E+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 | 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 |
| 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**<br>Eo=(alpha)(width)<br>(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 (m) | Amb-cur (cm/s) | P-dia (in) | Polutnt (col/dl) | Dilutn () | x-posn (m) | y-posn (m) | Time (s) | Iso dia (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
 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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 | 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
 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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 (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
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**<br>Eo=(alpha)*(width)$^{4/3}$<br>(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 |