The Influence of a Combined Sewage Outfall on the Chemical and Biological Quality of Salt Creek, Porter County, Indiana

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Introduction

The Salt Creek catchment represents an important NW Indiana watershed strongly influencing the socio-economic and recreational resources of Porter County. Intensive land use characterizes the areas adjacent to Salt Creek and today only about 11% of its watershed remains undisturbed (2). Although riparian lands have traditionally been dedicated to agriculture (54% in 1970), croplands are rapidly being replaced by urban and suburban expansion. Zoning officials have now reserved about 65% of the watershed for residential development, 20% to commercial ventures and only 18% to agricultural land use. There are presently 11 officially recognized domestic sewage sources discharging into Salt Creek or its tributaries. The potential impacts of sewage effluent on water and biological quality may be substantial, especially in the stream's upper reaches where urban development is concentrated and stream discharge is characteristically low.

The Indiana Dept. of Natural Resources (2) has estimated that Salt Creek represents 33% of the available salmon spawning tributaries in Indiana; 75% when the receiving waters of the East Little Calumet are included. In spite of this apparent fishery potential, efforts to sustain a viable population of Coho salmon in the stream, either as a "put and take" or as a naturally reproducing fishery, have been disappointing. Locally, well publicized fish kills in 1972, 1973, and 1979 served to highlight suspected water quality problems of Salt Creek. Studies by Cole and Assoc. (1), Ledet (5) and TenEch (8) inspected the water quality of Salt Creek, but were unable to agree on either the major sources of pollution, or its impact on recreational fishing. These studies, nevertheless, did agree that further investigation was needed before the environmental status of Salt Creek and the impact of combined sewage outfalls (CSO) could be fully assessed.

This paper described some of the limnological characteristics of Salt Creek and examines the impact of major sewage outfalls on stream sediment, water and biological quality.

Description of Study Area

Salt Creek originates as cool springs approximately 2.5 km due east of State Route 49 and about 3.8 km south of Valparaiso in Porter Co., Ind. (Figure 1). The stream meanders for about 39 km in a generally northward direction to its confluence with the east branch of the Little Calumet River, north of Portage, Ind. or about 244 m upstream of the Samuelson Road crossing. The Salt Creek watershed drains a 197.4 km^2 area and has 86.6 km of channel. Major tributaries which empty into Salt Creek include: Dammon Run, Swanson, Lamporte and Clark's Ditch; Squirrel, Pepper and Sager Creeks. Ledet (5) reported a mean summer discharge of 1.17 cu. m/sec for Salt Creek at its confluence with the East Little Calumet River, although Whitman (13) reported mean summer discharges between 1.2 and 4.69 cu. m/sec at a station which was 1.5 km upstream of the latter location. According to the DNR (2), organic loading of Salt Creek originates from 4 major sources: Valparaiso, S. Haven, Robinwood Subdivision and Porter County

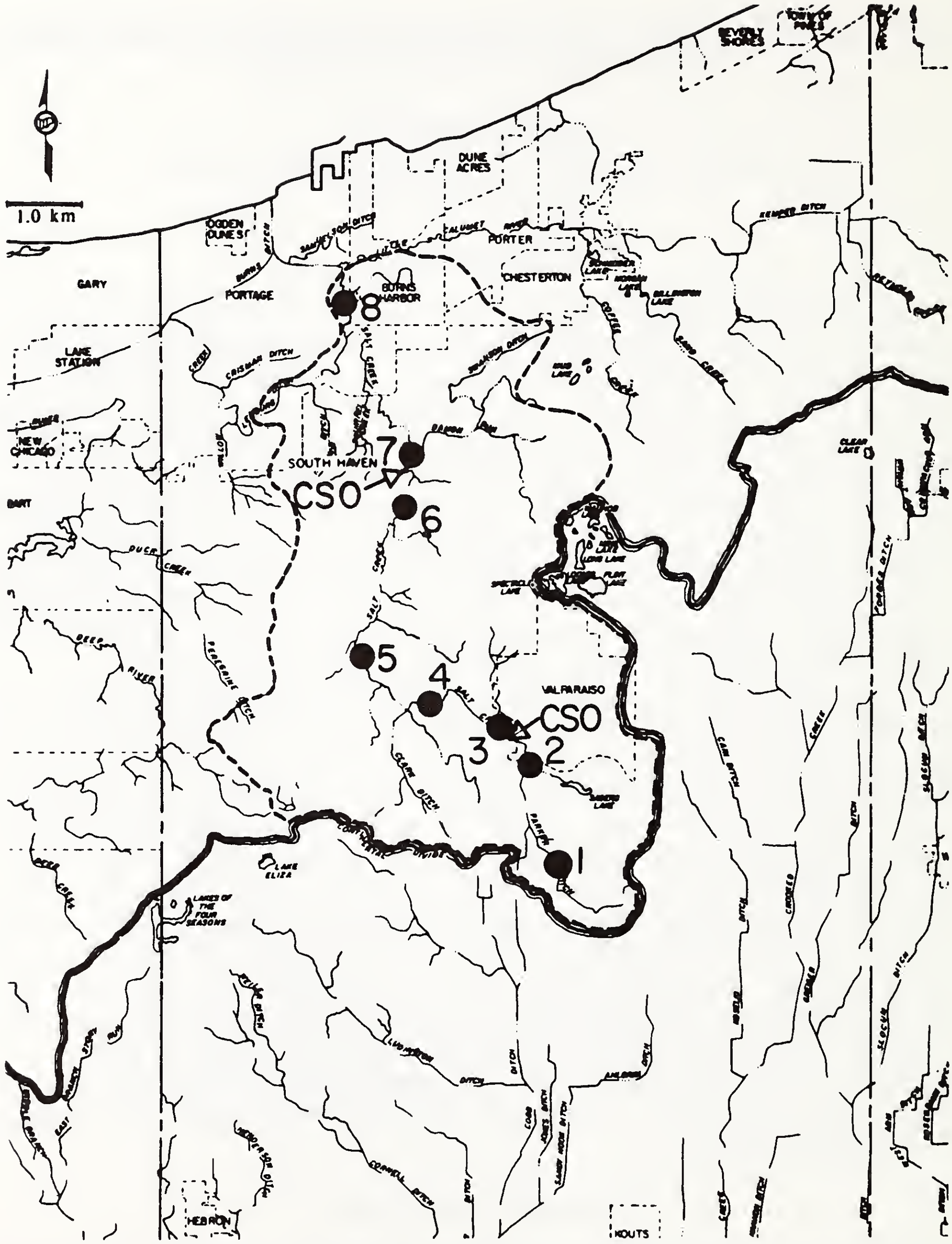

FIGURE 1. *Map of the Salt Creek watershed showing major combined sewage outfalls and sampling stations.*

Home. Other sewage treatment outfalls operate at subcapacity levels and presumably are more minor in impact. An area map showing sampling station locations is given in Figure 1.

Materials and Methods

Water, sediment and benthos samples were obtained along a three point transect representing lateral and center flow regimes. Eight stations were selected and sampled during July, Aug. and Sept. 1980 and Apr. 1981. Samples were collected, preserved and held according to conditions outlined by the U.S. Environmental Protection Agency (9, 11).

Dissolved oxygen, specific conductance, pH, temperature, and discharge were determined at the sampling sites. Dissolved oxygen was analyzed using the modified azide Winkler technique, specific conductance by a Lectro MHO meter, pH and temperature by a portable digital pH meter, and stream velocity by a General Oceanic Digital flow meter. Both velocity measurements and water quality samplings were performed at 60% of the sampling depth. Stream cross sectional area was determined at 1 m intervals across the stream transect at the lower 7 stations and every 0.5 m intervals at the uppermost station.

Laboratory water quality analyses included total ammonia nitrogen, total phosphates, and total suspended solids (non-filtratable residues at 105°C). Ammonia nitrogen was determined by subjecting 300 ml of stream water to Keldahl distillation and spectrophotometric analysis of the Nesslerized distillate. Nitrate nitrogen was determined using a Corning ion specific electrode. Total phosphate was determined by persulfate digestion and stannous chloride analysis. Total suspended solids (TSS) was assessed by filtering 200 ml of sample through a Whatman GF-1 glass fiber filter and then weighing the dried filter.

Sediment samples were obtained by inserting a 5 cm (I.D.) acrylic coring tube into the substrate to a 30 cm sediment depth. The tube's exposed end was then plugged, and the contents retrieved, measured and visually described. Cores were then transferred to Whirlpak bags, chilled and transported to the laboratory for immediate analysis. Samples were carefully mixed with a glass rod and screened through a #30 U.S. standard sieve before subsampling and analysis. These samples were then analyzed for ash-free dry weight and sediment oxygen demand. Sediment ash-free dry weight was obtained from a 10 gm subsamble and ignited in a muffler furnace at 550°C for 2 hrs. The resultant weight loss was taken as an estimate of organic content. Sediment oxygen demand was determined on 3 gms. of sediment using Gilson Respirometry. Reaction flasks were placed in water adjusted to 20°C and allowed to incubate for at least 4 hrs. at an oscillation rate of 30 cm/sec. Flasks were wrapped in aluminum foil and kept in the dark during the experiment in order to suppress autotrophic oxygen production. Differential gas readings were taken every 20 min. and later adjusted to standard temperature and pressure. The resultant slopes of oxygen uptake over time (as determined by regression analysis) were used to determine oxygen uptake rates. Except for the above modification, oxygen uptake analysis followed Umbreit et al. (12).

Triplicate benthos samples were taken with a standard Ekman grab sampler just upstream of the water and sediment quality transects. Samples were washed in a U.S. standard #30 mesh sieve and the contents transfered to quart jars and preserved in 10% formalin. Five percent rose bengal stain was added to facilitate the separation of the benthos from the debris. When practical, organisms were identified to genus.

Further details on methodology, materials, sampling techniques and station description may be found in Whitman (13).

Results and Discussion

Mean water quality trends are displayed in Figures 2a-f. Dissolved oxygen (DO), specific conductance, pH, total ammonia nitrogen, nitrate nitrogen, and total phosphate indicate that the Valparaiso CSO had a major impact on the ecology of Salt Creek. This phenomenon is especially evident during low flow conditions. Although DO during Aug. and Sept. was generally high just below the Valparaiso CSO (Station 3), DO decreased rapidly downstream. Streter and Phelps' calculations, after Linsley and Franzini (6), and empirical observations indicate that the

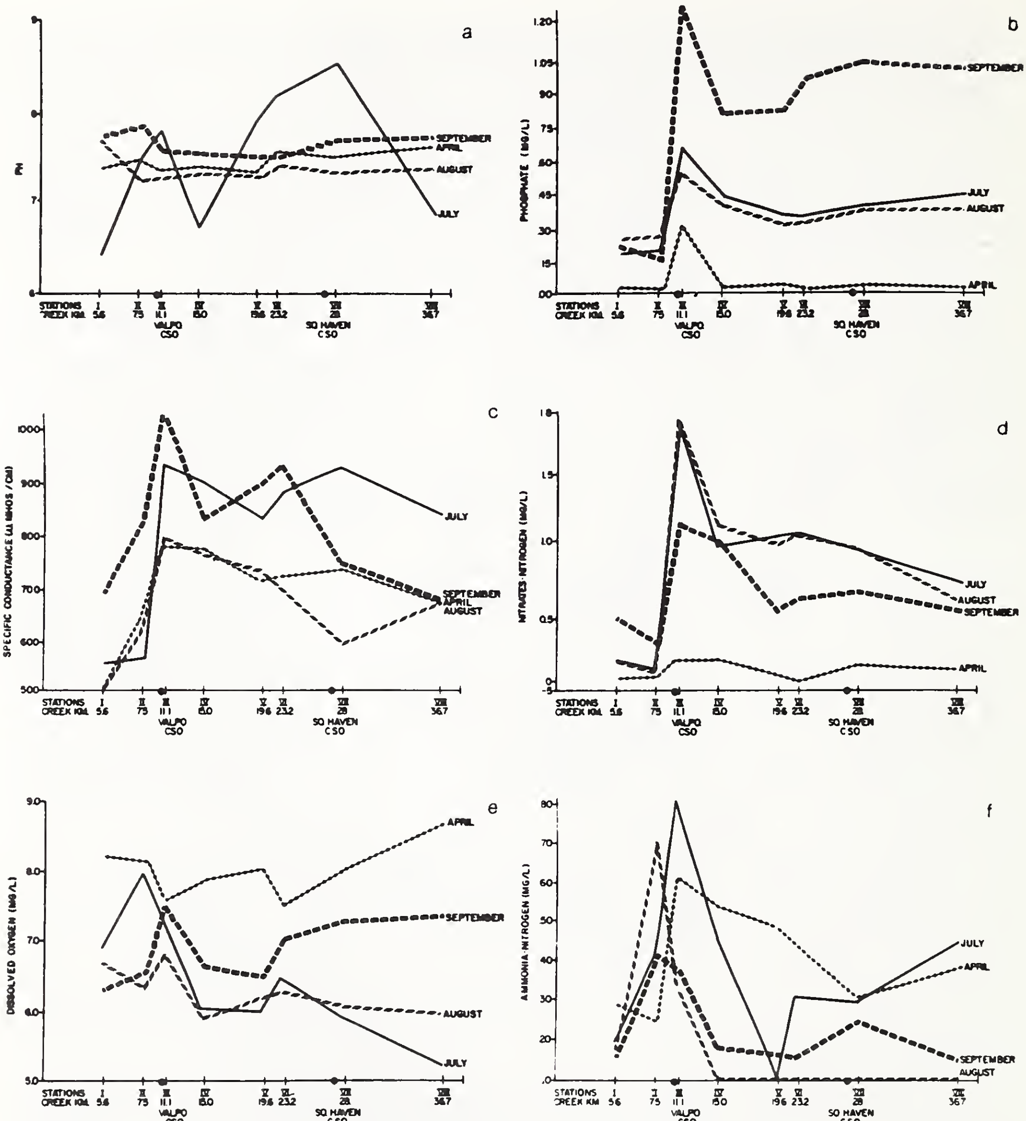

FIGURE 2a-f. *Mean pH, a; total phosphates, b; specific conductance, c; nitrates nitrogen, d; dissolved oxygen, e; and ammonia nitrogen, f; by stream kilometer for July, Aug. and Sept. 1980 and April 1981.*

oxygen sag point occurred between Stations 4 and 5. DO observations made in April suggest an oxygen balance quite unlike those seen during the warmer months. During the April outing, oxygen actually increased at Stations 4 and 5, while slightly decreasing at Stations 3 and 7. It is conceivable that under increased spring discharge the oxygen content of the stream is effectively lowered by the effluents from the Valparaiso and S. Haven combined sewage outfalls even after aeration. Cooler water, decreased biological activity, increased stream turbulence and discharge may have accounted for the rapid reoxygenation of water below Stations 3 and 6.

Figure 2c clearly shows a sudden rise in specific conductance at Station 3 followed by partial recovery to near pre-impacted levels some 37 km downstream during the Sept., Apr. and Aug. observations. July observations, in contrast, indicate little recovery of the stream from ionic loading. Low flows in July may have helped maintain point source effects. Similar relationships apparently exist for stream pH during July. During this month, pH dropped dramatically below the Valparaiso and S. Haven outfall. Other sampling periods show no significant decrease in pH along the stream (p = 0.05). Decreases in pH are likely due to carbon dioxide buildup from bacterial respiration of CSO derived organics. Pearson Correlation Coefficients indicate that pH is inversely correlated with sediment organics (p = 0.008), sediment oxygen demand (p = 0.017), and positively correlated with nitrate (p = 0.038), chloride (p = 0.017), and sulfate (p = 0.018).

Increased in ammonia nitrogen were observed at Station 2 in Aug., Sept. and Apr. and at station 3 in July and Apr. Ammonia decreased rapidly below the Valparaiso point source. A strong smell of sewage was noted during several of the preliminary visits at Station 2. The source of the odor has not been concretely identified and other water quality parameters have not generally been supportive of sewage releases at or above this station. Conversely, nitrate increased some 5 fold between Stations 2 and 3 during July and Aug. Both ammonia and nitrate increased only slightly (if at all) at the S. Haven CSO. Figure 2b shows that total phosphate greatly increased at Station 3 followed by some recovery at downstream stations. Unfortunately pre-impacted levels were not regained during decreased flows conditions of July, Aug. and Sept. The increased flow during April presumably aided the stream's recovery from phosphorus loading. Little, if any, increase in total phosphate was indicated for stations below the S. Haven CSO.

Figures 3a-d present mean values for sediment ash-free dry weight, clorophyll a extracted from periphyton growing on glass slides as described by Patricks et al. (7), sediment oxygen demand, and benthic species diversity.

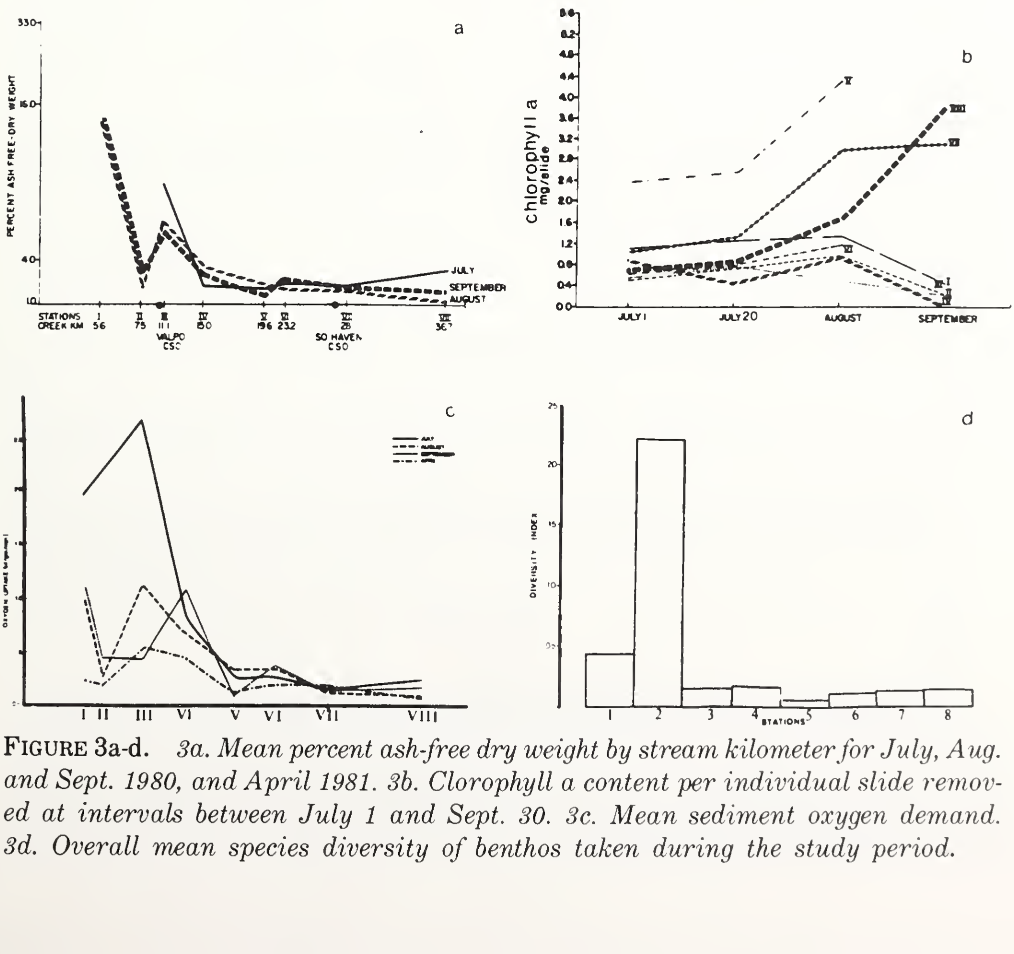

FIGURE 3a-d. *3a. Mean percent ash-free dry weight by stream kilometer for July, Aug. and Sept. 1980, and April 1981. 3b. Clorophyll a content per individual slide removed at intervals between July 1 and Sept. 30. 3c. Mean sediment oxygen demand. 3d. Overall mean species diversity of benthos taken during the study period.*

Sediments collected from Station 1 ranked highest in ash-free dry weight and were significantly higher than all, but Station 3 (p = 0.05). Sediment organics from Station 1 largely consisted of detritus-laden silts which presumably originated from a combination of: 1) detrital input from marshes that surround the creek's upper reaches, 2) leaf litter from the heavy canopy of vegetation along this stream stretch, and 3) possible organic particulate containing runoff from rural land use. Nutrient levels as well as periphyton productivity were also limited at the uppermost station. In contrast, organics taken from Station 3 consisted mostly of sludge deposited along the margins and banks of the stream. Periods of moderate to fast flows tended to expose the natural glacial till in the creek's center.

Results from oxygen uptake experiments (Figure 3c) support the conclusion that the Valparaiso CSO adversely impacts Salt Creek. In 3 of the 4 outings, sediments from Station 3 had the highest oxygen demand. Oxygen demand at this station was quite variable since samples from the creek's center were often composed of gravel and had a typically low organic content, unlike the sludge laden lateral portions. Earlier rains during Sept. exported sludge from Station 3 to Station 4 where it became trapped between dense stands of *Elodea.* Sludge resuspension exposed the underlying gravel and consequently lowered the substrate's oxygen demand.

Diurnal observations taken from pre- to post- rain storm events indicate that overloading of the Valparaiso CSO occurred even with moderate rainfall and resulted in anaerobic or near anaerobic conditions downstream (Figures 4). This phenomenon was observed in both the July and August diurnals. Given sufficient seasonal flow, some recovery is evident at some point downstream from the outfall. A case in point are the diurnals taken between 1850 hrs of July 25

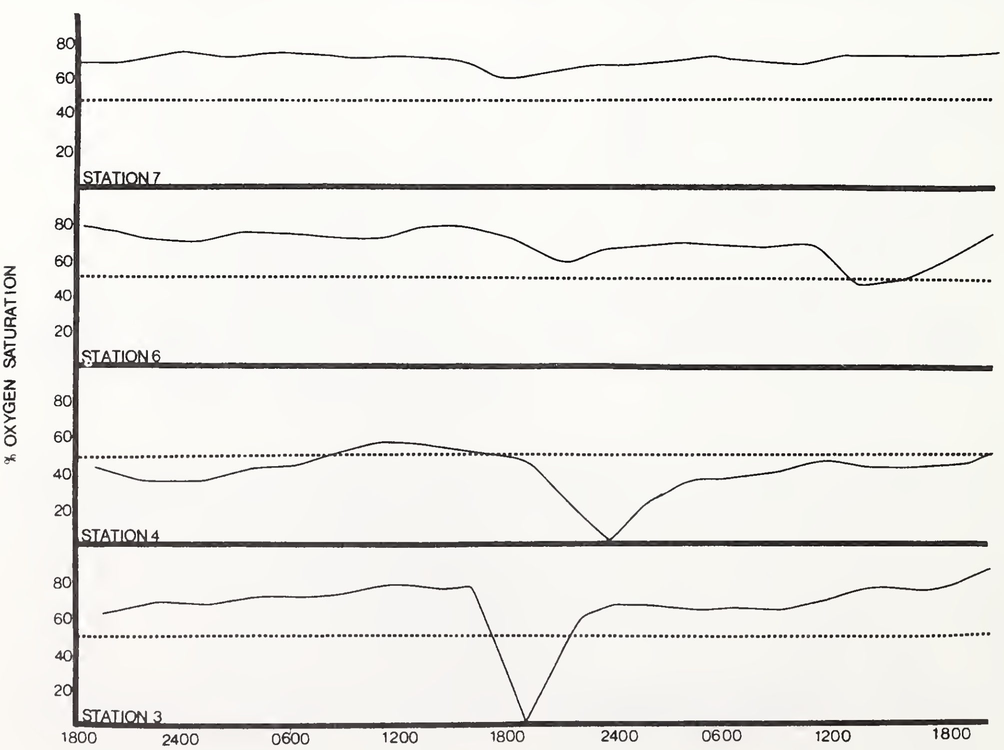

FIGURE 4. *Diurnal dissolved oxygen between 1815 hrs, July 25 to 1805 hrs July 26, 1980 at Salt Creek Stations 3, 4, 6, and 7. Station 2 was also monitored during Aug., Sept. and April diurnals.*

and 1805 hrs of July 26. During this diurnal, 0.51 cm of rain fell between 1500 and 1640 hrs of July 26 (maximum intensity occurred at 1610 hrs). DO readings at Station 3 fell from 7.2 ppm at 1605 to 0.25 ppm at 1903. Other stations sampled during this period remained between 4.7 and 6.6 ppm, reflecting more moderate decreases in DO over the proceeding observations. These latter depressions in DO are likely best explained by non-point source effects such as marsh or ground water displacement or surface runoff with appreciable immediate oxygen demands. DO at Station 3 quickly returned to near preimpacted levels at 2150 hrs or about 2.75 hrs after deoxygenation. The plume of poorly oxygenated water was detected as it passed Station 4 (4.3 km downstream of the Valparaiso CSO) at 2135 hrs with oxygen dropping from 4.7 to 1.9 ppm. Complete anaerobic conditions were experienced at Station 4 at 2330 hrs, some seven hrs after cessation of the rains. Evidence of the low oxygen plume was observed at station 6 between 1300 and 1500 hrs of the following day, with oxygen decreasing from 7.0 to 4.5 ppm. After traveling 12.6 km the plume was, unfortunately, not sufficiently oxygenated to meet the tolerance levels reported for most sports fish (10).

In contrast, oxygen levels below the S. Haven CSO decreased only slightly immediately after the rainstorm, although a release of untreated sewage was observed. Decreased perturbations are apparently suppressed by the increased discharge along this section of stream and more efficient aeration of effluent before release. Velocity of the contaminated plume ranged from 0.98 km/hr between Stations 3 and 4 and 1.33 km/hr between Stations 4 and 5. These calculations suggest a mean stream velocity of 34 cm/sec between stations 3 and 6, and are in general agreement with flow measurements taken during routine monthly outings.

During the August diurnal intermittent rains again resulted in even more prolonged anaerobic conditions downstream from the Valparaiso CSO. Station 2 was added as a control during this and subsequent outings and did not show significant perturbations associated with rainfall events.

The contrast between the bottom fauna of Station 2 and 3 further illustrates the impact of the Valparaiso CSO. Shannon Weaver Species Diversity Index, after Wilhm (14), above the outfall is nearly 9 fold greater than below it. The substrate underlying the riffle at Station 2 is largely composed of heterogenous concrete rubble. While Station 3 is also a riffle run, its bottom is composed of more uniform gravel in the center, while banks consist largely of deposited sludge. Although Station 2 should be expected to have higher diversity due to its greater flow rates and more heterogenous stoney substrate (4), this in itself probably does not account for the species diversity differences found. Both center and marginal areas of Station 3 are overwhelmingly dominated by the aquatic roundworm, *Tubifex*. This species is well known to be tolerant of organic pollution and its presence in large numbers is indicative of organic loading from sewage (3). In contrast, the bottom fauna of Station 2 is composed of a more balanced "clean" water community. For instance, *Baetis*, Heptagenniidae, Cordulidae, *Hydropsyche*, *Limnephilus*, *Stenemis*, Tipulidae and several pollution intolerant subfamilies of midges generally occur at this location.

Summary

Analyses of dissolved oxygen, specific conductance, pH, ammonia, nitrate, total phosphate, sulfate, chloride, sediment oxygen demand and organic content and biological species diversity during July, Aug., Sept. 1980 and Apr. 1981 of Salt Creek waters indicated that the Valparaiso Combined Sewage Outfall (CSO) was the major contributor to the degradation of the stream's water and sediment quality. There was less evidence of conspicuous negative impacts from South

Haven's CSO and most other point discharges into Salt Creek. The study revealed little evidence of organic and sediment loading from agricultural practices. Sand mining operations at the headwaters of Sager Creek above Sager Lake may significantly impact upstream ecosystems and potential salmon spawning areas. An undocumented sewage outfall between Horse Prairie Road and U.S. Highway 30 is strongly suspected although water quality data obtained at this point was inconsistent. Despite heavy pollution imposed on the stream by these point sources, the stream at base flow conditions appeared capable of limited recovery about 9.0 to 12.6 km downstream of the Valparaiso CSO. Unfortunately, the heaviest pollution took place at stream locations with the greatest salmon spawning potential. Diurnal analyses indicated that episodes of significant rainfall coincided with anaerobic conditions in areas downstream of the Valparaiso CSO and with depressed oxygen levels as far north as the State Highway 6 station. Under these water quality conditions, possible sediment loading from sand mining operations, and limited suitable spawning substrates, it is unlikely that Salt Creek's potential as a salmon fishery will improve.

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