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Project Summary

Effect of Dredging Lilly Lake, Wisconsin

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Lilly Lake is located in southeastern Wisconsin. It has a surface area of 37 ha and in 1977 had a maximum depth of 1.8 m and a calculated infilling rate of 0.5 cm per year. The basin contained up to 10.7 m of lightweight, organic sediments. Recreational activity was severely restricted due to periodic winter fish kills and dense growths of macrophytes throughout the summer. During the open water periods of 1978 and 1979, 683,000 m³ of sediment were removed with a 30-cm cutterhead dredge and transported via pipeline to two disposal sites. The dredging operation deepened the lake to a maximum of 6.6 m and afforded an excellent opportunity to evaluate the inlake and disposal site effects of the project. The inlake portion of the investigation included an assessment of water quality, aquatic biology, sediments, and hydrology before, during, and after completion of dredging. The evaluation of sediment disposal emphasized the impact on the nearby groundwater system and the value of using hydrosoils to enhance agricultural crop production. The study began in July, 1976 and extended through 1981, with some work continuing into the summer of 1982.

This Project Summary was developed by EPA's Environmental Research Laboratory, Corvallis, OR, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Lilly Lake is a 37 ha, natural, seepage lake located in southeastern Wisconsin. In the early 1970s, it was 1.8 m deep and infilling at a rate of 0.5 cm/yr. The basin contained up to 10.7 m of light-weight, organic sediments, with a water content of 90-98%. During July-October 1978 and May-August 1979, 683,900 m³ of sediment were removed with a 30-cm cutterhead dredge, deepening the lake to 6.6 m. Inlake water quality, aquatic biology, sediment characteristics, and hydrology were investigated before, during, and after completion of the project (1976-82).

Before dredging began, winter fish kills were common, and rooted macrophytes grew over the entire basin, reaching the surface in most areas. The fish population was dominated by slow growing bluegills, and natural reproduction of gamefish was poor. Had oxygen resupply/production been eliminated during the winter, dissolved oxygen concentrations would have approached zero within 25 days. Water quality was satisfactory in the summer. Chlorophyll *a* levels averaged under 5 µg/L, and at least 22 genera of algae were present. Chlorophyceae were dominant in terms of numbers and biomass. Macrophytes were represented by 12 submergent species, with a combined lakewide weighted average biomass of 685 and 335 g/m² in 1976 and 1977, respectively. These plants strongly influenced inlake dynamics and were a major problem in recreational usage of the lake. In 1977, groundwater inflow contributed 17 and 2% of the water and phosphorus loading to the lake, respectively.

During the dredging activity, lake levels dropped 1.5 m. This produced an increased groundwater inflow, including a halt in the outflow, with flow reversal in all of the previous outflow areas. As a result, inlake water chemistry showed more similarity to that of the groundwater, which is illustrated by increases in conductivity and total alkalinity. Because of sediment disturbance, there were also increases in ammonia nitrogen, total phosphorus, and biological oxygen demand (5-day) levels. However, inlake dissolved oxygen concentrations were not affected, and, in general, water quality remained within tolerable limits. The fish population did not appear to be stressed by the prevailing conditions. Initially, the algal population increased, peaking at 33 μg/L of chlorophyll *a*. Changes were also measured for gross primary productivity, numbers of algal cells, and total biomass; however, the population did not undergo any major change in diversity or relative composition. Apparently in response to the algal expansion, the zooplankter *Bosmina longirostris* greatly increased in number during the same period.

Since completion of the dredging project, the lake has refilled to pre-treatment levels. Compared to earlier concentrations, magnesium, sodium, potassium, chloride, conductivity, and total alkalinity were higher while total phosphorus was lower. In 1981 sediment oxygen demand and ammonia nitrogen release rates were similar to 1977. Nevertheless, the inlake water storage was increased by 2.3X, and winter dissolved oxygen levels remained above 7 mg/L at all depths. The ammonia nitrogen was apparently being quickly converted to other nitrogen forms (as in 1977), because only insignificant levels were found in the water column. Soluble reactive phosphorus release into the water column was minimal due to the toxic conditions, although it would become a significant phosphorus source under anoxia. In 1981, the lake was still polymictic, but thermal gradients up to 8°C were present on occasion. Low dissolved oxygen levels were found near the bottom during these periods of reduced mixing. Bottom temperatures reached 24°C; however, summer maxima were depressed at all depths due to the increased water volume.

By 1981, average summer chlorophyll *a* levels were again under 5 μg/L. Algal diversity and density were similar to the pre-dredging levels of 1978. There was a shift in species composition, represented by the appearance of six genera of Chrysophyceae. These were co-dominant with the Chlorophyceae in terms of biomass. The benthic invertebrate community was relatively sparse both before and after dredging; however, numbers and diversity were greater in 1981. The populations of *Hyalella azteca* and *Pericoma* sp. were down, but Oligochaetes, *Caenis* sp., and several genera of chironomids responded to the improved inlake conditions. Many of the latter are known to be good fish food organisms. Dredging and drawdown was a major disruption for the rooted submergent vegetation. In 1980, species diversity was reduced to six, and the lake bottom was inhabited primarily by a macrophytic algae, *Chara* sp. This is often a pioneer species for new habitat. By 1982 the *Chara* sp. was being replaced by rooted macrophytes, and the diversity of species had increased somewhat. The plant community was still evolving, but the existing characteristics included: (1) growth over 75% of the lake area, to a depth of 3.7 m; (2) top 1.2-1.8 m of the water column weed-free, except in the shallow, near shore area; (3) lakewide weighted average biomass under 100 g/m^2; and (4) lower biomass over sand versus muck bottom. The lower biomass over sand was also true before dredging but is important because of the greatly enlarged area of sand bottom post-treatment.

Although dredging removed the phosphorus-rich upper sediments, resulting in a major reduction in most phosphorus forms (especially sodium hydroxide extractable phosphorus), the sediments were still the most important reservoir of phosphorus within the lake. However, phosphorus transport directly into the water column was minimal, based on a combination of measurement and predictive equation. Groundwaters furnished 46% of the water loading in 1981 but only 9% of the phosphorus. Several models were used with the water and phosphorus loadings before and after dredging to predict a chlorophyll *a* level for the lake. All of the models suggested that low chlorophyll *a* concentrations would be present in the lake, correlating well with actual measurements.

The lake sediments were transported via pipeline to two disposal sites. The primary site, a modified abandoned gravel pit, was used in 1978 and 1979, eventually receiving about 540,000 m^3 of sediment. The remainder of the sediments were placed in a low diked area on agricultural land. This site was used in 1979 only. Changes to the groundwater systems were monitored with observation wells at both sites plus private drinking water wells at the gravel pit. Parameters of interest at both sites included water levels, nitrate plus nitrite nitrogen, ammonia nitrogen, pH, and conductivity. In addition, chemical oxygen demand was measured at the diked area and the following at the gravel pit site: chloride, total organic nitrogen, total dissolved phosphorus, total phosphorus, arsenic, barium, cadmium, copper, iron, lead, mercury, selenium, silver, zinc, and chromium.

The results were similar at each of the disposal sites. The response time for a particular well was related to soil permeability and distance from the diked area or gravel pit basin. The greatest impact was observed in wells located adjacent to the sites, especially where permeable soils were present. Impact duration was short because the lake sediments quickly inhibited continued seepage of water away from the sites. In general, the surrounding groundwater systems were not affected significantly as a result of lake sediment disposal. In 1983, the modified gravel pit was still retaining water; however, the sediments at the diked area were landspread, dried, and incorporated into the terrestrial soils during 1980-81. By 1983 the area was growing corn.

Laboratory, greenhouse and field studies, begun in 1980 and terminated in 1982, were set up to determine the effects of applications of sediment from the lake on agricultural crops. The laboratory studies included a survey of sediments from 11 other Wisconsin lakes, and the greenhouse study included three additional sediments so that chemical properties and plant responses to this sediment could be compared with chemical properties and crop responses from other sediments.

The sediment survey included analyses of the 12 sediments for pH, total carbon, chemical oxygen demand, loss on ignition, total nitrogen, ammonia nitrogen, total phosphorus, organic phosphorus, phosphorus extracted with 0.5*M* sodium bicarbonate, phosphorus equilibrated in 0.01*M* calcium chloride, and total zinc, manganese, copper, cadmium and lead. A study of nitrogen and phosphorus released or immobilized on incubation was also included. Lilly Lake sediment had the highest pH, total carbon, chemical oxygen demand, loss on ignition, total nitrogen and nitrogen release on three month's incubation. It also showed the greatest decrease in phosphorus equilibrating in calcium chloride after incubation. The sediments showed wide ranges in many of the factors, particularly in those associated with pH and organic matter content.

The four sediments used in the greenhouse study were selected to give wide ranges in pH (5.1 to 7.7), chemical oxygen demand (3.5 to 28.7 mg/L), total nitrogen (0.35 to 2.69 mg/L) and carbon/phosphorus ratio (64-1420). Sediment concentrations equivalent to 0, 10, 30, 90 and 270 mT/ha were established in 1.5 dm^3 pots of Plainfield sand and Withee silt loam. Corn was planted and harvested after eight weeks.

Factors investigated in the greenhouse experiment included yield, tissue concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc, boron, and plant uptake of nitrogen, phosphorus and potassium. Statistical analyses showed highly significant differences associated with the soil used for all factors except yield and copper concentration. Differences associated with sediment source were significant at the 5% level or greater for all factors except phosphorus, potassium and boron concentrations. However, only concentrations and uptakes of nitrogen showed differences that were great enough to be important from a practical standpoint. The New Richmond flowage sediment did increase the zinc concentration in the plant tissue more than the other sediments, but the concentration was not excessive.

Although there was a sizable, significant variation in nitrogen concentration and uptake associated with the different sediments, there was no effect of application rate beyond the first increment. Application rate did significantly affect calcium, magnesium, sulfur and manganese concentrations, but except for manganese the effects were not great. Increasing rates of high pH Lilly Lake sediment decreased manganese concentrations in the plant, whereas increasing rates of the acidic Lake Tomah sediment increased manganese concentrations.

The field studies were set up on a Fox silt loam in 1980. Lilly Lake sediment additions equivalent to 0, 22.4, 44.8 and 39.6 mT/ha of dry sediments were made. There were four replicates in a latin square design. Sudan grass was planted and was harvested twice. Even though the site was an old alfalfa field, significant yield and nitrogen uptake responses over the control were obtained in both harvests. There were no significant differences between different rates of sediment application.

The field experiment of 1981 and 1982 was on a Hebron silt loam at a different site because sediment from an adjoining lagoon was spread over the original site. The same experimental design was used at the new site which was previously in pasture, and corn was grown both years. No significant differences in yield, or in nitrogen or phosphorus concentrations or uptakes occurred in 1981. Grain yields could not be obtained in 1982 because of cow damage, but concentrations of the following elements were determined in ear leaves at silking and in the corn grain: nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, iron, copper, aluminum, manganese, cobalt, arsenic, cadmium and lead. The only significant effect associated with sediment addition was an increase in the nitrogen concentration in the grain at the highest sediment rate.

Both the greenhouse and field results suggest that, of the factors measured, the only beneficial effect to crops from the application of Lilly Lake sediment would be an increase in nitrogen availability which would probably continue to be effective for a number of years. No harmful effects of sediment application were apparent.

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The complete report, entitled "Effect of Dredging Lilly Lake, Wisconsin," (Order No. PB 85-117 042; Cost: $13.00, subject to change) will be available only from:
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