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State-of-the-Art: Sand And Gravel Industry

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STATE-OF-THE-ART: SAND AND GRAVEL INDUSTRY

by

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ABSTRACT

This report presents an overview of the sand and gravel industry in the United States and its relationship to the environment. The fate and effects of sediment generated by this surface mining activity on the benthic, planktonic, and fish communities of our waterways are discussed in detail. Problems of the sand and gravel industry, types of operations, status of current treatment technology, and legislation affecting the industry are reviewed.

CONTENTS

SECTION I

CONCLUSIONS

1. The production of sand and gravel represents the largest non-fuel mining operation in the United States. Production is reported from every state with the distribution pattern concentrated in areas of high population density. Sand and gravel production is expected to double by 1980, and forecast demand for this commodity ranges from 300 to 400 percent increase by the year 2000.

2. Storm runoff and plant process water are the two main sources of water pollution associated with sand and gravel production. Sediment loads, from several hundred to several thousand mg/l, are detrimental to: (1) aesthetic values, (2) stream biota, (3) downstream water quality for domestic and commercial uses, and (4) the ability of a natural body of water to purify itself.

3. Surface mining for sand and gravel has disturbed over 1,000,000 acres. A recent study by the Soil Conservation Service, as printed in the Congressional Record of January 1, 1974, estimated that 4,418,710 acres had been disturbed by all surface mining activities. Of the total 2,542,682 acres requiring reclamation, sand and gravel mining operations were responsible for 35 percent; coal, 37 percent; and all other mining, 28 percent. Unlike coal and iron surface mining that are confined to specific geographical areas, sand and gravel operations are widely distributed throughout the United States; hence, more people are directly affected by the adverse effects than any other mining operation.

4. Three different methods of sand and gravel excavation are practiced: (1) dry pit, sand and gravel is removed above the water table; (2) wet pit, raw material is extracted by means of a dragline or barge-mounted

dredging equipment both above and below the water table; and (3) dredging, sand and gravel is recovered from public waterways, including lakes, rivers, estuaries, and oceans. All methods require approximately 600 gallons of process water per ton to rid this product of mud, clay, and other debris. The total volume of process waters utilized represents over 500 billion gallons per year.

5. The most common treatment practice employs the use of holding ponds for the purpose of solid separation. This method has proved adequate for process waters containing small amounts of colloidal matter. For the more refractory colloidal fines, settling aids have been utilized with success. A small percentage of process waters cannot be adequately clarified to meet designated discharge standards regardless of the treatment method employed.

6. Dewatering and ultimate disposal of waste fines are two of the more serious problems facing the sand and gravel industry. Accumulations of 500 tons per day of solid waste material is generated in the larger operations. Final disposition of this material will, in many cases, be financially more burdensome than the initial waste treatment process.

7. Great Britain, Japan, and the Netherlands are currently recovering appreciable amounts of ocean-dredged sand and gravel from depths of 20 to 100 feet. Ocean dredging in the United States is minimal at the present time. In 1972, 25 percent of the national production of sand and gravel was consumed by the urban areas of the 21 states bordering the ocean. Estimates by the Corps of Engineers indicate 75,000 square miles are suitable for sand and gravel recovery from the coastal zones of the United States. With improved technology, greater demand, urban encroachment, and the increasing cost of land transportation, it is reasonable to assume that ocean mining for sand and gravel will become a significant domestic source of supply within ten years.

SECTION II

RECOMMENDATIONS

1. Research should be conducted on methods to remove finely dispersed colloidal fines (smaller than 200 mesh) that remain in suspension in sand and gravel effluents despite the utilization of settling aids. Methodologies to be considered for removal purposes should include gas flotation, tube or lamellae settlers, and microfiltration devices.

2. A survey of sand and gravel producers currently utilizing advanced treatment procedures for the removal of suspended fines from their waste discharges should be conducted. The survey should be made the subject of a report delineating successful treatment technologies with cost considerations, and receive wide distribution among members of the industry.

3. Studies should be undertaken to determine effective and economical means of dewatering refractory clay slimes from sand and gravel processing procedures, especially industrial glass-sand production.

4. Research should be initiated to determine methods for the removal or containment of suspended solids generated from dredging operations for sand and gravel on public waterways. While past efforts to contain these sediments utilizing diking techniques, silt curtains, and bubble barriers have not been totally successful, these procedures should be reinvestigated.

5. Since ocean mining of sand and gravel in the United States is certain to become an important domestic source of this product within a few years, research should be undertaken to determine the impact of ocean dredging operations on the marine environment. An investigation such as the NOMES project (New England Off-Shore Mining Environmental Study) should be coordinated among the interested agencies and approved for funding.

6. Governmental control bodies, Federal, State, and local, should develop a uniform set of rules, regulations, and guidelines for sand and gravel operations to assist producers in planning their mining operations.

SECTION III

INTRODUCTION

Based on physical volume, the sand and gravel industry represents the largest non-fuel industry in the United States. In 1972, 5,384 domestic plants produced 913 million tons of this product with a value of 1.1 billion dollars, as reported by the Bureau of Mines. Sand and gravel production was reported from all of the states, and active or latent deposits are located in almost every county. Figure 1 shows percentage production of sand and gravel by EPA regional divisions.

Construction use accounts for 96 percent of all sand and gravel produced; hence, forecast figures for the construction industry may be used to estimate future aggregate production. Utilizing these estimates, production of sand and gravel is expected to double by 1980. Long-range forecast demand for this product for the year 2000 range from 3.2 to 4.0 billion tons, an increase of 300 to 400 percent (Figures 2 and 3).

For the processing of a ton of sand or gravel, a minimum of 600 gallons of water is required to remove clay, mud, and other undesirable substances. For 1972, this figure represented well over 500 billion gallons that was utilized for washing purposes.

Contrary to most industrial effluents, sand and gravel wash waters contain essentially one component, sediment, that exerts a detrimental ecological impact on the environment. Due to the greatly increased concentration of suspended solids, sand and gravel processing waters may not be discharged under present regulations without prior treatment. Unfortunately, in many instances, wash waters from active installations, as well as storm runoff from both active and abandoned

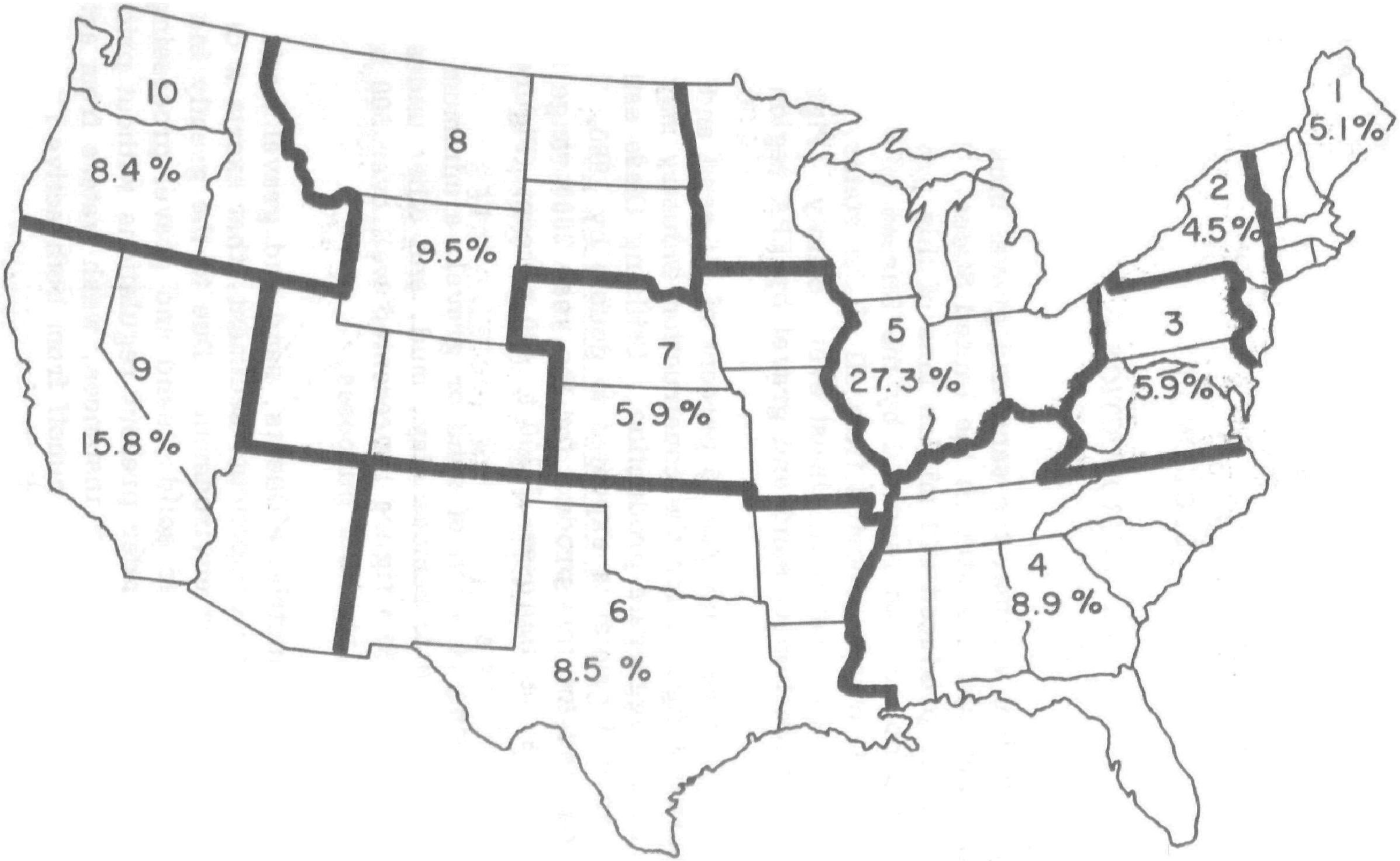

FIGURE 1 - PERCENTAGE DISTRIBUTION OF SAND AND GRAVEL PRODUCTION BY REGIONAL DIVISION 1972

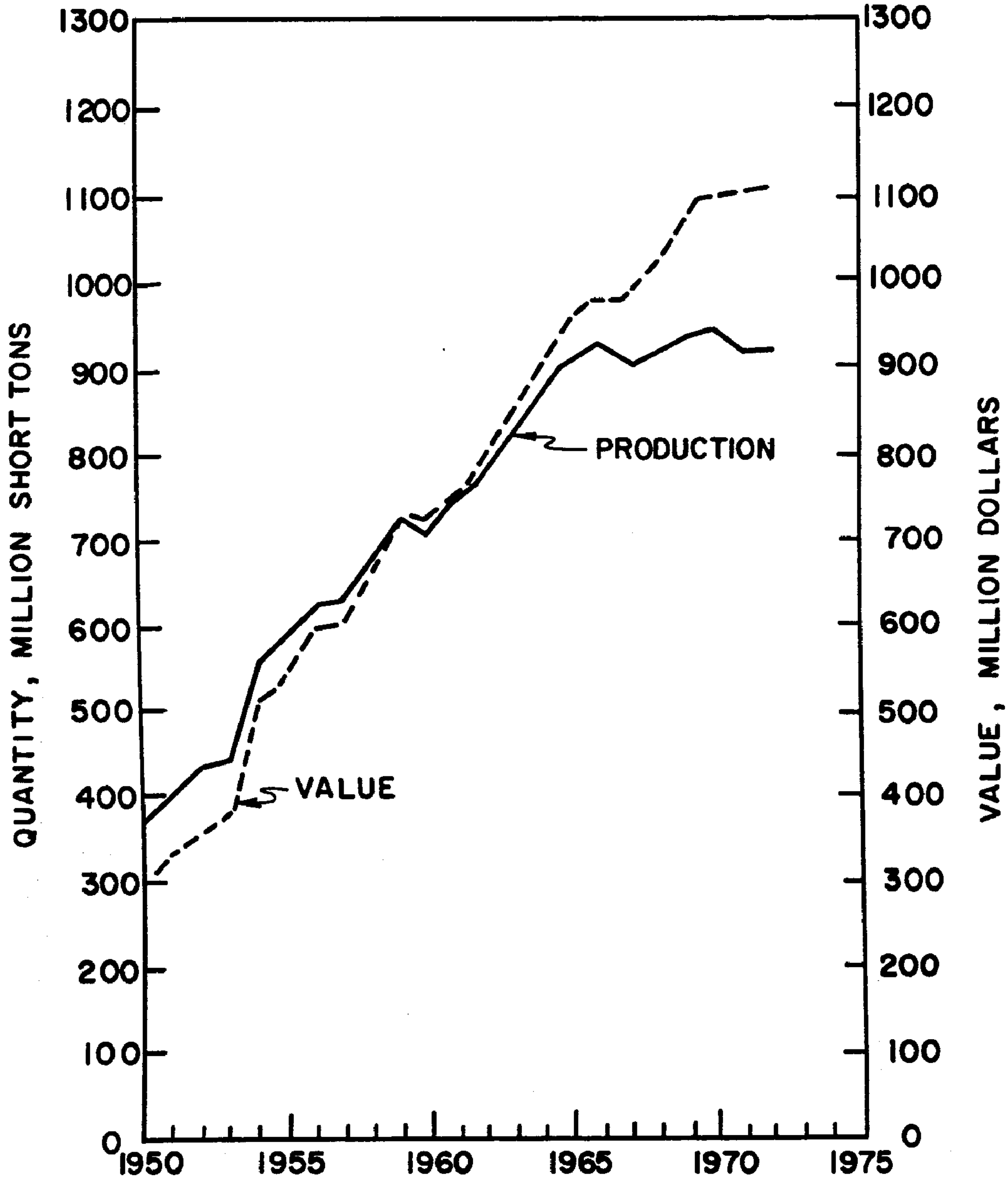

FIGURE 2 – PRODUCTION & VALUE OF SAND & GRAVEL IN THE UNITED STATES

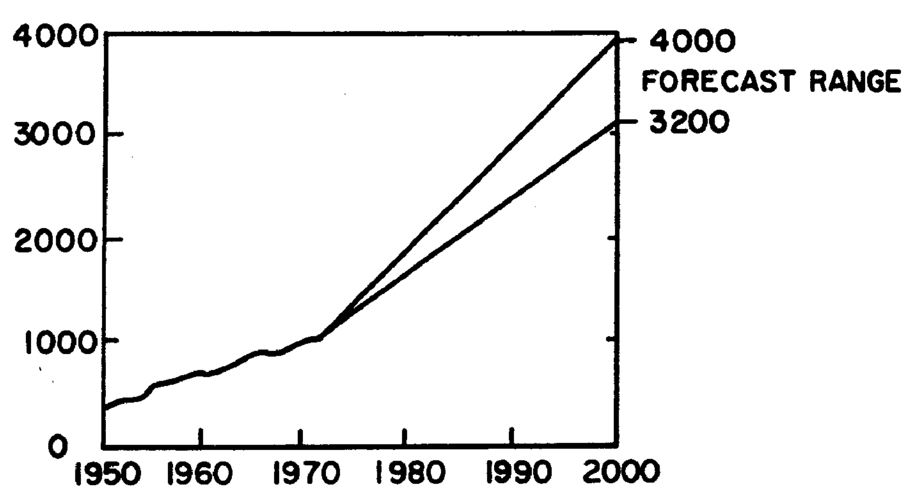

FIGURE 3 – PRODUCTION FORECAST FOR SAND AND GRAVEL

facilities, are being released directly to surrounding surface waters. This situation has occasioned complaints from environmentalists and other concerned parties with regard to degradation of water quality for other users, deleterious effects on the biota of the receiving waters, and deterioration of the environment from an aesthetic standpoint.

Following siltation, an unsightly turbid body of water offers few recreational opportunities. Gravel shallows, once providing nesting areas for trout, bass, salmon, and other sport fish are covered and not available for these purposes. The benthic population is severely reduced, with some species disappearing. Rocky areas harboring organisms, while providing protective cover for fish larvae and nesting areas, no longer exist. Turbidity, by affecting light penetration, reduces the thickness of the euphotic zone, thus seriously affecting the productivity of the planktonic and benthic community. Reduced numbers of organisms result in a significant reduction of fish production and carrying capacity of this water. The natural ability of a stream to purify itself is dependent upon the existence of viable communities of bacteria, benthic, and planktonic organisms. Solids that settle from suspension also carry organisms plus unstable organic matter. Consequently, the characteristic population increase response to organic waste discharges will not exist in silt-laden waters.

In addition to water pollution, as of 1972, surface mining in the United States had resulted in the disturbance of 3,935,000 acres of land. Of this total, only 35 percent has been reclaimed for useful purposes. Areas disturbed by this activity are currently increasing at a rate in excess of 200,000 acres per year. Due to the expected rapid expansion of surface mining, it is estimated that 5.5 million acres will have been disturbed by this method of mineral extraction by 1980.

The Department of the Interior, by directive of Public Law 89-4, March, 1965, completed a comprehensive study on surface mining in 1967. The report which followed, "Surface Mining and Our Environment," U.S. Department of the Interior, July, 1967, delineated the problems and environmental significance associated with surface mining activities.[1] Findings of the study by members of the Bureau of Sport Fisheries and Wildlife identified two million acres of fish and wildlife habitat damaged by surface mining: 13,000 miles of streams (135,970 surface acres), 281 natural lakes (103,630 surface acres), and 1,687,288 acres of land. Due to the increase in surface mining since 1967, a 20 percent increase in the above figures would be a conservative estimate.

Virtually all land disturbed by surface mining was attributed to eight mining activities: coal, 41 percent of the total; sand and gravel, 26 percent; stone, gold, phosphate, uranium, iron, and clay, 33 percent (Table 1).[2] These figures were based on all surface mines, active and abandoned, up to and including 1964. Of particular interest, based on data reported by the producers to the U.S. Department of the Interior, in 1964 alone, 153,000 acres of land were disturbed by surface mining. Of the total, sand and gravel accounted for 60,000 acres (40 percent); coal, 46,000 acres (30 percent); stone, 21,000 acres (16 percent); clay and phosphates, each 9,000 acres (5 percent); and the remaining minerals, 8,000 acres (4 percent).

Table 1. PRINCIPAL SURFACE-MINED COMMODITIES AND ESTIMATES OF DISTURBANCE[a]

Commodity	Acres Disturbed	Percent of Total
Coal	1,614,000	41
Sand and Gravel	1,024,000	26
Stone	315,000	8
Gold	236,000	6
Phosphate	236,000	6
Iron	196,000	5
Uranium	196,000	5
Clay	118,000	3
Pegmatite		
Gypsum		
Copper		
Barite		
Chromite		
Peat		
Pumice		
Total	3,935,000	100

[a] Revised from table in Resource Publication 68, Bureau of Sport Fisheries and Wildlife, 1968, to include 1972 production figures.

Currently sand and gravel production accounts for 1,024,000 surface acres disturbed through excavation processes. Improved technology, more massive equipment, and greater demand is resulting in the economic exploration of lower grade sand and gravel deposits, thus increasing the ratio of acres disturbed per ton of sand and gravel produced. With the mining of this commodity expected to double by 1980, and increase three to four times by the year 2000, the environmental significance of surface mining and sand and gravel is evident.

SECTION IV

LITERATURE REVIEW

SEDIMENT TRANSPORT

The fate of sediment entering natural bodies of waters and its ultimate distribution is complicated somewhat by the variables involved: particle size, stream depth and velocity, and flow variations resulting from seasonal fluctuations. Due to these variables, sediment transport in a stream can vary from a few feet to several miles.

Sediments have been classified most often according to size. Twenhofel (1961)[3] lists eleven categories of sediment classifications. These range from clay particles that measure less than 1/256 mm to boulders with a diameter of 257 mm or more. In considering sediment and its effect on the environment, the more harmful sizes would be the smaller particles, classifed as clay or fine mud, and loam.

Twenhofel (1961)[4] stated that a current of 0.18 mph would suspend brick clay and a stream velocity of 0.72 mph would move fine mud and loam. Average stream velocities in many instances exceed the above values, but in areas of reduced flow such as pools or stream widenings, the necessary velocity to suspend fine mud or loam is not attained, resulting in the deposition of solids on the bottom. Colloidal particles that remain in suspension necessitate expensive treatment procedures downstream.

Cooper (1956),[5] studying sediment transport versus stream velocities, concluded that during a spring freshet the banks are washed and the stream bed is scoured. During the early part of the high flow, transportable material is removed from the stream. As the freshet passes, the availability of transportable material decreases rapidly, leaving the bed relatively free of fine sediment.

The percent contribution of suspended solids from sand and gravel effluents to the total silt load in a stream has often been stated in an effort to minimize its significance. Average yearly sediment loads carried by a given stream are measurable and in most cases are relatively high. However, the elevated natural loads occur during periods of high flows when increased stream velocities scour banks and bottoms and reduce accumulated siltation. Sand and gravel plants operate the year round; hence, silt is deposited during periods of normal or low flow. Once these particles have become consolidated to form beds, a much greater velocity of water is required to dislodge the sediment.

SEDIMENT EFFECTS

Innumerable studies concerning the effects of silt on stream biota have been conducted. Some of the more pertinent findings related to sand and gravel operations will be summarized in the following discussion:

Benthic Community

The benthic community, composed of attached algae and aquatic invertebrates on lake and stream beds, act as a sensitive indicator of siltation since their numbers are adversely affected by sediment. Most of the organisms thrive abundantly in an environment of gravel and rubble that provides adequate shelter and surface area to grow and reproduce. Sediments that fill the interspaces or cover this productive area reduce or eliminate the number of benthic organisms. Small amounts of silt, not readily apparent, can result in a serious reduction of benthic organisms. Since benthic organisms comprise a significant part of fish diets, a reduction in their numbers will exert a concomitant effect on fish prevalent in the area.

Bottom sampling for the purpose of recovering benthic organisms has been used extensively in the past, and is presently the method of choice for the detection and measurement of silt pollution. The method entails the collection of numerous representative bottom samples above and below sources of silt introduction, followed by the enumeration and identification of the organisms present. This technique has provided valuable information as to the direct effect of inorganic silt on fish food organisms and sediment transport in waterways.

Tarzwell (1937)[6] and Gaufin and Tarzwell (1952)[7] rated different substrates according to their ability to support macroinvertebrate populations, using a scale from one to 452. Shifting sand, supporting the fewest numbers, rated one, while gravel and rubble rated over 400. All substrate mixed with inorganic silt rated 27 or less.

Bartsch (1960)[8] found that the effect of inorganic sediment from a glass manufacturing plant on the Potomac River was still evident 13 miles below the outfall. Ziebell and Knox (1957),[9] studying the effects of a gravel washing operation on the South Fork of the Chehalis River, Washington, found the recovery of bottom fauna to normal concentration 6.5 miles below the outfall. Cordone and Pennoyer (1960)[10] noted that silt below a gravel washing plant had reduced the bottom organisms to 75 percent of normal ten miles downstream. Reports published by the Oregon State Game Commission, et al, (1955)[11] and Wilson (1957)[12] showed that silt from a gold dredge operation on the Powder River resulted in the siltation of 15-20 miles of that stream. Jackson (1963)[13] concluded that benthic organism reductions may approach 75 to 80 percent for distances 10 to 50 miles below sources of silt pollution.

Planktonic Community

Algae are commonly considered as the most basic member of the animal food chain, and any reduction effects of sediment on algal numbers are of critical importance to the entire stream community. Sediment is believed to destroy algae by abrasive action, physical settling, covering and smothering attached algae, and reducing illumination necessary for photosynthesis.

Cordone and Pennoyer (1960)[10] found that an abundant population of algae pads was virtually destroyed by sediment discharge into the Truckee River, California.

Lackey, Morgan, and Hart (1959)[14] reported a series of experiments testing the ability of sediment of different sizes to settle blooms of Golenkinia and Euglena. Sand, muck, and clay were all quite effective in settling the plankton.

Mackenthun (1969),[15] studying a section of the Etowah River in Georgia affected by silt pollution, found only 126 planktonic algal cells per ml represented by two genera. A control stream in the same watershed but unaffected by silt pollution yielded ten times the above number of algal cells and was comprised of ten algal genera.

Fish Population

The availability of food for fish depends ultimately upon the growth of green plants (algae and higher aquatic plants). The prevalence of plants and fish food fauna will decrease after introduction of silt. The decrease will likely be evident at concentrations of 100 ppm suspended solids and above. Water containing higher concentrations of suspended matter is unlikely to produce an adequate plant life which will consequently be evidenced in poorer fisheries.

Herbert and Richards (1963)[16] reported the results of a questionnaire sent to river boards in England inquiring about the abundance of fish in water containing suspended solids of industrial origin. Their conclusion was that fish are apparently unharmed at concentrations of suspended solids below 100 ppm, but definite reductions were observed at 300 ppm.

Herbert, Alabaster, Dart, and Lloyd (1960)[17] noted normal brown trout populations at sediment concentrations of 60 ppm with a 15 percent decrease of the normal population density in waters carrying 1,000 to 6,000 China clay wastes. No trout were found in another stream where the concentration of suspended stonedust from a granite crushing mill ranged from 11,000 ppm near the mill to 185 ppm at the tributary's junction with another stream.

Sumner and Smith (1939)[18] noted that the king salmon avoided entering the turbid water of the Yuba River, California, and preferentially entered the clear tributaries.

Bachmann (1958)[19] reported that cutthroat trout stopped feeding and sought cover when the turbidity was increased slightly to 35 ppm.

Cleary (1956)[20] reporting on streams in Iowa noted that during sporadic periods of high turbidity, smallmouth bass nested, spawned, and hatched. However, streams experiencing long periods of erosion silt produced few fingerlings or good fishing.

Generally, natural stream turbidities seldom exceed 100 ppm during normal flows; however, 3,000 to 4,000 ppm are not uncommon during periods of heavy runoff and Cross (1950)[21] has reported colloidal clay concentrations as high as 30,000 ppm in some Oklahoma streams.

Wallen (1951),[22] conducting experiments on the direct effect of turbidity on fish, used 16 species of warm water fish in controlled aquarium investigations. Findings were that most individuals of all species exposed to 100,000 ppm turbidity for a week or longer survived. Survival of fish at these greatly increased turbidities would tend to indicate that lower turbidities are not harmful. That fish can withstand short periods of high turbidity, such as occur during periodic flooding, would be expected for survival purposes.

Although the above research concludes that fish are not killed by solids concentrations higher than those normally found in nature, several longer term studies employing lower suspended solids concentrations indicate long-range detrimental effect. One study by Griffin (1938),[23] working with rainbow trout at concentrations of 270 ppm, reported increased mortality, higher incidence of fin rot, and thickened gill epithelium at the increased level of suspended solids. Other studies by Herbert and Richards (1963),[16] using both coal washings and wood fibers, showed that growth rates decreased as the suspended solids increased from 50 to a 100 to 200 ppm.

It can reasonably be concluded that high concentrations of several thousand ppm suspended solids can be tolerated for short periods of time without causing death, but a much lower concentration of 100-300 over a long period of time can result in death, slowed growth rate, and susceptibility to disease. These lower concentrations may also kill weaker fish that would otherwise survive in a more favorable environment.

Fish Reproduction

Silt exerts its most disastrous effects on fish in the area of reproduction; notably, spawning, fish egg and fish larvae survival. It is during this initial period of development that fish are most vulnerable. Direct damage to adult fish by sediment is evident long after the more insidious indirect damage to fish populations has occurred through destruction of eggs, alevins, and spawning areas.

There is evidence, Stuart (1953),[24] that some salmonoid avoid spawning in gravel areas that have been consolidated by sediment infiltration. Additionally, it was noted that fish larvae could tolerate small amounts of silt in holding traps if the silt was added intermittently. Continuous additions of silt resulted in death of the trout larvae from gill inflammation.

Alderdice, Wickett, and Brett (1958)[25] showed that salmon eggs required one ppm oxygen in the surrounding water during the early stages and seven ppm at later stages to hatch successfully. Wickett (1954)[26] concluded that the amount of oxygen available to developing eggs depends not only on its concentration but on the rate of flow over the eggs. A similar and contributing effort by Alderdice and Wickett (1959)[27] concluded that carbon dioxide produced by the eggs, if not carried away, decreased the ability of the eggs to use available oxygen. A study by Stuart (1953)[24] showed that silt in suspension adhered to the surface of fish eggs and prevented their hatching. He attributed this finding to the prevention of sufficient respiratory exchange of oxygen and carbon dioxide between the eggs and surrounding water.

Hobbs (1937),[28] conducting a study on natural reproduction of king salmon, brown and rainbow trout and observing mortality of eggs in gravel beds, stated that, "The bulk of losses, which irrespective of species of fish, occur in varying intensity in different streams and in different redds of the same streams are attributed to a common factor, sediment. Where redds are very clean, losses are very slight, and where redds are very dirty, losses are heavy." He states further that there is sufficient evidence to show that decreased permeability in redds results in a greater loss of eggs than where, other conditions being equal, the redd material is more permeable.

Fish Species Composition

Following siltation, food for many fish species is not present in the affected stream. Rocky areas are covered, eliminating cover for smaller fish and nesting areas for larger ones. Many fish species are sight feeders and due to foraging difficulties, avoid turbid water if possible. Less desirable, mud-tolerant species will predominate; hence, fish species composition will be adversely affected by silt intrusion into a natural body of water.

Trautman (1957),[29] studying species modification due primarily to silt states that, "The fish fauna had changed from a species complex dominated by fishes requiring clear and/or vegetated water to one dominated by those species tolerant of much turbidity of water and bottoms composed of clay silts. There has been a shift from large fishes of great food value to smaller species unfit as human food or large fishes of interior food quality."

Diversified fish populations before siltation in the Ohio region, studied by Trautman, contained pike, walleye, catfish, buffalo, sucker, drum, and sturgeon. Environmental changes, caused by silt, altered the population to that of brown and black bullhead, channel catfish, white crappie and carp. The author also reported a reduction or elimination of 51 fish species in the Middle Harbor Lake in Ohio, due to the elimination of fish habitats by siltation. The remaining fish killed by rotenone consisted of 90 percent carp, goldfish, hybrids, and dwarfed bullheads.

An extensive study by Buck (1956),[30] examining the effects of turbidity on largemouth bass, bluegill sunfish, redear sunfish, and channel catfish, utilized farm ponds in Oklahoma. Twelve ponds were separated into the following turbidity classes: (1) clear ponds with average turbidities of less than 25 ppm, (2) intermediate ponds with a range of turbidities from 25 to 100 ppm, and (3) muddy ponds with turbidities in excess of 100 ppm. In the study all ponds were treated with rotenone and then restocked. The following findings are summarized (Figures 4 and 5):

1. At the end of two growing seasons, the average total weight of fish in clear farm ponds was approximately 1.7 times greater than in ponds of intermediate turbidity and approximately

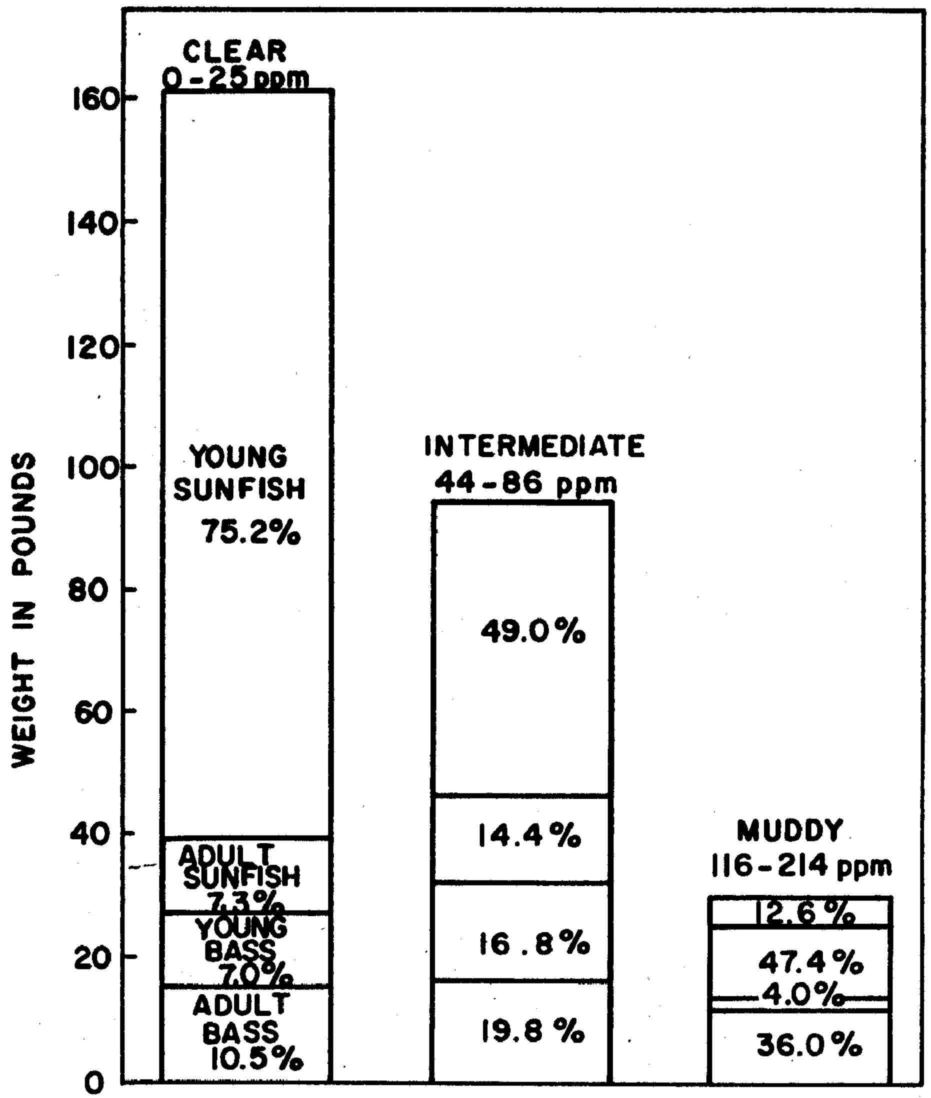

FIGURE 4 - FISH GROWTH AND COMPOSITION

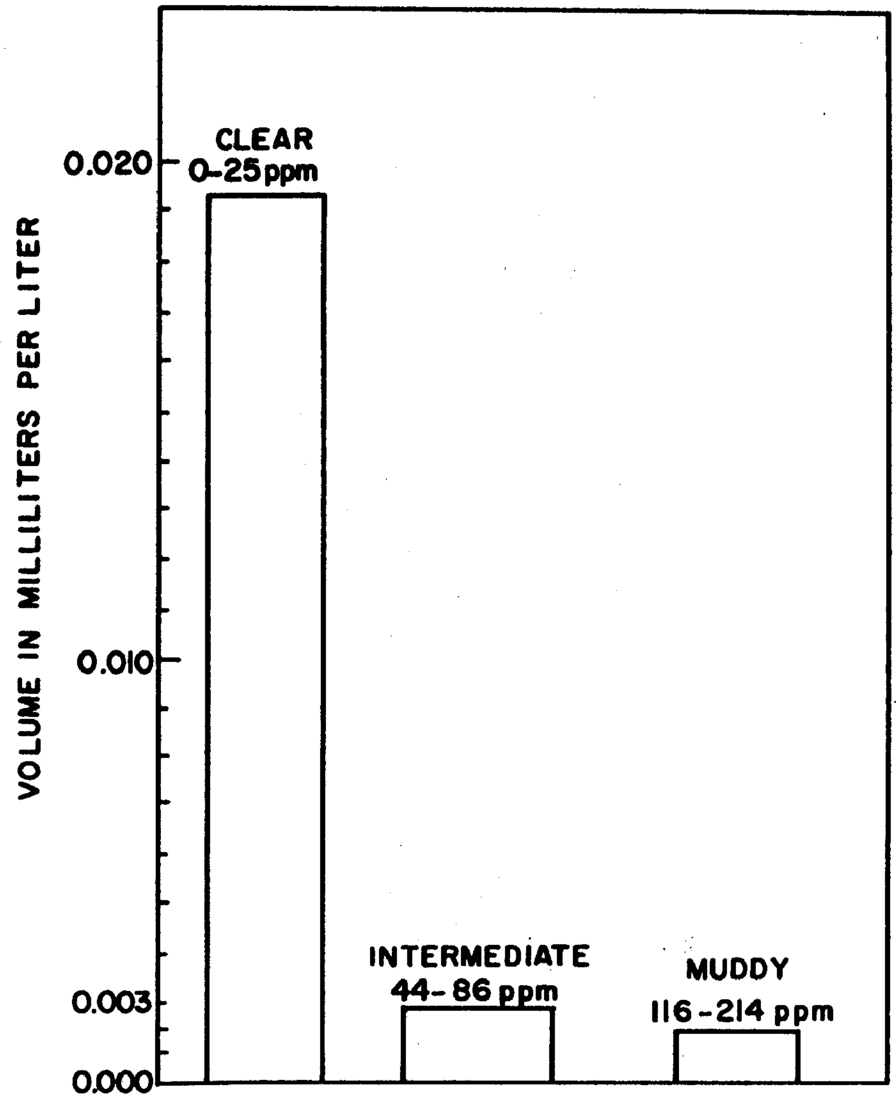

FIGURE 5 - NET PLANKTON

5.5 times greater than in muddy ponds. Differences were due to faster growths by all species and to greater reproduction in clear ponds, particularly by bluegills and redear sunfish.

2. Of the three species used in farm ponds, largemouth bass were affected by turbidity in both growth and reproduction. Redear sunfish appeared less retarded in growth than did bluegills during the first year, but the two sunfishes appeared equally restricted in both growth and reproduction during the second year.

3. Average volume of net plankton in surface waters of clear ponds during the 1954 growing season was eight times greater than in ponds having intermediate turbidities; 12.8 times greater than in the most turbid ponds.

In an effort to obtain comparative data on larger lakes, Buck designed a project that utilized two Oklahoma reservoirs--one muddy and one clear. Lake Heyburn, a 1,070-acre lake, was selected as the muddy lake and Upper Spavinaw, with 3,192 acres, was selected as the clear lake. The lake study results paralleled those from farm ponds.

1. Growth of largemouth bass, white crappie, and channel catfish was much slower in turbid Heyburn than in clear Upper Spavinaw reservoir.

2. Growth of flathead catfish was the most favorable of any Heyburn species studied, and is apparently well adapted to the turbid environment.

3. The number of species, as well as individuals of all scaled fish, was low in the turbid Heyburn reservoir. This finding was attributed to a lack of successful reproduction in the turbid waters and also to competition from the better adapted catfishes.

4. An extreme scarcity of forage species was noted, particularly gizzard shad, along with a limited development of carnivorous fish species at Heyburn.

5. Lake Heyburn largemouth bass and white crappie populations exhibited unusual dominance by older individuals. This finding was attributed to successively smaller year classes as a result of increasing turbidities.

6. In 1954 the average volume of plankton in surface waters was 13.8 times greater in Upper Spavinaw than in Heyburn, and average volume from the 60-foot depth at the clear reservoir was greater than the combined total from surface, 15-foot depth, and 30-foot depth in the muddy reservoir. The contrast was least marked in 1955, possibly due to the somewhat lower average turbidities recorded at Lake Heyburn that year.

7. The clear reservoir attracted more anglers, yielded greater returns per unit of fishing effort, as well as more desirable species, and was immeasurably more appealing from an aesthetic standpoint.

In reviewing the literature on siltation, it became evident that the major part of research investigations had taken place in streams that for the most part were isolated from other pollution sources. These virgin streams, except for silt, were relatively free of man's degradating influences. Fortunately, the areas still exist, enabling concerned individuals to study siltation problems in an atmosphere free from the many complicating variables existing in populated areas. Information gained in these studies has provided an invaluable insight into the effects of siltation on many of our streams.

In summary, the literature reviewed to date indicates that a precise minimum concentration of inorganic solids detrimental to maintaining good fisheries has not been unequivocally established. There is sound evidence, based on the numerous research projects completed in this area, however, that the suspended solids concentrations listed below are meaningful approximations.

0-25 ppm--No harmful effects on fisheries.
25-100 ppm--Good to moderate fisheries.
100-400 ppm--Unlikely to support good fisheries.
400 and above ppm--Poor fisheries.

SECTION V

TYPES OF SAND AND GRAVEL MINING OPERATIONS

Three different methods of sand and gravel excavation are practiced: (1) dry pit, sand and gravel removed is above the water table; (2) wet pit, raw material extracted by means of a dragline or barge-mounted dredging equipment both above and below the water table; and (3) dredging, sand and gravel is recovered from public waterways, including lakes, rivers, and estuaries. Figure 6 illustrates a typical sand and gravel processing system.

Over 5,000 domestic plants in the United States fall into the above categories. A breakdown of their percent contribution of the total production is as follows: dry pit, 50 percent; wet pit, 30 to 40 percent; and dredging on public waterways, 10 to 20 percent. Considerable production variations exist within the industry, with the larger operations producing over 3.5 million tons per year. The smaller, part-time operations may produce less than 1,000 tons. Capital outlay required ranges from $20,000 for marginal producers to larger investments in excess of $10 million.

Although some of the larger operations are still releasing detrimental silt loads to public waterways, many of the major installations are now using totally closed systems or releasing only a small percentage of their process water after effective treatment. Many of the low volume or part-time producers, due to their relatively small or intermittent effluents, have continued to operate without treatment. Release of this sediment-laden plant process water has been overlooked by the environmentalists and many state agencies whose energies have been directed toward the more sensational forms of pollution.

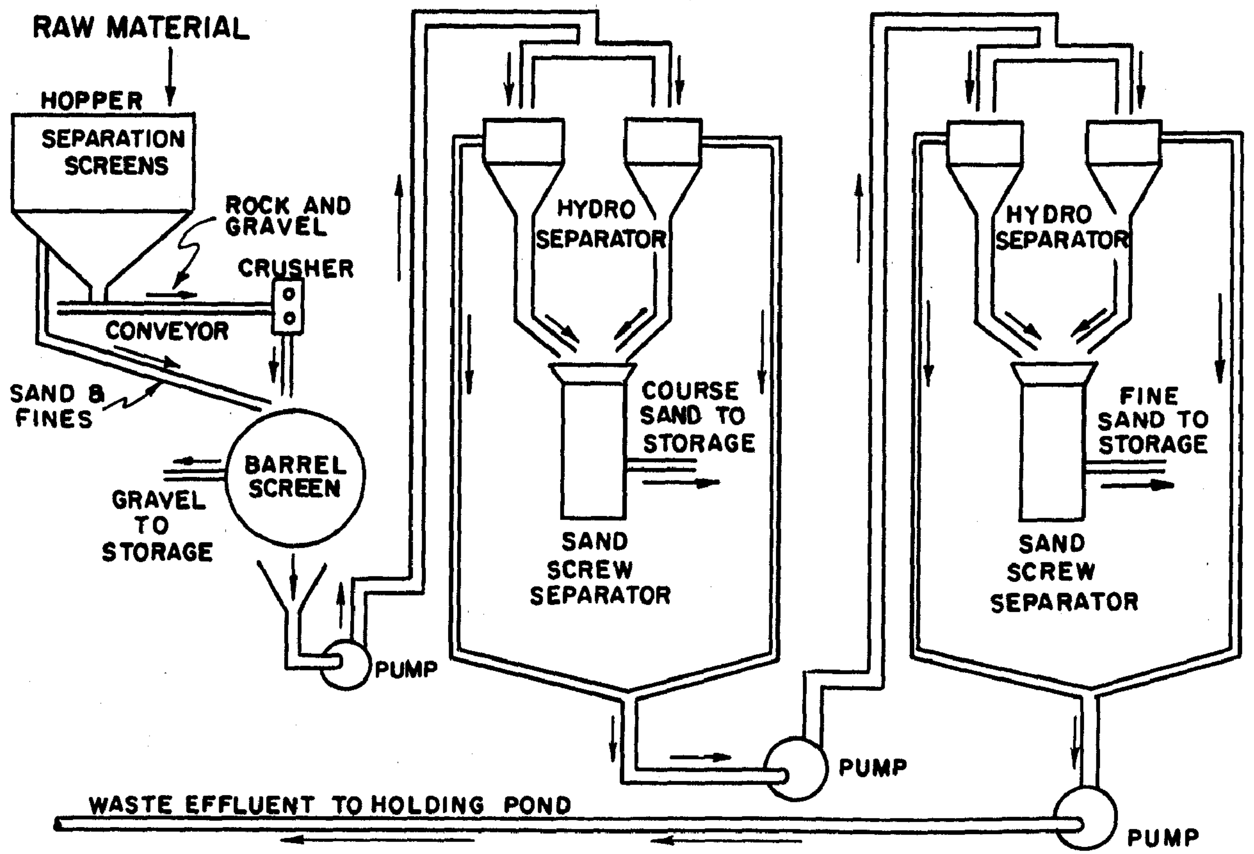

FIGURE 6 — TYPICAL SAND AND GRAVEL PROCESSING SYSTEM

INTERMITTENT

Numerous sand and gravel producers operate on a part-time or intermittent schedule. The percent contribution of this type of operation to the total national output is of significance. The operations, in many cases, are carried out on a demand or seasonal basis, enabling an operator to produce aggregate in response to periods of peak demand. Some plants operate only a few days a month, during which time sand and gravel is stockpiled to meet future demands. The same pollution potential exists in these intermittent operations as with plants operating full-time. Many of the operations have to remove considerable volumes of water from the pit area before initiating each recovery operation. Although some operations do not wash the material being recovered, suspended solids included in or generated by the high volume discharge may exert excessive loading on the receiving body of water.

TEMPORARY

Sand and gravel production figures do not reflect immediate vicinity use of aggregate for rural roads and some highway construction purposes. Sand and gravel produced in this manner is usually removed without processing by the dry pit method, and transported directly to the usage site. As no water is employed for processing, effluents are not of concern; nevertheless, considerable damage may be inflicted on the environment through subsequent erosion from storm runoff. With minimal additional effort during excavation, retaining dikes could be constructed to contain runoff. Additionally, slope steepness during and following completion of the mining operation could be minimized without undue difficulty. Such procedures would greatly reduce erosion and provide a rehabilitative base for returning the land to productive use.

Operations of this nature exist in almost every county in the United States. Many of the areas are mined for only a few weeks before being abandoned; hence, are not subject to adequate regulation. Individually, these operations produce relatively small amounts of sand and gravel; collectively, however, annual production with related erosion and siltation is significant. Storm runoff from one of these temporary operations is capable of producing a silt load exceeding the yearly output of a well-managed sand and gravel plant.

DREDGING

The dredging operation involves the removal of raw material from lake, estuary, or stream beds by means of a ladder, clam shell, or cutter head dredge. The material is either processed directly on the dredge and loaded on barges, or transported hydraulically to shore-based processing plants. Processing dredged material requires the same steps as the dry or wet pit operation; screening, washing, and grading to various sizes.

Effluents from barge-processing units contain essentially the same high suspended solid concentrations as those generated by a land-based operation, while additional solids are placed into suspension by the action of the recovery assemblies. Depending on water velocities and particle size, turbid plumes consisting of suspended solids can be visible for several miles downstream. After leaving the barge, reliable effluent sampling is technically difficult. Literature reviewed to date indicates that little effort has been expended tracing silt from barge sources. As has been noted earlier and documented in numerous reports, continuous additions of silt from any source are undesirable. While the major portion of the studies concerning silt from sand and gravel operations have concentrated on land-based types, conclusions from these studies should also be applicable to barge operations. It would not be logical to assume that an effluent released in the middle of a river would have less effect than an outfall on the side.

Current technology pertaining to successful treatment of barge effluents is inadequate. Flocculants, silt curtains, and baffles have been tried with only temporary and uneconomial success. Dikes have been used to effectively eliminate dredge spoils from entering public waterways in situations of restricted mining area and relatively shallow water.

OFF-SHORE

The Corps of Engineers has estimated that 50,000 square miles of the Atlantic Coast contain sand and gravel deposits suitable for off-shore mining with another 25,000 square miles available in the Pacific and Gulf of Mexico coastal areas.

While production of sand and gravel by ocean dredging currently comprises only a small percent of total United States production, it is expected to increase significantly within the next few years. A recent article reported that roughly 25 percent of the nation's total sand and gravel consumption or 225 million tons was consumed by the urban areas of the 21 states bordering the oceans.[31] Consumption in these areas is expected to at least double and possibly triple by 1985, placing considerable pressure on current land-based facilities. As urban areas expand, sand and gravel deposits will become less available due to zoning restrictions. Recovery operations will necessarily be displaced to outlying areas, thereby increasing the distance and cost of distribution of this product. On this assumption, it is then reasonable to conclude that ocean mining for sand and gravel will become a necessity within 10 years.

Ocean-going dredges, capable of dredging in 100 feet of water, are expensive as compared to dredges now being used in rivers and estuaries. Seventy-five dredges valued at $100 million are now in economical use in Great Britain. The majority of the deposits presently being worked are from one to 20 miles off-shore at depths of 60 to 100 feet. Operating costs range from 35 to 49 cents per ton, placing ocean mining in a strong competitive position in the United Kingdom. Currently 16 percent or 20 million tons per year is being ocean-mined with demand in the year 2000 expected to reach two billion tons per year in Great Britain. In Japan, 18 percent of all sand and gravel comes from ocean dredging, and the Netherlands are currently using considerable amounts of dredged material.

The effect of off-shore mining of sand and gravel on environmental quality is yet to be defined. The NOMES project (New England Off-Shore Mining Environmental Study) was scheduled to recover a million cubic yards from a Massachusetts Bay test site in an effort to gain some insight into ocean mining and its effect on the marine environment. The study was temporarily cancelled in July, 1973, primarily by environmentalists who feared the findings of the study would clear the way for ecologically harmful explorations of coastal areas and associated fishing grounds. Cancellation of this long-term research project delays indefinitely the scientific determination of whether or not ocean mining of sand and gravel should proceed. At present the NOMES project is given less than a 50 percent chance of being reinstituted.

The Coastal Zone Management Act of 1972 provided for the establishment of the Office of Coastal Management in the Commerce Department. By providing two-thirds funding, the Federal Government is encouraging the states to identify coastal reserves and boundaries, determine land and water use as pertaining to environmental impact, and conduct the necessary research to determine the effect of ocean mining on off-shore ecosystems. Hopefully, meaningful information will be derived from this research delineating the relationship between ocean mining and the environment.

In its final report June 28, 1973, The National Commission on Materials Policy encouraged further research into all aspects of ocean mining. The Commission recommended that the Federal Government "encourage orderly development of the undersea mineral resources and essential deepwater port facilities and expedite settlement of related environmental issues with all possible speed."

SECTION VI

STATUS OF CURRENT TREATMENT TECHNOLOGY

Waste from municipal or other industrial sources are responsible for the more visible types of pollution such as fish kills; nevertheless, the final effects of silt pollution are more permanent than the effects of organic pollution. Elimination of organic waste discharges results in rapid recovery of water quality. In contrast, silt pollution, due to its ability to alter the physical nature of a stream, is relatively irreversible. Pollution from sand and gravel sources are less obvious and in many instances overlooked by the public and regulatory agencies who tend to direct their attention towards the more sensational forms. Because of an uninformed public and political priorities, many streams continue to receive excessive amounts of silt from sand and gravel effluents.

HOLDING PONDS

The most common treatment method practiced in the industry today is the retention of wash waters in settling ponds. Treatment by the ponding method requires construction of new ponds or utilization of an area previously excavated during the mining process. The size and number of treatment ponds vary considerably; usually, any configuration that enables the suspended matter to settle satisfactorily before wasting or reuse is considered adequate. One of the major problems confronting the sand and gravel industry is the availability of sufficient land area to construct adequate holding ponds. Many of the operations are located near urban areas where additional land is either not available or prohibitively exhorbitant in cost.

However, if the land requirements can be met, the settling characteristics of the waste are then determined to insure that adequate clarification will occur naturally within the allotted detention time of the treatment ponds. Determination of the physical characteristics of the effluent is vital before attempting full-scale pond treatment. Regardless of the detention time available, adequate suspended solid and turbidity reduction in some effluents cannot be attained without additional treatment.

SETTLING AIDS

To expedite settling and minimize the necessity for large settling ponds, some operators have installed systems that introduce flocculating agents to the effluent stream to assist in clarification. Capital expenditures for these systems have varied from elaborate systems in excess of $100,000 to extremely simplified systems consisting of a mixing barrel with an attached hose that only roughly meters chemicals into the effluent.

Prior to implementation of full-scale treatment, a plant survey to determine all points of suspended solids entry into the process waters is conducted. Generally, attempts are made to reduce or concentrate suspended solids normally discharged through the use of physical methods; e.g., the manipulation of plant processing procedures. Following optimization of in-plant procedures, technical expertise is usually solicited to obtain assistance in determining the most effective means of chemical treatment. Several manufacturers are now producing flocculating agents, consequently considerable marketing competition exists. Some companies, in an effort to merchandise their product, will send specialists on request to assist in developing an optimum treatment system. This service particularly benefits the small operators who may not have the available personnel or required technology to perform the necessary preliminary testing.

Maximum information concerning the physical and chemical characteristics of the waste to be treated should be obtained before progressing to the full-scale process. Engineering parameters taken into consideration prior to chemical treatment are: total flow through the plant; flow variations due to production fluctuations; and most important, flow characteristics of settling ponds. Chemical metering, mixing, and detention times must be optimized to attain efficient treatment. Proper construction and utilization of settling ponds can mean the difference between an efficient economical treatment system and an inadequate expensive one.

Quite often, despite extensive laboratory testing, types of chemicals or chemical concentrations may require altering before satisfactory treatment is attained. Once the proper conditions are determined, sediment removal by means of flocculent addition is relatively uncomplicated with many operators able to control the process in spite of varying effluent loadings.

The cost of chemical treatment for sand and gravel effluents ranges from one to five cents per ton of product produced. This variation is due to the initial outlay cost for equipment, the chemical selected, the amount of chemical used, and labor required to maintain the treatment system. In many cases, due to fixed labor cost, treatment expense will decrease as production increases. Considerable variations in the price of chemicals necessitate a critical assessment of chemicals employed.

CLOSED SYSTEMS

In some instances clarification by the use of flocculent aids has been successful to the extent that the total wastewater from the final holding pond can be reused, thus, creating a closed system of treatment whereby no process waters leave the premises. In other applications a high percentage of the total effluent can be recycled. The determining factors on effluent reuse are the purity of the product desired and the amount of suspended solids in the water to be recycled. In many operations concentrations of suspended solids can be as high as 500 ppm and still have a recycling capability.

Fortunately for many sand and gravel companies, either through extensive planning or coincidence, effluents never leave company property. As has been pointed out, some effluents enter large holding ponds or go through extensive treatment before ultimate reuse. Natural containment of waste fines exists in areas where effluents enter low lands or marsh areas owned by the producing company. In instances where silt from effluents or storm runoff is contained on the premises, damage to the environment is eliminated.

Additionally, many operators are voluntarily practicing extensive rehabilitation of mined areas to reclaim the areas for real estate development and improve the public image of the company.

WASTE FINES

Currently, one of the most serious problems facing the sand and gravel industry is ultimate disposal of waste fines. From one to twenty percent of the total raw material processed will be classified as waste fines. Using a realistic figure of five percent waste fines and production figures quoted earlier, it can be estimated that larger operations will have an accumulation of 500 tons per day of solid waste.

Fortunately, many operations have sufficient land area available for disposal of this waste. Some use previously mined areas, obsolete sedimentation ponds, or open land areas to disperse the sludge for drying. Even with favorable space accomodations, however, waste fines handling can be financially quite burdensome. Periodically, in many operations, sediment basins fill to capacity, requiring the use of drag-line and trucks to remove and dispose of sediment accumulations.

Problems concerning waste fines handling are compounded in operations that lack the necessary land for convenient disposal. Many sand and gravel companies continue to operate in areas where the marketing of waste fines for top soil and fill material is not economical. For these operators, it becomes of prime necessity to extract as much marketable material as possible down to the 100 mesh range. In this manner large amounts of fines are eliminated from accumulation in settling ponds.

Cyclone separators, widely used throughout the industry for the purpose of solid separation and material gradation, have proven highly successful in reducing the amount of waste fines released to settling ponds. One plant was originally cleaning a settling pond every six months at a cost of $10,000; with the addition of one cyclone separator (cost $2,000), cleaning intervals were extended to 18 months.

One additional problem of waste fines handling concerns the drying characteristics of the recovered sludge. Due to the varying nature of this material and the different disposal techniques utilized, drying times can range from a week to several years. Factors affecting drying times are: sludge thickness and permeability, disposal site drainage, and climatic conditions affecting rate of evaporation. Generally, assuming adequate space is available, sludge thicknesses of two feet will dry within one to three weeks.

SEDIMENT BY-PRODUCT RECOVERY

If the sediment is of the quality of topsoil or fill dirt, and a readily accessible market exists in the immediate area, sediment recovery can prove to be a profitable operation. In many instances, it is advantageous to mix coarser material with the sludge to facilitate drying and enhance the quality of the finished product. Some operators have added commercial fertilizer to waste fines to yield a profitable product from this once burdensome material. Since many sand and gravel operations are located near metropolitan areas, the economic feasibility of combining municipal sludge with waste fines to produce a marketable fertilizer or soil conditioner is a possibility.

Waste fines have also been utilized for the production of building bricks. With the increased demand for construction materials, activity in this area is expected to increase. Some operators are currently stockpiling suitable material for this eventuality.

It is misleading to imply that all waste fines can eventually be channeled into useful or profitable products, since the sand and gravel industry generates roughly 90 million tons per year. If only a portion of this material can be converted into useful products, however, the effort would be of benefit from an environmental standpoint.

REHABILITATION

Rehabilitation of mined areas has received increased attention over the past few years. Abandoned sand and gravel pits have been recognized as potentially high value real estate. Since many of these areas are located in or near metropolitan areas, their use as construction sites, golf courses, residential areas, recreational parks, or sanitary land-fills are now being considered. Consulting firms have been established that are concerned almost solely with restoration of mined areas or pre-planning for ultimate reuse of areas to be mined. Companies with portable equipment designed for land reclamation are now in operation.

Prior to initiating excavation, many operators are using consultants in landscape architecture to plan their operation. Using this approach, the sand and gravel is systematically removed, the overburden conserved, and the land restored to productive use as the mining process progresses. Maximum utilization of manpower and equipment can be attained by this method of operation. Other companies, with assistance from Soil Conservation and Forestry Service personnel, are planning site operations based on a sound program of rehabilitation.

In areas of low land values, restoration is not profitable for the sand and gravel producer; hence, rehabilitation of the depleted site is oftimes neglected. Since a large portion of the land used for aggregate production is leased, there is a reluctance on the part of the producer to invest in the necessary rehabilitation measures.

SECTION VII

LEGISLATION AFFECTING THE INDUSTRY

In 1899 Congress passed the Rivers and Harbors Act which initially affected all industries. Enforcement of this law has, until recently, been limited to those industries discharging matter to navigable waters which would interfere, become destructive, or hazardous to navigation. Recent court decisions have allowed a broader interpretation of the act.

In an effort to improve the water quality of our streams, lakes, and coastal waters, the Federal Government has applied the provisions of the Rivers and Harbors Act of 1899 to the general problems of water pollution. Following passage of the Rivers and Harbors Act, a number of laws were enacted in an effort to reduce or eliminate pollution of the natural waters of the United States.

In 1912 the next major bill, the Public Health Service Act that dealt with human health factors in relation to water pollution, was passed. The Water Pollution Control Act was passed in 1948, and in 1956 the Federal Water Pollution Control Act became law. The Water Quality Act of 1965 established the Federal Water Pollution Control Administration under the Department of the Interior. In 1967 the Air Quality Act was passed and in 1969 the National Environmental Policy Act. In 1970 the FWPCA(FWQA) was reorganized and became EPA, and Congress passed the Mining and Minerals Policy Act.

A number of other bills, over 100 in all, concerned with pollution abatement have been passed from 1899 to the present. To clarify, consolidate, and update this mass of environmental legislation, Congress passed the Federal Water Pollution Control Act Amendments of 1972.

The Mining and Minerals Policy Act of 1970 concerns mining in general and includes the sand and gravel industry. The act defines the general relationship between the Federal Government and the mining industry. Section 2 reads as follows:

"The Congress declares that it is the continuing policy of the Federal Government in the national interest to foster and encourage (1) the development of an economically sound and stable domestic mining and minerals industry, (2) the orderly development of domestic mineral resources and reserves necessary to assure satisfaction of industrial and security needs, and (3) mining, mineral, and metallurgical research to promote the wise and efficient use of our mineral resources. It shall be the responsibility of the Secretary of the Interior to carry out this policy in such programs as may be authorized by law other than this Act. For this purpose the Secretary of the Interior shall include in his annual report to Congress a report on the state of the domestic mining and minerals industry, including a statement of the trend in utilization and depletion of these resources, together with such recommendations for legislative programs as may be necessary to implement the policy of this Act."

On February 10, 1970, during the President's message on the environment, he proposed that state and federal water quality standards be amended to impose precise effluent requirements on all industrial and municipal sources. Nine months later on December 23, 1970, an executive order was issued by the President that delegated the responsibility of issuing discharge permits to the Corps of Engineers and the determination of the quality of water being discharged to EPA. In announcing this program, the Refuse Act Permit Program, the President stated that the establishment of the program would enhance the ability of the Federal Government to enforce water quality standards and provide a major strengthening of efforts to clean up our nation's waters by applying the provisions of the Rivers and Harbors Act of 1899 to the problems of water pollution.

The Refuse Act Permit Program, which went into effect July 1, 1971, made it illegal to discharge materials into a navigable water or tributary without a permit from the U.S. Army Corps of Engineers. A permit would be issued if the material to be discharged met the applicable water quality standards, or if a schedule of amelioration of the quality of water to be discharged was approved that would bring the effluent quality within applicable standards by a specific date. The Federal Water Pollution Control Act Amendments of 1972 transferred the authority to issue permits to EPA, which has subsequently delegated this responsibility to States meeting specified requirements.

THE FORMATION OF STATE LAWS

Virginia, in 1939, became the first state to enact a surface mining law applicable to the sand and gravel industry. In 1941 and 1943, Indiana and Illinois enacted surface mining laws which included the sand and gravel industry. In 1967 the Department of the Interior, under Congressional mandate, made a study of surface mining and mined-land reclamation entitled "Surface Mining and Our Environment." By pointing out the failure of mining industries in the past to reclaim and restore mined surface areas, the study served as an impetus to many states to enact surface mining and mined-land reclamation laws. Additionally, many producers voluntarily initiated sound reclamation practices.

To date, 35 states have enacted statutes regulating surface mining of minerals. Of these, 21 specifically relate to the sand and gravel industry. Many producers are now operating under local, state, and federal laws. The disparity between the laws creates problems with regard to the varying degrees of control.

In brief, an outline of the developing pattern of requirements of most state regulations are: effluent characterization, flow diagrams, amounts of waste water discharged, a mining plan, a reclamation plan, and performance bonding prior to the initation of the mining operation. An annual or semi-annual report of activity is required with stipulated penalties for failure to comply.

Depending upon state and local requirements, a mineral producer may be required to pay \$25-\$100 per year to obtain a permit, plus a fee based on the number of acres involved in the operation. An employment fee dependent upon the average number of employees in the organization may also be required. A document including the starting date, the proposed movement or mining plan, the termination date, and an engineer's reclamation plan is necessary in some states. The reclamation plan defines such items as degree of slope, amount of topsoil to be replaced on the mined areas, and the type of vegetation required. To insure that reclamation is accomplished, a bond of $150 to $1,000 per acre may be required subject to forfeiture for non-compliance. Some state statutes specify criminal penalties plus fines should a company operate without a valid permit or in violation of permit requirements.

Sand and gravel operations are faced with a myriad of problems: proper land use, pollution of air and water, noise, surface mining regulations, bonding, reclamation, taxes, and federal, state, and local laws and ordinances. The larger sand and gravel firms have been able to solve these problems by retaining competent legal and technical personnel; however, without assistance from the administering agencies, smaller producers may be forced out of business.

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This report presents an overview of the sand and gravel industry in the United States and its relationship to the environment. The fate and effects of sediment generated by this surface mining activity on the benthic, planktonic, and fish communities of our waterways are discussed in detail. Problems of the sand and gravel industry, types of operations, status of current treatment technology, and legislation affecting the industry are reviewed. (Newport-EPA)

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