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A Survey of the Late Summer Benthos Community in the Vicinity of the C. P. Crane Generating Station

For

State of Maryland

Department of Natural Resources

and

Power Plant Siting Program

by

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Abstract

A survey of the sediment distribution in the vicinity of the C. P. Crane Generating Station, Bengies, Maryland showed that the sediments in the creeks receiving the plant's cooling water discharge were predominantly soft clayey-silt. The benthic invertebrate taxa found in these sediments were typical of the communities found in oligohaline waters of Chesapeake Bay. Comparisons of the benthic community in the discharge area with the communities in two reference areas of similar sediment type revealed an apparent reduction in the discharge area population of the dominant amphipod, *Leptocheirus plumulosus*, in August. The spatial distribution of the dominant bivalve, *Rangia cuneata*, a species that is susceptible to cold-related dieoffs in upper Chesapeake Bay, suggested that the power plant discharge plume has exerted a protective effect on its adult population during recent winters. Other benthic invertebrates exhibited spatial distributions that appeared to have resulted from the hydraulic regime established by the plant, or from modifications of predator-prey interactions in the vicinity of the cooling water discharge.

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Introduction

This report presents the results of a survey of the community of benthic macroinvertebrates in the vicinity of the C. P. Crane Generating Station, Bengies, Maryland, an oil fired power plant operated by the Baltimore Gas and Electric Company. This survey was intended as the initial step in the evaluation of the impact of the power plant's cooling system on this community, and is part of a comprehensive study that will determine whether modifications to the cooling system are necessary to protect the biota in the adjacent estuaries. According to Maryland water quality regulations (State of Maryland 1978), facilities that release heated water must use a discharge system that "will assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the receiving water." Furthermore it must be demonstrated "that plant cooling water entrainment does not affect a spawning or nursery area of consequence for Representative Important Species," which are defined in the law.

The design of the present study was based on the premise that if population densities of the invertebrate species in the area subjected to the excess heat carried by the cooling water plume differ significantly from population densities in suitable reference areas, this is evidence of a power plant effect. Such an effect can be the result of heated water coming into direct contact with the benthic organisms, or it can be a consequence of the entrainment of planktonic larvae or nektonic predators in the cooling water as it passes through the power plant or mixes with the receiving water. The study was scheduled for the late summer, when the highest water temperatures and, consequently, the maximum power plant effects could be expected.

The C. P. Crane Generating Station is located between two tidal creeks that are adjacent to the Gunpowder River, a tributary of upper Chesapeake Bay (Fig. 1). The water in this section of the bay and in its tributaries is oligohaline to fresh, and originates mostly in the Susquehanna River drainage basin. The power plant cooling water is pumped, at a rate of approximately 650 ft^3 (18.4 m^3) per second from Seneca Creek and is discharged into Saltpeter Creek. On flood tide some of the cooling water mixes with the tidal flow that enters Dundee Creek, therefore this creek as well as Saltpeter Creek is considered part of the discharge area. A small portion of the discharged cooling water is recirculated to the intake, via Seneca Creek, and another portion enters Seneca Creek directly through a hole in the discharge canal wall (Binkerd et al. 1978). This hole is maintained, intentionally, to prevent winter ice from blocking docks used by barges which deliver the oil used to power the plant's generators. The power plant is operated at full capacity (approximately 400 megawatts) only during the day, and is cut back to approximately 100 megawatts during the night.

The intake and discharge area creeks are shallow, with depths of 1-2 meters in most sections. The Gunpowder River is only slightly deeper, except in channel areas downstream from the mouth of Saltpeter Creek. A state park marina is located near the head of Dundee Creek, and a privately operated marina is on the north shore of Seneca Creek, upstream from the power plant intake. Cottages and docks line the shore of upper Seneca Creek, and to a lesser extent upper Saltpeter Creek, and recreational boating, fishing, and crabbing are pursued intensively throughout the study area (personal observation).

The summer 1978 benthos study was conducted for the State of Maryland Power Plant Siting Program (PPSP). Concurrent studies also supported by this agency included a physical impact study (Binkerd et al. 1978) and a plankton study (Grant and Berkowitz 1979). In addition a comprehensive study conducted by Ecological Analysts, Inc., and supported by the power company, is in progress, and studies of the finfish, submerged aquatic vegetation, and extensions of the studies of the plankton and benthos will be supported in the future by PPSP. No previous benthos studies have been conducted in the C. P. Crane study area, but a study conducted in the Bush River, a bay tributary adjacent to the Gunpowder River (Johns Hopkins University 1973), and a study that compared Baltimore Harbor with a control area (Pfitzenmeyer 1971) produced data that are relevant to the interpretation of the present study results.

Methods

The summer 1978 benthos survey consisted of a preliminary sampling run, July 17-18, and a final sampling run, August 16-19. The main purpose of the preliminary run was to select stations for the final run, and this was accomplished by surveying the water temperature distribution and the composition of the sediment and the benthic community in several areas in the intake and discharge creeks and the Gunpowder River. In the final run benthos samples were taken, according to a balanced statistical design, in a series of strata that were believed, on the basis of the July survey, to represent areas that differed mainly in their exposure to the power plant cooling water. The following sampling and analytical methods were employed in the two sampling runs:

Station Selection

Thirty stations were included in the July sampling run. Eighteen of these were distributed throughout the discharge creek area, in order to establish the characteristics of the dominant sediment type and to detect any obvious patterns of benthos distribution that could relate to the power plant discharge. The remaining twelve stations were allocated between Seneca Creek and the Gunpowder River, to provide a sediment survey and preliminary benthos assessment of these two potential reference areas.

On the basis of the July survey results, four discharge strata and two reference strata were chosen for sampling in August. Five stations were selected randomly for each stratum, from lists of possible pairs of coordinates taken from a 0.1 nautical mile grid superimposed on a chart of the sampling area. When sampled at an intensity of 4 grabs per station, this allowed for a total sediment area of 1 m^2 to be taken from each stratum.

Physiocochemical Parameters

At each sampling station the invertebrate and sediment samples were accompanied by measurements of total water depth, using a sounding line weighted with a flat plate that would not penetrate into the bottom, and of the Secchi Disk transparency. In addition, surface and bottom water samples were taken for determinations of temperature, salinity, and dissolved oxygen.

Temperature was measured in the field with a Hydrolab model RT-125 research thermometer, equipped with a model L5-A50 thermistor probe. Salinity samples were analyzed in the laboratory using a Beckman model RS-7B salinometer. Dissolved oxygen samples were fixed in the field according to the standard Winkler method, and returned to the laboratory for titration.

Sediment Composition

Sediment samples were taken in both July and August, using a K.B.® type heavy duty corer with a 20 inch (50.8 cm) long, 2 inch (5.08 cm) inside diameter core tube (Wildco Model 2400). The top 15 cm segment of each core was extruded in the field into a plastic bag and stored on ice. In the laboratory the contents of each bag were homogenized and approximately 10 g of the wet homogenate were weighed into a tared crucible for determination of organic content by loss on ignition (American Public Health Association 1965). Ignition was performed for one hour at 500°C. For the July samples a second aliquot of each wet homogenate was screened through a 63 micron pore size sieve for separation into a sand fraction (greater than 63 microns) and a silt-clay fraction (less than 63 microns). The relative oven dry weights (105°C) of these fractions were obtained. A third aliquot was wet sieved in the same manner. The sand fraction of this aliquot was dried (125°C) and its particle size distribution was obtained using the VIMS Rapid Sand Analyzer (Zeigler *et al*. 1960). The particle size distribution of the fine particle fraction was obtained using a Coulter Counter model TA® (Coulter Electronics, Inc.). The fine and coarse size distributions were combined graphically, and from the graphs the sand, silt, and clay percentages for each benthos station were obtained.

Benthic Invertebrates

The benthos samples were taken with a .05 m^2 Ponar grab (Wildco Model 1725). The samples were sieved on site through a 0.5 mm mesh screen, and the organisms retained were preserved in a formalin solution containing the stain Phloxine B. Counts and identifications were made using a dissecting microscope (Olympus Model SZ-III), at magnifications of 7X - 80X. Chironomid heads were examined under a compound microscope at 200X.

Data Analysis

The August benthos data for each of the major taxonomic entities were subjected to a one-way analysis of variance, and significant differences (.05 level) among the sampling strata were identified using the Student-Newman-Keuls' test (Steel and Torrie 1960). Log or square root transformations were performed when necessary to normalize the data prior to analysis. The community parameters of species diversity and species richness were calculated as follows (Margalef 1958, Pielou 1966):

$$H = -\sum_{i=1}^{s} \left(\frac{Ni}{N}\right) \log_2 \left(\frac{Ni}{N}\right)$$

$$\underline{d} = \frac{s-1}{\text{InN}}$$

where S = number of species in sample

N = number of individuals in sample

Ni= number of individuals of the i th species

Fig. 1 Legend

● Saltpeter Creek Sta. E22-23, G21, J20, L19-20
(in area that became stratum I in August)

○ Saltpeter Creek Sta. H19-20, L20-21

+ Dundee Creek Sta. I28, J26, IJ25, K25-26
(in area that became stratum IV in August)

◆ Dundee - Saltpeter Sta. L22-23, M23, N23-24, P22
(in area that became stratum II in August)

X Saltpeter Creek Sta. P19-20, ST20-21, T21-22, R16-17
(in area that became stratum III in August)

■ Seneca Creek Sta. B13
(in area that became stratum V in August)

□ Seneca Creek Sta. I12, KL9, GH11, OP8, P4-5

▲ Gunpowder River Sta. AA27, GG24-25
(in area that became stratum VI in August)

△ Gunpowder River Sta. U26-27, VW12, Z12, GG13

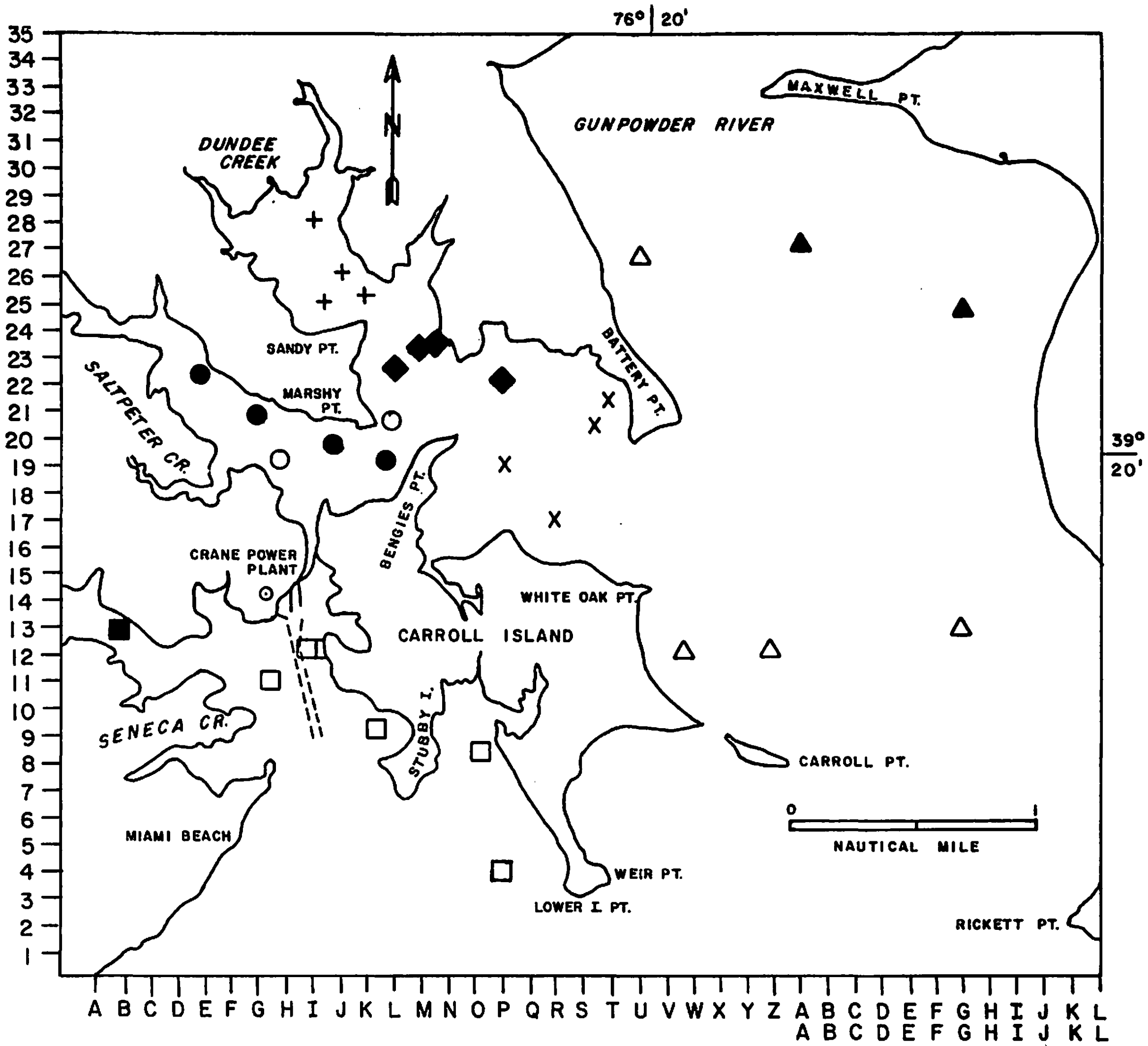

Fig. 1 Preliminary station locations
July 17-18, 1978

July Sampling Run

Sampling Design

The locations of the stations sampled during the July preliminary benthos study are shown in Fig. 1. At most of the stations one benthos grab and one sediment core sample were taken, along with related physiochemical measurements. At four stations, P22 and R16-17 in lower Saltpeter Creek, and GH11 and OP8 in Seneca Creek, five benthos samples were taken so that the sampling intensity required to provide reliable estimates of invertebrate population densities and species richness could be determined. The sediment analyses for all the stations and the taxonomic workup of the invertebrate samples from the five-grab stations were completed in time for planning of the August full scale benthos sampling run.

Qualitative Results

Higher Aquatic Plants

The shallow, inshore areas of Dundee, Saltpeter, and Seneca Creeks support communities of rooted higher aquatic plants, that were observed during the July and August benthos sampling runs. Higher plants are significant to the invertebrate ecology of aquatic systems as they provide a habitat for epifaunal invertebrates (Marsh 1970, Lamoreaux 1957), and as they provide shade, shelter, and a spawning medium for fishes and other predators of benthic invertebrates (Sculthorpe 1967). In addition the rhizome mat elaborated by the higher plants may provide a haven for infaunal invertebrates, by inhibiting the foraging of predators (Orth 1971). The higher aquatic plant community in the C.P. Crane study area consists principally of the following two species:

Vallisneria americana - This species is referred to variously as wild celery, tape grass, or eel-grass. It occurs along the East Coast from the Gulf of Mexico to Nova Scotia, predominantly in tidal fresh water (Stevenson and Confer 1978). Under laboratory conditions, *V. americana* could not be maintained at salinities greater than 4.2 ppt (Bourn 1934). Growth can occur within the temperature range of 19 - 50°C, and the green form does not overwinter. The temperature range optimal for growth is 33 - 36°C (Wilkinson 1963). Leaves may attain a length of 1.8 m (Schuett and Alder 1927), with the upper ends floating, parallel with the water surface. The occurrence of *V. americana* in estuaries is restricted to shallow water (0.5 - 1 m in Currituck Sound, N. Carolina - Stevenson and Confer 1978), implying that it requires relatively high light intensities for growth.

Reproduction of V. americana can occur vegetatively, through the growth of stolons (runners), and through tubers (Sculthorpe 1967). Sexual reproduction is accomplished through the release of free floating male flowers and the production of female flowers that reach the water surface while remaining attached to elongated peduncles. After fertilization at the water surface the peduncles coil downward and submerge the resulting fruit.

The distribution of V. americana in the Chesapeake Bay was documented for the period 1971 - 76 by the U. S. Fish and Wildlife Service Migratory Bird and Habitat Research Laboratory. The study revealed a general decline in occurrence in the tributaries of the bay during this period, but an increased occurrence at stations sampled in the Back, Middle, and Gunpowder Rivers in 1974 and 1975. In 1976, however, no V. americana was recorded at these stations (Stevenson and Confer 1978). Because of their occurrence primarily in shallow water, beds of V. americana are susceptible to severe damage from wave turbulence and from boat propellers (Lamoreaux 1957). In the 1960's this species appeared to have declined in the Susquehanna Flats in relation to an explosive growth of Myriophyllum spicatum (Stevenson and Confer 1978).

Myriophyllum spicatum - This macrophyte, known commonly as Eurasian watermilfoil, occurs widely in Europe, Asia, and parts of Africa (Springer 1959). It was introduced into North America around the turn of the century, and has since become established in many lakes in the eastern U. S. and southern Canada. In the Chesapeake Bay area M. spicatum was found sporadically until the mid 1950's, when it began a burst of growth that continued until the mid 1960's. Since then the occurrence of this species has decreased, and it now occupies scattered areas in the upper bay and its tributaries (Stevenson and Confer 1978).

The salinity range within which growth of _M. spicatum_ can be maintained is 0 - 20 ppt (Rawls 1964) but salinities below 10 ppt are the most favorable (Boyer 1960). Growth can occur within the temperature range of 0.1 - 30°C (Anderson _et al_. 1965).

M. spicatum has been found to grow best in mud and sandy-mud sediments in Chesapeake Bay (Anderson 1972). It requires relatively high light intensities, and can grow in water more than 2 m deep, if clear (Southwick 1972). Areas subjected to severe water turbulence are unfavorable for _M. spicatum_ establishment (Stotts 1961).

Vegetative reproduction by this species may be accomplished by fragmentation (apparently the method by which it spread so rapidly in Chesapeake Bay), growth of rhizomes, and axillary buds (Patten 1956). Sexual reproduction occurs by aerial pollination of female flowers, which are then resubmerged. Seed germination is accelerated by freezing and drying (Patten 1955). The foliage dies back in the late fall, grows up from roots in the spring, and reaches maximum growth in the late summer (Haven 1961).

One of the unfavorable consequences of the _M. spicatum_ growth explosion in the 1955 - 65 period was the competitive elimination of beds of other species, including _Vallisneria americana_, that are more useful as food for waterfowl. Thus the mixture of

M. spicatum and *V. americana* in the C. P. Crane study area cannot be considered as a stable plant association, and rapid, wide fluctuations in abundance from year to year of either or both of these species may be expected.

Invertebrate Infauna

The benthic invertebrate species found in the C. P. Crane study area were typical of the communities in the oligohaline sections of other tributaries of Chesapeake Bay (Bush River - Johns Hopkins University 1973, Patapsco and Chester Rivers - Pfitzenmeyer 1971, James River - Jordan et al. 1976). This section is an attempt to summarize the biological information for the major species, that may be useful in interpreting their spatial distributions at the Crane site.

Rangia cuneata - Live specimens of this brackish water clam were found at every station sampled during the summer 1978 benthos survey. The study area is near the northern limit of the geographical range of this species, which at present extends from Texas to the head of Chesapeake Bay (Gallagher and Wells 1969). In the tributaries of the bay R. cuneata is subject to winter dieoffs (Pfitzenmeyer and Drobeck 1964, Hopkins 1970, Jordan et al. 1977) during prolonged exposure to water of low temperature and low salinity (Cain 1972). Toward the southern limit of its range it occurs in Lake Ponchartrain, where temperatures of the open water range from 9 - 34°C, and shallow water temperatures reach 39°C (Darnell 1958).

In the James River R. cuneata has been found in a variety of sediments, ranging in coarseness from fine mud to coarse sand (Peddicord 1973). During the study period of August 1970 through March 1972 the highest population densities were found in mud, while the largest individuals and highest growth rates occured in sand. The slower growth in mud may have been an indirect effect of a layer of highly turbid water that existed immediately above the sediment in muddy areas. Clams in these areas took in heavier loads of solids than did clams in sandy areas, and expended greater amounts of energy to clean their filtering systems. More frequent cleaning resulted in reduced effective feeding time at the mud stations (Peddicord 1973). The longitudinal range observed for adult R. cuneata in an estuary characteristically extends upriver to the limit of salinity penetration under extreme low flow conditions. The downriver limit is determined by competition with oysters and other estuarine animals (Cain 1972). Adults are osmoconformers at salinities above 10 ppt, and osmoregulate as salinity decreases below this level (Hopkins et al. 1972). Adults can tolerate salinities of 0 ppt, but embryos and larvae cannot. In tests of the survival of embryos and larvae at several combinations of salinity and temperature, Cain (1972) found the optimum salinity range for embryos to be 6-10 ppt at test temperatures between 18 and 29°C, and the optimum range for larvae to be 2-20 ppt at temperatures between 8 and 32°C. Growth of embryos and larvae was best at combinations of high temperatures and high salinities, within these ranges.

Within suitable habitats, R. cuneata adults exhibit a clumped spatial distribution (Hopkins 1970) in the surface layer of the sediment, in contact with the overlying water (Peddicord 1973). Populations are established and recruitment to existing populations occurs by the setting of planktonic larvae. Movement of adults along the bottom is minimal, as shown by Cain (1972) who was able to recover up to 93% of a group of marked individuals a year after their introduction into an experimental plot. Populations observed in the James River ranged in density from several hundred per m^2 in mud sediments to less than 50 per m^2 in sand sediments (Peddicord 1973). Population densities of over 8000 per m^2 have been reported for the Bush River (Johns Hopkins University 1973), but most of these were immature individuals less than 7 mm in length. A study in the Neches River, Texas yielded an average of 254 four year old clams per m^2 (Hopkins 1970).

The James River population was found by Cain (1972) to spawn in early and mid summer and again in late fall and winter. Spawning could be triggered by a salinity change up from 0 ppt or down from 10 ppt. The larvae are planktonic until they reach the setting size of about 0.3 mm. Setting occurred in the James River in July and August, but the peak period for setting was November - January. The latter period may be favorable for the survival of the set, as there is characteristically a high availability of detritus derived from disintegrating macrophytes (Cain 1972).

The age and growth patterns within a North Carolina population of _R. cuneata_ were studied by Wolfe and Petteway (1968). From their data they constructed a von Bertalanffy growth curve which predicts the following age-length relationships:

Age (yr)	Shell Length (mm)
0	0.375
1	16.0
2	28.3
3	38.0
4	45.8
5	50
-	-
10	75

From the inspection of gonadal tissue, Cain (1972) concluded that sexual maturity in the James River population could be achieved by individuals with a shell length of approximately 14 mm, i.e. age of approximately one year.

R. cuneata is morphologically a typical filter feeder, and examination of its stomach contents has revealed primarily unidentifiable detritus, combined with smaller proportions of sand and protistans (Darnell 1958). Tracer studies by Tenore et al. (1968) demonstrated that individual R. cuneata may extract phosphorus and zinc from the bottom sediments, suggesting that this species may directly ingest sediment deposits.

A study of the stomach contents of predators in Lake Pontchartrain (Darnell 1958) showed that R. cuneata was important in the diets of anchovies, blue catfish, freshwater and black drum, spot, croaker, and blue crabs. Approximately 8.8% of the food consumed by ducks in Back Bay, Virginia and Currituck Sound, North Carolina in 1962 (Bureau of Sport Fisheries and Wildlife et al. 1965) consisted of R. cuneata. This amounted to approximately 83,000 lb, dry weight, of clam tissue consumed in that year.

Based on this background information, one would expect to encounter adult R. cuneata in the C. P. Crane study area in sediments ranging from sand to mud. The spatial distribution would be clumped, and population densities of up to several thousand per m^2 would be expected in mud, while lower population densities but larger individuals would be found in sand. Adults would be vulnerable to winter kill when subjected to fresh water and near freezing temperatures for extended periods, but would be expected to withstand summer temperatures up to at least 39°C. Planktonic larvae would be present wherever the salinity exceeded that of fresh water, and primarily during the periods of May - August and October - January. The recruitment of new set to the benthic population would occur primarily in the July - August and November - January periods. Newly set individuals would average about 0.3 mm length and would rapidly achieve a size retainable by a 0.5 mm mesh sieve. The benthic R. cuneata population would be exploited as food by anchovies, catfish, spot, croaker, blue crabs, and other nektonic species known to occur in the study area (Darnell 1958, Johns Hopkins University 1973). Resident and migratory waterfowl would also be expected to consume benthic R. cuneata.

Leptocheirus plumulosus - This amphipod species was present in every benthos sample collected in the study area in July and August 1978, and was more abundant than any other type of organism except nematodes.

The geographical range of L. plumulosus extends from northern Florida to Cape Cod, Massachusetts. Within this range it may be found in mud, detritus, and sandy mud sediments overlain by non-stagnant brackish water (Bousfield 1973). Although this species is characteristically found at salinities below about 8 ppt in lower Chesapeake Bay estuaries (Feeley and Wass 1971), individuals exposed to experimental salinities of up to 31 ppt behaved normally (Sanders et al. 1965).

In its natural habitat L. plumulosus lives in the upper 7 cm of the sediment in a vertical burrow 5 - 7 cm long (Sanders et al. 1965), the walls of which are constructed of sand grains and detritus particles (Bousfield 1973). The animal maintains a current of oxygenated water through the burrow, which isolates it from the reduced conditions of the surrounding sediment but which also subjects it to the full range of salinity exhibited by the overlying water (Sanders et al. 1965).

The reproductive period cited for this species by Bousfield (1973) is May - September, although Feeley and Wass (1971) reported the presence of ovigerous females in March. Eggs are retained in the female brood pouch, and development proceeds directly, with no special larval forms (Gosner 1971). The life cycle is annual, and two broods of young may be produced by an individual female. An adult may be 10 - 13 mm in length (Bousfield 1973).

Maximum population densities observed have been over 700 per m^2 in the Bush River, Maryland (Johns Hopkins University 1973), over 2140 per m^2 in the James River, Virginia (Bender et al. 1975), and over 23,000 per m^2 in the Pocasset River, Massachusetts (Sanders et al. 1965).

Although no obligately planktonic stages are involved in the L. plumlosus life cycle, dispersal of populations by water currents is highly probable. Individuals have been observed to leave their burrows and forage at high and low tides (Sanders et al. 1965). They also have been found in plankton samples taken at night in the Pamlico River, North Carolina (Williams and Bynum 1972). L. plumulosus specimens were present in samples obtained in the period January - July, and were most abundant in February and March samples. The greatest numbers were found in plankton samples taken on the new moon.

The food material utilized by L. plumulosus consists of organic particles and microalgae suspended in the water. Particles in the water flowing through the burrow are trapped by setae attached to the anterior thoracic appendages, and transferred to the mouth (Bousfield 1973). The L. plumulosus, themselves, are fed upon primarily by crabs and fish.

At the C. P. Crane site this amphipod may be encountered throughout the full range of sediment types present. Occupying burrows in the upper 7 cm of the sediment, it should be sampled effectively with a Ponar grab. Recruitment of young to the overall population should occur mainly during the spring and summer, while dispersal of planktonic adults would be expected principally during the winter and spring. Predators would include fish and crabs.

Corophium lacustre - This species of amphipod is an epifaunal tube dweller, and therefore would be more abundant in higher plant beds than in the soft sediments sampled in the summer 1978 survey (Bousfield 1973). It was present in most of the samples taken, however, and was the second most abundant amphipod collected.

C. laustre occupies a geographical range on the east coast of the U. S. from Florida to the Bay of Fundy, and is also found in western Europe. It is found most frequently in shallow and lower intertidal environments, in marshy banks, on pilings, and on aids to navigation, where it lives in muddy tubes, feeding on particles scraped from surrounding surfaces by its setose antennae (Bousfield 1973). Salinities associated with its occurrence in Chesapeake Bay have ranged from .05 to 22 ppt, but occurrence at salinities greater than 10 ppt is infrequent (Feeley and Wass 1971).

Reproduction occurs mainly from May through September. The young resemble the adults, and remain in the tubes with their parents for some time after hatching. The life cycle is annual (Bousfield 1973).

Dispersal may occur by chance entrainment by tidal currents. Also, the occurrence of C. lacustre in nocturnal surface zooplankton samples has been reported. Williams and Bynum (1972) found C. lacustre in plankton samples from the Pamlico River, N. Carolina throughout the year, but in greatest numbers in May and August. More individuals were collected on the new than on the full moon.

Scolecolepides viridis - This was the most abundant polychaete species in the study area in July and August 1978. Along the East Coast it ranges from Cape Hatteras north to Nova Scotia. Adults inhabit vertical, mucus-lined burrows in the sediments of estuarine zones where salinities are generally below 15 ppt (Gosner 1971, George 1966). In experiments conducted by George (1966) in Nova Scotia, salinities below 2.5 ppt were lethal to eggs and larvae, and salinities between 2.5 and 5 ppt inhibited growth. Development of eggs and larvae was unaffected by salinity in the range of 10 - 30 ppt. The rate of larval development increased with increasing temperature within the range 2 - 20°C. Eggs, larvae, and adults could live and grow normally during prolonged exposure to a temperature of 30°C, while temperatures between 34 and 35°C were lethal.

Individuals of S. viridis could survive cooling to -5°C, but could not tolerate ice crystal formation.

In the natural environment, reproduction appears to be mediated by the annual water temperature cycle. Gamete formation coincides with the fall in temperature following the summer maximum. Spawning is triggered by the rising temperature in the spring, and has been reported in February and March in Connecticut and in late March and early April in New Hampshire and Nova Scotia (George 1966). The larvae are planktonic and photopositive for approximately the first 40 days of development. At this age they become photonegative and begin to test the sediment for suitability for burrowing. Adults achieve sexual maturity in less than one year, and may reach a length of 140 mm and width of 3 mm.

Adults have elongate palpi that they use to sweep the substratum for microscopic food particles (Gosner 1971). Gut contents of S. viridis have been found to include sand, detritus, diatoms, filamentous algae, and nematodes (George 1966).

In the present study area, S. viridis adults may be encountered in all sediments soft enough to permit burrowing. Planktonic larvae would be expected in the late winter and early spring, with recruitment to the benthic population in March - May. Fish and crabs would be expected to utilize the benthic population as a food source.

Cyathura polita - C. polita, the most abundant isopod at the C. P. Crane site, has been reported from every state on the East Coast from Maine to Louisiana (Burbanck 1962). In the Chesapeake Bay area it is most commonly found on debris-covered shallow sand bottoms, and less commonly in softer substrates in deeper waters

(Wass *et al*. 1972). Eelgrass bottoms may support especially large populations (Gosner 1971). Sediments under moving water, and which are not anaerobic, are preferred (Burbanck 1962). *C. polita* is typically found upstream from the mouths of rivers and streams, near the upper limit of penetration of salt water. The population density tends to decrease with distance from a freshwater inflow (Burbanck 1963). Embryos can develop normally at salinities ranging from 0 - 30 ppt, while juveniles and adults osmoregulate similarly at salinities between 0 and 32 ppt (Kelley and Burbanck 1976).

Adults live in unlined burrows, 5 - 7.5 cm deep in the sediment. The anterior end of the animal is characteristically oriented toward the open end of the tube. A few young individuals may be found in the surface layer of the sediment when an algal mat is present (Burbanck 1962).

The period for reproduction on Cape Cod is late May to late August (Burbanck 1962). Eggs and juveniles remain in the female marsupium until the first molt of the fully developed juvenile, which occurs from 21 - 27 days after development begins (Kelley and Burbanck 1976). Sexual maturity is reached at a size of approximately 12 mm, and individuals may live for as long as 3 years (Burbanck 1962). Population densities may range from 100 to 4000 per m^2 (Gosner 1971).

In a 5 year study on Cape Cod, Burbanck (1962) found populations of *C. polita* in similar locations and with similar population densities on sampling dates spaced several years apart. An individual occupies a restricted spatial range, and may complete its entire life cycle within an area of a few meters (Burbanck et al. 1964). Burbanck (1962) postulated that dispersal of individuals is accomplished by chance broadcasting by local wave action and currents. Nocturnal swimming activity may also occur.

C. polita exists on a varied diet, which may include detritus, algae, dead animals, and occasionally live gammarid amphipods which it is capable of killing and eating. On Cape Cod it is known to be included in the diet of winter flounder, brook trout, and black ducks (Burbanck 1962).

In the C. P. Crane study area, C. polita would be expected to be most abundant as infauna in higher aquatic plant beds, less abundant in detritus-covered sandy sediments, and least abundant in mud. It is sufficiently sedentary and lives close enough to the sediment surface to be effectively sampled with the Ponar grab. Recruitment of juveniles to the population should occur throughout the summer, with most of the juveniles remaining within a few meters of their parents' burrows. Predators on the C. polita population in the study area should include fish, crabs, and waterfowl.

Tubificidae - Individuals belonging to this family of oligochaetes were found throughout the study area in the summer 1978 benthos samples. They feed on organic material in the bottom sediment deposits in which they live. Large population densities tend to be associated with sediments rich in organic matter, originating naturally or from pollution with sewage. Tubificids reproduce sexually, principally in the late summer, and embryos develop in cocoons deposited among plants or detritus aggregates. Aquatic oligochaetes range in length from 1 - 30 mm (Pennak 1953), so it is likely that many small individuals would escape through a .5 mm sieve.

Dipteran larvae - Most of the dipterans collected at the C. P. Crane site were chironomid (midge) larvae. These larvae occur among aquatic plants and on the bottom sediments of fresh and brackish waters, where most species feed on algae, higher plant tissue, and detritus (Pennak 1953), and some species feed on oligochaetes as well (Loden 1974). Adults emerge and mate during the summer, so this is the period of lowest abundance of final instar larvae in the benthic population. The maximum numbers of species and final instar larvae are present in the benthos in the spring (Roback 1953). Dipteran larvae are important in the diet of nektonic predators, especially catfish (Darnell 1958). Final instar chironomid larvae range in length from 2 - 30 mm, (Pennak 1953) and those near the lower limit of this range would be less effectively retained by a 0.5 mm sieve than would those of larger size.

Nematodes - These organisms were present in most of the July and August benthos samples. Nematodes are characteristically less than 10 mm long, and sufficiently slender that most of the individuals originally present in a Ponar grab sample undoubtedly passed through the 0.5 mm sieve, leaving an unknown proportion to be quantified. Feeding types within this group include detritivores, herbivores, and carnivores. Newly hatched individuals resemble the adults, and there is no planktonic life stage (Pennak 1953).

Quantitative Results

Physicochemical Parameters

During the July sampling run, the benthic invertebrate samples were taken on July 17, and the sediment core samples were taken the following day. The physicochemical parameters were measured on both days, principally in the morning on an ebbing tide, and these results appear in Tables 1 and 2.

The water temperatures observed in the creek systems during the sediment sampling on July 18 were on the average more than 1°C higher than the temperatures in the same areas on July 17. The explanation for this difference can be found in the power plant generating schedule, presented in Fig. 5.1 in Binkerd et al. 1978. On both the 17th and the 18th the plant was generating at full capacity from approximately 1000 to 2200 hr, and the discharge temperature peaked at 1800 hr. The plant had operated at only partial capacity on July 16, however, and this was reflected in initial and peak discharge temperatures that were lower the next day than on July 18, which followed a day of maximum power output. During the benthos sampling on July 17 the temperatures in Dundee and Saltpeter Creeks were recorded in the morning, and reflected the relatively low heat buildup during the preceding day. The temperatures observed in the creeks on the morning of July 18 resulted from the heat buildup during the more typical operating day of the 17th, and were more representative of the summer temperature distribution in the study area.

The salinity measurements on July 17 and 18 yielded only one sample with a level exceeding 2.0 ppt. Higher salinities were present in Seneca Creek and at the Gunpowder River stations downstream from the mouth of Saltpeter Creek, than were found in the

Table 1
Physicochemical data; July 17, 1978 benthos sampling run

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (° c)	Sal. (‰)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Dundee	I28	0800	0	25.40	1.13	6.38	.32	1.40	mud
			1	25.20	1.39	6.06			
	J26	0815	0	25.70	1.18	5.86	.38	1.70	mud
			1.25	25.60	1.17	6.16			
	IJ25	0822	0	25.65	1.16	6.24	.42	1.50	mud
			1.0	25.50	1.16	6.44			
	K25-26	0830	0	25.85	1.19	5.94	.41	1.87	mud
			1.5	25.75	1.19	5.72			
	L22-23	0839	0	26.00	1.21	5.76	.38	1.37	mud
			1.0	25.85	1.20	5.06			
	M23	0847	0	26.00	1.21	5.98	.40	1.53	mud
			1.0	25.75	1.21	5.74			
	N23-24	0853	0	25.95	1.19	6.44	.33	1.66	mud
			1.25	25.80	1.20	6.34			
Upper Saltpeter	E22-23	0922	0	26.15	1.23	5.20	.25	1.34	mud
			1.0	26.00	1.22	5.22			
	G21	0929	0	27.00	1.28	5.74	.26	1.56	mud
			1.25	26.80	1.28	5.84			
	H19-20	0935	0	27.35	1.31	5.82	.33	1.52	muddy sand
			1.0	27.00	1.31	5.58			
	J20	0942	0	27.30	1.33	5.86	.29	1.70	mud
			1.25	27.15	1.34	5.76			

-2- Table 1 (cont.)

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (‰)	D.O. (mg/1)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Upper Saltpeter	L20-21	0948	0	27.20	1.30	5.46	.28	1.40	mud
			0.9	26.90	1.30	5.30			detritus present
	L19-20	0954	0	27.50	1.35	6.61	.32	1.72	mud
			1.25	27.50	1.35	6.12			
Lower Saltpeter	P22	1008	0	27.10	1.34	6.12	.32	2.10	mud
			1.75	26.70	1.36	6.04			
	T21-22	1018	0	25.40	1.12	6.79	.85	1.67	mud
			1.25	25.30	1.12	6.96			macrophytes present
	ST20-21	1027	0	26.60	1.30	6.18	.31	2.03	mud
			1.75	26.50	1.27	5.79			
	R16-17	1035	0	25.50	1.14	6.73	.41	1.70	mud
			1.25	25.10	1.15	6.10			
	P18-19	1047	0	26.00	1.16	6.87	.45	1.48	mud
			1	25.75	1.16	6.71			
Seneca	B13	1325	0	27.00	1.06	6.47	.39	2.10	mud
			1.75	25.55	1.11	5.41			
	I12	1335	0	26.25	1.42	7.41	.39	4.53	mud
			2.75	24.80	1.42	6.26			
	GH11	1350	0	26.70	1.38	7.28	.58	2.03	mud
			1.75	25.25	1.35	6.53			
	KL9	1400	0	26.70	1.36	6.81	.61	1.26	mud
			1.00	25.85	1.36	6.49			

-3- Table 1 (cont.)

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (‰)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Seneca	OP8	1410	0	26.25	1.41	7.53	.51	2.19	muddy sand
			1.75	25.00	1.45	6.57			
	P4-5	1415	0	25.80	1.43	7.83	.56	2.70	mud
			2.25	24.35	1.85	6.47			
Gunpowder River	AA27	1440	0	27.40	0.45	7.89	.21	2.18	mud
			2	24.50	0.48	6.16			
	U26-27	1450	0	27.50	0.55	8.20	.22	1.20	muddy sand
			.75	27.00	0.58	8.38			
	GG24-25	1500	0	27.00	0.51	8.71	.24	2.25	mud
			2	24.20	0.79	6.49			
	GG13	1510	0	24.75	1.52	6.85	.32	3.08	mud
			2.75	24.50	1.55	6.96			
	Z12	1520	0	25.45	1.11	7.26	.35	2.27	mud
			2	25.45	1.31	7.00			
	VW12	1527	0	27.65	1.23	8.45	.40	1.89	muddy sand
			1.25	26.20	1.47	7.55			

Table 2
Physicochemical data; July 18, 1978 sediment sampling run

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (‰)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Dundee	I28	0813	0	26.80	1.23	6.98	.45	1.70	mud
			1.25	26.30	1.19	6.96			
	J26	0839	0	26.85	1.20	6.59	.47	1.84	mud
			1.5	26.60	1.21	6.69			
	IJ25	0845	0	27.75	1.21	6.65	.47	1.73	mud
			1.25	27.60	1.18	6.61			
	K25-26	0855	0	26.85	1.21	7.00	.41	1.90	mud
			1.5	26.55	1.21	6.67			
	L22-23	0905	0	27.90	1.27	6.24	.21	1.47	mud
			1.0	27.00	1.27	6.47			
	M23	0921	0	27.00	1.26	6.71	.43	1.77	mud
			1.25	26.80	1.26	6.61			
	N23-24	0930	0	26.60	1.21	6.32	.37	1.79	mud
			1.25	26.60	1.21	6.47			
Upper Saltpeter	E22-23	0938	0	28.60	1.32	6.54	.40	1.53	mud
			1.0	28.20	1.33	6.36			
	G21	0948	0	29.00	1.34	6.32	.41	1.75	mud
			1.25	28.60	1.34	5.84			
	H19-20	0957	0	28.90	1.35	6.30	.40	1.58	muddy sand
			1.0	28.65	1.36	6.36			

 Table 2 (cont.)

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (‰)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Upper Saltpeter	J20	1024	0	30.25	1.43	7.20	.41	1.87	mud
			1.5	29.00	1.35	6.18			
	L20-21	1032	0	27.90	1.30	5.14	.39	1.43	mud, detritus present
			1.0	27.85	1.30	7.46			
	L19-20	1041	0	29.85	1.43	7.56	.51	1.86	mud
			1.5	28.10	1.38	6.46			
Lower Saltpeter	P22	1050	0	28.40	1.32	6.92	.38	2.20	mud
			1.75	27.50	1.24	6.74			
	P18-19	1058	0	27.50	1.21	6.92	.51	1.63	mud
			1.0	26.80	1.20	6.26			
	R16-17	1107	0	27.45	1.20	6.72	.60	1.75	mud
			1.25	26.55	1.21	6.50			
	ST20-21	1115	0	28.00	1.26	6.74	.40	2.00	mud
			1.5	27.20	1.23	6.46			
	T21-22	1122	0	27.55	1.16	7.68	.82	1.74	mud
			1.25	26.85	1.16	7.68			macrophytes present
Gunpowder River	U26-27	1134	0	27.20	0.54	7.28	.19	1.12	muddy sand
			1.75	26.90	0.56	6.82			
	AA27	1142	0	26.20	0.54	7.08	.20	2.27	mud
			2.0	25.35	0.59	6.92			
	GG24-25	1150	0	26.70	0.46	8.12	.23	2.20	mud
			2.0	25.00	1.00	6.34			

-3- Table 2 (cont.)

Creek	Station	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (‰)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Type
Gunpowder River	VW12	1210	0	27.65	1.24	7.47	.47	1.88	muddy sand
			1.25	25.95	1.28	6.81			
	Z12	1218	0	27.80	1.13	7.71	.36	2.20	mud
			2.0	25.15	1.36	6.49			
	GG13	1228	0	27.65	0.80	8.85	.31	2.87	mud
			2.5	25.05	1.19	6.28			
Seneca	B13	1250	0	27.60	1.09	7.28	.51	2.02	mud
			1.75	26.05	1.16	5.65			
	I12	1300	0	27.35	1.44	9.36	.57	3.70	mud
			2.5	25.90	1.46	7.14			
	IJ12	1310	0	27.75	1.46	9.57	.59	1.18	muddy sand
			.75	27.65	1.46	9.08			
	GH11	1323	0	27.50	1.44	10.18	.50	2.21	mud
			1.75	26.00	1.42	7.14			
	KL9	1332	0	27.40	1.42	7.92	.68	1.28	mud
			.75	27.30	1.41	8.18			
	OP8	1345	0	27.65	1.59	6.96	.54	2.03	muddy sand
			1.75	25.95	1.72	6.61			
	P4-5	1354	0	26.35	1.70	7.61	.50	2.60	mud
			2.0	25.05	2.06	6.69			

Dundee-Saltpeter System. The lowest salinities on both dates were at the upstream Gunpowder River stations. The salinities at the upper Saltpeter Creek stations on July 18 were elevated relative to those at the Dundee Creek and lower Saltpeter Creek stations, reflecting the higher salinity cooling water introduced from Seneca Creek. Patterns similar to this were observed during ebbing tides sampled as part of the physical impact study (Binkerd et al. 1978, Figs. 5.39 and 5.49).

Dissolved oxygen concentrations declined with depth at some of the deeper stations sampled in July. Concentrations in bottom samples increased progressively with time of day, so that the last area sampled on each date had an average bottom oxygen level of over 7.0 ppm, compared with an average of 5.9 ppm on July 17 and 6.6 ppm on July 18 for Dundee Creek, the area sampled first. On both dates upper Saltpeter Creek exhibited the lowest bottom dissolved oxygen concentrations. The majority of the bottom dissolved oxygen concentrations were below saturation, and supersaturation was detected only at station IJ12, in Seneca Creek, on July 18.

The total water depth was lowest in Dundee and upper Saltpeter Creeks (approximately 1.6 m), greatest in Seneca Creek and the Gunpowder River (approximately 2.2 m), and intermediate in lower Saltpeter Creek (approximately 1.8 m). The deepest station was I12, adjacent to the power plant barge canal in Seneca Creek.

Quantitative Sediment and Benthos Results

The quantitative results of the July 18 sediment survey are summarized in Table 3. The stations are grouped by creek, and are identified by their location coordinates (Fig. 1). The stratum designations appearing beside some of the station coordinates refer to the sampling areas chosen subsequently for the August sampling run, and identify the July stations whose data may be directly compared with the August data for the corresponding areas. The sediment characteristics summarized include median particle diameter, expressed in both phi and micron units, percentages by weight of the sand, silt, and clay size fractions, and the organic content as loss on ignition.

Figure 2 is a three variable plot of the sediment particle size characteristics. Most of the sediment samples contained less than 20% sand and between 46 and 78% silt. These formed a cluster in the section of the plot that represents the clayey-silt sediment category. The sand content of the remaining samples ranged from 23 to 99%. The symbols represent the creeks within which the samples were taken, and samples from areas that became sampling strata in August are identified appropriately.

Figures A1 - A30 in the appendix are cumulative size frequency distribution plots of sediment particle size for the July benthos stations. In these figures the Rapid Sand Analyzer results for the coarse particle fractions were combined graphically with the Coulter Counter results for the fine fractions. For some samples this data treatment left a discontinuity in the curve in the region of the 4.0 phi (63 micron) particle size, where the two methods overlap.

Table 3

Summary of sediment analysis results; July 18, 1978

Creek	Station	Stratum*	Median Particle diameter Mdφ	Mdμ	% sand >4.0φ >63μ	% silt 4.0φ-8.0φ 63μ-3.9μ	% clay <8.0φ <3.9μ	Loss on ignition % by wt.
Saltpeter	E22-23	I	6.68	10	10.8	78.2	11.0	11.58
	G21	I	6.48	13	15.8	73.2	11.0	11.00
	J20	I	7.27	6	14.5	50.5	35.0	8.78
	L19-20	I	7.75	5	11.6	49.4	39.0	9.05
	H19-20		2.80	150	90.3	5.5	4.2	1.49
	L20-21		3.75	75	68.5	22.5	9.0	21.18
Dundee	L22-23	II	7.40	6	12.3	52.7	35.0	10.86
	M23	II	6.50	12	9.8	77.2	13.0	10.46
	N23-24	II	6.96	8	17.7	55.8	26.5	9.95
Saltpeter	P22	II	6.71	10	16.4	60.6	23.0	11.02
	P18-19	III	7.35	6	11.1	53.9	35.0	9.74
	ST20-21	III	7.10	7	13.0	56.0	31.0	9.23
	R16-17	III	7.02	8	19.2	46.4	34.4	7.52
	T21-22	III	7.20	6	11.9	54.1	34.0	8.98
Dundee	K25-26	IV	7.00	8	16.7	61.3	22.0	11.03
	IJ 25	IV	7.00	8	14.4	57.6	28.0	11.20
	J26	IV	7.17	6	10.4	60.6	29.0	11.41
	I28	IV	7.05	8	12.6	60.4	27.0	11.95
Seneca	B13	V	6.68	11	18.9	61.1	20.0	10.99
	GH11		6.03	15	23.7	55.3	21.0	8.05
	I12		2.88	150	61.2	34.8	4.0	4.03
	IJ12		2.04	240	98.8	0.2	1.0	0.32
	KL9		4.85	38	46.1	38.9	15.0	7.46
	OP8		2.65	160	75.2	12.8	12.0	2.82
	P4-5**				52.4			3.22

Table 3 (continued).

Creek	Station	Stratum*	Median Particle diameter Mdϕ	Mdμ	% sand >4.0ϕ >63μ	% silt 4.0ϕ-8.0ϕ 63μ-3.9μ	% clay <8.0ϕ <3.9μ	Loss on ignition % by wt.
Gunpowder R.	U26-27		3.10	110	96.0	2.0	2.0	0.84
	AA27	VI	7.20	6	7.8	65.7	26.5	9.19
	GG24-25	VI	6.95	9	9.5	68.0	22.5	7.65
	VW12		3.00	120	64.2	21.3	14.5	4.18
	Z12		6.10	15	39.0	43.0	18.0	5.33
	GG13		7.05	8	19.1	49.4	31.5	6.42

*Strata used for establishing August benthos stations
**Fine particle size distribution not determined

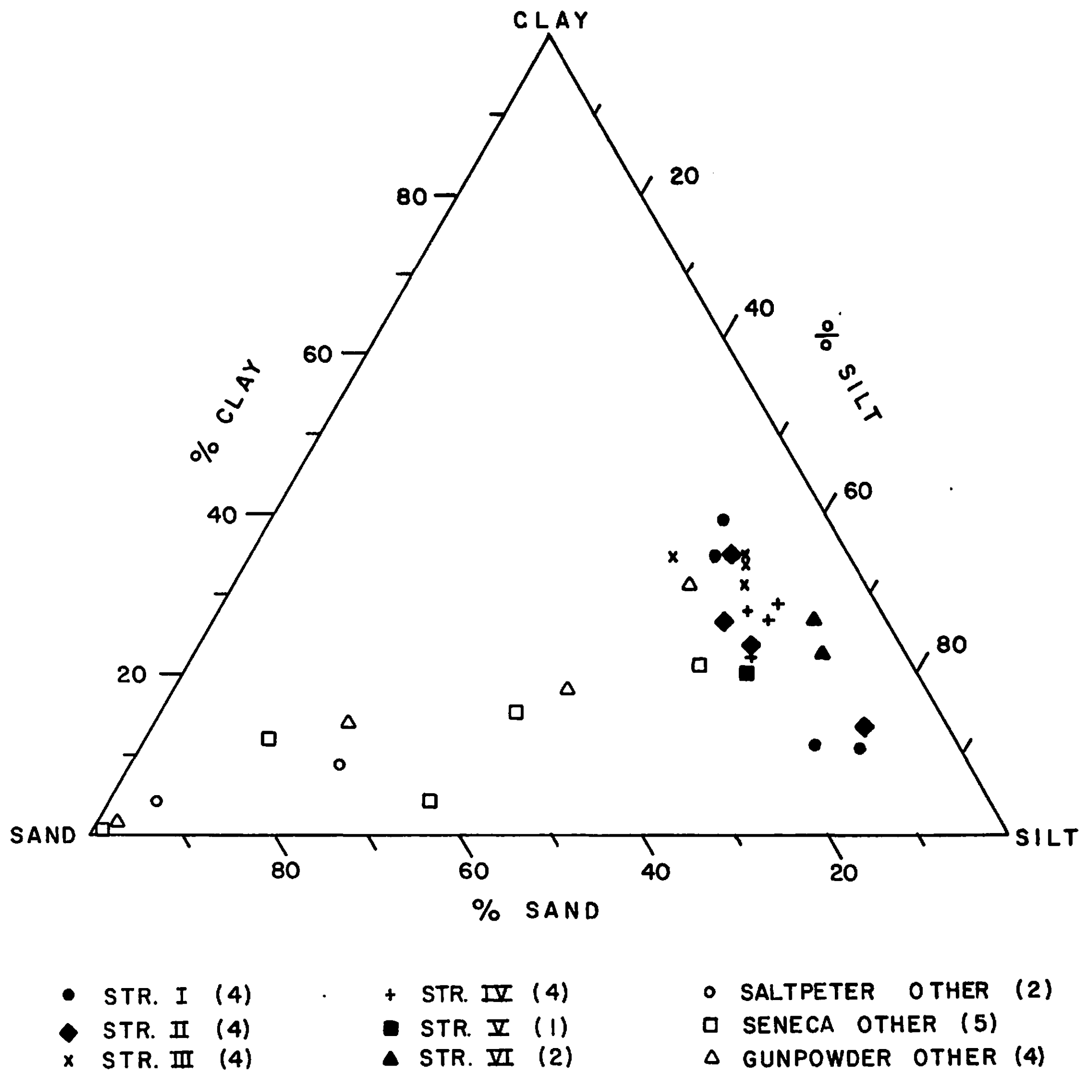

Fig. 2 Three variable sediment diagram,
July 18, 1978

The population densities of the benthic invertebrate species collected on July 17, calculated as numbers of individuals per 0.1 m^2 of sediment surface, are presented in Tables 4 through 12. The species composition varied little from station to station in Dundee Creek, where the sediments sampled were uniformly clayey-silt (Tables 3 and 4). In upper Saltpeter Creek (Table 5), four of the stations (E22-23, G21, J20, and L19-20) had this type of sediment. The fifth station, (H19-20), which was closest to the power plant discharge, had a sandy substrate with a relatively low organic content, and its community differed from those of the first four stations in having a greater number of species and individuals of polychaetes. Station L20-21, located off Marshy Point, also differed in sediment type from the first four upper Saltpeter stations. Large amounts of coarse detritus were present at this station, and the loss on ignition of the sediment sample was correspondingly high. This station exhibited the highest population density of Nereis succinea found at the study site in the 1978 summer survey. The lower Saltpeter Creek stations (Table 6), which all had clayey-silt sediments, yielded samples similar in composition to those from upper Saltpeter Creek, except that Rangia cuneata population densities appeared to be higher, and Leptocheirus plumulosus densities appeared lower. Station P22 (Table 7), also in lower Saltpeter Creek, exhibited the highest R. cuneata population densities found in the July survey. P22 was one of the stations at which 5 samples were taken in July, and the population densities presented in Table 7 were calculated, proceeding from left to right, using the raw counts from the successive combinations of the replicate samples indicated. The

Table 4

Benthic macroinvertebrate population densities; July 17, 1978

Dundee Creek Stations

				No./0.1m^2			
Station	L22-23	M 23	N23-24	K25-26	IJ 25	J26	I28
%LOI*	10.86	10.46	9.95	11.03	11.20	11.41	11.95
Organism							
Pelecypoda							
Rangia cuneata	112	122	180	102	32	100	20
Gastropoda							
Hydrobia sp. 1							
Hydrobia sp. 2		2			4	2	
Polychaeta							
Scolecolepides viridis	2	18	12	10	2	6	
Nereis succinea							
Hypaniola grayi				4	2		
Oligochaeta							
Tubificidae	16	32	16	90	2	4	6
Isopoda							
Cyathura polita	20	28	24	40	22	34	18
Chiridotea almyra	2						2
Edotea triloba							
Amphipoda							
Leptocheirus plumulosus	206	134	136	144	98	112	132
Corophium lacustre	2	22	4		2	4	14
Gammarus sp.	6		4	2	4	2	4
Monoculodes edwardsi							
Diptera							
Procladius sp.	4	4	2	8		8	
Cryptochironomus sp.	6	6	2		4		
Nematoda	8	22	34	16		12	8
Total No.	384	390	414	318	172	284	204
Total No. (excluding nematodes)	376	368	380	302	172	272	196

*Sediment organic content as % loss on ignition.

Table 5

Benthic macroinvertebrate population densities; July 17, 1978

Upper Saltpeter Creek Stations

No./0.1 m^2

Station	E22-23	G21	J20	L19-20	H19-20	L20-21
%LOI *	11.58	11.00	8.78	9.05	1.49	21.18
Organism						
Pelecypoda						
Rangia cuneata	24	38	82	64	112	196
Gastropoda						
Hydrobia sp. 1						14
Hydrobia sp. 2		2	4	2		
Polychaeta						
Scolecolepides viridis			2	10	64	22
Nereis succinea					12	28
Hypaniola grayi					8	28
Oligochaeta						
Tubificidae	16	32	10	14	34	42
Isopoda						
Cyathura polita	10	14	10	24	28	16
Chiridotea almyra						6
Edotea triloba						
Amphipoda						
Leptocheirus plumulosus	422	408	224	262	316	200
Corophium lacustre	6		6	2		14
Gammarus sp.	30			10		70
Monoculodes edwardsi						
Diptera						
Procladius sp.			2	4		2
Cryptochironomus sp.	12			2	2	2
Nematoda	2					
Total No.	522	494	340	394	576	640
Total No. (excluding nematodes)	520	494	340	394	576	640

*Sediment organic content as % loss on ignition.

Table 6

Benthic macroinvertebrate population densities; July 17, 1978

Lower Saltpeter Creek Stations

	No./0.1 m^2		
Station	P18-19	ST20-21	T21-22
%LOI *	9.74	9.23	8.98
Organism			
Pelecypoda			
Rangia cuneata	118	308	72
Gastropoda			
Hydrobia sp. 1			
Hydrobia sp. 2	2	6	2
Polychaeta			
Scolecolepides viridis	10	10	4
Nereis succinea			
Hypaniola grayi		2	8
Oligochaeta			
Tubificidae	6	14	14
Isopoda			
Cyathura polita	14	38	14
Chiridotea almyra	2		
Edotea triloba			
Amphipoda			
Leptocheirus plumulosus	100	300	106
Corophium lacustre			118
Gammarus sp.	2	4	22
Monoculodes edwardsi			2
Diptera			
Procladius sp.	6	6	10
Cryptochironomus sp.			
Ephemeroptera			
Caenis sp.		2	
Nematoda		78	2
Total No.	260	768	374
Total No. (excluding nematodes)	260	690	372

*Sediment organic content as % loss on ignition.

Table 7

Benthic macroinvertebrate population densities; July 17, 1978

Lower Saltpeter Creek Stations (cont.)

Cumulative No./0.1 m^2

Station P22
%LOI*11.02

Sample Combination	A	A+B	A+B+C	A+B+C+D	A+B+C+D+E
Organism					
Pelecypoda					
Rangia cuneata	428	332	430	399.5	386
Gastropoda					
Hydrobia sp. 1	4	3	3.3	2.5	2
Hydrobia sp. 2	10	6	4	3	3.2
Polychaeta					
Scolecolepides viridis	14	10	12.7	13.5	12
Nereis succinea					
Hypaniola grayi	4	4	2.7	2.5	2
Oligochaeta					
Tubificidae	206	217	149.3	124	102
Isopoda					
Cyathura polita	26	22	26.7	32.5	30.8
Chiridotea almyra	6	3	2	1.5	1.2
Edotea triloba					
Amphipoda					
Leptocheirus plumulosus	190	158	196	198.5	192
Corophium lacustre			.7	.5	.4
Gammarus sp.		2	4	4.5	3.6
Monoculodes edwardsi	4	2	1.3	1	.8
Diptera					
Procladius sp.	10	9	7.3	7	6
Cryptochironomus sp.	2	5	3.3	4	3.2
Nematoda	44	49	35.3	31.5	25.2
Nemertean		1	.7	.5	.4
Total No.	948	823	879.3	826.5	770.8
Total No. (excluding nematodes)	904	774	844	795	745.6

*Sediment organic content as % loss on ignition.

Table 8

Benthic macroinvertebrate population densities; July 17, 1978

Lower Saltpeter Creek Stations (cont.)

Cumulative No./0.1 m^2

Station R16-17
%LOI*7.52

Sample Combination	A	A+B	A+B+C	A+B+C+D	A+B+C+D+E
Organism					
Pelecypoda					
Rangia cuneata	60	67	77.3	86.5	84
Gastropoda					
Hydrobia sp. 1					
Hydrobia sp. 2	2	2	2	1.5	1.2
Polychaeta					
Scolecolepides viridis	28	20	21.3	22.5	21.2
Nereis succinea					
Hypaniola grayi			1.3	1.5	1.6
Oligochaeta					
Tubificidae	62	59	57.3	49.5	44
Isopoda					
Cyathura polita	26	26	26.7	25	24.4
Chiridotea almyra		1	1.3	1	1.2
Edotea triloba					
Amphipoda					
Leptocheirus plumulosus	86	95	106	113	116.8
Corophium lacustre		1	1.3	1	1.2
Gammarus sp.		1	.7	.5	.4
Monoculodes edwardsi					
Diptera					
Procladius sp.	6	7	11.3	12.5	10.4
Cryptochironomus sp.	2	4	2.7	2	2.4
Nematoda	34	26	32.7	24.5	20.8
Total No.	306	309	341.9	341	329.6
Total No. (excluding nematodes)	272	283	309.2	316.5	308.8

*Sediment organic content as % loss on ignition.

Table 9

Benthic macroinvertebrate population densities; July 17, 1978

Seneca Creek Stations

Station	B13	I12	KL9	P4-5
	No./0.1 m^2			
%LOI*	10.99	4.03	7.46	3.22
Organism				
Pelecypoda				
Rangia cuneata	28	380	276	66
Gastropoda				
Hydrobia sp. 1			4	10
Hydrobia sp. 2	6	16	6	20
Polychaeta				
Scolecolepides viridis	2	50	18	28
Nereis succinea				
Hypaniola grayi		8	14	6
Oligochaeta				
Tubificidae	12	6	140	
Isopoda				
Cyathura polita		40	14	14
Chiridotea almyra		2		
Edotea triloba			2	
Amphipoda				
Leptocheirus plumulosus	594	232	312	190
Corophium lacustre	6	8		14
Gammarus sp.	2		80	8
Monoculodes edwardsi				
Diptera				
Procladius sp.	10		12	2
Cryptochironomus sp.	2		2	6
Nematoda		4	74	
Total No.	662	746	954	364
Total No. (excluding nematodes)	662	742	880	364

*Sediment organic content as % loss on ignition.

Table 10

Benthic macroinvertebrate population densities; July 17, 1978

Seneca Creek Stations (cont.)

Cumulative No./0.1 m^2

Station GH11
%LOI*8.05

Sample Combination	A	A+B	A+B+C	A+B+C+D	A+B+C+D+E
Organism					
Pelecypoda					
Rangia cuneata	378	250	288	319.5	333.6
Gastropoda					
Hydrobia sp. 1		2	2	6	4.8
Hydrobia sp. 2	28	19	21.3	23.5	25.6
Polychaeta					
Scolecolepides viridis	36	24	30	32	29.6
Nereis succinea					
Hypaniola grayi				.5	.4
Oligochaeta					
Tubificidae	14	11	8	22.5	23.6
Isopoda					
Cyathura polita	38	23	25.3	28.5	28.4
Chiridotea almyra					
Edotea triloba					
Amphipoda					
Leptocheirus plumulosus	390	244	232	255.5	264.8
Corophium lacustre	10	6	4.7	5	4
Gammarus sp.	2		1.3	1	1.2
Monoculodes edwardsi					
Diptera					
Procladius sp.	2	2	2.7	2	2
Cryptochironomus sp.	4		1.3	1	1.6
Nematoda				5	5.6
Nemertean				1.5	1.2
Total No.	902	581	616.6	703.5	726.4
Total No. (excluding nematodes)	902	581	616.6	698.5	720.8

*Sediment organic content as % loss on ignition.

Table 11

Benthic macroinvertebrate population densities; July 17, 1978

Seneca Creek Stations (cont.)

Cumulative No./0.1 m^2

Station OP8 %LOI*2.82 Sample Combination	A	A+B	A+B+C	A+B+C+D	A+B+C+D+E
Organism					
Pelecypoda					
Rangia cuneata	72	63	56	61.5	62
Gastropoda					
Hydrobia sp. 1		1	.7	.5	.8
Hydrobia sp. 2		4	2.7	3.5	4
Polychaeta					
Scolecolepides viridis	64	45	36	32.5	32
Nereis succinea	4	3	2.7	3.5	2.8
Hypaniola grayi	28	26	20.7	23	23.6
Oligochaeta					
Tubificidae	6	6	5.3	16	15.2
Isopoda					
Cyathura polita	22	20	17.3	17	16.4
Chiridotea almyra	2	1	.7	.5	.4
Edotea triloba					
Amphipoda					
Leptocheirus plumulosus	328	396	359.3	399	394.8
Corophium lacustre	198	148	110	120	106.8
Gammarus sp.	8	8	6	8	7.2
Monoculodes edwardsi			.7	.5	.4
Diptera					
Procladius sp.	8	6	4	4	3.6
Cryptochironomus sp.	4	2	1.3	2.5	3.6
Nematoda					
Nemertean	2	1	.7	.5	.4
Total No.	746	730	624.1	692.5	674
Total No. (excluding nematodes)	746	730	624.1	692.5	674

*Sediment organic content as % loss on ignition.

Table 12

Benthic macroinvertebrate populations densities; July 17, 1978

Gunpowder River Stations

No./0.1 m^2

Station	U26-27	AA 27	GG 24-25	VW 12	Z 12	GG 13
%LOI*	0.84	9.19	7.65	4.18	5.33	6.42
Organism						
Pelecypoda						
Rangia cuneata	20	4	6	194	150	178
Gastropoda						
Hydrobia sp. 1		4	2	6		
Hydrobia sp. 2	12	12	14	34	8	34
Polychaeta						
Scolecolepides viridis	14	4	34	54	12	40
Nereis succinea	4			2		
Hypaniola grayi	2			6		
Oligochaeta						
Tubificidae	58	32	12	58	12	2
Isopoda						
Cyathura polita	8	12	40	74	34	52
Chiridotea almyra				6		
Edotea triloba						8
Amphipoda						
Leptocheirus plumulosus	210	82	282	334	296	324
Corophium lacustre	68		2	14		
Gammarus sp.	4		2	30	12	2
Monoculodes edwardsi						
Diptera						
Procladius sp.	20	2	8	2	10	
Cryptochironomus sp.	6			4		2
Nematoda	4	14	50	36	10	
Total No.	430	166	452	854	544	642
Total No. (excluding nematodes)	426	152	402	818	534	642

*Sediment organic content as % loss on ignition.

population densities for the final lower Saltpeter Creek station, R16-17 (Table 8), were calculated in the same way.

Compared to Dundee and Saltpeter Creeks, Seneca Creek exhibited more variation in sediment composition from station to station (Table 3). At station B13 the particle size distribution and organic content of the sediment were similar to these characteristics of the sediment in the other two creeks. At the other Seneca Creek stations, the sediments were coarser and had lower organic content, ranging from 2.82 to 8.05% loss on ignition.

The species composition of the July benthos did not differ between Seneca Creek and the Dundee-Saltpeter system. Within Seneca Creek, larger numbers of Nereis succinea, Hypaniola grayi, and Corophium lacustre were found at the stations with the coarser sediments (Tables 9-11). Five samples were taken at each of stations GH11 and OP8, and the population densities were calculated using successive combinations of sample counts.

The Gunpowder River sediment composition also varied widely from station to station (Table 2). Stations U26-27 and VW12, which were the closest to shore, had sediments predominated by sand. The sediments at stations AA27 and GG24-25 were the most similar to the Dundee and Saltpeter Creek mud sediments.

Among the Gunpowder River stations the major faunal difference was in the abundance of Rangia cuneata. The population density of this species was much lower at the stations upstream from the mouth of Saltpeter Creek (Table 12), although large amounts of fragmented shell material present at these stations suggested that dense R. cuneata populations had existed there in the past. More individuals of the amphipod species Corophium lacustre and more species and individuals of polychaetes were collected at the coarse sediment than at the fine sediment stations in the Gunpowder River.

Conclusions - July Benthos Sampling Run

The main purpose of the July sampling run was to obtain preliminary sediment and benthos data upon which to base the design of the quantitative benthos sampling in August. The results of the sediment survey indicated that the bottom type in the Dundee-Saltpeter Creek system was less variable, and in general less coarse and of higher organic content than the bottom types in Seneca Creek and the adjacent Gunpowder River. The benthic community composition also showed less spatial variation in Dundee and Saltpeter Creeks. The situation was similar to that observed in the Calvert Cliffs region of Chesapeake Bay (Mountford et al. 1977), where a higher "natural noise level" in the community composition was observed for transitional, muddy sand communities than for communities found in more strictly sand or mud sediments. Since variability of sediment type in the August sampling run could have introduced extraneous variance into the benthos data, the major emphasis in the selection of the August stations was standardization based on sediment composition. The August reference station locations were selected in two areas outside Dundee and Saltpeter Creeks, that according to the July survey had organic-rich mud sediments closely resembling those in the vicinity of the power plant discharge. The first of these reference areas was located in upper Seneca Creek (encompassing July station B13-Fig. 1), and the second was in the upstream Gunpowder River area (surrounding July station AA27).

The sampling intensity for the August sampling run was determined by examining the benthos counts for the four stations at which five replicate grab samples were taken in July (Tables 7, 8, 10, and 11).

In the calculations of the population densities and total numbers of species collected at these stations, the results for five grabs combined (A+B+C+D+E) differed little from the results for four grabs combined (A+B+C+D). For the August design, therefore, four grabs per station were considered sufficient.

August Sampling Run

Sampling Design

The field effort in August was allocated among the six sampling strata indicated in Fig. 3. These strata were established in areas that the July sediment analyses had shown were occupied by clayey-silt substrates having organic contents ranging from about 9 to about 11.5% (loss on ignition). Strata I-IV were obviously within the zone susceptible to power plant thermal effects, while strata V and VI were considered to be sufficiently distant from the plant to serve as reference sites. Strata I-III in Saltpeter Creek were arranged along a longitudinal gradient of elevated water temperature that was observed on July 18. On this date the bottom water temperatures in the stratum I area ranged from 28.1 to 29.0°C, in the stratum II area from 27.0 to 27.8°C, and in the stratum III area from 26.5 to 27.2°C (Table 2). The temperature range in Dundee Creek (stratum IV) was 26.3 - 27.6°C, which overlapped the range observed in stratum II and encompassed the range observed in stratum III. Similar gradients were observed during the physical impact study conducted by Aquatec, Inc. (Binkerd et al. 1978; Figs. 5.25, 5.34, 5.43, 5.58, 5.67, 5.76). Their study concluded that the maximum excess temperatures due to the power plant discharge occurred in upper Saltpeter Creek (benthos stratum I), followed by lower but still detectable temperature elevations in lower Saltpeter Creek (Benthos stratum III). The excess temperature range for Dundee Creek overlapped the range for lower Saltpeter Creek, according to the Aquatec study.

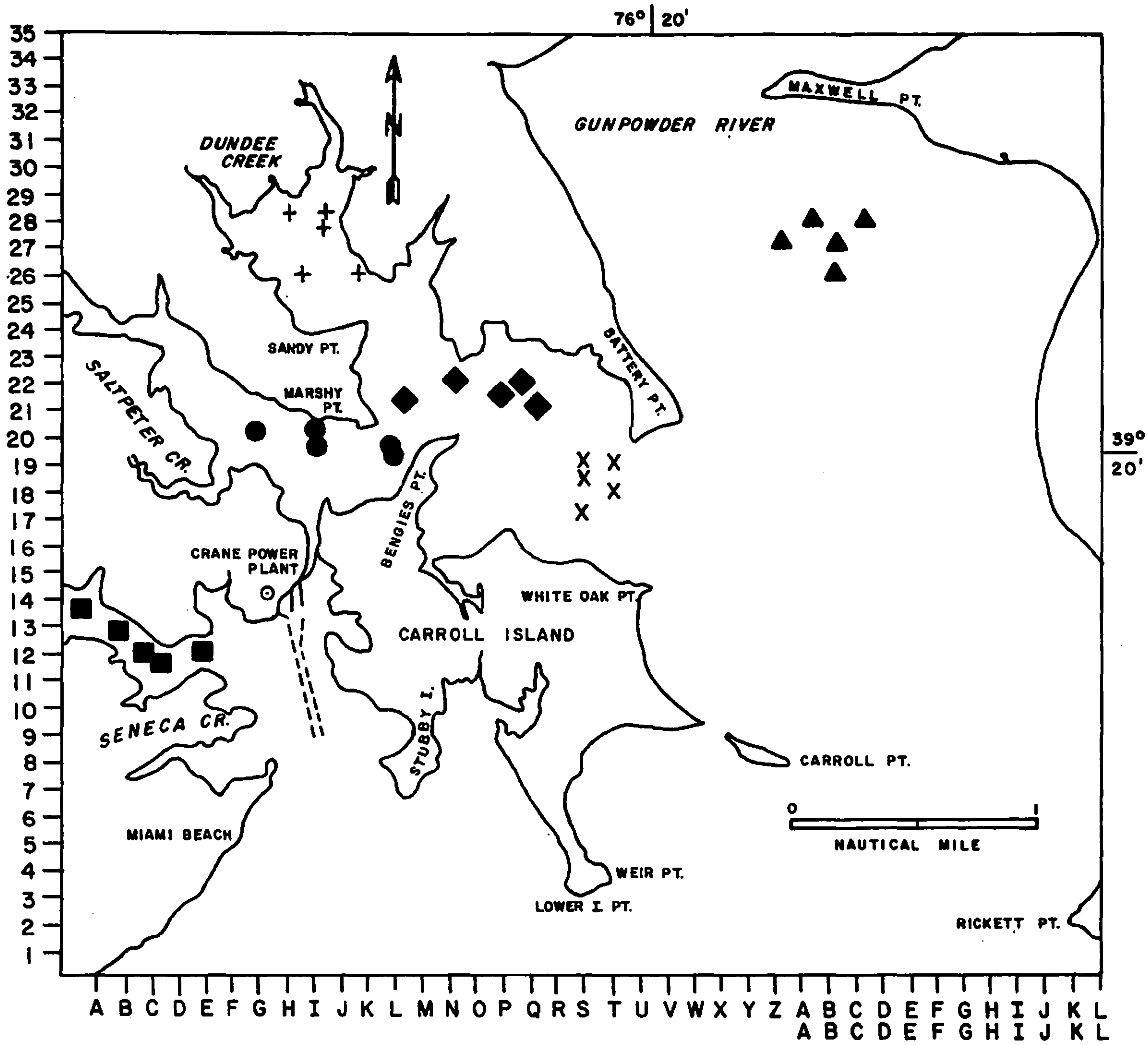

Fig. 3 Final station locations
August 16-19, 1978

● Stratum I
◆ Stratum II
X Stratum III
+ Stratum IV
■ Stratum V
▲ Stratum VI

The bottom water temperatures observed in the stratum V section of Seneca Creek and in the stratum VI area of the Gunpowder River on July 18 were 26.05°C and 25.35°C, respectively. Using a mathematical model to analyze the temperature data in the physical study, Binkerd et al. (1978) concluded that recirculation of heated discharge water via the Gunpowder River into Seneca Creek resulted in an increase in water temperature of 0.5°F (approximately 0.3°C) in the intake area. Presumably this increase would be in addition to any temperature elevation caused by heated water directly entering the intake area through the hole in the discharge canal wall, which is 4 feet wide by 3-4 feet deep, according to Binkerd et al. (1978). The bottom water in the benthos stratum V area in upper Seneca Creek was unlikely to have been within the range of the effect of the recirculated discharge water, but the possibility of a hole in the wall effect cannot be dismissed.

Results

Physicochemical Parameters

The August benthos sampling was accomplished in two full-day and two half-day periods (Table 13). The highest bottom water temperature (33.9°C) was observed at station I20 in stratum I, which was sampled during the afternoon, when temperatures were expected to approach the upper limit of the diel range. The average bottom temperature in stratum I, 32.4°C, was approximately 1°C above the average observed during the afternoon of August 16 in stratum IV (31.4°C), and 2.3°C above the average for control stratum V (30.1°C) in the afternoon of August 17. The average bottom temperatures for the other three strata, which were sampled in the morning between 0720 and 0935 hr, ranged from 28.1°C in stratum III to 29.3°C in stratum II, with the reference stratum VI mean at an intermediate value of 28.5°C. The difference between the averages for the two reference strata, 1.6°C, was similar to the diel ranges of approximately 1.7 - 2.8°C observed for Seneca Creek during the physical impact study (Binkerd _et_ _al_. 1978, Figs. 5.1 and 5.2).

The lowest salinities were measured in stratum VI, the highest in stratum I. The overall bottom salinity range for the study area was 0.85 ppt, from 1.42 ppt at station AA28 in stratum VI to 2.27 ppt at station I20 in stratum I.

Dissolved oxygen showed little tendency to stratify vertically, but did exhibit distinct diel changes. The average morning bottom water dissolved oxygen concentration during the study period was

Table 13
Physico-chemical data, August 1978 benthos sampling dates

Stratum	Station	Date	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (o/oo)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Loss on Ignition (%)	Sediment Type
I	L19-20	8-18	1333	0	34.25	2.30	6.98	.67	1.37	9.62	mud
				1.0	32.55	2.26	7.22				
	L19		1348	0	34.95	2.28	7.00	.66	1.29	9.20	mud
				1.0	32.00	2.26	7.34				
	I20		1400	0	35.00	2.29	7.16	.65	1.31	9.33	mud
				.75	33.90	2.27	6.98				
	I19-20		1415	0	35.40	2.29	7.06	.71	1.30	9.10	mud
				.75	32.30	2.24	7.26				
	G20		1435	0	31.40	2.21	7.12	.46	1.10	10.32	mud
				.5	31.40	2.22	6.96				
II	LM21	8-18	0830	0	29.95	2.20	5.98	.49	1.46	11.14	mud
				1.0	29.65	2.20	6.58				detritus, macrophytes present
	NO22		0845	0	28.95	2.13	6.26	.58	2.15	11.11	mud
				1.75	29.25	2.12	6.18				
	P21-22		0906	0	29.55	2.16	6.48	.67	2.22	11.70	mud
				1.75	29.25	2.16	6.38				
	PQ22		0916	0	29.40	2.15	6.46	.70	1.86	10.57	mud
				1.5	29.25	2.15	6.16				
	Q21		0935	0	29.45	2.16	6.48	.68	2.06	9.67	mud
				1.75	29.25	2.16	6.42				macrophytes present

Table 13 (cont.)
Physico-chemical data, August 1978 benthos sampling dates

Stratum	Station	Date	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (o/oo)	D.O. (mg/1)	Secchi Depth (m)	Total Depth (m)	Sediment Loss on Ignition (%)	Sediment Type
III	S19	8-19	0748	0	28.10	1.59	6.28	.45	2.21	9.55	mud
				2.0	28.10	1.61	6.38				
	S18-19		0802	0	28.35	1.65	6.30	.38	2.19	10.05	mud
				1.75	28.10	1.61	6.28				
	S17		0816	0	28.60	1.75	6.48	.52	2.25	8.33	mud
				2.0	28.50	1.92	6.34				
	T18		0830	0	28.10	1.62	6.86	.45	2.23	9.17	mud
				2.0	28.00	1.63	6.56				
	T19		0843	0	27.90	1.54	6.52	.40	2.23	8.84	mud
				2.0	27.80	1.62	6.58				
IV	H28	8-16	1550	0	31.35	1.72	7.78	.53	1.40	11.38	mud
				1.0	31.35	1.69	8.04				macrophytes present
	I28		1600	0	31.35	1.90	7.46	.50	1.44	11.51	mud
				1.0	31.30	1.90	7.28				
	I27-28		1615	0	31.45	2.04	7.52	.58	1.64	11.51	mud
				1.25	31.40	2.03	7.44				macrophytes present
	HI26		1630	0	31.40	1.78	8.48	.62	1.46	12.10	mud
				1.0	31.05	1.79	7.56				macrophytes present
	JK26		1640	0	32.05	2.18	7.62	.55	1.70	10.84	mud
				1.5	32.00	2.18	7.54				macrophytes present

Table 13 (cont.)
Physico-chemical data, August 1978 benthos sampling dates

Stratum	Station	Date	Time (EDT)	Sample Depth (m)	Temp. (°c)	Sal. (o/oo)	D.O. (mg/l)	Secchi Depth (m)	Total Depth (m)	Sediment Loss on Ignition (%)	Sediment Type
V	E12	8-17	1236	0	29.95	2.00	7.58	.42	2.55	10.23	mud
				2.25	29.45	2.16	6.16				macrophytes present
	CD12		1300	0	30.15	1.97	7.46	.53	1.83	10.96	mud
				1.5	30.05	1.97	7.68				
	C12-13		1310	0	30.30	2.45	7.56	.54	1.83	11.18	mud
				1.5	30.15	1.96	7.28				
	B13		1325	0	30.40	1.90	7.86	.52	2.02	11.68	mud
				1.75	30.25	1.96	7.64				
	A13-14		1338	0	30.55	1.88	7.76	.44	1.81	11.92	mud
				1.5	30.45	1.89	8.14				
VI	Z27	8-17	0720	0	28.50	1.56	6.46	.41	2.63	9.68	mud
				2.25	28.45	1.59	6.86				
	BB27		0736	0	28.55	1.55	6.74	.41	2.47	8.46	mud
				2.0	28.50	1.58	6.48				
	BB26		0752	0	28.75	1.75	6.46	.43	2.53	8.32	mud
				2.25	28.65	1.77	6.58				
	CC28		0807	0	28.65	1.40	6.48	.38	2.50	7.66	mud
				2.25	28.65	1.47	6.52				
	AA28		0823	0	28.40	1.41	6.46	.36	2.42	7.75	mud
				2.0	28.45	1.42	6.64				

6.46 mg/l, while the average afternoon concentration was 7.37 mg/l. The average bottom concentration was at the saturation level in the three strata sampled in the afternoon, but because of the elevated temperature in stratum I, this area exhibited lower actual concentrations than did strata IV and V.

The total water depth measured during sampling averaged 1.27 m in stratum I, 1.95 m in stratum II, 2.22 m in stratum III, 1.53 m in stratum IV, 2.01 m in stratum V, and 2.51 m in stratum VI. Sediment loss on ignition ranged from 7.66% at station CC28 in stratum VI to 12.10% at station HI26 in stratum IV.

Quantitative Benthos Results - August Spatial Patterns

The invertebrate population densities determined from the August benthos samples appear in Tables 14-19. Each table summarizes the data, by station, for a single sampling stratum. For each station the numbers of individuals of each species are tabulated separately for each of the 4 samples taken (designated by the letters A-D). These numbers are expressed as individuals per .05 m^2, the area encompassed by a single grab sample. The final population density estimate for each species, calculated from the combined counts for the 4 samples, is expressed as individuals per 0.1 m^2. The total number of individuals, summed over all species, has been calculated for each sample, and for each station the total number per 0.1 m^2, including and excluding nematodes, has been included. Because of their small size, nematodes are not reliably retained by the methods normally used to separate benthic invertebrates from sediment samples. The population densities determined for these organisms in the present study therefore represent unknown, and probably small, fractions of the actual densities originally present in the samples.

In Table 20 the total numbers of individuals and numbers of species per unit area, including and excluding nematodes, for each station are summarized by stratum. Species richness and species diversity values are also tabulated.

Tables 21 and 22 summarize the results of analyses of variance performed on the August benthos data. Stratum means for % loss on ignition, population densities of the major species, and community parameters have been compared, using the Student-Newman-Keuls' test (Steel and Torrie 1960). The strata that

Table 14
Benthic macroinvertebrate counts; Stratum I; August 18, 1978

Station	G20 No./.05 m^2				No. 0.1 m^2	I20 No./.05 m^2				No. 0.1 m^2	I19-20 No./.05 m^2				No. 0.1 m^2	L19-20 No./.05 m^2				No. 0.1 m^2	L19 No./.05 m^2				No. 0.1 m^2
Sample / Organism	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Pelecypoda																									
Rangia cuneata	11	17	16	21	32.5	24	24	20	20	44	27	26	25	34	56	23	13	18	37	45.5	15	13	23	14	32.5
Mytilus edulis																									
Gastropoda																									
Hydrobia sp. 1			2	2	2			1		.5	1	1		2	2						1				.5
Hydrobia sp. 2	1	1			1		1			.5	1	2		1	2	2				1	2	1			1.5
Polychaeta																									
Scolecolepides viridis	1	4	4		4.5	6	3	6	7	11	6	15	15	14	25	1	7		2	5	6	4	6	4	10
Nereis succinea														1	.5										
Oligochaeta																									
Tubificidae	8	9	11	10	19	19	18	22	19	39	38	72	28	46	92	32	22	11	17	41	23	22	8	55	54
Isopoda																									
Cyathura polita	4	11	9	8	16	17	61	14	12	52	19	21	13	12	32.5	10	9	46	7	36	6	47	10	11	37
Chiridotea almyra																									
Edotea triloba			2	1	1.5	1				.5		1	1	2	2						1	1		1	1.5
Amphipoda																									
Leptocheirus plumulosus	22	24	34	32	56	30	39	19	44	66	60	64	47	59	115	38	18	33	25	57	34	34	41	46	77.5
Corophium lacustre		1			.5				1	.5		1	5		3	4	1			2.5		1			.5
Gammarus sp.				1	.5																1				.5
Monoculodes edwardsi																									
Decapoda																									
Rhithropanopeus harrisii																									
Diptera																									
Procladius sp.	8	11	15	20	27	21	7	13	11	26	3	14	1	6	12	10	15	12	17	27	7	15	8	12	21
Cryptochironomus sp.		1		2	1.5	1	2			1.5	4	5	2	8	9.5	2	6	1		4.5	2	1	1	1	2.5
Ceratopogonidae														1	.5							1		2	1.5
Zygoptera																									
Coenagrionidae																									
Trichoptera																								1	.5
Nematoda	7	8	3	6	12	6	9	6	11	16	18	12	5	11	23	26	37	26	26	57.5	33	31	30	31	62.5
Total No.	62	87	96	103	174	125	164	101	125	257.5	177	234	142	197	375	148	128	147	131	277	131	171	127	178	303.5
Total No. (excluding nematodes)					162					241.5					352					219.5					241

Table 15

Benthic macroinvertebrate counts; Stratum II; August 18, 1978

Station	LM21 No./.05 m²				No. 0.1 m²	NO22 No./.05 m²				No. 0.1 m²	P21-22 No./.05 m²				No. 0.1 m²	PQ22 No./.05 m²				No. 0.1 m²	Q21 No./.05 m²				No. 0.1 m²
Sample	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Organism																									
Pelecypoda																									
<u>Rangia cuneata</u>	25	26	23	16	45	39	39	28	35	70.5	62	51	49	55	108.5	18	24	16	33	45.5	48	52	38	49	93.5
<u>Mytilus edulis</u>			1		.5																				
Gastropoda																									
<u>Hydrobia</u> sp. 1	1	2	3	1	3.5						3	2			2.5	2				1		1			.5
<u>Hydrobia</u> sp. 2		1	1	1	1.5	6		2	2	5	1	3	2	2	4				2	1		2			1
Polychaeta																									
<u>Scolecolepides viridis</u>	1	2	1	1	2.5	4	1	2	4	5.5	3	4	2	3	6	8	3	6	5	11	3	7	2	2	7
<u>Nereis succinea</u>				1	.5																				
Oligochaeta																									
Tubificidae	43	22	9	33	53.5	14	35	21	17	43.5	41	22	31	29	61.5	16	14	13	14	28.5	11	14	29	24	39
Isopoda																									
<u>Cyathura polita</u>	5	4	6	4	9.5	14	10	10	12	23	4	10	7	8	14.5	15	14	8	6	21.5	11	9	3	8	15.5
<u>Chiridotea almyra</u>	1		1		1			1		.5							1			.5					
<u>Edotea triloba</u>	5	4	6	5	10	7	3		6	8	2	5	1	2	5	1	3			2				1	.5
Amphipoda																									
<u>Leptocheirus plumulosus</u>	35	18	15	28	48	36	39	38	27	70	44	48	43	34	84.5	29	32	33	22	58	28	22	29	36	57.5
<u>Corophium lacustre</u>	16	5	6	3	15	4				2			1	1	1		4	1		2.5		1			.5
<u>Gammarus</u> sp.			1		.5	1		1		1	2			2	2		1			.5			1	1	1
<u>Monoculodes edwardsi</u>																									
Decapoda																									
<u>Rhithropanopeus harrisii</u>																									
Diptera																									
<u>Procladius</u> sp.	22	12	26	23	41.5	13	9	11	6	19.5	29	23	27	13	46	12	19	11	14	28	22	16	14	9	30.5
<u>Cryptochironomus</u> sp.	18	2	4	19	21.5	6	4	2	2	7	7	2		3	6	4	4	2	1	5.5	1		4	1	3
Ceratopogonidae	2				1		1			.5															
Zygoptera																									
Coenagrionidae			11		5.5																				
Trichoptera																									
Nematoda	38	32	43	27	70	252	203	122	109	343	69	88	103	109	184.5	57	83	57	68	132.5	87	107	103	93	195
Total No.	212	130	157	162	330.5	396	344	238	220	599	267	258	266	261	526	162	202	147	165	338	211	231	223	224	444.5
Total No. (excluding nematodes)					260.5					256					341.5					205.5					249.5

Table 16
Benthic macroinvertebrate counts; Stratum III; August 19, 1978

Station	S19 No./.05 m²				No. 0.1 m²	S18-19 No./.05 m²				No. 0.1 m²	S17 No./.05 m²				No. 0.1 m²	T19 No./.05 m²				No. 0.1 m²	T18 No./.05 m²				No. 0.1 m²
Sample	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Organism																									
Pelecypoda																									
Rangia cuneata	28	17	16	16	38.5	10	14	9	24	28.5	13	14	20	18	32.5	51	42	47	22	81	27	18	24	35	52
Mytilus edulis																									
Gastropoda																									
Hydrobia sp. 1									2	1			2		1	5		1		3	1				.5
Hydrobia sp. 2	1			1	1	1	1	1	1	2		1			.5		4	3	4	5.5	1	1	1	1	2
Polychaeta																									
Scolecolepides viridis	6	8	6	2	11	8	4	8	3	11.5	2	1	7	4	7	6	2	4	5	8.5	6	2	11	3	11
Nereis succinea																									
Oligochaeta																									
Tubificidae	9	12	9	15	22.5	13	12	10	15	25	5	12	17	15	24.5	19	37	19	11	43	8	2	13	3	13
Isopoda																									
Cyathura polita	19	12	8	9	24	6	18	10	9	21.5	9	12	9	13	21.5	11	10	9	5	17.5	14	9	12	7	21
Chiridotea almyra											1				.5										
Edotea triloba				1	.5				1	.5		1	1		1	1				.5					
Amphipoda																									
Leptocheirus plumulosus	37	29	13	20	49.5	19	17	19	21	38	27	32	35	25	59.5	51	60	57	24	96	24	26	35	22	53.5
Corophium lacustre	1				.5			1		.5		1			.5						1				.5
Gammarus sp.			2	1	1.5							1			.5	3	4	1		4	1				.5
Monoculodes edwardsi																		1		.5					
Decapoda																									
Rhithropanopeus harrisii																									
Diptera																									
Procladius sp.	9	20	5	10	22	8	20	10	17	27.5	8	8	12	13	20.5	17	23	11	3	27	9	27	12	12	30
Cryptochironomus sp.	1	2	2		2.5		2	1	2	2.5	1	1	1	1	2	3	2	1		3	1		1		1
Ceratopogonidae								1		.5															
Zygoptera																									
Coenagrionidae																									
Trichoptera																									
Nematoda	169	131	157	112	284.5	190	143	157	171	330.5	61	94	90	117	181	207	299	189	159	427	124	158	103	126	255.5
Total No.	280	231	218	187	458	255	231	227	266	489.5	127	178	194	206	352.5	374	483	343	233	716.5	217	243	212	209	440.5
Total No. (excluding nematodes)					173.5					159					171.5					289.5					185

Table 17
Benthic macroinvertebrate counts; Stratum IV; August 16, 1978

Station	JK26 No./.05 m^2				No. 0.1 m^2	HI26 No./.05 m^2				No. 0.1 m^2	I27-28 No./.05 m^2				No. 0.1 m^2	I28 No./.05 m^2				No. 0.1 m^2	H28 No./.05 m^2				No. 0.1 m^2
Sample	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Organism																									
Pelecypoda																									
Rangia cuneata	13	24	10	7	27	8	1	6	8	11.5	9	3	8	6	13	1	8	5	8	11	8	7	1	5	10.5
Mytilus edulis																									
Gastropoda																									
Hydrobia sp. 1												1			.5										
Hydrobia sp. 2	2	1	1	2	3				1	.5	1				.5			1		.5	1				.5
Polychaeta																									
Scolecolepides viridis	3	1	1	4	4.5	1		2	3	3	1		3	6	5	1	2			1.5	1	4	3	2	5
Nereis succinea																									
Oligochaeta																									
Tubificidae	1	6	3	2	6	11	17	24	9	30.5	4	2	4	5	7.5	3	4	8	6	10.5	4		5		4.5
Isopoda																									
Cyathura polita	9	7	5	8	14.5	5	5	8	14	16	12	7	7	3	14.5	5	7	8	8	14	12	3	3	3	10.5
Chiridotea almyra																		1		.5					
Edotea triloba		1	1		1								1		.5			1	1	1					
Amphipoda																									
Leptocheirus plumulosus	18	15	5	9	23.5	16	9	3	13	20.5	10	6	10	9	17.5	13	17	24	14	34	10	10	18	16	27
Corophium lacustre	1				.5						2	1	4		3.5				1	.5	2	42		1	22.5
Gammarus sp.						1				.5												1			.5
Monoculodes edwardsi																									
Decapoda																									
Rhithropanopeus harrisii																			1	.5					
Diptera																									
Procladius sp.	1	4	3		4	7	6	2	3	9	5		2	2	4.5	1		1	4	3	5	6	1	2	7
Cryptochironomus sp.		1			.5	2			1	1.5	1				.5	1			1	1	1	3			2
Ceratopogonidae							2			1															
Zygoptera																									
Coenagrionidae																							1		.5
Trichoptera																									
Nematoda	12	36	24	34	53	7	9	18	8	21	46	23	22	10	50.5	23	22	44	41	65	46	3	6	7	31
Total No.	60	96	53	66	137.5	58	49	63	60	115	91	43	61	41	118	48	60	93	85	143	90	79	38	36	121.5
Total No. (excluding nematodes)					84.5					94					67.5					78					90.5

Table 18
Benthic macroinvertebrate counts; Stratum V; August 17, 1978

Station	E12 No./.05 m^2				No. 0.1 m^2	CD12 No./.05 m^2				No. 0.1 m^2	C12-13 No./.05 m^2				No. 0.1 m^2	B13 No./.05 m^2				No. 0.1 m^2	A13-14 No./.05 m^2				No. 0.1 m^2
Sample	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Organism																									
Pelecypoda																									
Rangia cuneata	26	17	17	27	43.5	27	32	15	36	55	14	16	9	9	24	11	6	6	8	15.5		1	1	1	1.5
Mytilus edulis																									
Gastropoda																									
Hydrobia sp. 1																									
Hydrobia sp. 2		2	1	2	2.5			1		.5	1		1		1				1	.5					
Polychaeta																									
Scolecolepides viridis						1			1	1	1		1	1	1.5			1		.5		2	1	3	3
Nereis succinea																									
Oligochaeta																									
Tubificidae	27	22	19	27	47.5	24	16	29	19	44	13	24	18	37	46	17	10	33	35	47.5	34	22	14	16	43
Isopoda																									
Cyathura polita	46	7	4	4	30.5	3	3	4	3	6.5		3	1	2	3										
Chiridotea almyra																									
Edotea triloba		2	1	1	2		1			.5				2	1										
Amphipoda																									
Leptocheirus plumulosus	85	60	48	83	138	195	144	143	129	305.5	215	171	138	199	361.5	119	187	211	140	328.5	81	33	62	31	103.5
Corophium lacustre						1	1	1	1	2	3	1	1		2.5										
Gammarus sp.		1	2	1	2	1				.5	1			5	3			1		.5					
Monoculodes edwardsi																									
Decapoda																									
Rhithropanopeus harrisii																									
Diptera																									
Procladius sp.	4	11	2	9	13		2	3	4	4.5	7	3	4	6	10	4	3	2	6	7.5	7	4	1	10	11
Cryptochironomus sp.	2	5	2	3	6		1	2	2	2.5	4	2	1	6	6.5	2	2	5	4	6.5	1	1			1
Ceratopogonidae																			2	1					
Zygoptera																									
Coenagrionidae																									
Trichoptera																									
Nematoda	14	18	16	11	29.5	7	6	15	9	18.5	5	5	7	6	11.5	1	1	3	1	3		2		1	1.5
Total No.	204	145	112	168	314.5	259	206	213	204	441	264	225	181	273	471.5	154	209	262	197	411	123	65	79	62	164.5
Total No. (excluding nematodes)					285					422.5					460					408					163

Table 19
Benthic macroinvertebrate counts; Stratum VI; August 17, 1978

Station	Z27 No./.05 m^2				No. 0.1 m^2	AA28 No./.05 m^2				No. 0.1 m^2	BB27 No./.05 m^2				No. 0.1 m^2	BB26 No./.05 m^2				No. 0.1 m^2	CC28 No./.05 m^2				No. 0.1 m^2
Sample	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total	A	B	C	D	Total
Organism																									
Pelecypoda																									
Rangia cuneata	1	3	1	2	3.5	3	5		2	5	2	2	2	2	4	1	4	3		4	2	3	2		3.5
Mytilus edulis																									
Gastropoda																									
Hydrobia sp. 1	1				.5				1	.5	1	1		1	1.5						1			1	1
Hydrobia sp. 2	1	3	1		2.5	4	3	2	3	6	1	10	1	2	7	2	1	2	3	4	2	3	1	2	4
Polychaeta																									
Scolecolepides viridis	1	2	3	3	4.5	12	8	10	11	20.5	5	5	5	7	11	3	8	9	3	11.5	9	9	9	5	16
Nereis succinea																									
Oligochaeta																									
Tubificidae	31	7	33	20	45.5	45	18	1	33	48.5	18	20	8	34	40	59	52	29	34	87	23	24	25	16	44
Isopoda																									
Cyathura polita	7	6	10	4	13.5	11	9	13	16	24.5	12	9	9	11	20.5	11	16	13	14	27	12	8	11	12	21.5
Chiridotea almyra																					1				.5
Edotea triloba												2			1									1	.5
Amphipoda																									
Leptocheirus plumulosus	31	26	71	38	83	69	65	67	62	131.5	59	64	47	53	111.5	56	52	77	64	124.5	54	98	49	53	127
Corophium lacustre	3			2	2.5	1	2	1	1	2.5		1		6	3.5									1	.5
Gammarus sp.			1	1	1		2		2	2		1	2	2	2.5			2	2	2					
Monoculodes edwardsi																							1		.5
Decapoda																									
Rhithropanopeus harrisii																									
Diptera																									
Procladius sp.	12	6	9		13.5	8	11	8	16	21.5	14	9	9	7	19.5	12	9	6	7	17	15	12	10	12	24.5
Cryptochironomus sp.		1		1	1	1	1		1	1.5						1	1	1		1.5				1	.5
Ceratopogonidae																									
Zygoptera																									
Coenagrionidae																									
Trichoptera																									
Nematoda	75	37	57	9	89	125	69	10	99	151.5	43	60	49	61	106.5	100	79	53	111	171.5	128	141	176	112	278.5
Total No.	163	91	186	80	260	279	193	112	247	415.5	155	184	132	186	328.5	245	222	195	238	450	247	298	284	216	522.5
Total No. (excluding nematodes)					171					264					222					278.5					244

Table 20

Benthic macroinvertebrate community parameters, August 1978

	Including nematodes						Excluding nematodes					
Stratum	I	II	III	IV	V	VI	I	II	III	IV	V	VI
No. individuals/0.1 m^2	174	330.5	458	137.5	314.5	260	162	260.5	173.5	84.5	285	171
	257.5	599	489.5	115	441	415.5	241.5	256	159	94	422.5	264
	375	526	352.5	118	471.5	328.5	352	341.5	171.5	67.5	460	222
	277	338	716.5	143	411	450	219.5	205.5	289.5	78	408	278.5
	303.5	444.5	440.5	121.5	164.5	522.5	241	249.5	185	90.5	163	244
No. species/0.1 m^2	13	18	12	11	10	12	12	17	11	10	9	11
	12	14	13	11	12	12	11	13	12	10	11	11
	14	13	14	12	12	12	13	12	13	11	11	11
	10	14	13	13	10	10	9	13	12	12	9	9
	15	13	12	12	7	14	14	12	11	11	6	13
Species richness	2.326	2.931	1.795	2.031	1.565	1.978	2.162	2.876	1.939	2.028	1.415	1.945
	1.982	2.033	1.938	2.108	1.806	1.824	1.822	2.164	2.170	1.981	1.654	1.793
$D = \frac{S-1}{\ln N}$	2.193	1.915	2.216	2.306	1.787	1.898	2.047	1.886	2.333	2.374	1.631	1.851
	1.600	2.233	1.825	2.418	1.495	1.473	1.484	2.253	1.941	2.525	1.331	1.421
	2.450	1.968	1.807	2.292	1.176	2.077	2.370	1.993	1.916	2.220	0.982	2.183
Species diversity	2.747	3.180	1.959	2.507	2.422	2.331	2.562	3.089	2.644	2.515	2.177	2.135
	2.708	2.140	1.805	2.762	1.553	2.389	2.529	2.703	2.758	2.540	1.359	2.699
H' (bits/individual)	2.738	2.585	2.253	2.564	1.371	2.462	2.563	2.542	2.576	2.761	1.236	2.298
	2.778	2.638	1.994	2.300	1.105	2.242	2.576	2.750	2.526	2.393	1.050	2.074
	2.791	2.334	2.034	2.844	1.461	1.998	2.591	2.396	2.506	2.718	1.399	2.145

Table 21

Among strata ANOVA summary, Benthic macroinvertebrates, August 1978
Student-Newman-Keuls' test results; means not sharing an
underline are significantly different (α≤.05)

Sediment % LOI	Stratum	VI	III	I	II	V	IV
retransformed ($\sqrt{X+\frac{1}{2}}$) mean		8.4	9.2	9.5	10.8	11.2	11.5
Rangia cuneata	Stratum	VI	IV	V	I	III	II
retransformed (log x) mean No./0.1 m^2		4.0	13.6	16.8	41.2	43.2	68.1
Scolecolepides viridis	Stratum	V	IV	II	I	III	VI
retransformed (log (X+1)) mean No./0.1 m^2		1.0	3.6	5.9	9.3	9.6	11.5
Leptocheirus plumulosus	Stratum	IV	III	II	I	VI	V
retransformed (log x) mean No./0.1 m^2		23.9	56.5	62.4	71.6	114.0	220.3
Cyathura polita	Stratum	V	IV	II	VI	III	I
retransformed (log (X+1)) mean No./0.1 m^2		2.9	13.8	16.1	20.9	21.0	32.6
Procladius sp.	Stratum	IV	V	VI	I	III	II
retransformed ($\sqrt{X+\frac{1}{2}}$) mean No./0.1 m^2		5.3	8.9	19.0	21.7	24.8	31.9
Cryptochironomus sp.	Stratum	VI	IV	III	I	V	II
retransformed (log (X+1)) mean No./0.1 m^2		0.8	1.0	2.1	3.2	3.9	7.0
Tubificidae	Stratum	IV	III	II	V	I	VI
retransformed ($\sqrt{X+\frac{1}{2}}$) mean No./0.1 m^2		10.4	24.7	44.4	45.5	46.1	51.8
Nematoda	Stratum	V	I	IV	VI	II	III
retransformed (log x) mean No./0.1 m^2		7.8	27.5	40.8	146.9	162.9	284.4

Table 22

Among strata ANOVA summary, Benthic Community parameters, August 1978 Student-Newman-Keuls' test results; means not sharing an underline are significantly different ($\alpha \leq .05$).

Total individuals	Stratum	IV	I	V	VI	II	III
retransformed (log x) mean No./0.1 m^2		126.5	269.2	338.1	383.7	435.5	477.5
Total individuals (excluding nematodes)	Stratum	IV	III	VI	I	II	V
retransformed (log x) mean No./0.1 m^2		82.3	190.9	232.6	235.8	259.1	326.1
No. spp.	Stratum	V	IV	VI	I	III	II
mean No./0.1 m^2		10.2	11.8	12.0	12.8	12.8	14.4
No. spp. (excluding nematodes)	Stratum	V	IV	VI	I	III	II
mean No./0.1 m^2		9.2	10.8	11.0	11.8	11.8	13.4
Species richness	Stratum	V	VI	III	I	II	IV
D = (s-1)/(ln N)		1.566	1.850	1.916	2.110	2.216	2.231
Species richness (excluding nematodes)	Stratum	V	VI	I	III	IV	II
D = (s-1)/(ln N)		1.403	1.839	1.977	2.060	2.226	2.234
Species diversity	Stratum	V	III	VI	II	IV	I
H' (bits/individual)		1.582	2.009	2.284	2.575	2.595	2.752
Species diversity (excluding nematodes)	Stratum	V	VI	I	IV	III	II
H' (bits/individual)		1.444	2.270	2.564	2.585	2.602	2.696

differed the least, according to these tests, were three discharge strata, I, II, and III, in Saltpeter Creek. Sediment organic content was higher in stratum II, while the nematode population density was lower in stratum I. The population densities of the other species did not differ significantly among the three strata. The other discharge stratum, IV, in Dundee Creek, had lower population densities of Rangia cuneata, Leptocheirus plumulosus, Procladius sp., Tubificidae, and total individuals than any of the Saltpeter Creek strata, a lower Scolecolepides viridis density than strata I and III, and a lower nematode density than strata II and III.

The reference strata differed from each other and from the discharge strata as follows: Stratum VI, in the Gunpowder River, was lowest in sediment organic content and R. cuneata population density, but higher than all of the discharge strata in L. plumulosus density. Stratum V, in Seneca Creek, had the lowest population densities for S. viridis, Cyathura polita, and nematodes, the lowest average number of species per unit area, and the lowest species richness and species diversity values. It also had a significantly lower population density of R. cuneata than did stratum II, in the discharge area. However, in this stratum the L. plumulosus population density was higher than in any of the other strata, including the Gunpowder River control.

Based on the analyses of variance, L. plumulosus was the only invertebrate species whose August spatial distribution suggested that its population had been damaged by or was avoiding the power plant plume. The other species had population densities in the discharge strata that were as high or higher than their densities in the reference strata, suggesting that during the study period they may have benefited from the presence of the power plant plume.

The distribution patterns of some of the minor species also showed apparent differences among the strata. Edotea triloba and Cryptochironomus sp. were most abundant in stratum II (Tables 15 and 21), particularly at station LM21. This station was near Marshy Point (Fig. 3), which the July sediment survey had indicated was a source of coarse detritus. Large amounts of the detritus had appeared in the sediment sample taken at station L20-21 (Fig. 1) in July, and a small amount was visible in the benthos samples taken at LM21 in August. Since the population densities of E. triloba and Procladius sp. appeared to decline with distance from Marshy Point (Table 15), it seems more appropriate to attribute the relatively high average population densities of these species in stratum II to the atypical sediment environment near Marshy Point than to the location of the stratum relative to the power plant. Within stratum II the highest population density of Corophium lacustre was observed at station LM21, and this may also have been related to the detritus and rooted plants present there. The lowest population density of nematodes in stratum II occurred at this station, and could have been a consequence of predation by the relatively large population of Cryptochironomus sp., a dipteran carnivore (Curry 1958), at this location.

One of the species for which the August analysis of variance results suggested a positive response to the power plant plume was the brackish water clam, Rangia cuneata. This species exhibited the highest population densities in strata I, II, and III, in Saltpeter Creek. An attempt to achieve a more thorough understanding of the distribution of this species in relation to the power plant was made by examining the size frequency distributions of the individuals collected in the different sampling strata. These results appear in Tables 23 and 24, for individuals greater than 30 mm and less than 30 mm in total length, respectively. The graphical summary in Fig. 4 shows that in August clams in the larger size range appeared only in the samples from strata I-IV, in Saltpeter and Dundee Creeks. Moreover stratum I, in the immediate discharge vicinity, yielded the largest individual and the largest median clam size. The median large clam size in stratum I corresponded to a theoretical age of 6 yr (Wolfe and Petteway 1968), while those in the other discharge strata corresponded to an age of 4 yr. This suggested that either a different age group predominated in stratum I or that overall growth rate of adult clams in stratum I exceeded the rate in the other strata, by between 2 and 3 mm per year, over the last 4 years. The probable reason for the presence of adult clams in the discharge strata, versus their absence from the August reference strata, is protection from winter dieoffs in the area encompassed by the cooling water plume.

Table 23

Rangia cuneata size frequency distributions, August 1978, individuals >30 mm

	Stratum									
	I		II		III		IV		V	VI
Maximum shell dimension (mm)	No./m²	% of Total	No./m²	% of Total	No./m²	% of Total	No./m²	% of Total		
35.1-36.0										
36.1-37.0									(none collected)	
37.1-38.0					1	.2				
38.1-39.0										
39.1-40.0										
40.1-41.0					1	.2				
41.1-42.0			1	.1	3	.6	1	.7		
42.1-43.0			1	.1	5	1.1	2	1.4		
43.1-44.0					2	.4				
44.1-45.0			4	.6	7	1.5				
45.1-46.0			3	.4	3	.6	1	.7		
46.1-47.0					5	1.1				
47.1-48.0			4	.6	4	.9	4	2.7		
48.1-49.0			3	.4	2	.4	4	2.7		
49.1-50.0	1	.2	2	.3	3	.6				
50.1-51.0	1	.2	1	.1	2	.4	3	2.1		
51.1-52.0			1	.1	2	.4				
52.1-53.0			1	.1	1	.2				
53.1-54.0	2	.5	1	.1			1	.7		
54.1-55.0	5	1.2					2	1.4		
55.1-56.0			2	.3						
56.1-57.0	3	7								
57.1-58.0	4	1.0								
58.1-59.0	1	.2								
59.1-60.0	1	.2								
60.1-61.0	1	.2								
61.1-62.0	2	.5	1	.1						
62.1-63.0	1	.2								
63.1-64.0										
64.1-65.0										
65.1-66.0										
66.1-67.0										
67.1-68.0	1	.2								

Table 24

<u>Rangia cuneata</u> size frequency distributions, August 1978, individuals <30 mm

Maximum shell dimension (mm)	Stratum I No./m²	I % of Total	II No./m²	II % of Total	III No./m²	III % of Total	IV No./m²	IV % of Total	V No./m²	V % of Total	VI No./m²	VI % of Total
0.5-1.0	116	27.6	96	13.2	24	5.2	16	11.0	7	2.5	7	15.9
1.1-2.0	92	21.9	70	9.6	8	1.7	15	10.3	1	.4	3	6.8
2.1-3.0	106	25.2	167	23.0	110	23.7	56	38.4	29	10.3	3	6.8
3.1-4.0	53	12.6	316	43.5	206	44.3	26	17.8	131	46.5	1	2.2
4.1-5.0	18	4.3	45	6.2	59	12.7	10	6.8	78	27.7	3	6.8
5.1-6.0	10	2.4	2	.3	11	2.4	3	2.1	24	8.5	2	4.5
6.1-7.0	1	.2	2	.3	1	.2	1	.7	4	1.4	2	4.5
7.1-8.0	1	.2			1	.2			3	1.1	2	4.5
8.1-9.0									2	.7	1	2.2
9.1-10.0											1	2.2
10.1-11.0					1	.2					1	2.2
11.1-12.0											2	4.5
12.1-13.0											1	2.2
13.1-14.0	1	.2									1	2.2
14.1-15.0												
15.1-16.0			1	.1								
16.1-17.0												
17.1-18.0					1	.2					1	2.2
18.1-19.0									2	.7		
19.1-20.0									1	.4	2	4.5
20.1-21.0											2	4.5
21.1-22.0			1	.1							2	4.5
22.1-23.0					1	.2	1	.7			1	2.2
23.1-24.0											3	6.8
24.1-25.0			1	.1							2	4.5
25.1-26.0					1	.2					1	2.2
26.1-27.0												
27.1-28.0												
28.1-29.0												
29.1-30.0												

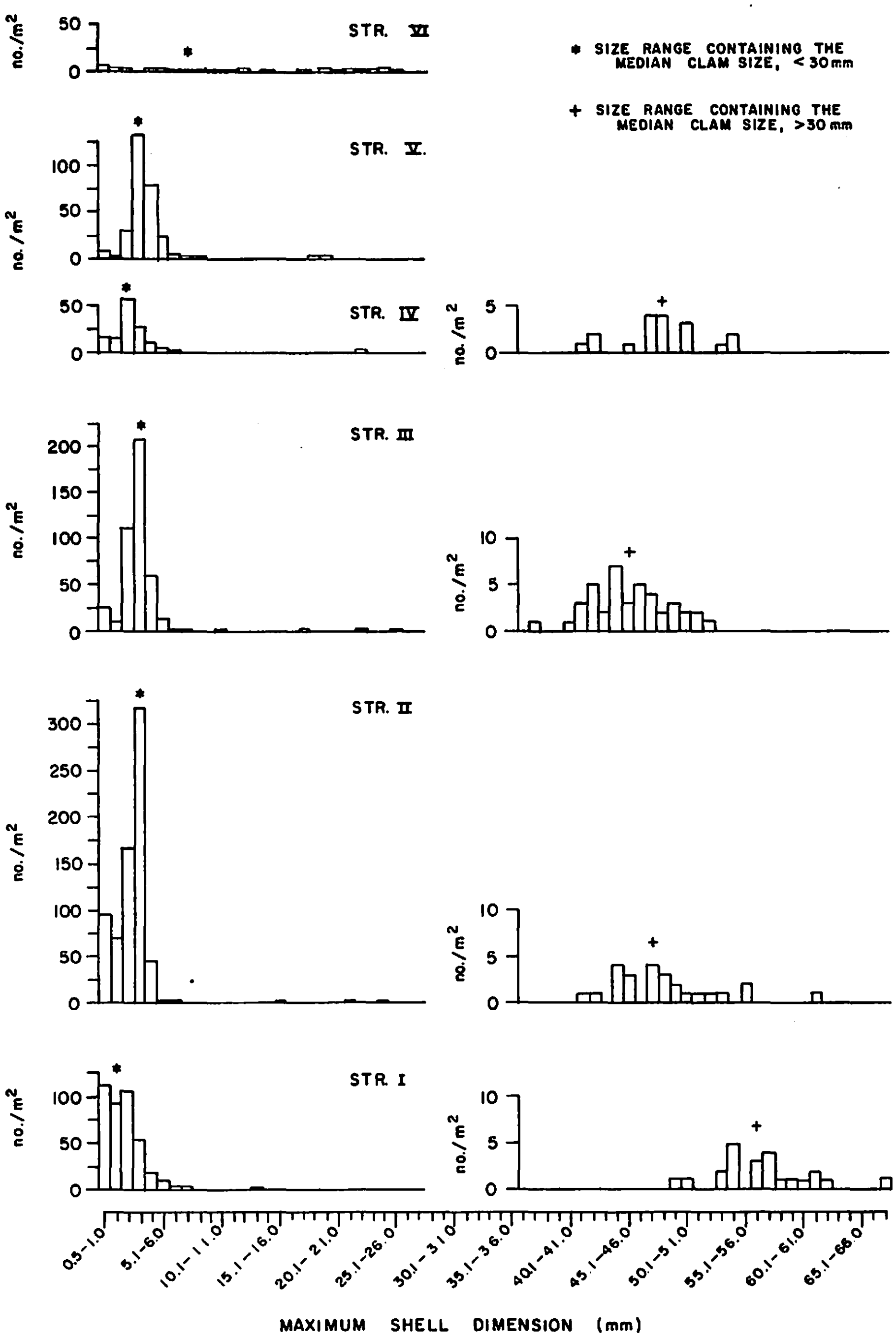

Fig. 4 Rangia cuneata size frequency distributions, August 1978

The clams between 0.5 and 30 mm in total length were most abundant in stratum II, and the median sizes of clams in this range were similar in strata II, III, and V. The median small clam size was lowest in stratum I. The population densities of clams in the size ranges of 0.5 - 1.0 mm, 1.1 - 2.0 mm and 2.1 - 3.0 mm were similar in strata I and II in August, while the numbers of individuals 3.1 - 4.0 mm in length were significantly lower in stratum I (Table 25). This suggests that although similar numbers of *R. cuneata* larvae may have set in the two areas, survival of juveniles during the initial period of their benthic existence was less successful in the immediate vicinity of the discharge than it was farther downstream in Saltpeter Creek. The lowest overall abundance of juvenile *R. cuneata* in the discharge area was observed in stratum IV, Dundee Creek. This was probably a consequence of a slower rate of exchange between Dundee Creek and the waters outside. This situation was exemplified by the slower rate of flushing of dye out of Dundee Creek than out of upper and lower Saltpeter Creek, which directly received the cooling water pumped through the plant, during the physical impact study (Binkerd *et al*. 1978, p. 116). Thus fewer planktonic *R. cuneata* larvae would have been introduced into stratum IV than would have been available for setting in strata I-III. A similar difference in hydraulic characteristics could account for the relatively low numbers of juvenile clams collected in stratum V. This area, in Seneca Creek, was upstream from the power plant intake, and probably flushed less rapidly than did strata I-III. As shown in Table 18, the numbers of *R. cuneata* individuals, which were almost all juveniles, varied widely among the stations in

Table 25

ANOVA Summary: Comparisons of population densities of small size categories of <u>Rangia cuneata</u> among strata I, II, and III (Saltpeter Creek), August 1978 Student-Newman-Keuls' test results; means not sharing an underline are significantly different ($\alpha \leq .05$)

Shell length 0.5-1.0 mm	Stratum	III	II	I
retransformed (log x) mean No./0.1 m^2		2.4	8.9	11.0
		———	———	———
Shell length 1.1-2.0 mm	Stratum	III	II	I
retransformed (log(x+1)) mean No./0.1 m^2		0.5	5.1	8.9
		———	———	———
Shell length 2.1-3.0 mm	Stratum	III	I	II
retransformed (log x) mean No./0.1 m^2		9.3	10.2	15.6
		———	———	———
Shell length 3.1-4.0 mm	Stratum	I	III	II
retransformed (log x) mean No./0.1 m^2		4.9	18.2	24.2
		———	———	———
Shell length 4.1-5.0 mm	Stratum	I	II	III
retransformed (log x) mean No./0.1 m^2		1.3	3.1	5.4
			———	———
		———	———	

stratum V. As shown in Fig. 3, these stations comprise a series that parallels the course of upper Seneca Creek, extending from station E12, nearest the power plant intake, upstream to station A 13-14. An analysis of variance was performed comparing the R. cuneata population densities at these stations, and the Student-Newman-Keuls' test yielded the following results (.05 level):

Station:	A13-14	B13	C12-13	E12	CD12
retransformed (log(X+1))mean No./.05m^2	.68	7.5	11.6	21.2	26.2

Thus the juvenile clam abundance declined significantly toward the upstream end of Seneca Creek, which probably received fewer planktonic R. cuneata larvae than did the stations further downstream.

Low setting activity in stratum VI could have been due to a low availability of planktonic larvae, but the relatively low salinities in this area could also have been less favorable for larval survival than the salinities in the creeks.

Quantitative Benthos Results - Changes between July and August

The July preliminary sampling run was not intended to produce sufficient quantitative benthos data to evaluate the effects of the power plant. However, it did yield some comparative estimates of population densities and spatial distributions that can be examined to further elucidate some of the August findings.

The July *Rangia cuneata* size frequency distributions appear in Tables 26 and 27 and in Figs. 5 and 6. As in August, the largest adult clams collected in July were found in the stratum I area (Fig. 5). The median large clam sizes were similar in the two months in the stratum I, II, and IV areas, as were the population densities. The stratum III area median had been lower in July, however, corresponding to a theoretical age of 3 yr, while the population densities of large clams had been higher. Most of the stratum III samples taken in July came from station R16-17, a 5-sample station, and the sediment at this station was coarser and lower in organic content then the sediments at the other stratum III stations (Tables 3 and 13). Thus the apparent changes in the adult *R. cuneata* population between July and August were probably due to changes in the station locations.

In July, samples from Seneca Creek and Gunpowder River stations yielded *R. cuneata* in the large size range. The Gunpowder River station was VW12 (Fig. 1), which is in shallow water just downstream from the mouth of Saltpeter Creek. The Seneca Creek station was OP8, at 5-sample station in Hawthorn Cove on the opposite side of Carroll Island from Saltpeter Creek. The occurrence of large *R. cuneata* at these locations is not inconsistent

Table 26

Rangia cuneata size frequency distributions, July 1978, individuals >30 mm

(No./m^2 in each area)

Maximum shell dimension (mm)	Area: Str. I	Str. II	Str. III	Str. IV	Str. V	Middle Seneca	Lower Seneca	Str. VI	Lower Gunpowder
32.1-33.0			5						
33.1-34.0			5						
34.1-35.0			2.5						
35.1-36.0			7.5						
36.1-37.0			20				10		
37.1-38.0			12.5				10		
38.1-39.0			25				6.7		
39.1-40.0			17.5				10		
40.1-41.0			5				6.7		
41.1-42.0		6.7	12.5	5					
42.1-43.0		2.2							6.7
43.1-44.0		2.2	2.5	5					
44.1-45.0							3.3		
45.1-46.0									
46.1-47.0				5					
47.1-48.0				5					
48.1-49.0				5					
49.1-50.0		2.2							
50.1-51.0									
51.1-52.0	3.3	4.4							
52.1-53.0		2.2							
53.1-54.0		4.4							
54.1-55.0		2.2							
55.1-56.0									
56.1-57.0									
57.1-58.0	3.3								
58.1-59.0									
59.1-60.0									

Table 26 (continued)

Maximum shell dimension (mm)	Area								
	Str. I	Str. II	Str. III	Str. IV	Str. V	Middle Seneca	Lower Seneca	Str. VI	Lower Gunpowder
60.1-61.0									
61.1-62.0									
62.1-63.0									
63.1-64.0									
64.1-65.0	3.3								
65.1-66.0									
66.1-67.0									
67.1-68.0									
68.1-69.0									
69.1-70.0	3.3								

Table 27

Rangia cuneata size frequency distributions, July 1978, individuals <30 mm

(No./m^2 in each area)

Maximum shell dimension (mm)	Area								
	Str. I	Str. II	Str. III	Str. IV	Str. V	Middle Seneca	Lower Seneca	Str. VI	Lower Gunpowder
0.5-1.0			8						
1.1-2.0	25	58	105	100		3	13	7	140
2.1-3.0	270	1091	492	320	40	111	30		567
3.1-4.0	140	1220	298	120	40	649	53	13	507
4.1-5.0	45	296	70	55	120	1051	43		213
5.1-6.0	20	87	22	25	40	614	37	7	107
6.1-7.0	10	22	12			289	17		13
7.1-8.0	5	18	2			174	33		33
8.1-9.0	10	4	2			60	17		33
9.1-10.0			5		20	49	37	7	
10.1-11.0			2			51	17		7
11.1-12.0						37	10		27
12.1-13.0						31	20	7	20
13.1-14.0						29	40		53
14.1-15.0						40	67		13
15.1-16.0						37	37		7
16.1-17.0						31	57	7	7
17.1-18.0			2			14	40	7	13
18.1-19.0						17	10	13	7
19.1-20.0			2			3	7		7
20.1-21.0		2				6		7	
21.1-22.0						3		7	
22.1-23.0									
23.1-24.0								7	
24.1-25.0									
25.1-26.0						6			

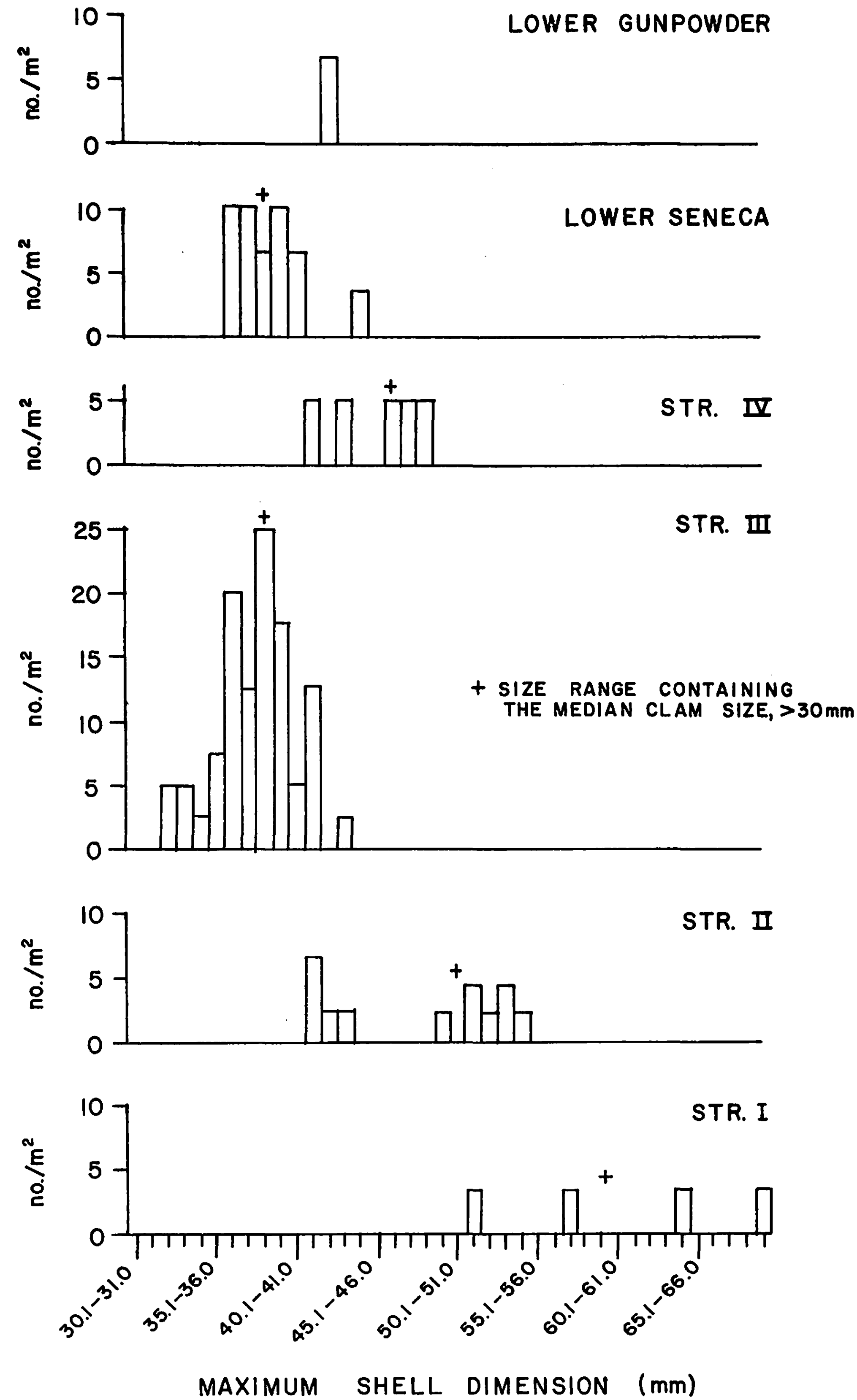

Fig. 5 *Rangia cuneata* size frequency distributions, July 1978, individuals > 30 mm

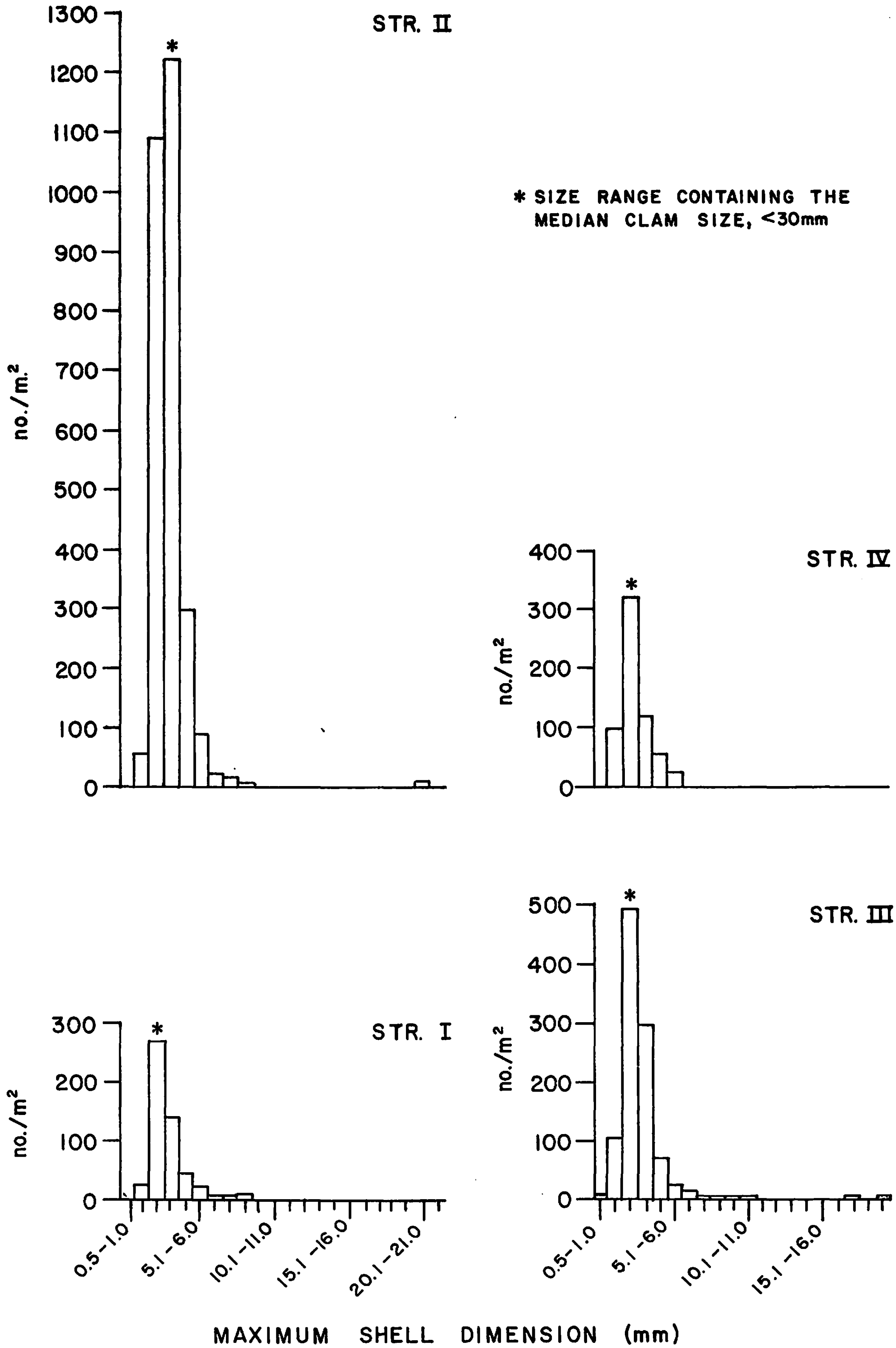

Fig. 6 Rangia cuneata size frequency distributions, July 1978, individuals < 30 mm

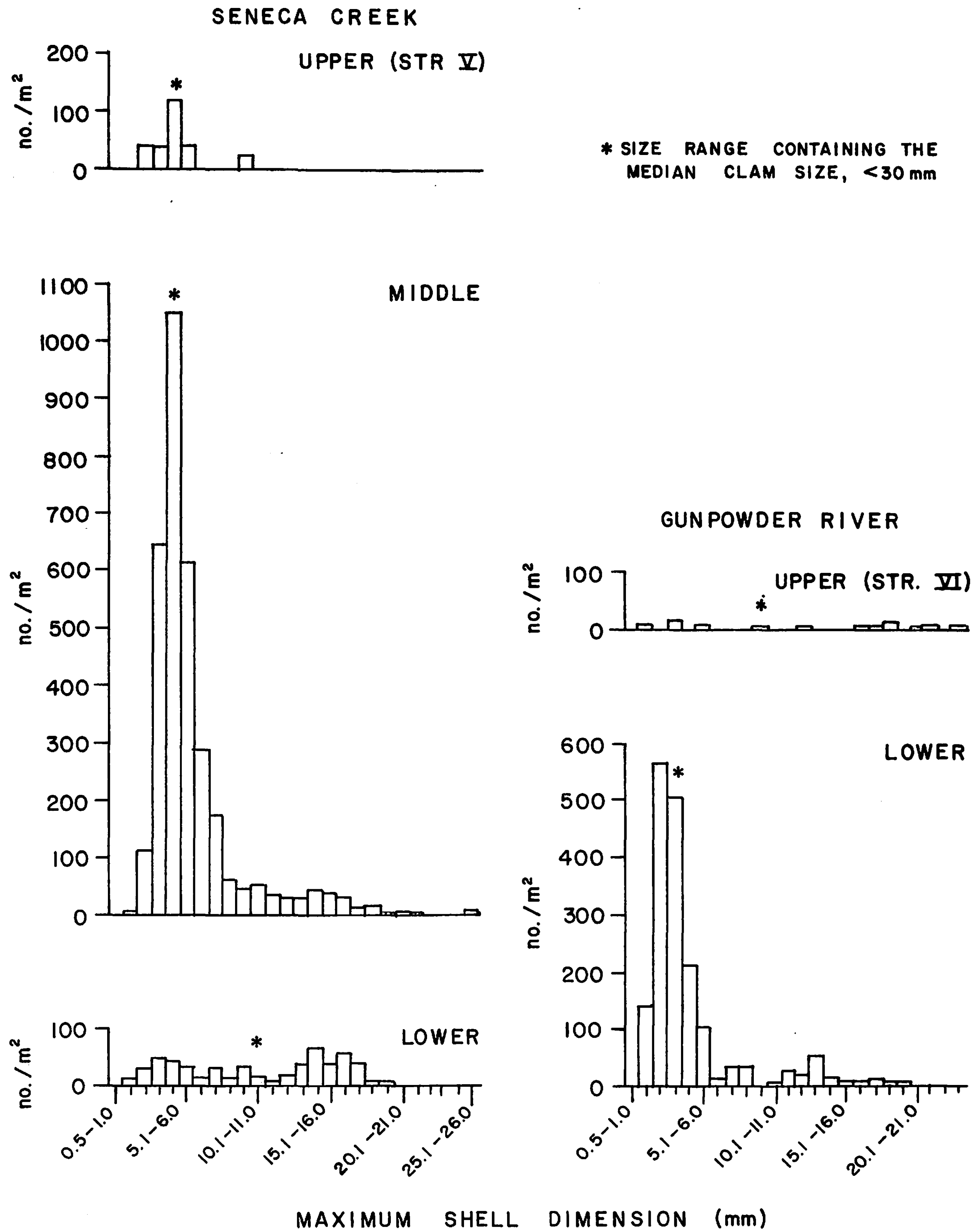

Fig. 6 (continued)

with the hypothesis derived from the August data, that the power plant plume has protected part of the adult population from temperature-related mortality during recent winters. The investigators performing the physical impact study detected concentrations of dye, released at the power plant discharge at 5.0 ppb, of 2.0 ppb at the location of July benthos station VW12, and of 0.1 ppb off Lower Island Point, below Hawthorn Cove (Binkerd et al. 1978, Fig. 5.21). Thus both VW12 and OP8 are within the zone of the potentially protective effect of the power plant plume.

The July samples yielded many more R. cuneata in the small size range than did the August samples (Fig. 6). This indicates that the juvenile population that had set in the spring and early summer experienced a high mortality during the July-August period. The August samples, however, contained more individuals in the 0.5 - 1 mm size range, indicating that more setting activity was actually taking place at that time.

In July, as in August, the overall abundance and median size of juvenile R. cuneata were greater in strata II and III than in stratum I. Relatively few juveniles were collected at station B13, in Stratum V in upper Seneca Creek, in July. The populations in middle Seneca Creek, however, were comparable to those found in Saltpeter Creek in July, except for the presence of larger numbers of individuals greater than 10 mm in length in the Seneca Creek samples. The size interval from 10 - 20 mm brackets the theoretical one year old size of 16 mm (Wolfe and Petteway 1968), indicating that these clams were survivors from the 1977 reproductive period. Clams in this year class were also found in July in lower Seneca Creek, and in the Gunpowder River especially at stations downstream from Saltpeter Creek. The lower Gunpowder River stations yielded many more juveniles, in all size categories, than did the stations in the stratum VI area in July.

For the study area as a whole, it appears that the survival of the *R. cuneata* year classes three years and older has been most successful in Saltpeter and Dundee Creeks, and in lower Seneca Creek within the zone of penetration of the power plant plume. Survival of the 1977 year class was best in lower and middle Seneca Creek and in the area of the Gunpowder River between Seneca and Saltpeter Creeks. The short-term survival of set appears to have been the most successful in middle Seneca Creek and lower Saltpeter Creek. However, the extreme rarity of individuals between 10 and 30 mm in size in Saltpeter Creek suggests that very little eventual recruitment to the reproducing population of *R. cuneata* in this creek may be expected to result from the 1978 year class.

There were no observations made during the summer benthos survey that provide an obvious explanation for the difference in intermediate size clam abundance between Seneca and Saltpeter Creeks. The salinity in Saltpeter Creek is slightly lower, and diel temperature ranges are wider due to the operating schedule of the power plant. These environmental factors may have some effect. It is also possible that the predation pressure on the clam population in the winter is more intense in the relatively warmer water of Saltpeter Creek, which would be attractive to nektonic species and which would retard ice formation, permitting greater access by waterfowl. Thus this feature of the *R. cuneata* population distribution may be an indirect power plant effect, operating by modifying natural biological interactions. The power plant could be envisioned as providing an annually renewed winter food resource, in the form of intermediate-size *R. cuneata*, in Saltpeter Creek by protecting the adult population in Saltpeter and Seneca Creeks during the winter, pumping large numbers of larvae into Saltpeter Creek during the reproduction periods, and maintaining elevated water temperatures in the winter. A survey for *R. cuneata* beds in other upper bay tributaries would indicate whether or not the adult population under the influence of the C. P. Crane plant is the only source of larvae in the vicinity, and would clarify the importance of the plant in maintaining this hypothetical trophic mechanism.

The analysis of variance performed on the August *Leptocheirus plumulosus* data revealed a possible negative power plant effect. Significantly lower population densities appeared in the discharge area than in the control areas. Comparisons of the July population densities with the August results (Table 28) show that in addition to the differences among the sampling strata observed in August, there had been sharp reductions in populations within the individual strata between the two sampling periods. These reductions were much more pronounced within the discharge strata, I-IV, than within the reference strata, V and VI, and provide further evidence that this species was unfavorably affected by the power plant discharge.

Among the other benthic species, population changes from July to August were either not detectable or did not appear to be related to the power plant. Greater numbers of nematodes were collected in August throughout the sampling area. *Hypaniola grayi*, a polychaete that had been present at several of the July stations, was not seen in August. In July the highest population densities of *H. grayi* occurred at stations with relatively coarse sediments,

Table 28

Leptocheirus plumulosus July and August stratum means

(Retransformed (log X) mean No./0.1 m^2)

Stratum	July	August
I	317.1	71.6
II	163.9	62.4
III	138.8	56.5
IV	120.2	23.9
V	396.6	220.3
VI	152.1	114.0

so it may be that it would have been encountered again in August if sampling had not been restricted to only soft mud sediments.

Conclusions - August Benthos Sampling Run

It was apparent from the August data that the spatial distributions of some of the invertebrate species present could be related to the presence of the power plant cooling water plume. The species exhibiting these apparent power plant effects were *Rangia cuneata* and *Leptocheirus plumulosus*, the most numerous benthic macroinvertebrates in the study area. Perhaps data obtained by sampling some of the less abundant species more intensively would have revealed additional plant-related distribution patterns.

The August data provided population estimates at one instant in time. Comparison of the July data with the August results revealed large temporal changes in invertebrate population densities, which supported the August conclusions and provided insights into possible mechanisms responsible for the *R. cuneata* population distribution. The benthic community at the C. P. Crane site is not temporally constant during the summer, nor, presumably, during any other period of the year. The most important conclusion that can be drawn from the 1978 summer benthos survey is that there appear to be power plant effects, but that more information on changes in population distributions with time is necessary to elucidate them.

Discussion

The results of the 1978 summer benthos survey at the C. P. Crane Generating Station suggested that the power plant was exerting a protective influence on the *Rangia cuneata* population in the discharge area. An opportunity to observe a potentially similar situation may be afforded by the proposed installation of a power plant on the upper Bush River. The population of *R. cuneata* in the Bush River was surveyed during a preoperational study in 1972 (Johns Hopkins University 1973), and extensive beds of adult clams were found in two areas, one of which was adjacent to the power plant site. Changes observed between April and July 1972 samples in the clam size frequency distributions at 9 sampling sites suggested to the authors that these beds were producing larvae that would contribute to the growth of beds further downstream, and that ultimately *R. cuneata* beds would be nearly continuous in the lower Bush River. However, discontinuities were present in the size frequency distributions in the same intermediate size range that was sparcely represented in the present study, indicating that in the early 1970's as well as in more recent years the survival varied widely among year classes in upper bay tributaries. Also, in the winter of 1976-77 pronounced mortalities of *R. cuneata* occurred in other bay tributaries (Jordan *et al*. 1977). Thus it seems doubtful that a resurvey of the Bush River *R. cuneata* beds would verify the expansion predicted from the 1972 study.

The major conclusion of the Bush River study concerning other invertebrate species was that most of their distributions seemed to correlate positively with the *R. cuneata* distribution. This applied to tubificids, chironomids, Leptocheirus plumulosus, and Scolecolepides viridis. A similar general observation could be made for the C. P. Crane study, with the main exception being Leptocheirus plumulosus in August. The overall comparability of the results of the two studies suggests that the benthic community at the C. P. Crane site was in most respects "normal" in relation to other similar communities, but that the spatial distributions of species such as Rangia cuneata, and the spatial and temporal distributions of species such as Leptocheirus plumulosus were modified by the hydraulic and thermal regimes imposed by the power plant.

The benthos study of the Patapsco and Chester Rivers in 1970 (Pfitzenmeyer 1971) revealed an invertebrate community that included the species found at the Crane site, along with numerous additional estuarine species that could tolerate the salinity range characteristic of these two rivers (5-15%) but not the lower levels occurring at Crane. Within the Patapsco River domestic and industrial pollution produced areas of contaminated sediment and depressed dissolved oxygen levels, that exhibited reduced population densities of several species. Among the species that seemed to be highly sensitive to these conditions were Rangia cuneata and Leptocheirus plumulosus, which also seemed to be the most sensitive to the influence of the power plant in the C. P. Crane study area. In contrast, Cyathura polita appeared to be the most tolerant crustacean in the Patapsco River, and Scolecolepides viridis and Tubificidae were two of the most tolerant taxa in the community as a whole.

Thus, although the Patapsco River and the C. P. Crane site were subjected to different types of environmental modification, the invertebrate communities in both areas showed responses that were specific to particular populations, and the species affected the most in the first area also showed the most distinct response patterns in the second.

Within the discharge creek system at the C. P. Crane study site, benthos population densities observed in August appeared to be related positively to the water exchange rates characteristic of different areas. The power plant continually pumps about 650 ft^3 (18.4 m^3) per second of water from Seneca Creek into Saltpeter Creek. Of the three creeks sampled in August, Saltpeter exhibited the highest population densities of most of the benthic species (Table 21). Dundee Creek experiences a slower water exchange than Saltpeter, and its populations of all the major species except nematodes were lower than the Saltpeter populations. In the distribution pattern in the Dundee-Saltpeter System, no distinction was evident between species with planktonic larvae (*Rangia cuneata* and *Scolecolepides viridis*) and species that brood their young in the benthic environment (*Leptocheirus plumulosus*, *Cyathura polita*, and Tubificidae). Entrainment by currents is known to be a mechanism for dispersal of brooder populations, so practically speaking their distributions in the study area should be just as dependent on hydraulic factors as the distributions of planktonic reproducers.

Hydraulic factors could also account for differences between population densities in the discharge creeks and the reference area in Seneca Creek. The reference area, upstream from the power plant intake, presumably experiences a slower water exchange than Saltpeter Creek or areas in Seneca Creek downstream from the intake, and exhibited lower population densities of several species in August. As an alternative to a strictly hydraulic mechanism, however, it is interesting to speculate that predator-prey interactions may have had some influence on these patterns. Two of the species that were less abundant in the Seneca reference area, *Cyathura polita* and *Scolceolepides viridis*, are tube dwellers that presumably would be available only to persistent foragers. *Leptocheirus plumulosus*, which was less abundant in Saltpeter in August, is also a tube dweller, but it is known to leave its burrow on slack tide and to appear nocturnally in the plankton. If the elevated temperatures in the discharge area enhanced this mobile behavior, *L. plumulosus* would have been more available to predators in Saltpeter Creek than in Seneca Creek. The power plant would also be expected to provide an abundance of moribund meroplankton, such as the chironomid pupae fed upon by spottail shiners at the Connecticut Yankee Power Plant (Merriman and Thorpe 1976), to the nektonic foragers of Saltpeter Creek. The predators in Saltpeter Creek could exploit these sources of food and engage in less foraging for infaunal species, such as *C. polita* and *S. viridis*. This type of mechanism is speculative, but perhaps the 1979 fish study will provide some understanding of the influence of the power plant on predator-prey interactions in the study area.

In the summer benthos survey at the C. P. Crane site the benthos distributions that revealed the most about the effects of the power plant were those that appeared within the discharge creek system. Comparisons of the discharge creeks with the reference areas in August yielded statistically significant differences, but interpretation of these differences was complicated by the fact that the reference areas were less than ideal. Seneca Creek receives recycled discharge water via the Gunpowder River under certain conditions, as well as cooling water directly through a hole in the discharge canal wall. Most of the reference area sampled was probably beyond the influence of these inputs, but it would still be desirable to have a reference more remote from any possible influence of the discharge under study. The recreational development surrounding upper Seneca Creek is more extensive than the development around Dundee and Saltpeter Creeks, and could also contribute to differences observed between the two systems.

In the reference section of the Gunpowder River (stratum VI), sediments were similar to those in the discharge area. The salinities in stratum VI, however, were consistently lower than in the other strata, a difference that could be accompanied by differences in the benthic communities. Moreover, since the Gunpowder is a river rather than a creek, considerations of scale enter into comparisons of this system with the discharge area creeks. These scale factors include such characteristics as the size of the drainage basin, exposure to wind-induced turbulence, intensity of motor boat activity, and relative areas occupied by attached aquatic plant beds.

Fortunately sufficient quantitative benthos data were obtained in the July study to clarify some of the results of the August data analysis--the Rangia cuneata distribution and the apparent negative power plant effect on Leptocheirus plumulosus. In the case of L. plumulosus, a temporal change in its population density in the discharge area that was more pronounced than the change in the control area made a stronger case for concluding that there was a power plant effect, than did the significant difference revealed in the August analysis of variance, by itself. The value of even an imperfect reference is enhanced when comparisons can be made over time as well as between locations at a single time.

These considerations emphasize the desirability of strengthening a follow-up study by increasing the effort invested in choosing reference areas and by including a series of sampling runs, all with adequate statistical designs. Reference creeks should be similar in sediment characteristics, but also similar in salinity regime and in exposure to recreational development, and strictly isolated from the influence of the power plant. Sampling runs should be scheduled in relation to significant events in the life cycles of the important species. Thus, in relation to Rangia cuneata, late spring and late summer sampling runs would assess the population prior to and after the summer reproductive period, while early winter and early spring sampling runs would bracket the winter period of reproduction and vulnerability to cold-induced mortality.

The summer 1978 benthos survey concentrated on the community in the soft mud sediments. This sediment type occupied most of the creek bottom area in Saltpeter and Dundee Creeks, and it was more likely to be consistent in community composition from one area to another than was an intermediate sandy silt type of sediment. The sediment at the discharge canal mouth, however, is predominately sand, so it would be of interest in a future study to compare this area with a suitable reference site, to evaluate the immediate localized effect of the cooling water. The higher aquatic plant beds, although apparently temporally variable over the study area, are probably much more productive of invertebrates than are soft mud habitats. Because of this and because the study area seems to be one of only a few remaining areas of Chesapeake Bay supporting *Vallisneria americana* and *Myriophyllum spicatum*, the plant beds should also be included in future work. A study of the plant beds should be extensive enough to determine if the power plant has played a role in the persistence of these species in the discharge creek system.

Most studies of power plants located on tidal rivers and estuaries have revealed effects on the benthos, that are limited to areas immediately adjacent to the cooling water discharges (Ecological Analysts, Inc. 1978). If the C. P. Crane plant is protecting a vestigial population of *Rangia cuneata* or decelerating the decline of a higher aquatic plant, its effect may be more extensive. Planktonic larvae of *R. cuneata* and free floating reproductive stages of the plants produced in the discharge area may contribute to the maintenance or establishment of these species in the Gunpowder River and in other parts of the upper Chesapeake Bay system.

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Appendix

Sediment Particle Size Distributions, 18 July 1978

Fig. A1

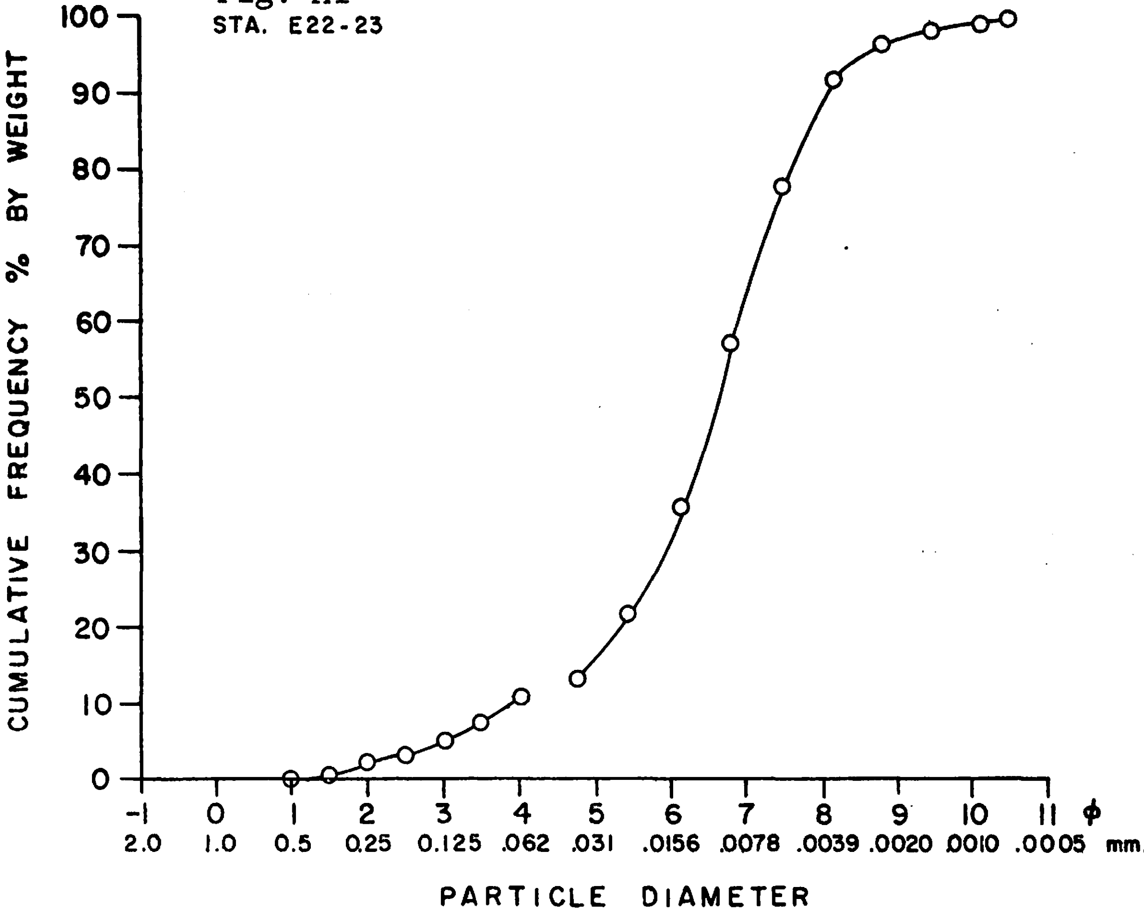
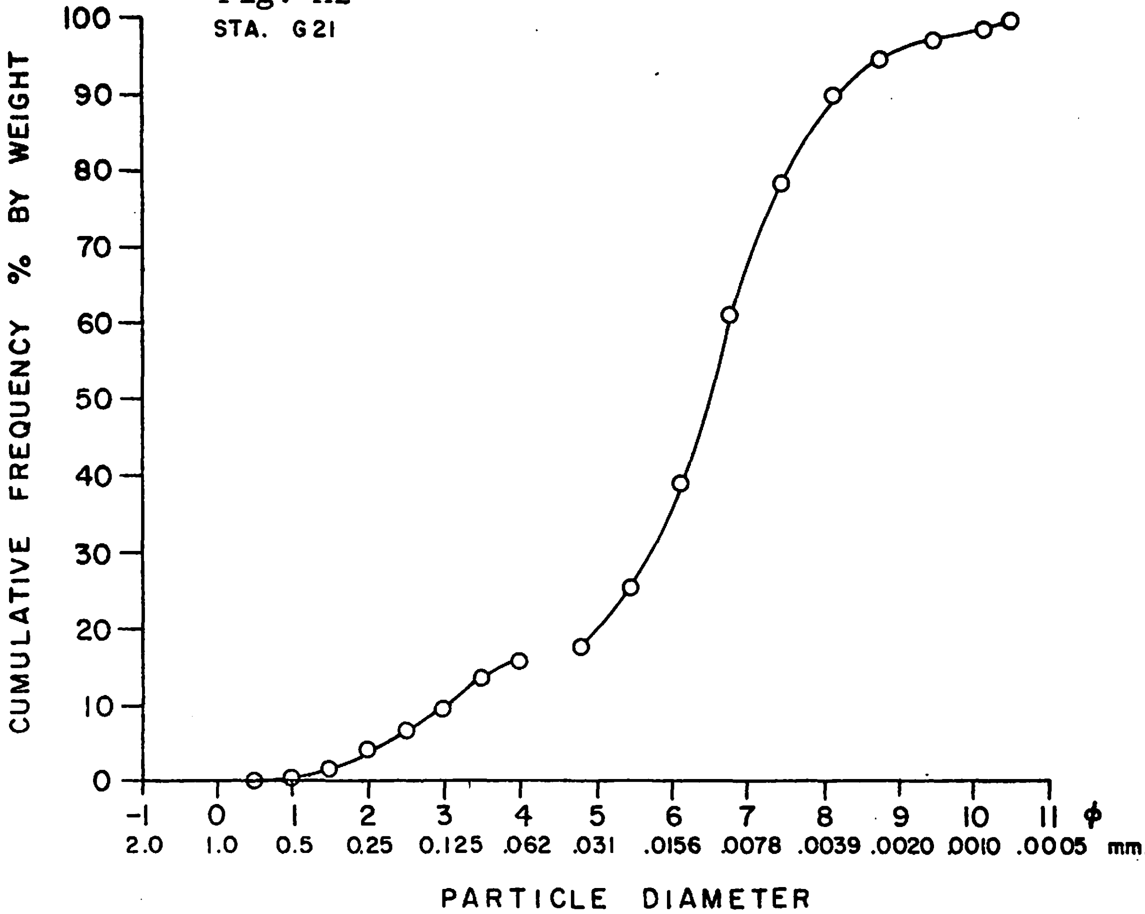

STA. E22-23
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A2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CUMULATIVE FREQUENCY % BY WEIGHT
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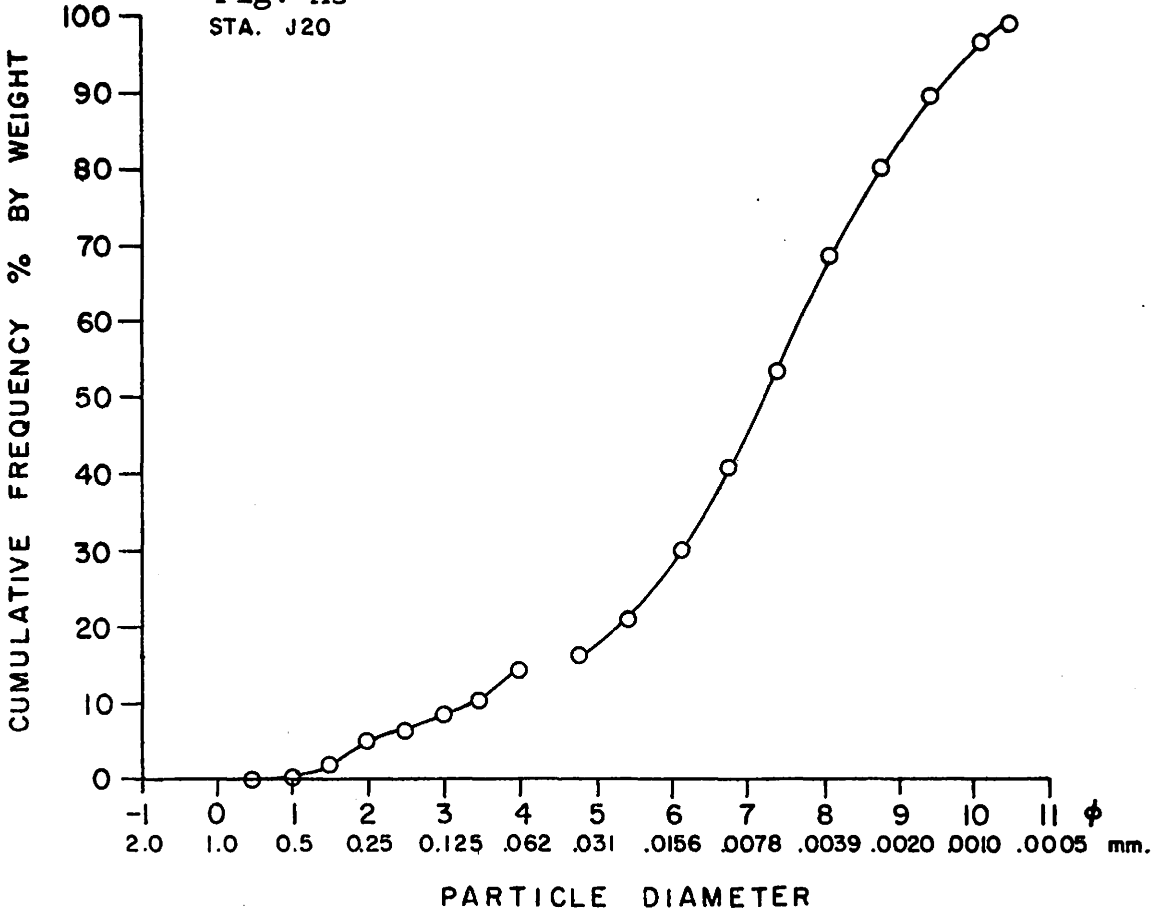
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A3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CUMULATIVE FREQUENCY % BY WEIGHT
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90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
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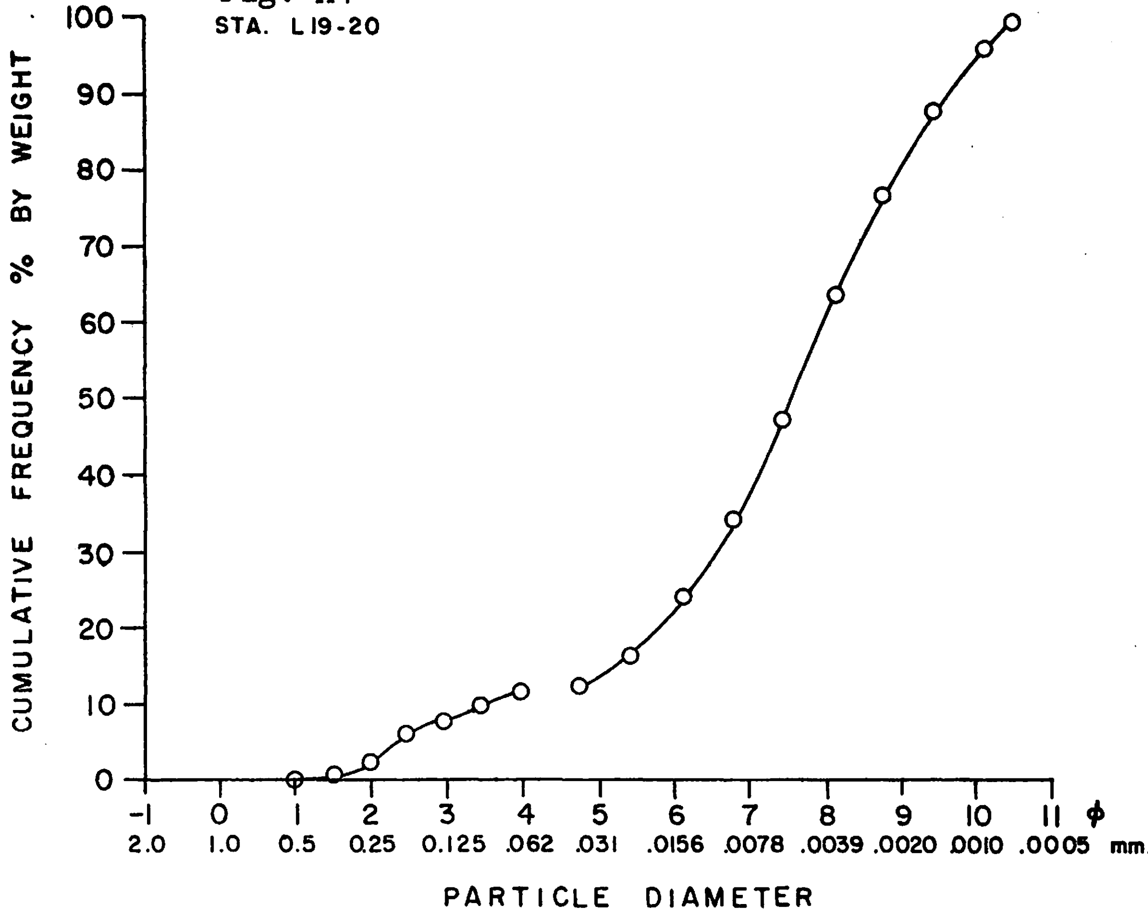
PARTICLE DIAMETER

Fig. A4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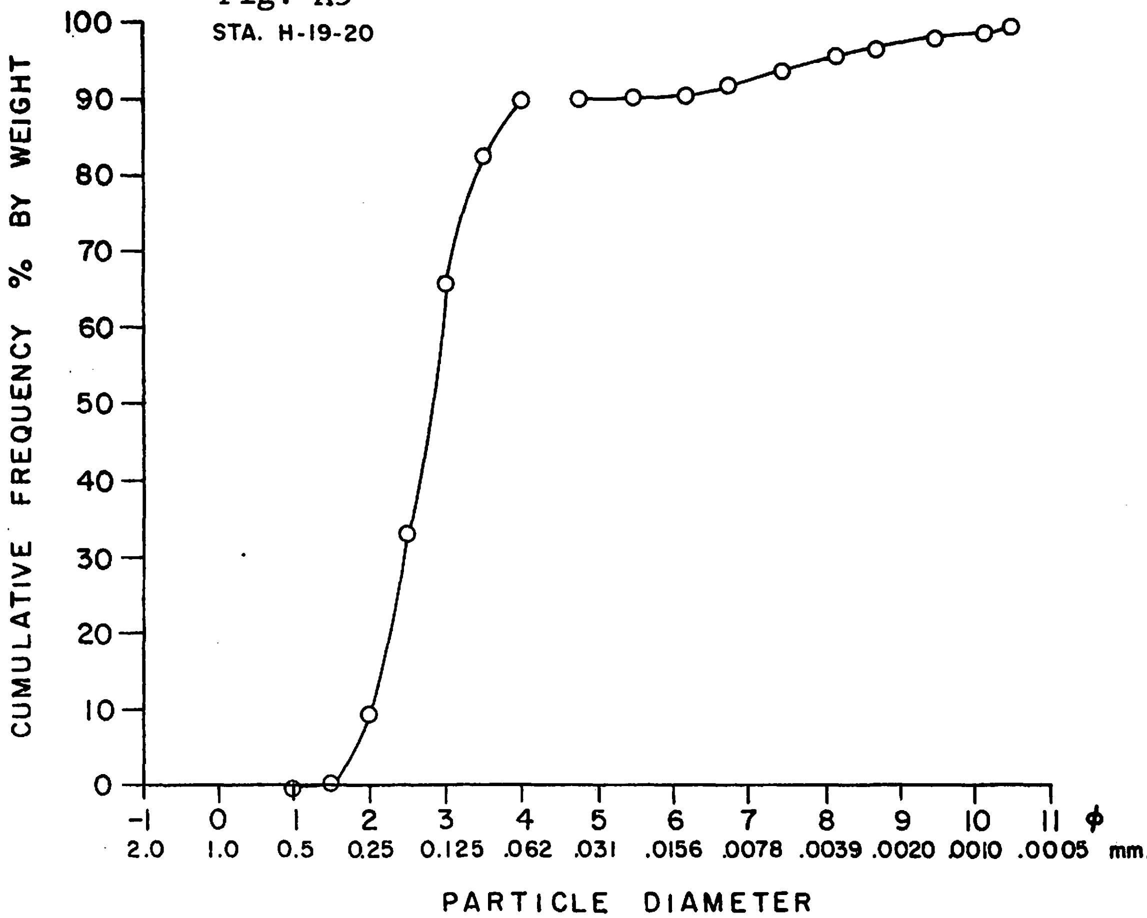
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A5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CUMULATIVE FREQUENCY % BY WEIGHT
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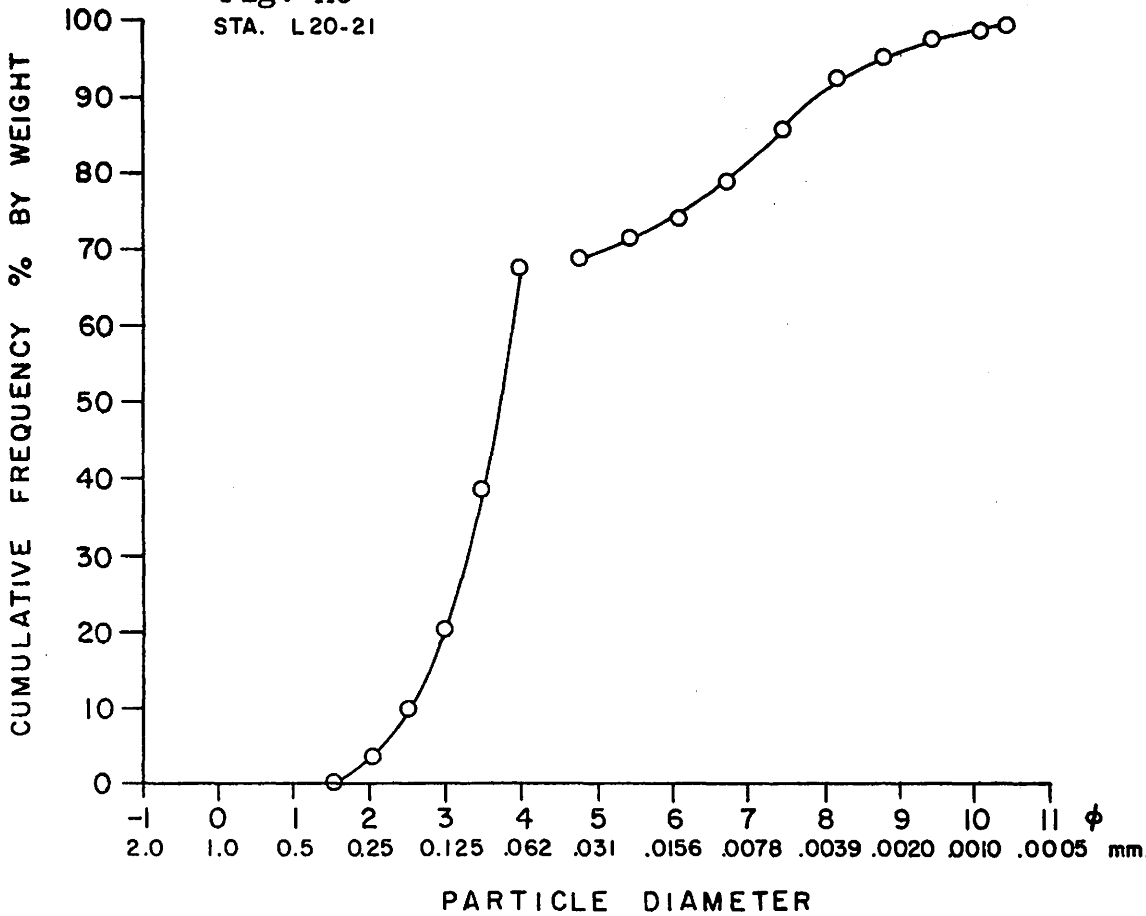
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A6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CUMULATIVE FREQUENCY % BY WEIGHT
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60
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40
30
20
10
0
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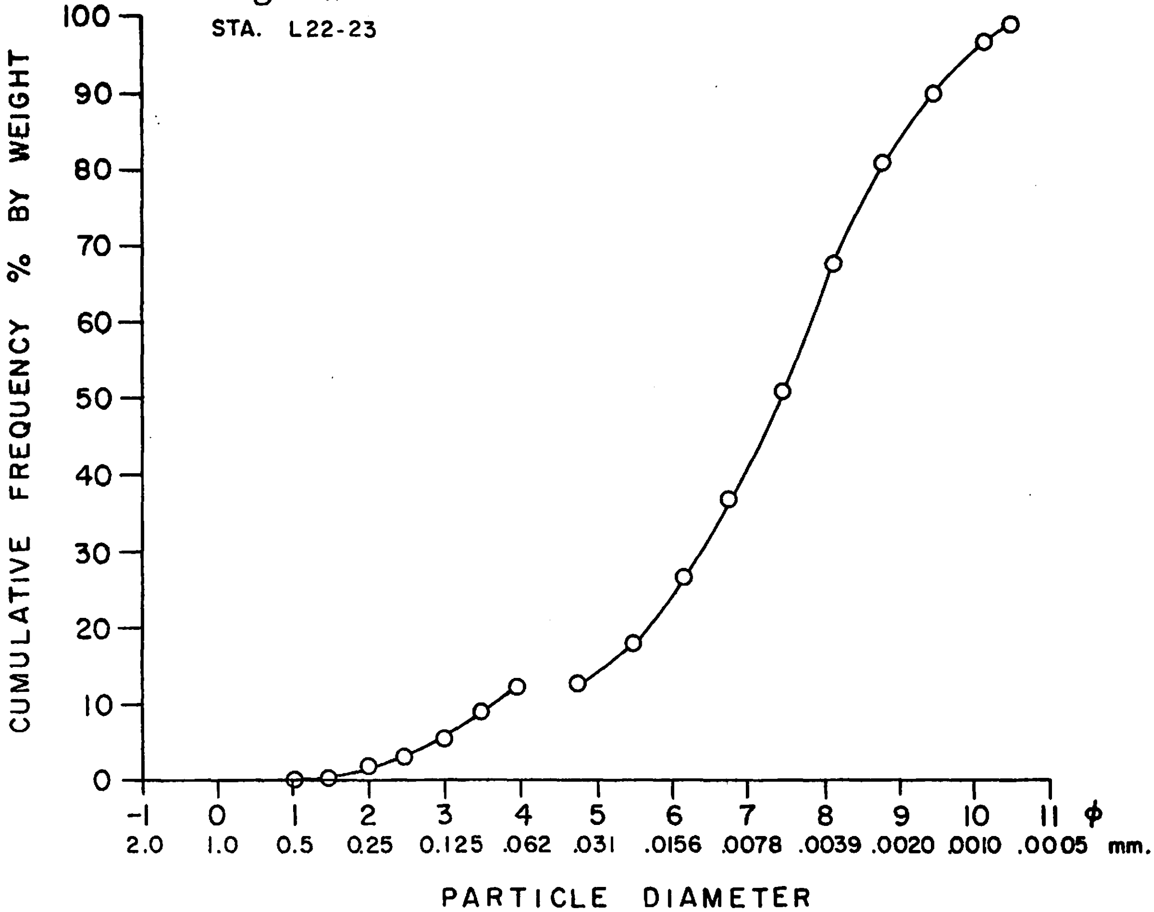
PARTICLE DIAMETER

Fig. A7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CUMULATIVE FREQUENCY % BY WEIGHT
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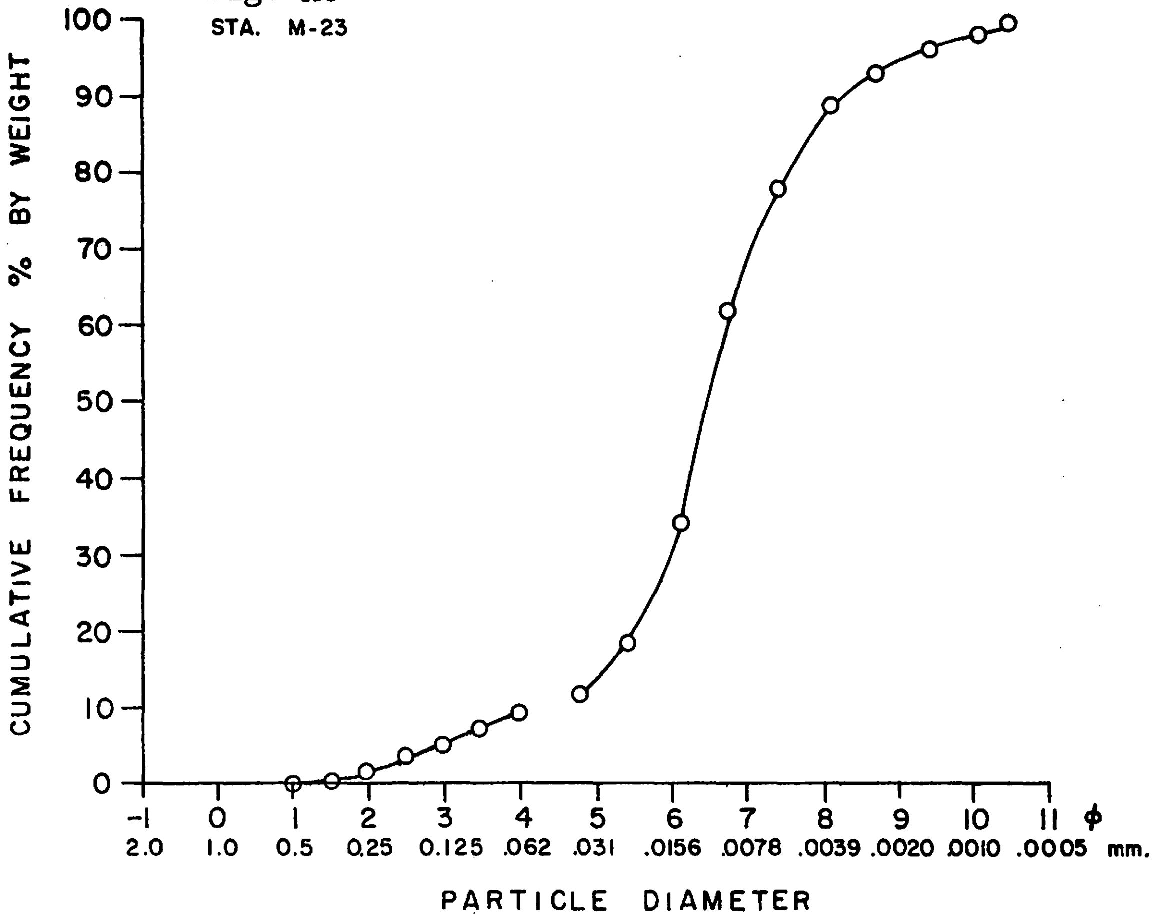
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A8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CUMULATIVE FREQUENCY % BY WEIGHT
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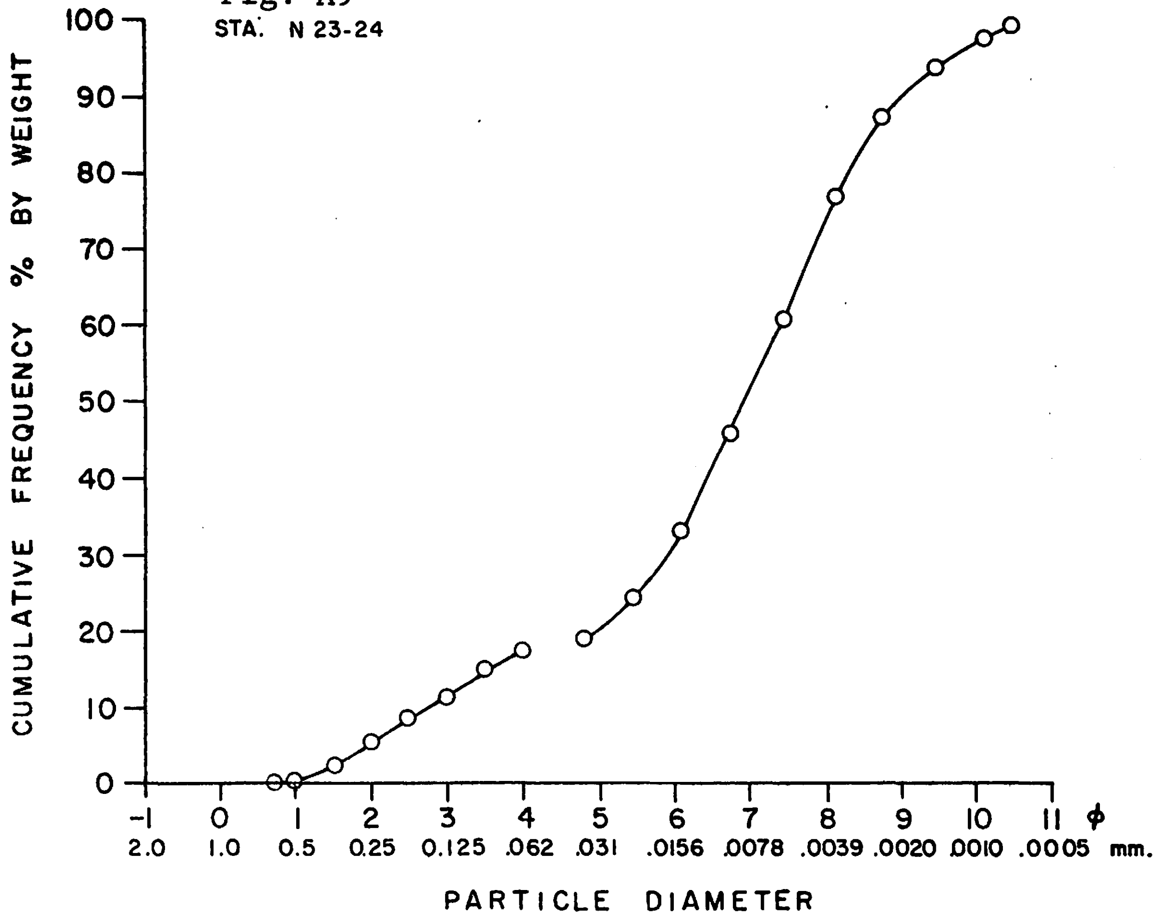
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A9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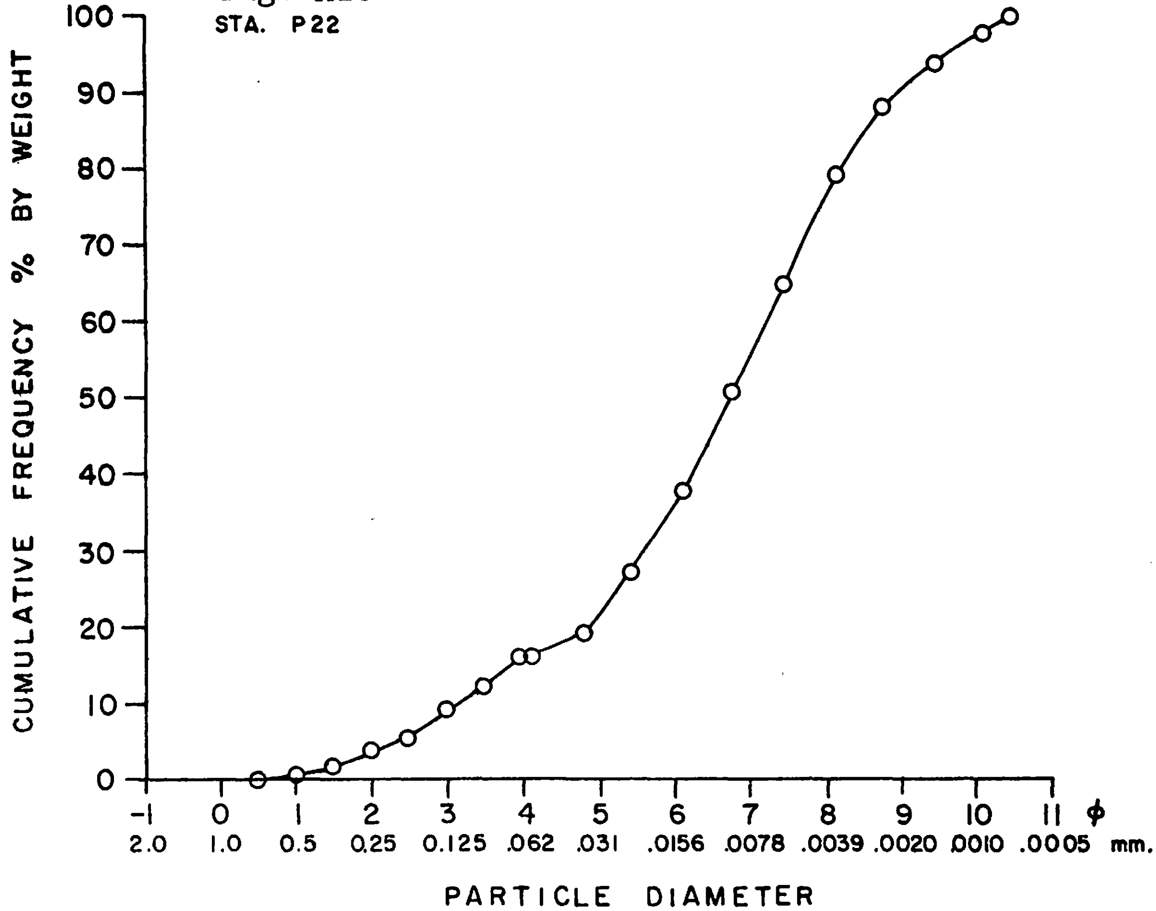
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A10


STA. P22
CUMULATIVE FREQUENCY % BY WEIGHT
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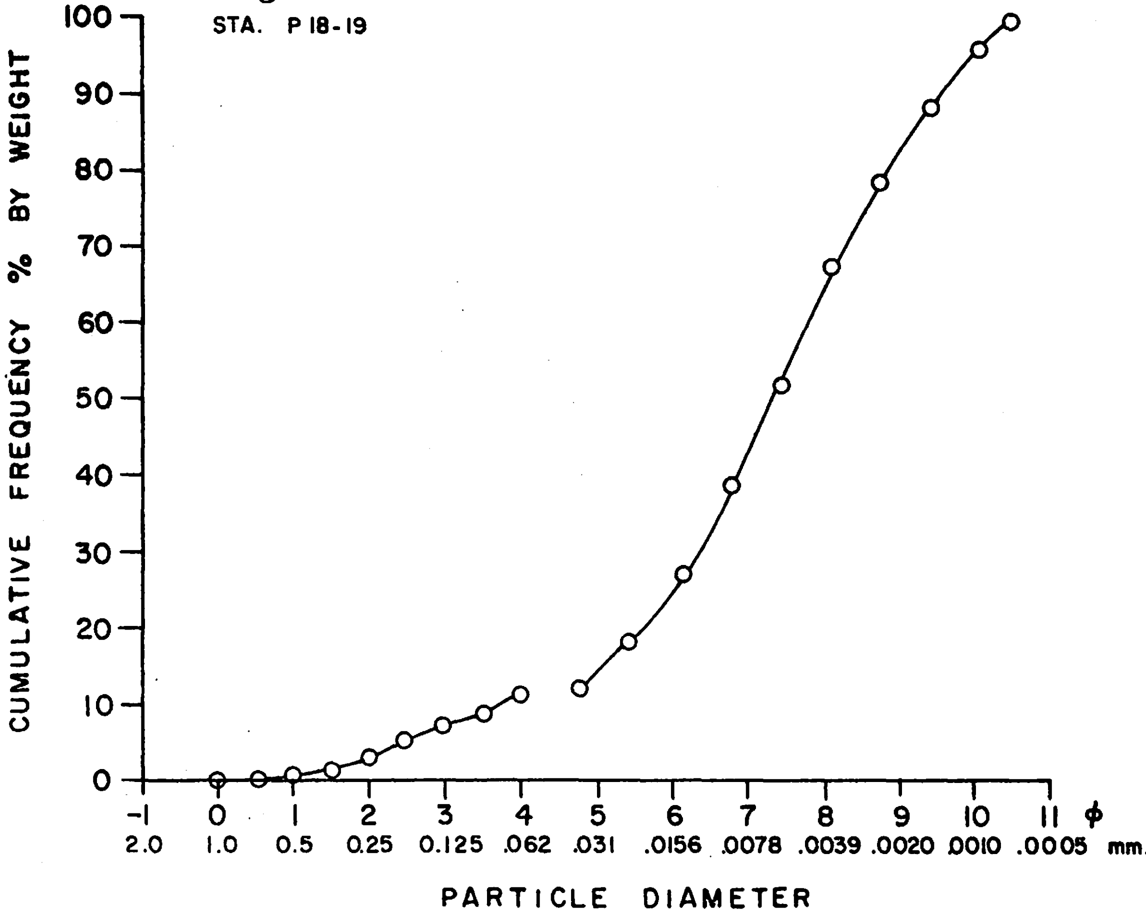
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A11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CUMULATIVE FREQUENCY % BY WEIGHT
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90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A12

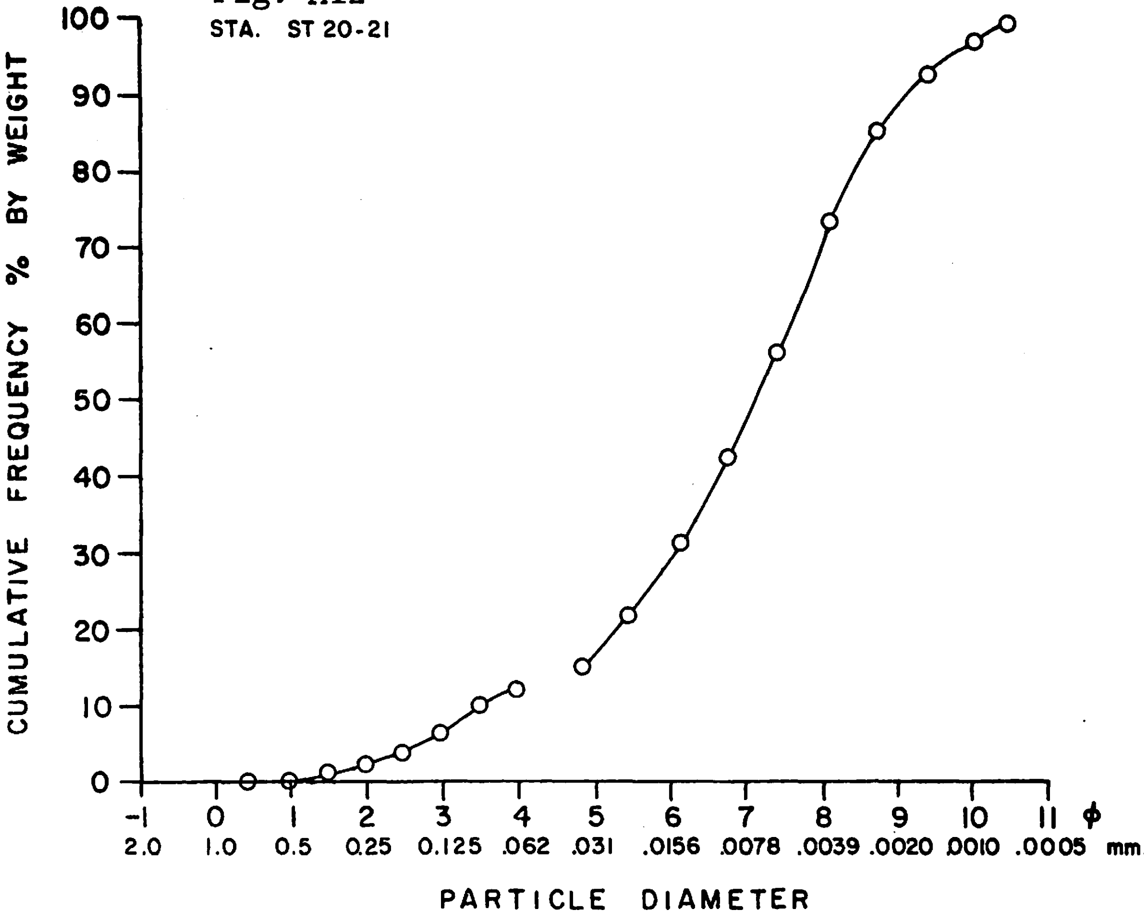

STA. ST 20-21
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A13

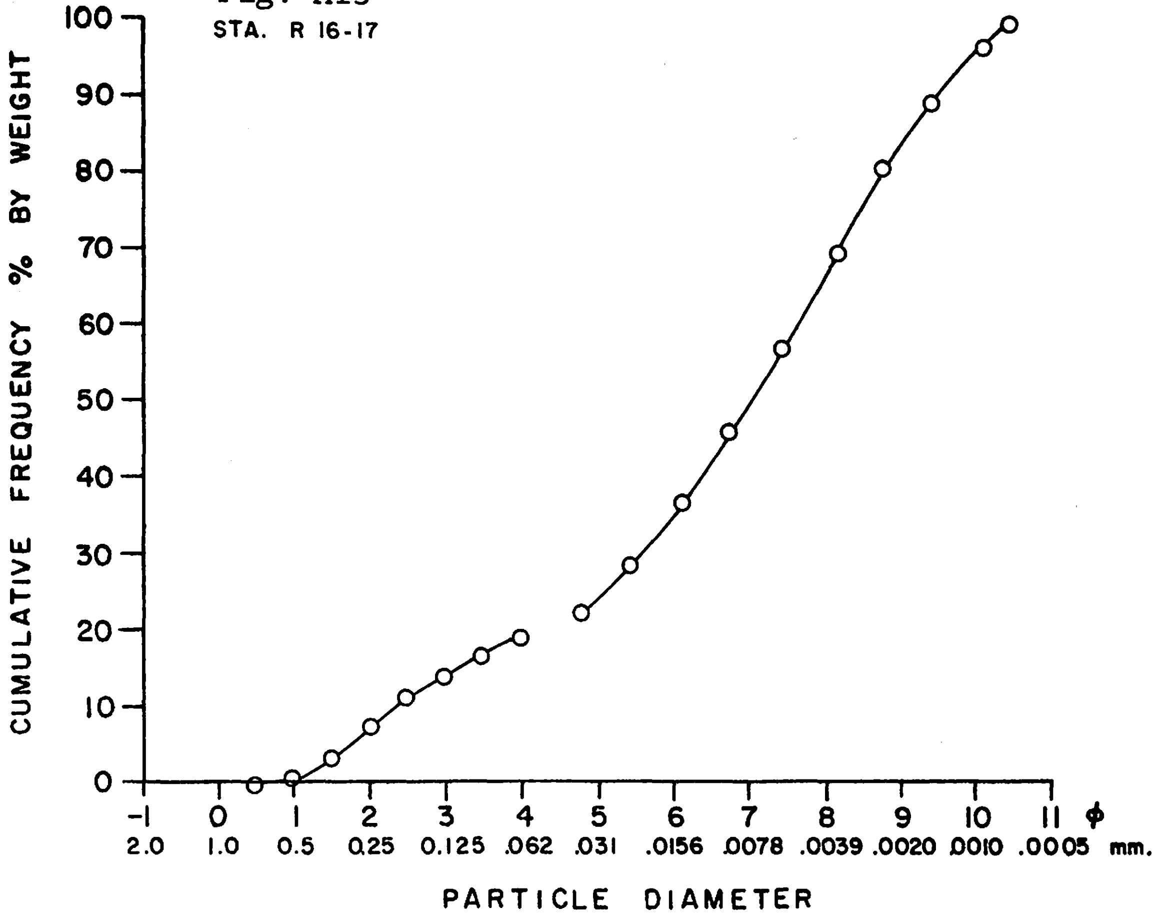

STA. R 16-17
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A14

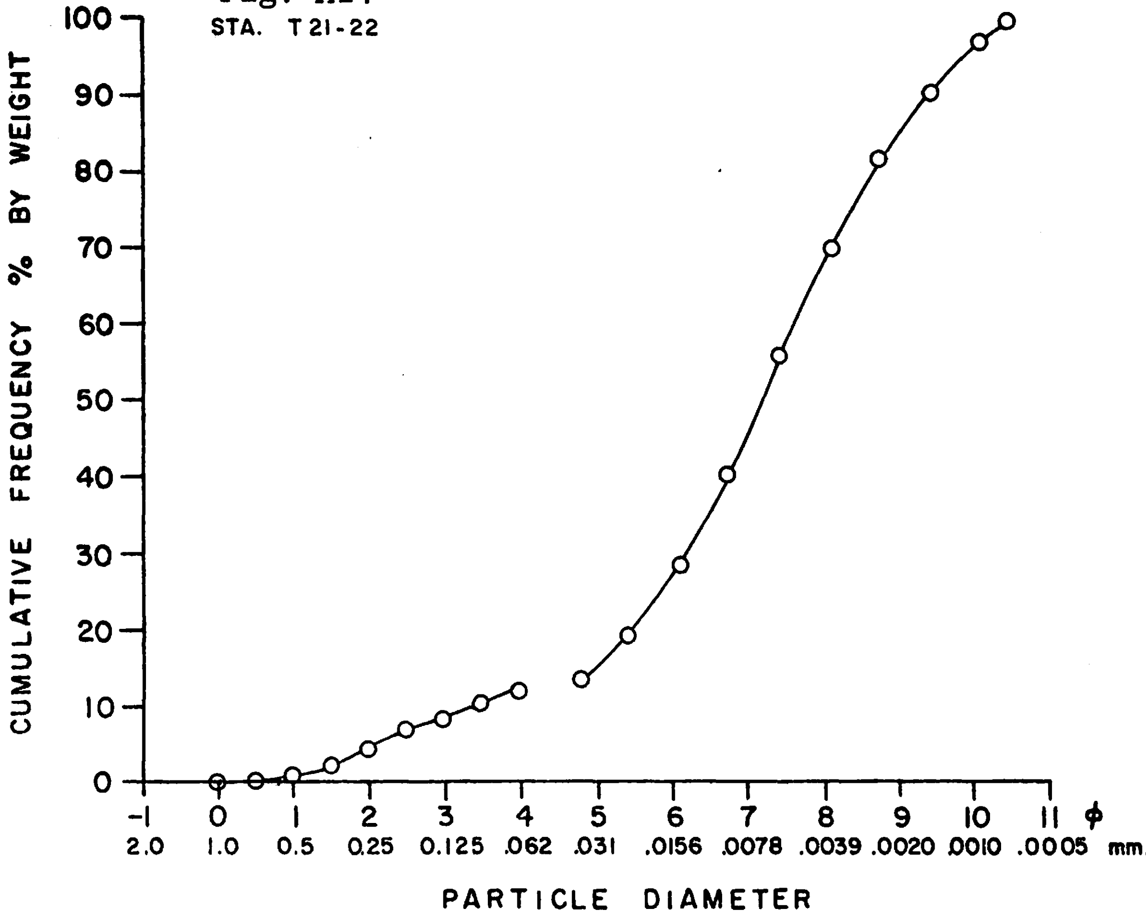

STA. T21-22
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
ϕ
2.0
1.0
0.5
0.25
0.125
.062
.031
.0156
.0078
.0039
.0020
.0010
.0005
mm.
PARTICLE DIAMETER

Fig. A15

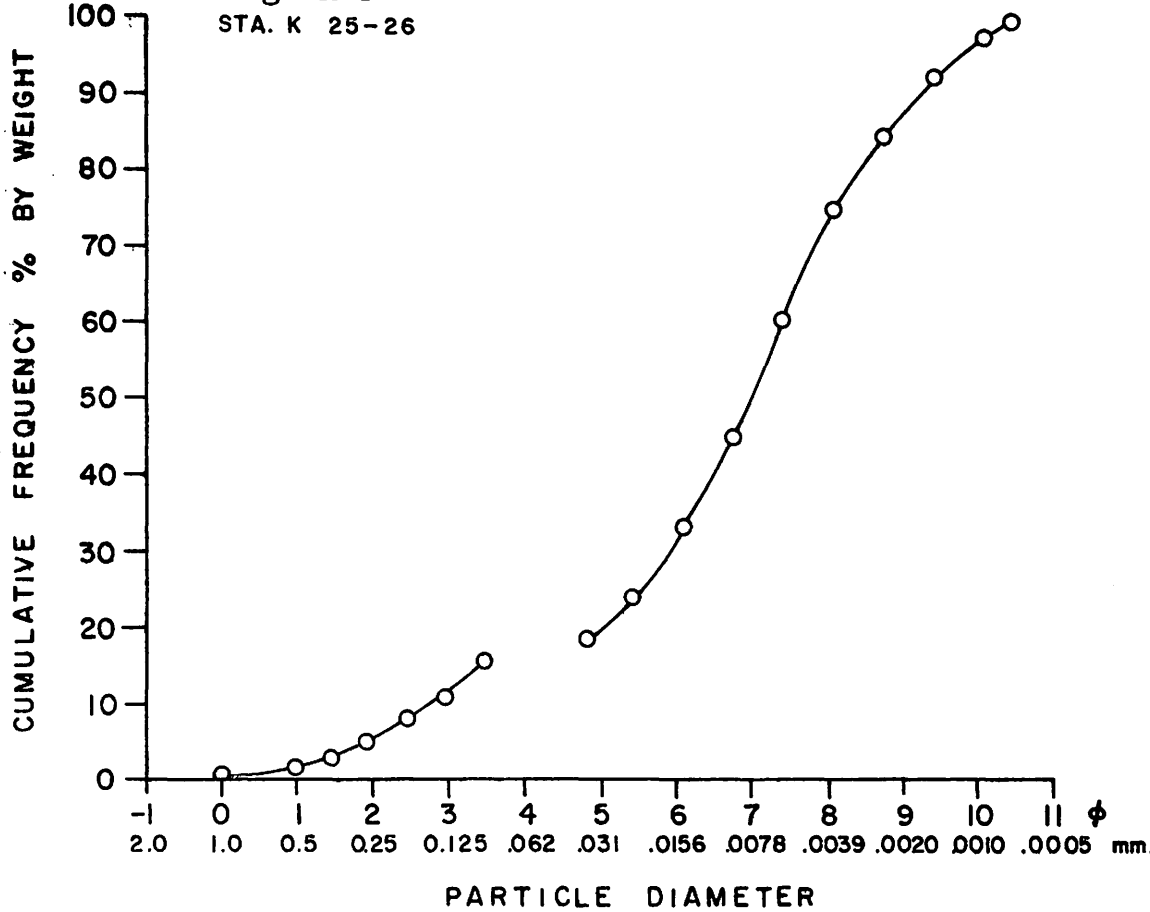

STA. K 25-26
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 2.0
0 1.0
1 0.5
2 0.25
3 0.125
4 .062
5 .031
6 .0156
7 .0078
8 .0039
9 .0020
10 .0010
11 .0005
φ
mm.
PARTICLE DIAMETER

Fig. A16

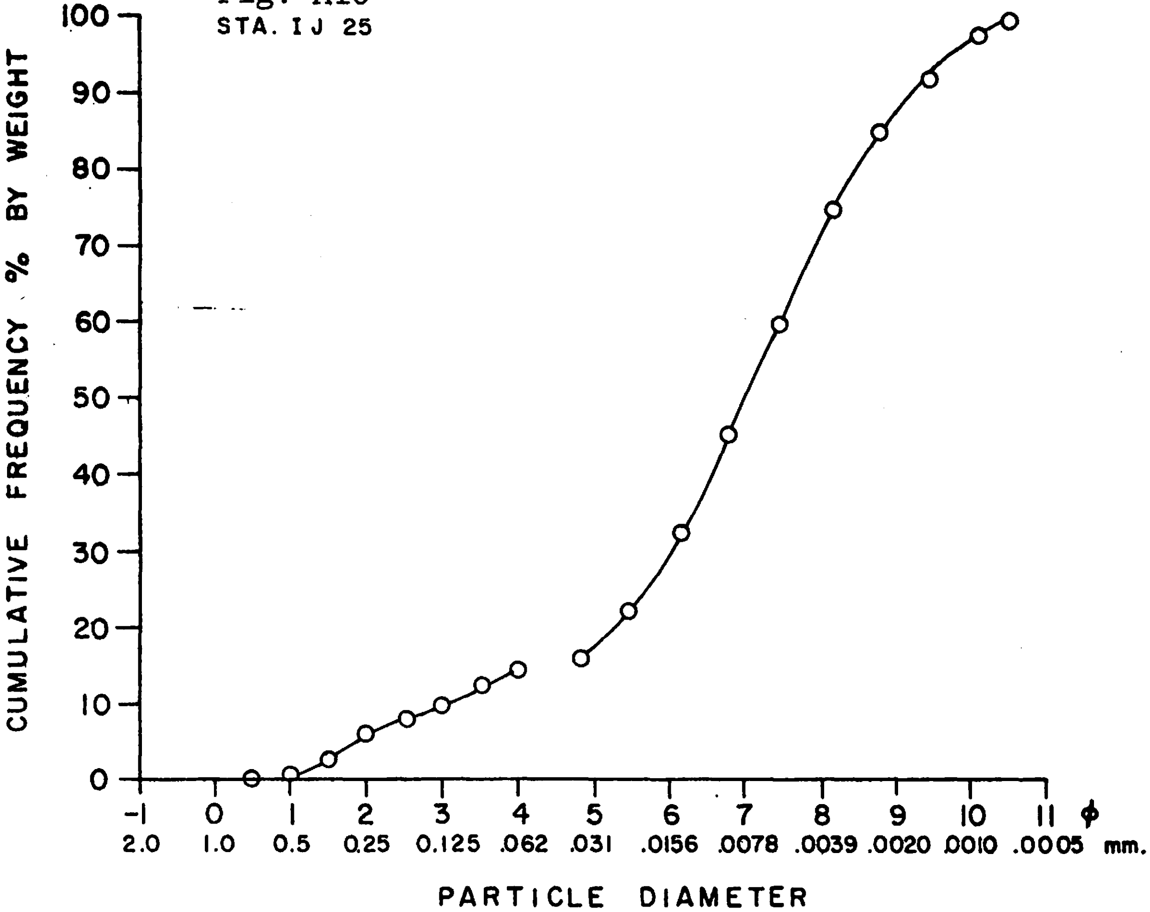

STA. I J 25
CUMULATIVE FREQUENCY % BY WEIGHT
0
10
20
30
40
50
60
70
80
90
100
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A17

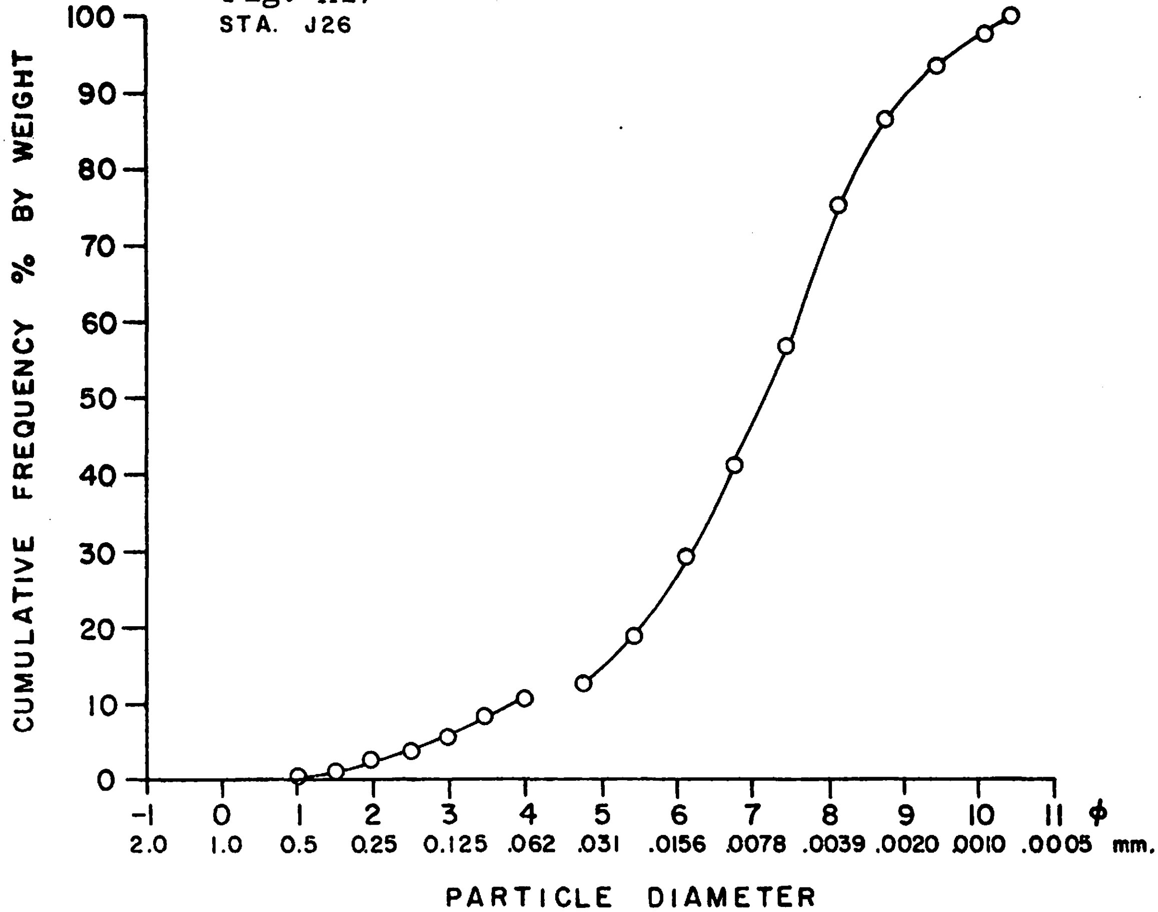

STA. J26
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A18

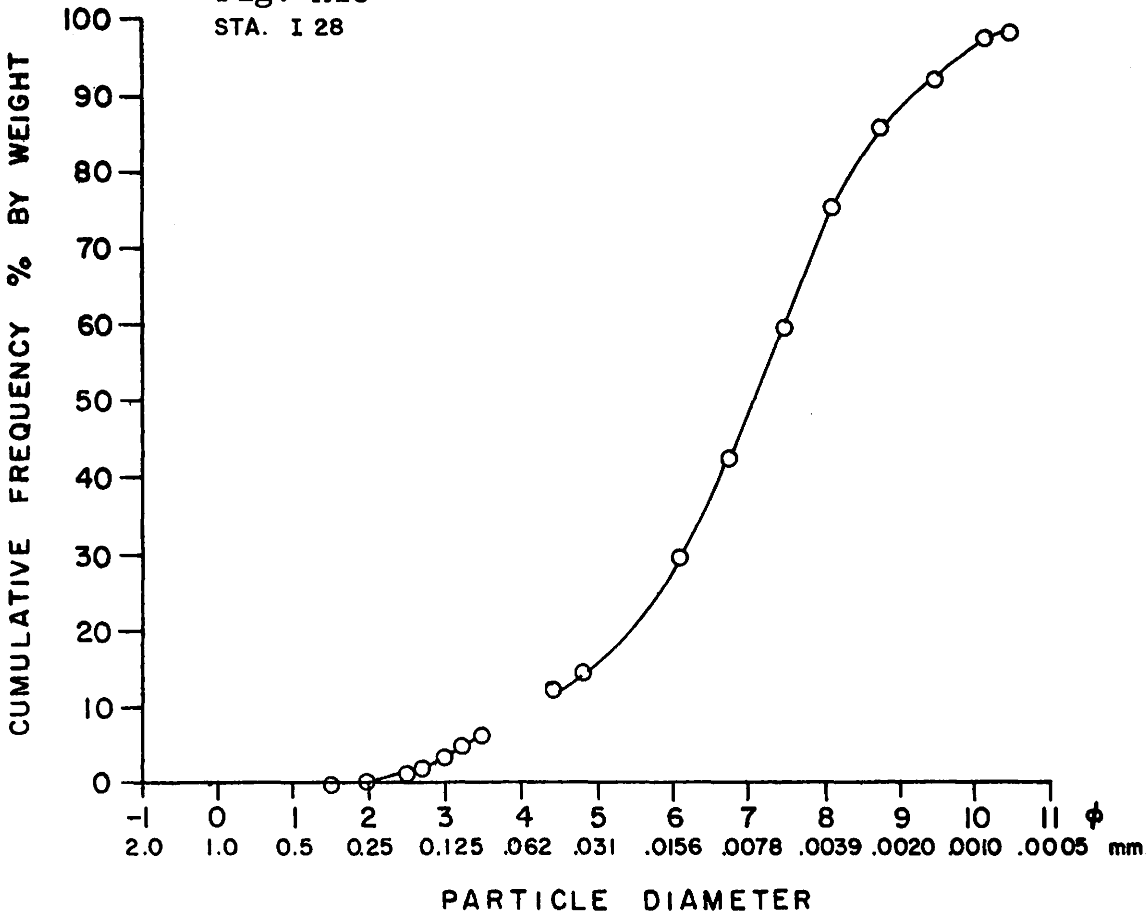

STA. I 28
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A19

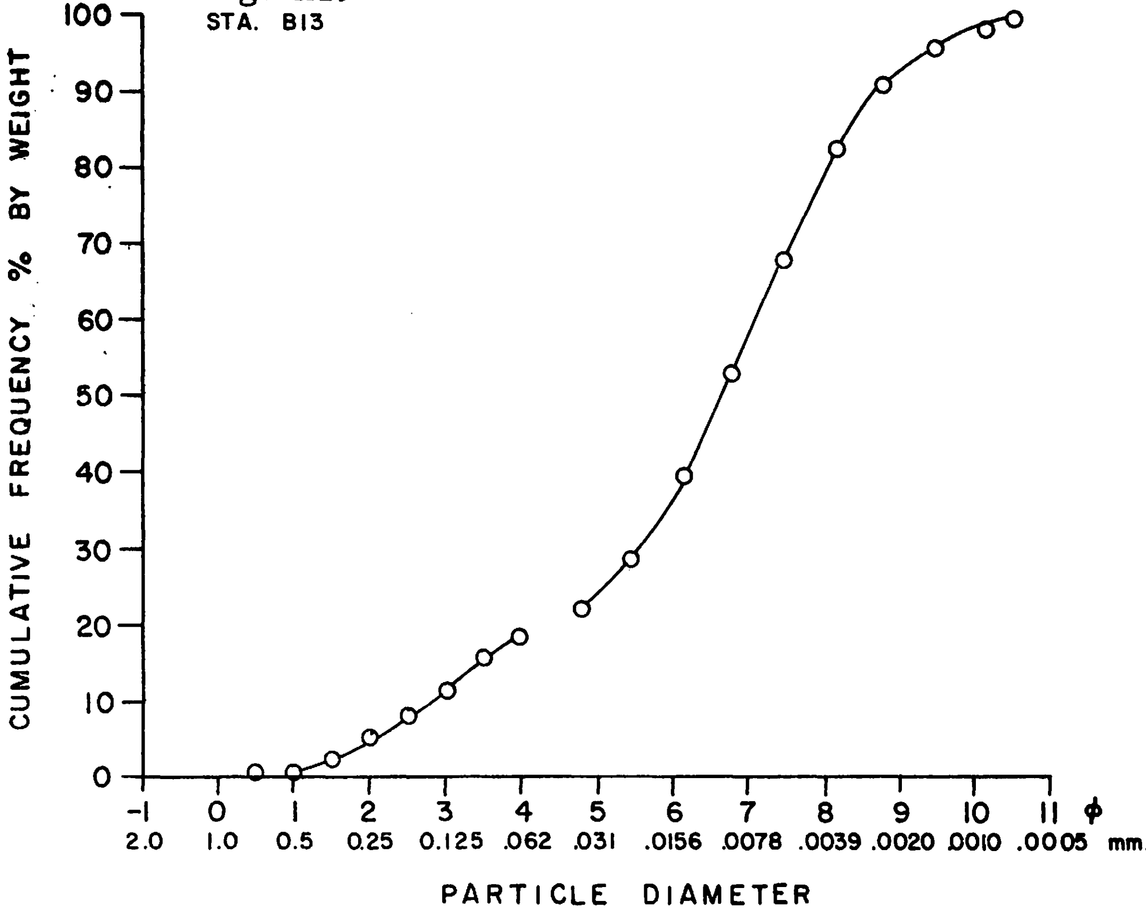

STA. B13
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A20

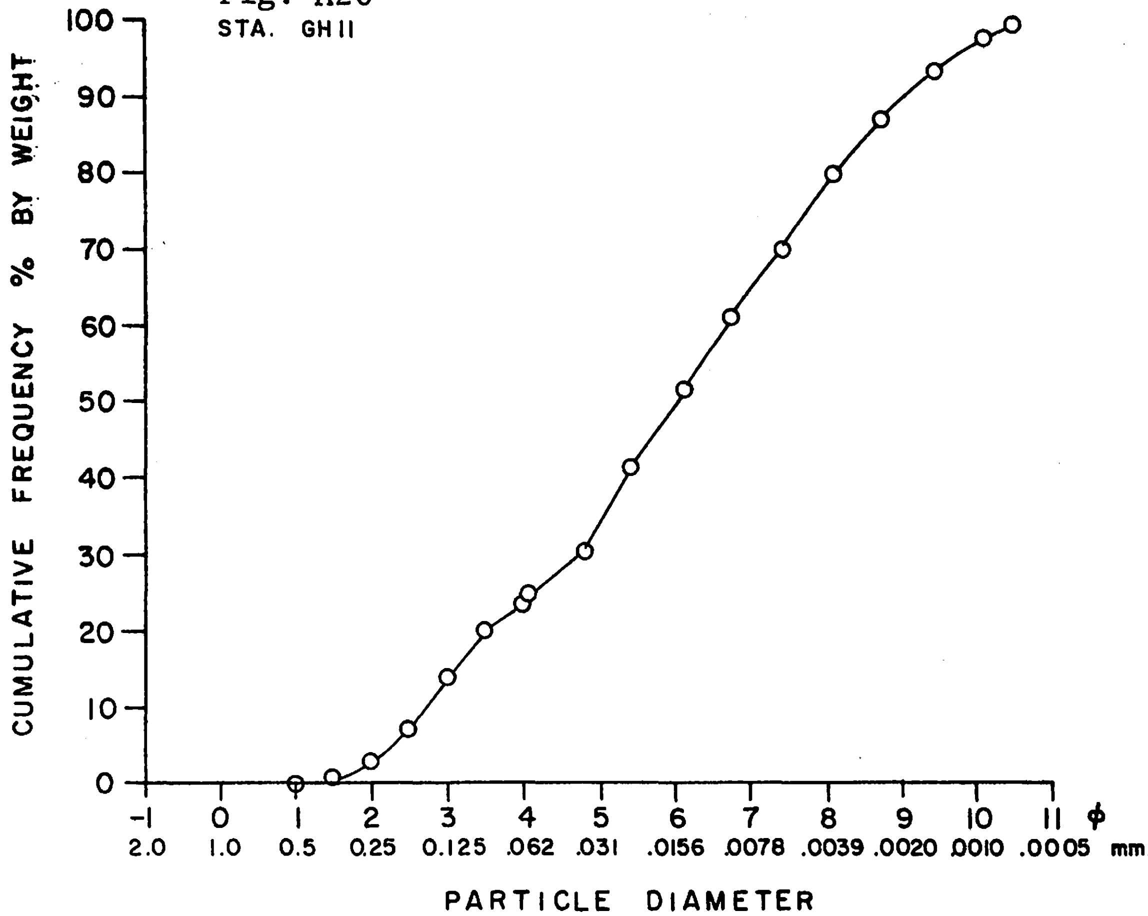

STA. GH11
100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE FREQUENCY % BY WEIGHT
-1
0
1
2
3
4
5
6
7
8
9
10
11
φ
2.0
1.0
0.5
0.25
0.125
.062
.031
.0156
.0078
.0039
.0020
.0010
.0005
mm.
PARTICLE DIAMETER

Fig. A21
STA. I12

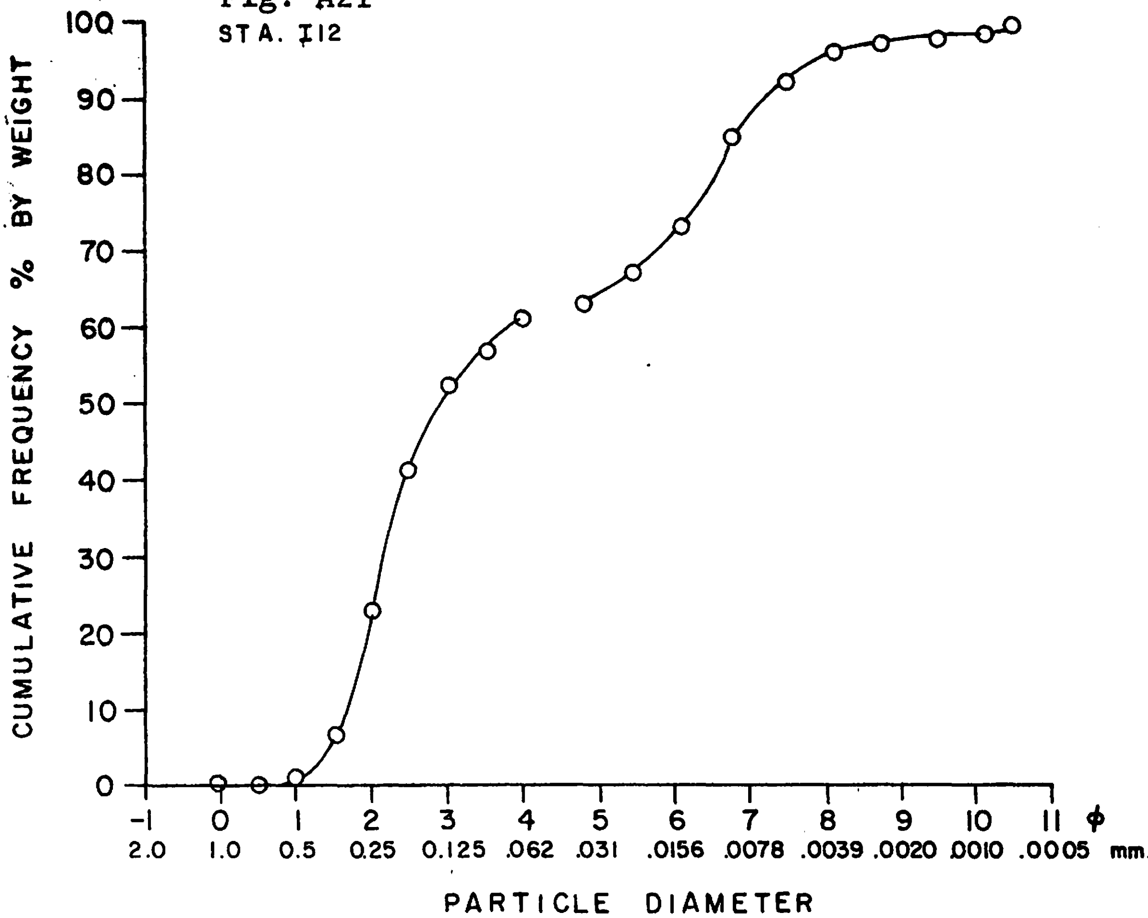


Fig. A22

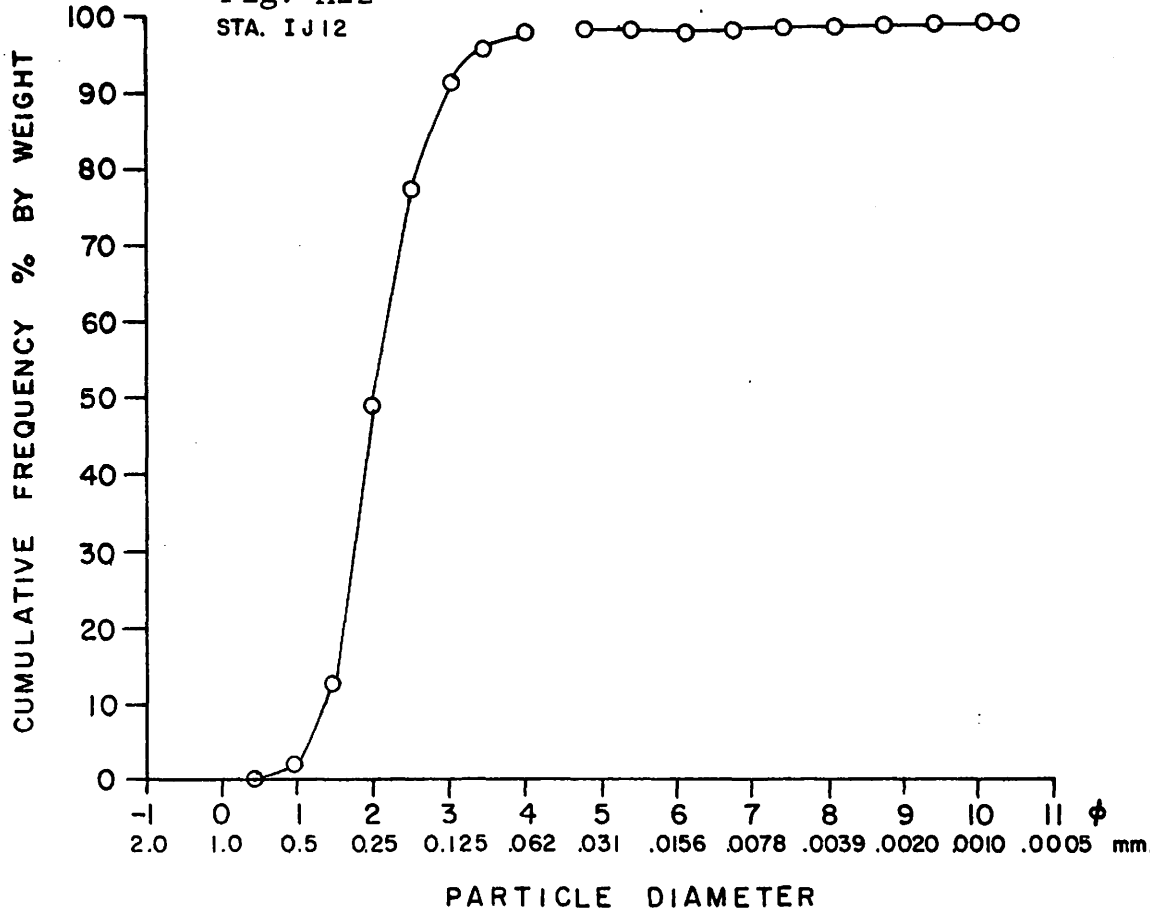

STA. IJ12
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A23

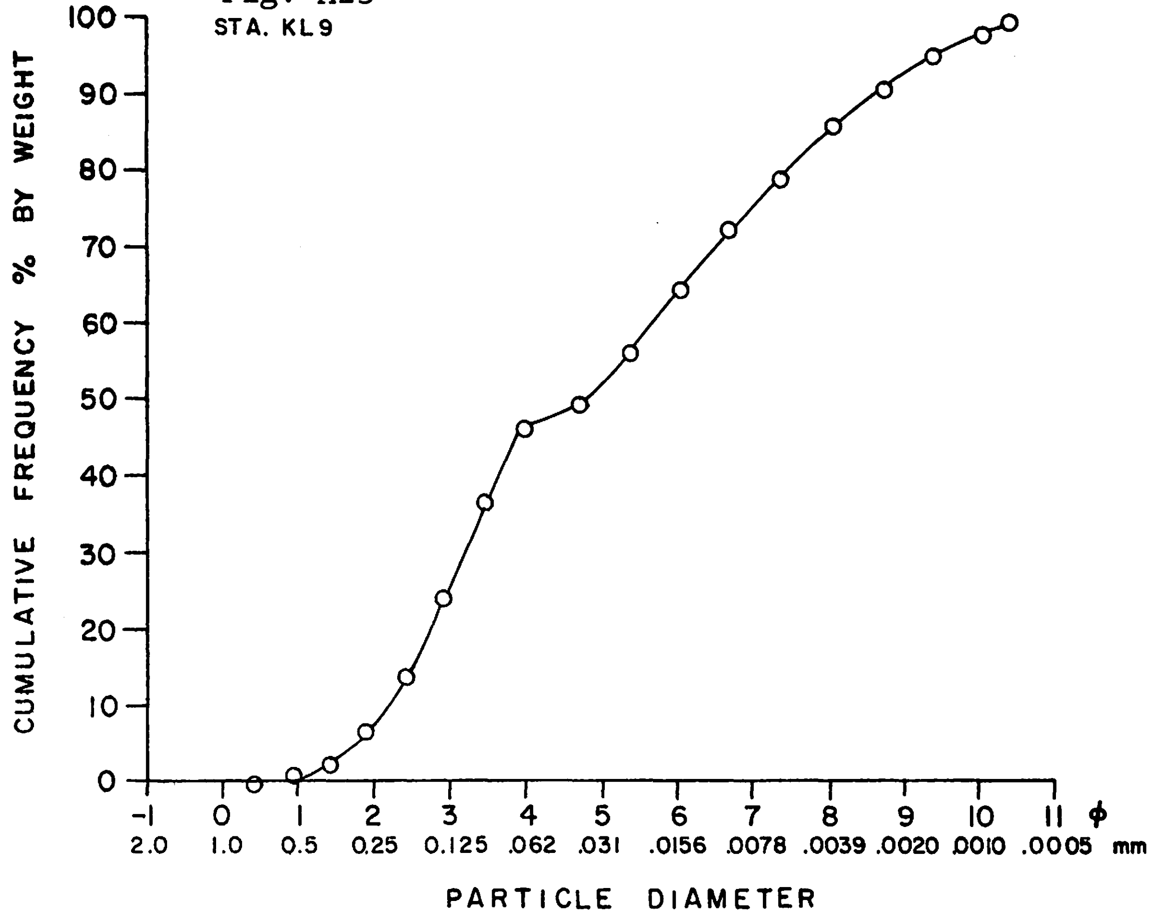

STA. KL9
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A24

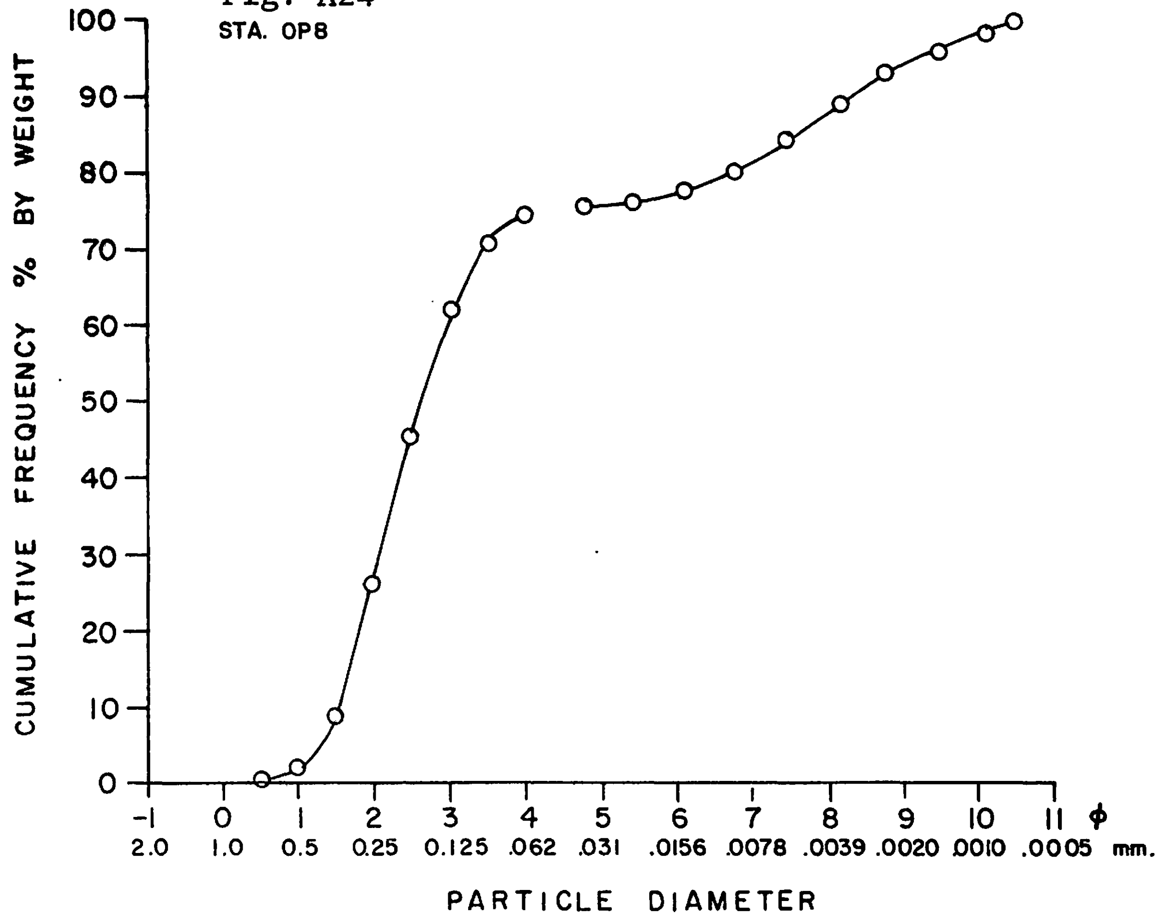

STA. OP8
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A25

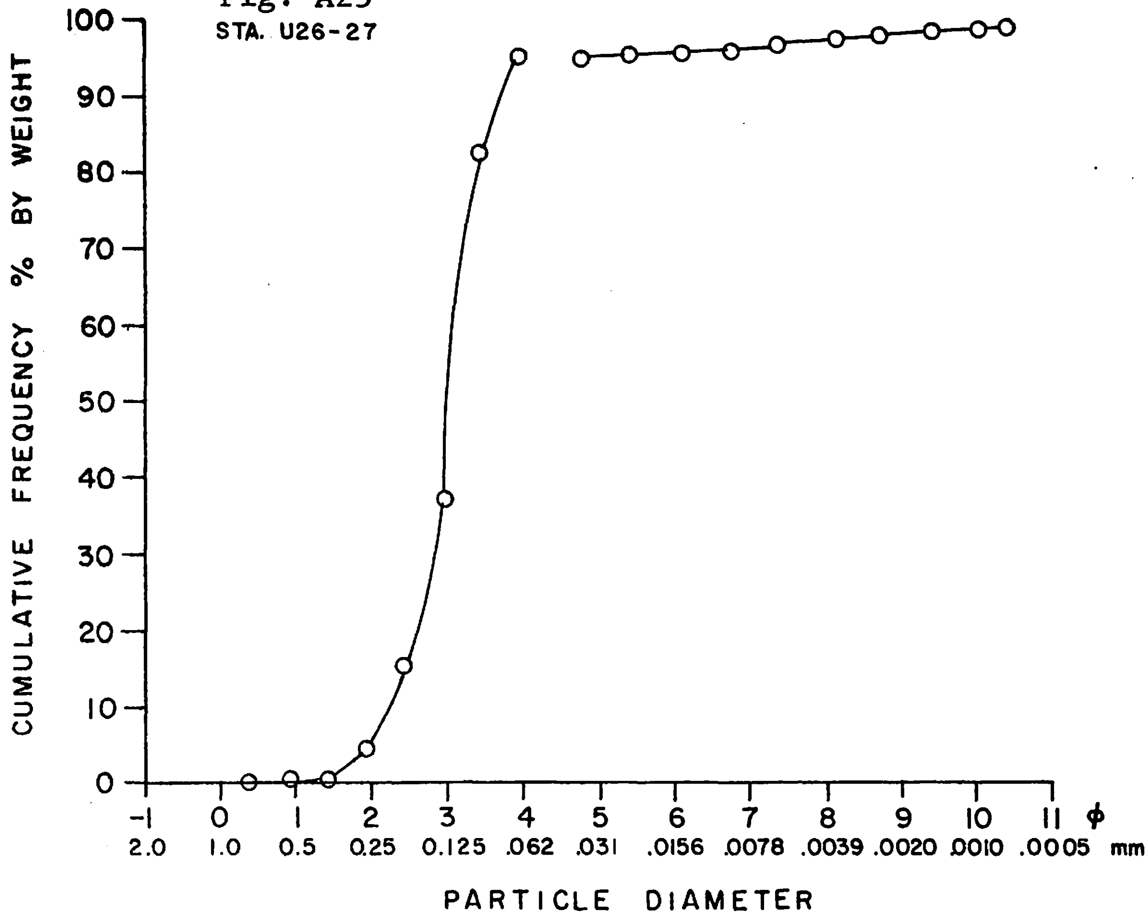

STA. U26-27
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A26

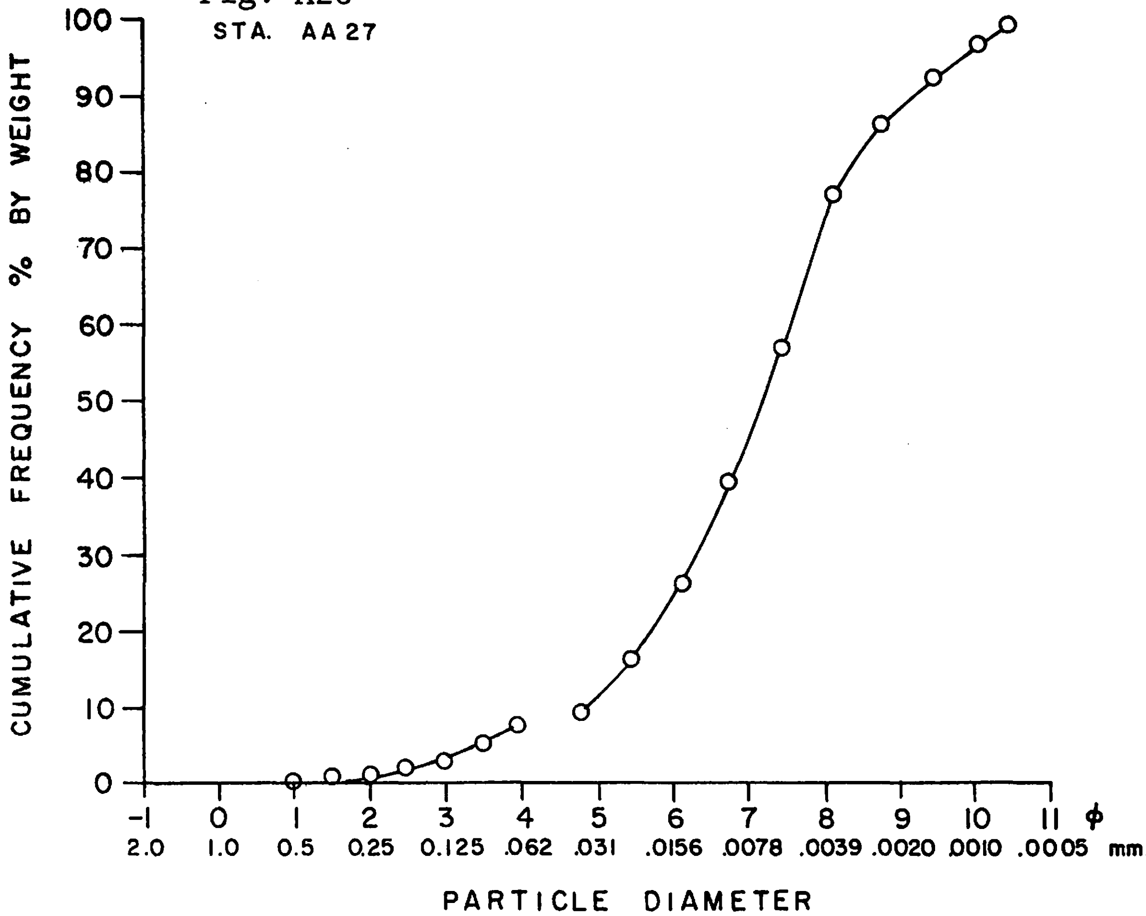

STA. AA 27
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A27

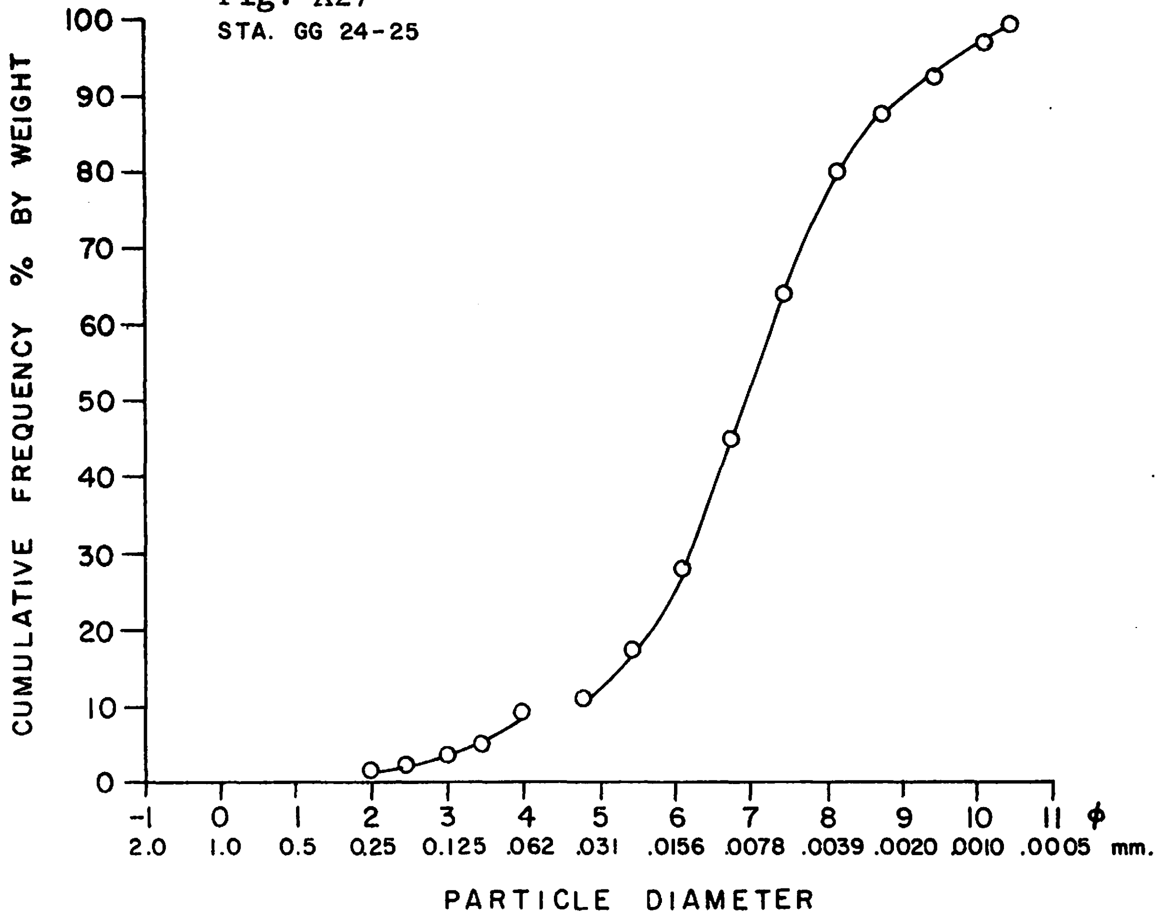
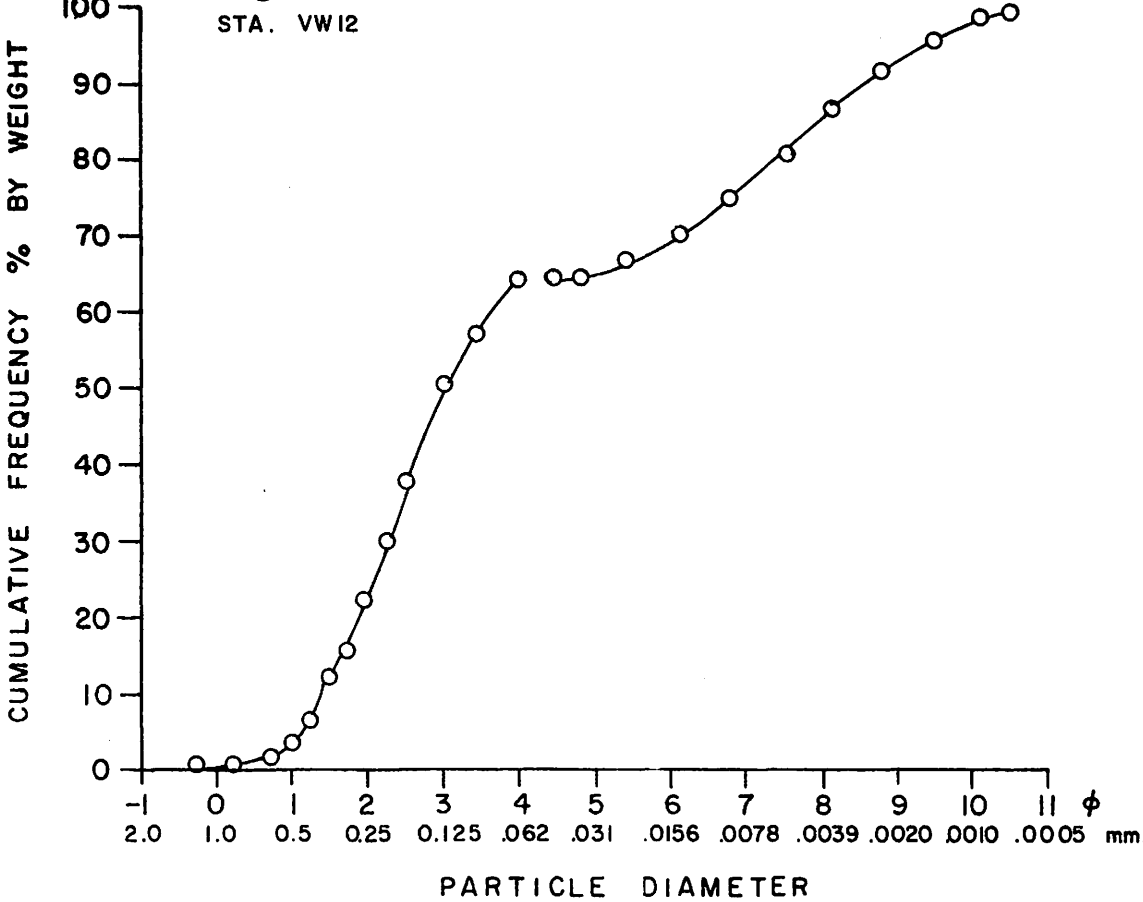

STA. GG 24-25
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

Fig. A28


STA. VW12
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

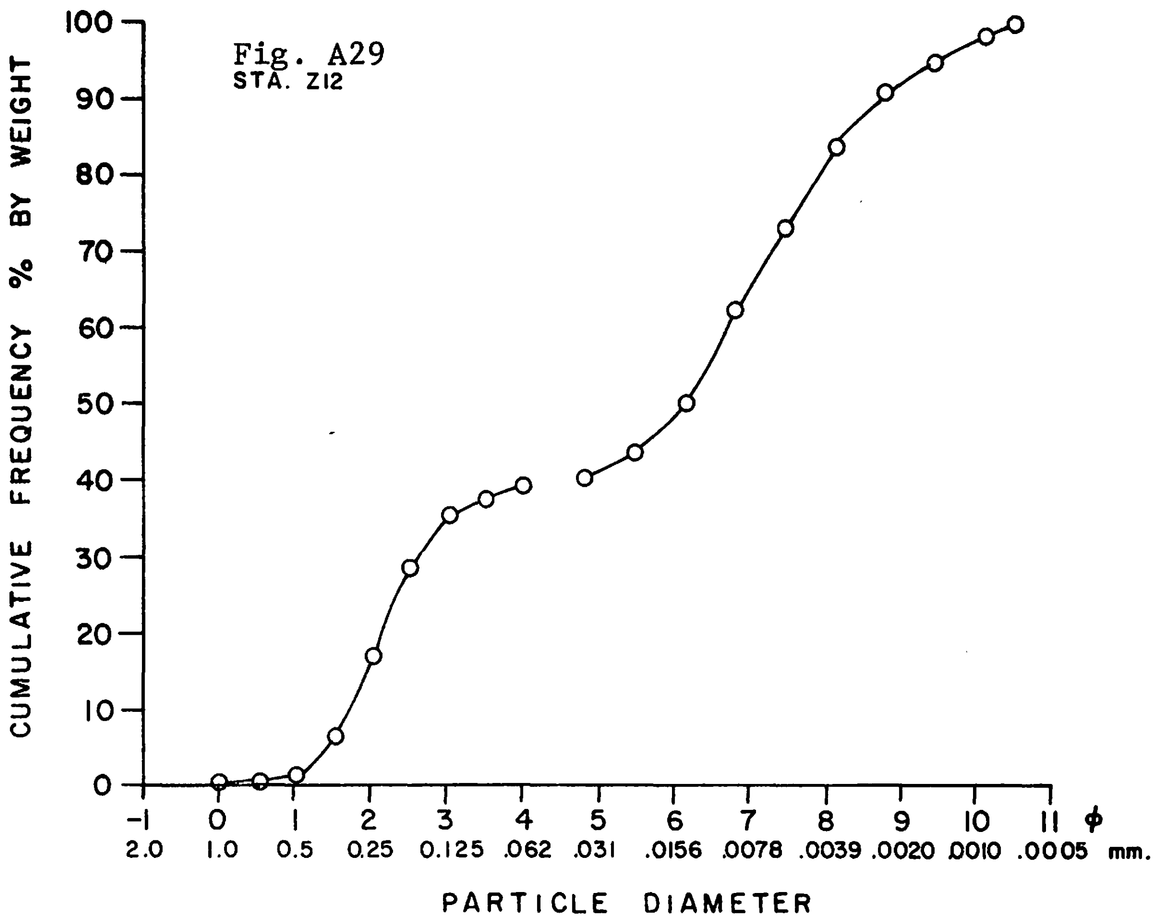


Fig. A29
STA. Z12
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 φ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER

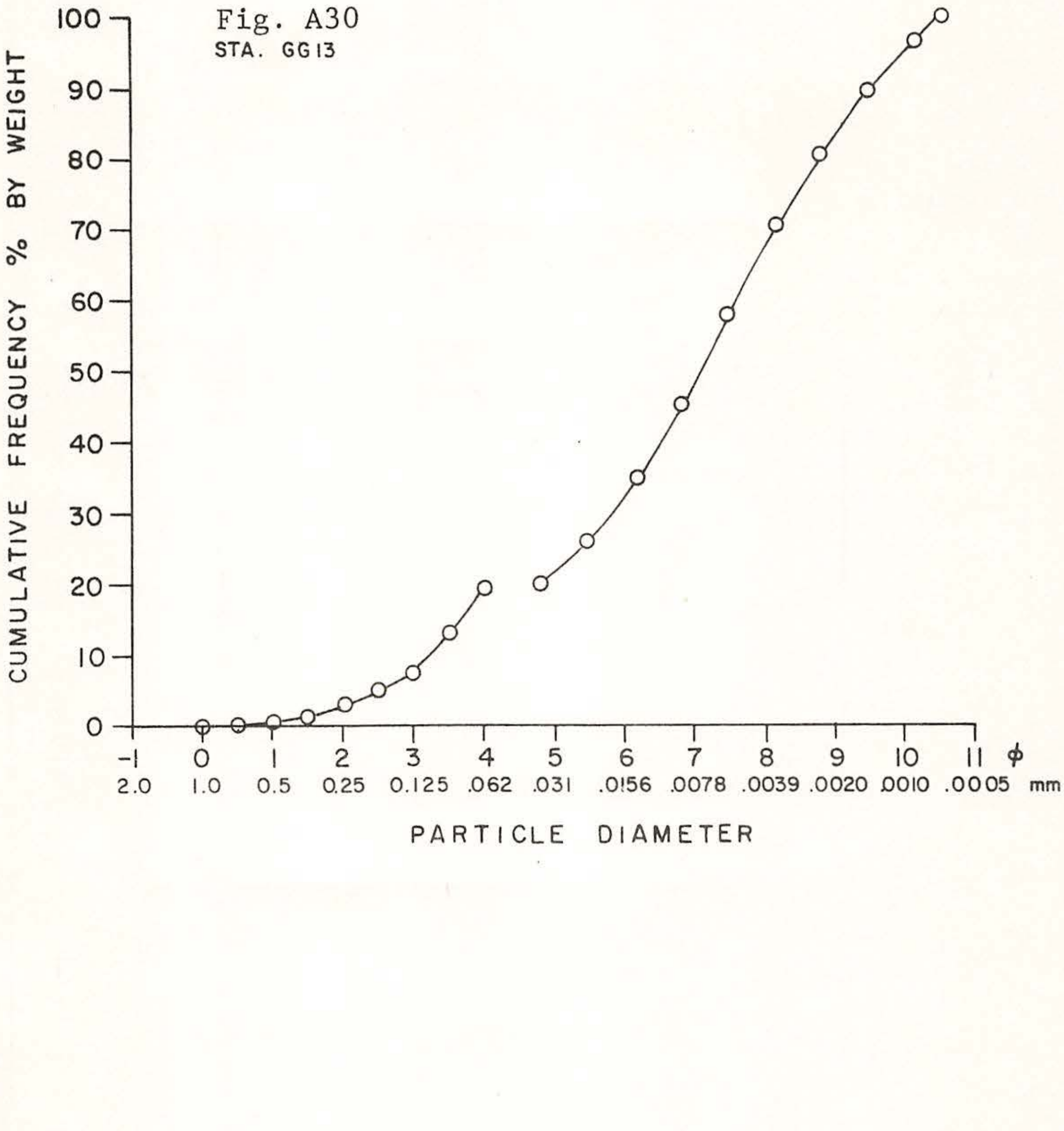


Fig. A30
STA. GG13
CUMULATIVE FREQUENCY % BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 ϕ
2.0 1.0 0.5 0.25 0.125 .062 .031 .0156 .0078 .0039 .0020 .0010 .0005 mm.
PARTICLE DIAMETER