Pollutional Load Allocation Study of the Grand Calumet River and Indiana Harbor Ship Canal

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The Federal Water Pollution Control Act Amendments of 1972 specify that all pollutional discharges shall implement a minimum acceptable level of wastewater treatment by July 1977. Additional wastewater treatment would be required as necessary to insure water quality stream standards. In those stream segments where additional treatment is believed required, Section 303(e) of the Amendments stipulates that a pollutional load allocation study be performed to assign maximum allowable loads for each discharge. One such segment which flows into Lake Michigan is the Grand Calumet River and Indiana Harbor Ship Canal located in northwest Indiana.

The Indiana Harbor Ship Canal is dredged to an approximate depth of twenty-four feet, slightly more than half way up the 4-mile main stem and one-half mile up the Lake George Branch. In this section, the complicated flow occasionally reverses away from the Lake for short periods of time due to effects of wind on the Lake's surface elevation. The remainder of the main stem continually flows towards the lake but the rate is very dependent on conditions in the dredged portion. The upper end of the Lake George Branch is slow moving and shallow and is only flushed during storms.

The nine-mile east branch of the river flows into the canal at an average discharge rate of approximately 950 cfs with an average velocity of 1.3 fps and a river depth of generally less than 8 feet. The flow of the west branch is complex as it divides into two sections; one generally flowing east to the canal and the other westward into Illinois. The point of equilibrium is in part affected by the climatic conditions on Lake Michigan and during extreme conditions the entire flow may shift westward. However, the dominant day-to-day factor is the culvert system in Hammond. Average velocity is not meaningful on the west branch but depths range from one to four feet. The major sources of flow are the municipal wastewater treatment facilities of Hammond and East Chicago whose combined flow averages 85 cfs. The only other municipal facility is Gary which discharges 82 cubic feet/sec. into the east branch.

Eight industries presently discharge through fifty-six existing pipes either to the canal, harbor or the river. The major portion of the flow (1.75 BGD) is provided by the three major steel industries; U.S. Steel, Youngstown Sheet and Tube Company, and Inland Steel Company. ARCO and E. I. duPont have significant discharges while U.S.S. Lead Refineries, Union Carbide and American Steel Foundries release minor volumes of wastewater.

Water quality throughout all sections is poor due to these wastewater discharges whose flow for all practical purposes represents the entire dry weather flow. The water quality standards for the problem constituents are given in Table 1. They are not those of a natural water system. As minimal as they first appear, they are now consistently violated and will cost millions of dollars to meet.

TABLE 1. *Water quality standards.*
for problem constituents
Indiana Harbor Ship Canal and the Grand Calumet River

Dissolved Oxygen	ave. 3.0 mg/l	min. 2.0 mg/l
BOD_5		max. 10.0 mg/l
Ammonia		max. 1.5 mg/l
Phenols		max. .010 mg/l
Cyanide		max. .100 mg/l
Phosphorus*		max. .100 mg/l
Sulfates		max. 75.0 mg/l
Chlorides*		max. 35.0 mg/l

* For waters which flow to Lake Michigan.

The minimum dissolved oxygen standard of 2 mg/l is often violated in the west branch, the Lake George Branch and the lower half of the Canal and at times the dissolved oxygen is completely exhausted. The low DOs are a result of high concentrations of BOD_5 and ammonia. BOD_5 values as high as 32 mg/l have been recorded in the west branch while the much larger flow of the east branch has remained below 10 mg/l. While major portions generally have ammonia concentrations 10 times above the standard, sections of the west branch consistently reach unbelievable values of 90 mg/l. This exorbitantly high concentration is due to potent coke plant discharges to the East Chicago sewer system from Youngstown and Inland. The east and west branches combine and quickly degrade, producing low DOs in the lower portion of the canal.

Although phenol violations are the most predominant in smaller flows of the west branch, violations are recorded throughout the system. Cyanides are a major problem in the east branch which in recent years recorded a maximum 15 times the standard. Even though both of these constituents are biologically reduced as flow proceeds to the lake, violations still occur at water quality stations nearest the lake. These high concentrations are primarily the result of discharges from the coke plant and blast furnace operations of the steel industries.

Phosphorus, which has shown a marked decrease due to the statewide ban, still violates the standard. However, this situation apparently is aggravated by the resuspension of phosphorus in river bed deposits which have accumulated over the years. One study estimates that the phosphorus load in the east branch alone exceeds 2.9 million pounds.

Major violations of sulfate only occur in the Lake George and west branches and do not pose a serious problem. On the other hand, chloride violations are system-wide and predominate in the winter. The annual loads related to the point sources and the road salt program, are approximately equal depending on the severity of the winter. However, the road salt load is discharged within a four-five month period causing the bias to winter violations.

The load allocation study is required to concentrate on the next five years by making allowances for economic and demographic growth. In the well established Calumet area there is little evidence of troublesome increases in population, additional sewer hook-ups, new industry or industrial restarts. Population trends during the 1960-70 decade shifted markedly from the previous decade, dropping from a 40% increase to around a 10% increase. The State Bureau of Census projects a 12.5% increase for the 1970-80 decade based on a constant completed fertility rate of all women. As family planning information and aid is disseminated and economic conditions continue to pinch, this rate is likely to continue to drop. With a dampened economic picture signified by the closing of several refineries, out-migration should negate some of the natural population increases.

East Chicago and Hammond are 98-99% sewered. Gary does have some sizable unsewered areas. The exact timing of sewering is always difficult to project but even so, these areas represent only a 5% increase in flow. Based on the factors just discussed, municipal flow was projected to increase 4% in East Chicago, 4.5% in Hammond and 6% in Gary in the next five years.

Discussions with local agencies revealed no major plans of increase in industrial discharges due to new industries nor do any of the existing industries plan to increase their discharges in the short time horizon of five years. The only real possibilities for increase are the refineries restarting. These would come under the new discharge restriction and therefore, would be severely limited.

The load allocation analysis was performed utilizing MULQUAL, a computerized water quality simulation program which projects temperature, dissolved oxygen concentration, nitrogenous and carbonaceous biochemical oxygen demands, benthal demands, and up to eight conservative minerals. MULQUAL is an extension of the Streeter-Phelps equations and expands on prior versions by O'Conner, Dobbins and others. The program has been interfaced with a non-linear programming algorithm allowing for the solution of the following general problem.

Minimize: Total Cost of Wastewater Treatment
Subject to: Water Quality Goals Satisfied

The Model was fit to the River and Canal by providing for 54 reaches. A total of 37 reaches had industrial and municipal wastes flowing into them. Many segments required incremental inflows and outflows. Special outflows were required as several swampy areas acted like reservoirs in the east branch causing reductions in flow. Combined sewer and water intakes were also included as incremental flows. Three headwaters were assumed in the basin; the east branch, and the west branch at the normal point of equilibrium, and the upstream end of the Lake George Branch.

The loads were allocated to account for differences due to seasonality and flow so that each constituent is allocated with respect to its critical conditions. The headwater flows under critical conditions were assumed to be zero for all constituents so that stream flow began with the first pipe discharge into each headwater section. As would be expected, dissolved oxygen was most depleted during warmer periods. In addition, we expected the decay of BOD_5, ammonia, phenols and cyanide to reflect seasonal changes since rates of oxidation are a function of temperature. However, seasonality of BOD_5, ammonia, and cyanides was not readily observable. Phenol samples exhibited a definite trend in changing rates of degradation. In the summer, phenol loads were reduced 50% while under the more critical conditions of winter the reduction dropped to 10%. Phenols were modeled as conservatives to allow for some error in the relationship between the discharges and the river in favor of water quality. Since minimum required treatment levels were stringent enough not to require major additional reductions when cyanides are treated as a conservative, the need for a more sophisticated approach diminished.

BOD_5 and ammonia were handled as non-conservatives in accordance with decay rates established in the field survey. These rates were adjusted so that better fits with the stream BOD and ammonia profiles were obtained. The traditional equation relating reaeration rates to stream velocity, depth and discharge was not well suited to the Canal. The depth was more controlled by lake elevation than by the discharge passing through it. The final reaeration rates represented the best compromise between acceptable values and best fit with the dissolved oxygen profile. Phosphorus, sulfates and chlorides were modeled as conservative minerals.

Average as well as the required maximum loads were allocated to better gauge the treatment cost, consequences to the lake and to apply minimum treatment levels which were specified as average values. After some investigative simulations, it was determined that the average loads should be allocated to insure values which were better than the stream standard by 30%. This slack would allow for allocation of maximum values which would insure standards. Once the model was calibrated, then initial computer runs set the discharges at minimum required treatment levels. This allowed for the isolation of discharges responsible for violations in each reach of the system. Cost functions were developed where responsibility rested with more than one discharge and the economic model was employed to yield a cost effective solution. This approach was required for BOD_5, ammonia, dissolved oxygen, chlorides and phenols.

The results of the study were submitted to the Indiana Stream Pollution Control Board in January of 1974. In March of 1974, preliminary conclusions from a study of the lake by IIT Research Institute revealed that the ammonia standards for the Canal would not insure water quality standards in the lake. The state made proper adjustments to the load allocations presented based on information provided by IIT Research Institute. In addition, they were able to equalize the responsibility for abatement of ammonia between all dischargers. The new ammonia loads along with the load allocation for other problem constituents were approved in July of 1974, and are presented in Table 2. To simplify the presentation, only the total loads to the system are given. They include allowances for intake loads as well as the net loads established for each discharge.

As one can see in the summary Table 2, drastic reductions are required of industries in phenols* (89%) and cyanides (90%). Both municipalities and industries must share the responsibility of reducing ammonia (64%). Reductions are needed at the three municipal discharges for phosphorus (38%), and BOD_5 (28%). Minor reductions were required in sulfates to meet standards on the west branch of the river.

TABLE 2. *Total loads allocated.*
to the
Indiana Harbor Ship Canal and Grand Calumet River

	Average Lbs/Day (% Reduced)	Maximum Lbs/Day (% Reduced)
Phenols	102_{89}	158_{97}
Cyanides	554_{90}	1612_{80}
Ammonia	11916_{64}	22583_{76}
Phosphorus	710_{38}	1538_{56}
BOD_5	57349_{28}	120182_{39}
Sulfates	597737_{6}	1000000_{11}
Chlorides	390668_{1}	760800_{1}

Recommendations were not made to reduce chlorides. The major concentrated sources were the municipal discharges. It was determined that the environmental and economic cost of the brine disposal related

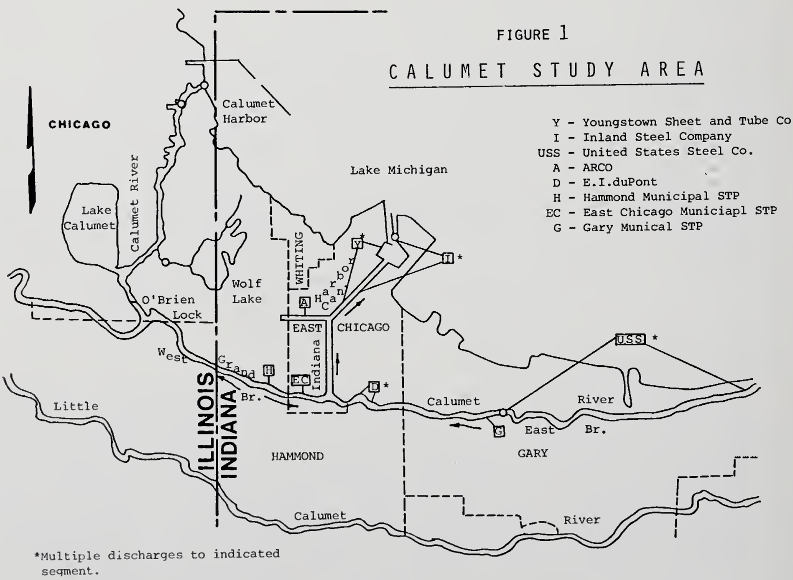

FIGURE 1
CALUMET STUDY AREA

* ( ) % reduction required in existing total average load.

to treatment was prohibitive. The other major source of chlorides in the system is the winter road salting program. Based on the loads derived for this source it is impossible to meet required chloride concentrations in the winter unless a substitute for salt were to be adopted. To date alternatives such as the use of cinders have presented even greater problems. Control of chlorides through diversion of the highly concentrated loads away from the lake was investigated. While the limited time did prevent a very detailed study there was substantial evidence that the consideration of a dam located at the junction of the river and canal to control water quality is worthy of immediate intensive investigation. The board has specifically recommended this be investigated.

For the loads which were allocated to insure water quality standards, a word of caution is in order. These loads were based on existing flows. If recycling is widely used by the industries, the drastic reduction in flow could spawn violations under the allocated loads. The banning of recycling is not an answer. Flow augmentation to replenish the system to the existing flows or complete diversion of the lower recycled flow away from the lake are better alternatives. The latter on presents the greatest reduction possible of the discharge of pollutants to the lake. It is expected this problem will be addressed as negotiations proceed between the dischargers and the state.

In summary, many specific questions of how to meet water quality standards and greatly reduce existing discharges of pollutants to the lake were answered. However, the detailed analysis has led to more general questions regarding the future of the river and canal and their relationship to Lake Michigan and the populace of the Calumet region.

References

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