Rick Starr 10/77

Siletz Bay

PHYSICAL CHARACTERISTICS

Physical Dimensions

A number of different figures concerning the surface area of the Siletz River estuary have been published (1). The Oregon Division of State Lands provides an official figure, however. The Division of State Lands credits the Siletz estuary with 1,187 total acres, with tidelands representing about 71% (775 acres) of that area (2). This shallow bay, 2.5 miles long and 0.25 to 1.0 miles wide, is the tenth largest bay on the Oregon coast (2). The main tributary to the bay is the Siletz River which has a watershed of 308 square miles (3, p.69). Schooner Creek and Drift Creek also flow into the Siletz Bay, and add about 56 square miles of watershed to the estuarine system (4, p. 8).

The Highway 101 bridge at river mile 2.2 marks the transition of the Siletz River into Siletz Bay. The southern portion of the bay has large expanses of tideflat, and water depths are shallow at high tide. The northern part of the bay has large tide flats, but depths at high tide are greater due to the presence of the main channel, and the proximity to the mouth of the bay. Rauw measured water depths in the Siletz estuary at four times in 1973(4). Graphs of depth versus river mile may be found on pages 89 and 90 of Rauw's thesis (4). Rauw's bathymetry data seem to have some inconsistencies, however it does provide an indication of water depths. A trend is observable from his data; water depths decrease from the mouth to about river mile 1.5, then increase slowly upstream. Depths in the estuary will vary depending on season, tidal stage, and river flow, thus influencing the volume of water in the estuary. Goodwin, et. al. portrayed this in another form by graphing the cross sectional area of the Siletz estuary as a function of distance from the mouth (5, p. 9).

Tides

"Tides in the Siletz area are of mixed diurnal-semidiurnal nature, with two unequal high tides, and two unequal low tides each lunar day (24.85 hours)"

(6, p. 34). The mean tidal range in the estuary is 5.0 feet and the mean tide level is 3.4 feet above the U.S. Pacific Datum (6, p. 34); this results in a tidal prism of 3.5 x 10^8 cubic feet (5, p. 28).

Rauw measured tidal current velocities at two places on the estuary four times in a year. He found that maximum flood current velocities occurred 80 to 100 minutes before maximum tidal heights at river mile 0.4, and 40 to 90 minutes before maximum tidal heights at river mile 2.3 (4, p. 52). Maximum ebb current velocities were found to be 120 to 216 minutes before minimum tidal heights at river mile 0.4, and 136 to 180 minutes before minimum tidal heights at river mile 2.3. This flow and velocity information, presented in degrees of phase lag, may be found on Table II of Rauw's thesis (4, p. 51).

Goodwin, et. al. also measured phase lags. In September, 1969, phase lags at four places in the estuary were recorded. Maximum flood current velocities occurred before maximum tidal height at every place measured. Maximum flood current velocities occurred 80 minutes earlier at Taft, 125 minutes earlier at Kernville, 150 minutes earlier at Howard's, and 105 minutes earlier at Stromes (5, p. 25).

Although slack water occurs near high and low waters, there is a lag time between slack water in the lower part of the bay and upstream. Rauw measured lag time between the Taft public dock and two points in the bay at four times during 1973. He found the lag time at the Siletz Moorage to average 20.4 minutes during high tide and 40.9 minutes at low tide in January; to average 42.5 minutes at high tide and 60.1 minutes at low tide in May; to average 36.9 minutes at high tide and 50.2 minutes at low tide in August; and to average 18.3 minutes at high tide and 45.3 minutes at low tide in November (4, p. 33).

Lag time at Sportsman's Landing was calculated to average 45.0 minutes at high tide and 70.7 minues at low tide in January; 51.3 minutes at high tide and 66.7 minutes at low tide in August, and 49.7 minutes at high tide and 92.5 minutes at low tide in November (4, p. 34).

Goodwin, et. al. measured the lag time in September, 1969, from Taft to three places in the estuary. At high tide lag time from Taft to Kernville was 30 minutes, from Taft to Howards was 80 minutes, and from Taft to Strome's was 125 minutes. At low tide lag time from Taft to Kernville was 45 minutes, from Taft to Howard's was 95 minutes, and from Taft to Strome's was 155 minutes (5, p. 25). At high slack lag time was 30 minutes at Kernville, 55 minutes at Howard's, and 80 minutes at Strome's. Low slack lag time was 25 minutes at Kernville, 65 minutes at Howard's and 155 minutes at Strome's (5, p. 25).

Rauw used aerial photography taken February 17, 1973 in conjunction with articulated dye streaks to determine circulation patterns in the bay. He found a reflection of ebb water currents to occur between the sand spit and Cutler City. On the day the photographs were taken, ebb waters followed the spit towards the mouth, whereupon the flow split with part of the current following the spit towards the mouth, and the other part reflecting towards the mouth of Schooner Creek. The ebb flow is then diverted by the water coming out of Schooner Creek so that the current turns toward the mouth. High tide current patterns are also complex, "but in a general sense the flow tends to fill the South Bay before reaching a maximum value in the riverine channel" (4, p. 56). Flood and ebb current are graphically portrayed in Rauw's thesis, and in the Siletz Wetlands Review (4, p. 57, 6. p. 38 and 39).

River Discharge

Three major streams contribute to flow into the Siletz estuary. The Siletz River, Schooner Creek, and Drift Creek combine to yield 1.8 x 10^6 acre-feet of water annually (2, p. 30). This runoff is not distributed evenly, however. The months of November through April account for about 80% of the average annual yield, with December through February accounting for almost 50% of the average annual yield (2, p. 30). The Mid Coast Basin study portrays similar information in the form of histograms showing annual yield from 1937 - 1964, and the monthly distribution of annual yield (2, p. 28, 29). River discharge is above 1600 cfs from November through April, while it is below 200 cfs during July, August and September. This fluctuation in river discharge corresponds to the annual distribution of precipitation; a stream hydrograph showing mean monthly precipitation and mean monthly river discharge may be found on exhibit 10 of the Siletz Wetlands Review (6, p. 34). Average monthly discharge of the Siletz River at river mile 42.6 is available on page 36 of the Siletz Wetlands Review (6). Locations of the stream gauging stations are also available in the Siletz Wetlands Review (6, p. 35).

Peak discharge, in the form of flood waters, is documented in Table 6 of the Siletz Wetlands Review (6, p. 41). Stream flooding occurs most often from November through February when the area receives the most precipitation. December, January, and February are especially prone to high river flows, as seven of the ten largest floods on record have occurred in these three months (6, p. 41). A flood hydrograph of the December 1964 flood, the sixth largest flood on record for the Siletz River, may be found on page 104 of the Environmental Geology of Lincoln County, Oregon (8). This publication also provides a narrative of some of the major floods on the Siletz. Information concerning flood discharge, flood frequency, and flood damage is presented on page 95 - 107 of the Environmental

Geology of Lincoln County, Oregon (8). Flood information is also available in the file on the Lincoln County Flood Insurance Program (9).

Flushing

Flushing time for the Siletz Bay was determined by Rauw for various river flows (4, pp. 91-95). Flushing time provides a rough estimate of the residence time of pollutants entering the estuary. The residence time of a pollutant influences the effect of the pollutant on water quality parameters. A longer flushing time indicates that a pollutant may have more time to alter the existing estuarine characteristics. This is only an estimation, however, as Rauw points out. "Flushing rates should be accepted only as crude estimates of pollutant transport rates since they depend on conditions such as mixing patterns, tidal ranges, riverflows, etc., which vary both spatially and temporally" (4, p. 95).

Although flushing rates (consequently pollutant residence times) vary for different parts of the estuary and for different hydraulic regimes, they provide useful tools for making decisions about the introduction of a pollutant to an estuary. Matson has shown, using the modified prism method of Ketchum, that flushing time decreases as river flow increases, and flushing time increases upstream (7, pp. 41 - 45).

Using the modified tidal prism method, Rauw determined flushing time for different parts of the estuary at three river discharges. He also determined flushing time using the fraction of fresh water method. At 109 cfs flushing time for the estuary was 3.0 days, at 349 cfs flushing time was 1.9 days, at 1870 cfs flushing time was 1.0 day, and at 2980 cfs flushing time was calculated to be 0.5 days

(4, p. 94). Matson pointed out that actual flushing time at high water may be less than calculated flushing time because the nearly stratified condition of the estuary inhibits mixing of salt and fresh water (7). McKenzie (10, p. 87), commenting on Matson's data states, "Thus since flushing time is inversely proportional to river flow, a pollutant could be expected to remain in the estuary for a much longer time during the summer than during the winter".

Mixing Characteristics

The great diversity of river flows combined with the prevalent semidiurnal tidal sequences creates a variety of mixing regimes in the estuary which vary seasonally and spatially. Burt and McAllister observed in 1957 and 1958 that the Siletz Bay was partially mixed in October and stratified in January and April (11). Rauw computed mixing characteristics using two different methods. Using the flow-ratio method and the salinity difference method, he arrived at two different sets of mixing classifications.

While he could not precisely classify the estuary, Rauw did generalize about the mixing conditions in the Siletz estuary. He suggested the estuary is partially mixed during high tide and well mixed during low tide in the spring. Summer low river flows encourage tidal diffusion resulting in a well mixed estuary. The estuary is either well mixed or partially mixed in the fall depending upon tidal stage and river discharge, while winter high flow promotes the formation of a weakly stratified estuary.

Thus, mixing characteristics vary not only seasonally but also as the water depth, circulation pattern, and tide change. In general, however, the tideflats will usually be well mixed, while the deeper parts of the estuary may be well mixed, partially mixed, or stratified. The mouth of the bay will almost always be well mixed due to the turbulence induced by tidal action.

Salinity

The mixing processes created by tidal action, river flow, density gradients, turbulence, and basin morphology influence salinity distribution. Salinity distribution will change continuously, but instantaneous measurements give an indication of the salt concentration in the water. Salinity characteristics for the Siletz Bay at four times in the year are graphically portrayed on exhibits 15 - 18 of the Siletz Wetlands Review (6, pp. 52 - 53). The same information is plotted on figures 22 - 23 of Rauw's thesis (4, pp. 76 - 77).

Salinities in the estuary vary depending on time of day, tidal stage, location in the estuary (horizontally and vertically), season, and river discharge. Rauw provides a description of the salinity distribution and mixing characteristics for four days (4, pp. 74 - 78). He describes the relative abundance of salt and fresh water at various parts of the estuary, and the salinity difference between surface and bottom waters at those points. He found salinities to be higher during periods of high tide, near the mouth, on the bottom, and during periods of low river flow. Salinities decrease upstream from the mouth, but decrease more slowly on the bottom. Rauw measured the limit of saline intrusion to be at river mile 21.0 when the river had a low flow of 96 cfs (4, p. 78). Burt and McAllister observed the limit of saline intrusion to be at river mile 12.7 in July 1958 (11).

Temperature

Water temperatures also vary depending on time of day, tidal stage, location in the estuary, season, and climatic and hydrologic regime. The river water entering the estuary is colder than the ocean water in the winter months, and warmer in the summer months; thus the relative amounts of river and ocean water in conjuntion with the seasonal mixing characteristics dictate water temperatures in estuarine deep water. Water temperature will be higher in shallow areas, areas with poor circulation such as Millport Slough, during low tide (except in winter); and in the summer.

Temperature gradients occur seasonally in the Siletz Bay. In the winter when river water temperatures are low bottom temperatures approximate surficial water temperatures. This condition change in the summer with high river temperatures. "Nearly isothermal conditions existed during periods of minimum salt and freshwater temperatures (sic) differences and strong vertical and longitudinal temperature gradients were evident during the summer" (4, p. 73). Figures 20 and 21 of Rauw's thesis show temperature versus river mile profiles for the bottom, mid-depth, and surface seasonally (4, pp. 71, 72). Table 11 of the Siletz Wetlands Review, lists temperature ranges for the Siletz estuary in 1973 (6, p. 54). Zinn documents temperature and salinity changes as well (13, pp. 58 - 61). Instantaneous water observations are found on pages 72 - 73 of Fish and Wildlife Resources of the Middle Coast Basin, Oregon, and their Water Requirements (16).

The Oregon Department of Environmental Quality monitored water temperature characteristics in the Siletz Bay from 1972-1975. Data were collected at six places in the estuary; the exact locations of the monitoring stations are listed in Appendix C, Table 13 of the "Proposed Water Quality Management Plan, Mid Coast Basin" (12). This document also summarizes the data collected. In the summer months from June through October water temperatures were lower near the mouth of the estuary than in the upper reaches of the estuary. Water temperatures varied from a range of 9 to 15^{o}C near Cutler City to a range of 15 to 22.5^{o}C 2.5

miles above Sunset Landing (12). Water temperatures in the winter months (November - May) were between 7 and 10^{o}C throughout the estuary, with areas near the mouth tending to be slightly warmer (12).

Dissolved Oxygen

Dissolved oxygen levels in the estuary are dependent upon rates of photosynthesis, biological respiration, anerobic decomposition, salinity, air pressure, and mixing processes. Dissolved oxygen (DO) is inversely related to temperature and directly proportional to pressure. Lower temperatures have higher DO levels, as do higher atmospheric pressures. DO levels are also inversely proportional to salinities; freshwater has greater solubility than seawater. Mixing processes are important in distributing dissolved oxygen throughout the estuary. As dissolved oxygen enters the estuary from atmospheric reaeration, stream inflow, ocean inflow, or biological means, it is distributed by turbulent mixing processes. Stratification of the estuary reduces the mixing processes, thus some parts can become oxygen deficient.

Oxygen in the water column can be depleted by respiration of plants and animals, the introduction of organic matter causing oxidation and bacterial decompostion, and through the oxidation of reduced inorganic compounds diffusing from anerobic bottom deposits (10, p. 117). Low levels of DO may be encountered if an area is high in organic material, poorly flushed, choked with plants, or rich in oxygen deficient deep ocean waters.

The Siletz Wetlands Review reported dissolved oxygen concentrations in the Siletz estuary. That document reported DO at river mile three to range from 9 to 12 mg/l in January, 8 to 9 mg/l in May, from 7 to 10 mg/l in August, and from 9 to 11 mg/l in December (6, p. 55). Rauw described DO concentrations as being much greater in fall and winter than in spring and summer (4, p. 80). He attributed the higher fall and winter DO levels to lower water temperatures. Profiles of dissolved oxygen concentration versus river mile are displayed in figures 24 and 25 of Rauw's thesis (4, p. 81 - 82).

The Oregon Department of Environmental Quality monitored dissolved oxygen characteristics in the Siletz Bay from 1972 to 1975. Data were collected at six places in the estuary; the exact locations of the monitoring stations are listed in Appendix C, Table 13 of the "Proposed Water Quality Management Plan, Mid Coast Basin" (12). DO levels were generally lower in the summer months than in the winter months. Dissolved oxygen ranged from 6.7 to 12.1 mg/l in the summer months (January - October) throughout the estuary and from 10.1 to 11.9 mg/l in the months of November through May (12, c-21).

Turbidity

Turbidity, a measure of suspended matter in the water column, is an easily observable water quality characteristic. Highly turbid water is detrimental to the biota of the estuary and has negative aesthetic impacts as well. The U.S. Public Health Service has determined that highly turbid water is unsuitable for drinking water. "The Public Health Service has established a maximum permissible JTU value of 5 for public water supplies" (6, p. 57).

Turbidity, related in Jackson Turbidity Units (JTU), for the Siletz estuary, was measured by Rauw at four different times. His results showed that, ". . . turbidity is proportional to riverflow, with consistently high levels reported for the Fall and Winter periods and lower value during Spring and Summer measurements" (4, p. 84).

Rauw measured spring high tide JTU values to be less than 5 JTU's, with a gradual decrease in the upstream direction. At low tide turbidities increased from 2.5 JTU's at the mouth to 4 JTU's at river mile 5 (4, p. 85). Summer high tide turbidities were between 0.5 and 1.0 JTU's throughout the estuary on the August day that measurements were taken. Rauw found summer low tide turbidities to gradually increase in the upstream direction, but were below 2.0 JTU's throughout the estuary (4, p. 86). Winter high tide turbidities measured by Rauw were between 2.0 and 3.0 JTU's in most of the estuary. Low tide exhibited a marked increase in turbidity, indicative of the influence of more turbid river water. Fall high tide turbidities, as determined by Rauw, increased upstream and JTU values greater than 5.0 were found everywhere in the estuary (4, p. 86). Fall low tide turbidities decreased with river mile but did not drop below 5.0 JTU's.

The Oregon Department of Environmental Quality monitored turbidity in the Siletz Bay from 1972 to 1975. Data were collected at six places in the estuary, the exact locations of the monitoring stations are listed in Appendix C, Table 13, of the "Proposed Water Quality Management Plan, Mid Coast Basin" (12). From the data presented it is apparent that turbidities are low for most of the year. JTU values of 0 to 4 were given as the range of turbidity measurements for the time period monitored (12). Undoubtably these turbidity values were exceeded at times, but the general indication is that the Siletz Bay has relatively clear water.

pH

pH for the Siletz estuary is documented in Rauw's thesis. pH is lower at night than in the day, and shows a slight decrease in the upstream direction. The pH declines upstream due to the influence of freshwater, which is more acidic than saltwater. Tidal flats also show a decrease in pH due to the production of H_2S. Winter and Spring river runoffs bring more acidic conditions in the estuary. A highly acidic condition can occur in December when there is apt to be a high runoff with a low spring tide. A discussion of the factors influencing pH may be found on page 58 of the Siletz Wetlands Review, and on pages 87 - 88 of Rauw's thesis (6; 4).

The Oregon Department of Environmental Quality monitored pH characteristics in the Siletz Bay from 1972 to 1975. Data were collected at six places in the estuary, the exact locations of the monitoring stations are listed in Appendix C, Table 13, of the "Proposed Water Quality Management Plan, Mid Coast Basin" (12). This document also summarizes the data collected. From the data presented, it is apparent that the more basic sea water dominates in the lower part of the estuary, as pH values were higher near the mouth than a few miles upriver. In the months of June through October pH values recorded were between 7.7 and 8.4 near the mouth and between 7.0 and 8.6, 2.5 miles above Sunset Landing (12). In the winter months of November through May appearance of the less basic freshwater was evident in that pH values were 7.3 to 8.1 near the mouth and 6.0 to 7.1, 2.5 miles above Sunset Landing (12).

Volatile Solids

Volatile solids, as measured in percent organic material in the bottom sediments (by weight), were determined at two times in 1973 by Rauw. He found an increase in volatile solids with distance from the mouth, probably due to the deposition of organic material from logs which used to be rafted in the estuary (4, p. 115). In March, 1973, volatile solids were less than 1 percent near the mouth, increasing to about 5 percent at river mile 2, and up to 10 percent at river mile 5 (4, p. 116). Rauw's August measurements were somewhat sporadic, but indicated an increase in volatile solids in the upstream direction with samples over 15 percent volatile solids observed (4, p. 115

Pathogens

Fecal coliforms, pathogenetic bacteria commonly found in sewage, are potentially dangerous to humans. "1973 EPA standards for swimming waters prohibit concentrations of fecal coliforms greater than a log mean of 200 coliforms per 100 ml of water. In nonswimming waters up to 2000/100 ml. is acceptable" (6, p. 60). Current State Department of Environmental Quality standards prohibit fecal coliform counts greater than 240 per 100 ml (12, D-2). In waters where shellfish are harvested for human use these standards are even stricter. The State Department of Environmental Quality sets a standard of 70 fecal coliforms per 100 ml for shellfish growing waters.

The Oregon Department of Environmental Quality determined coliform concentrations in the Siletz Bay for the years 1972 to 1975. Water samples were collected at six places in the estuary and analyzed in a laboratory. The exact locations of the sampling stations are listed in Appendix C, Table 13, of the "Proposed Water Quality Management Plan, Mid Coast Basin" (12). A summary of the computer stored data is also in that document. Fecal coliform counts in the lower portion of the estuary were low in the months of June through October with counts occurring in the range of 3-23 fecal coliforms per 100 ml (12, C-21). Fecal coliform concentrations gradually increased with river mile in the summer months, with a maximum of 150 FC / ~~100 ml measured 2.5 miles above Sunset Landing. From November through May fecal~~ coliform concentrations were greater in the lower part of the estuary than in the upper portion. Fecal coliform counts between 3 - 460 per 100 ml were registered 1.5 miles below the Highway 101 bridge, while near Sunset Landing the measured fecal coliforms were between 15 and 43 per 100 ml (12, c-21).

Total coliform concentrations followed a similar pattern. From June through October total coliforms were 3-460 per 100 ml opposite Cutler City and 29 - 1100 per 100 ml 2.5 miles above Sunset Landing. The months of November through May exhibited a reversal of this trend with 9-1100 TC per 100 ml occurring opposite Cutler City and 43-460 TC per 100 ml measured 2.5 miles above Sunset Landing (12). It is interesting to note, however, that both fecal coliform concentrations and total coliform concentrations were greater in the winter months when the predominate runoff from the land occurs. These higher figures may have been the basis for the statements made in the Siletz Wetlands Review that coliform counts in the estuary exceed standards set by the EPA for swimming waters (6, p. 60).

Sediments

A graph of mean grain size versus river mile may be found on page 112 of Rauw's thesis (4). He observed the mean grain size from the mouth of the estuary to river mile 2.5 to be approximately 0.35 mm. From about river mile 3 the mean grain size increases rapidly upstream; this does not seem to be affected by seasonal energy fluctuations (4, p. 111).

A map of the substrate of the Siletz Bay may be found in the notebook entitled "Benthic Flora and Fauna, and Substrate-Salmon River, Siletz Bay, Alsea Bay" (14). This map was prepared by the Oregon State Department of Fish and Wildlife. Tide-flats of the south bay consist mainly of soft mud and mud mixed with sand, while the northern part of the bay is primarily sand (15).

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