

AD-A152 155

INVESTIGATION OF COMPARATIVE MOSQUITO BREEDING IN
DREDGED MATERIAL DISPOS. (U) CITADEL CHARLESTON SC DEPT
OF BIOLOGY J VORGETTS ET AL. 1978 IYB-CONTRIB-78-04

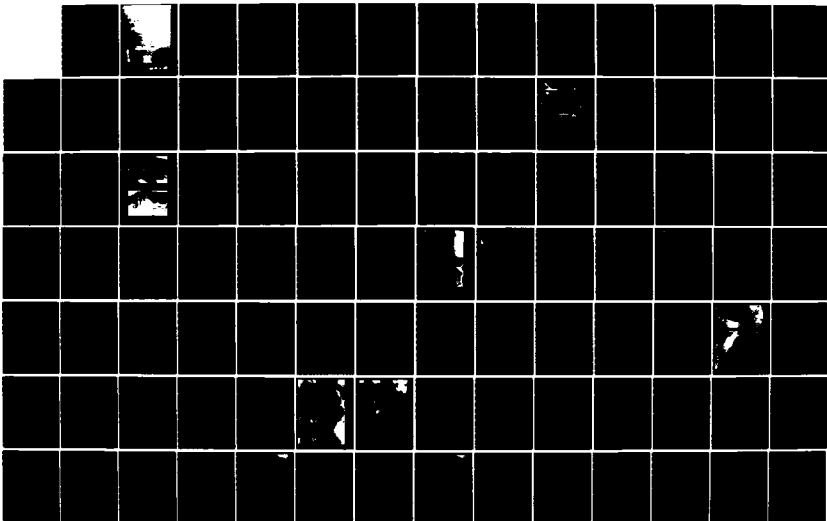
1/2

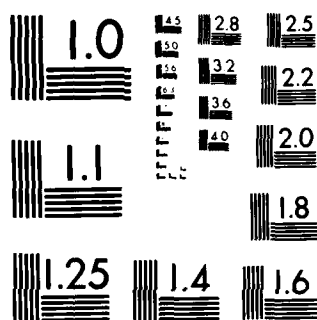
UNCLASSIFIED

DACM60-76-C-0032

F/G 6/6

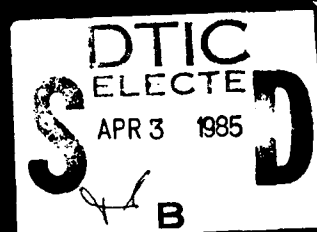
NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AD-A152 155



DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

INVESTIGATION OF COMPARATIVE MOSQUITO BREEDING IN
DREDGED MATERIAL DISPOSAL SITES USED IN THE
MAINTENANCE DREDGING OF THE ATLANTIC
INTRA-COASTAL WATERWAY IN
SOUTH CAROLINA

by
Joseph Vorgetts, Jr., M.S.
and
Wm. Bruce Ezell, Jr., Ph.D.
Department of Biology
The Citadel
Charleston, South Carolina

Contract No. DACW 60-76 C0032
Final Report
U.S. Army Corps of Engineers
Charleston District
P.O. Box 919, Charleston,
South Carolina 29402

DTIC
ELECTE
S APR 3 1985 D
B

DISTRIBUTION STATEMENT A

**Approved for public release
Distribution Unlimited**

1978
The Citadel: IVB Technical Contribution
78-01

TABLE OF CONTENTS

	<u>Page</u>
PREFACE	3
I. INTRODUCTION	5
II. BIOLOGY OF MOSQUITO SPECIES OCCURRING IN COASTAL AREAS.	7
Floodwater Mosquitoes	7
Non-Floodwater Mosquitoes	10
Medical Importance of saltmarsh Mosquitoes	11
III. MOSQUITO CONTROL IN COASTAL AREAS	13
IV. PHYSICAL FEATURES OF DIKED DREDGED MATERIAL DISPOSAL SITES	17
Structural Features	21
Features Developing after Disposal of Dredged Material	23
V. CHEMICAL AND BIOLOGICAL FEATURES OF DREDGED MATERIAL DISPOSAL SITES	31
Introduction.	31
Dredged Soil Chemistry	31
Literature Review	32
Materials and Methods	33
Results and Discussion.	35
Comparative Survey of Mosquito Breeding in Coastal Habitats of South Carolina	43
Materials and Methods	49
Results and Discussion	49 .
Summary and Conclusions	58
VI. INVENTORY OF DIKED DREDGED MATERIAL DISPOSAL SITES USED IN THE MAINTENANCE OF THE AIWW IN SOUTH CAROLINA	60

TABLE OF CONTENTS

	<u>Page</u>
VI. (Continued)	
Section 1: Horry County	63
Section 2: Georgetown County	74
Section 3: Charleston County	91
Section 4: Colleton-Beaufort Counties	146
VII. CONCLUSIONS AND RECOMMENDATIONS	155
Cultural Practices	156
Chemical Control Procedures.	160
LITERATURE CITED.	161

Approved by	
NTIS	☒
EDUC	☐
Other	☐
PER Form 50	
Project	
Priority Codes	
Author	
Title	
A-1	



PREFACE

1. This report represents the final compilation of all data and information developed from investigations conducted for fulfillment of a contract initiated by the United States Army Corps of Engineers (CE), Charleston District, Charleston, South Carolina (DACW 60-76-C-0031) on 23 September 1976 with The Citadel—The Military College of South Carolina.

2. The purpose of this contract was to complete a thorough study of diked dredged material disposal sites associated with the maintenance dredging of the Atlantic Intra-Coastal Waterway within the boundaries of the Charleston CE District. Observations of the substrate, drainage, vegetational and other physical and biological features of these disposal sites were made to qualitatively and quantitatively describe the extent of mosquito breeding associated with them. Observations of other types of saltmarsh habitats were made to provide comparative data. Field studies were conducted by aerial photographic surveillance of and on-site visits to all disposal areas within the Charleston CE District. Laboratory studies were conducted at The Citadel Biology Department.

3. Field and laboratory studies were conducted under the direction of the Principal Investigators, Mr. Joseph Vorgetts, Jr., Instructor and Research Associate, and Dr. William Bruce Ezell, Jr., Associate Professor at The Citadel, Department of Biology. The Contracting Officer for the Corps of Engineers was Col. Harry S. Wilson, Jr. The Contracting Officers Representative (COR) was Mr. John L. Carothers, Chief, Environmental Resources Branch.

4. The authors wish to express their appreciation to personnel of the Charleston CE District, especially Messrs. Braxton Kyzer, John Carothers, Hager Metts, Willard Mizzell and Lt. Randy Bolton for their assistance and unfailing cooperation throughout the duration of this project. The authors also offer an expression of gratitude to Mr. Max Askey, Director of the Charleston County Mosquito Abatement Program; Mr. Robert Zack, Director of the Georgetown County Mosquito Abatement Program; Mr. David Arnold, Director of the Lowcountry Vector Control Program, Mr. Tommy Strange, Supervisor of Waterfowl Management—South Carolina

Department of Wildlife and Marine Resources and the personnel of these agencies who were extremely helpful and cooperative in locating and monitoring some of the sampling sites established for this study. An expression of thanks is also extended to Mr. Fritz Aichele of the South Carolina Coastal Council whose help with securing aerial photographs was invaluable. Publication of the final report was made possible by a special grant from The Citadel Development Foundation (CDF) and special thanks are extended to Cols. J. R. Woods and J. K. Reed for the administrative assistance they provided throughout the duration of this project. A final, special note of gratitude is extended to Mr. James Campbell, Mosquito identification specialist, for his dedicated assistance with the taxonomic work necessary for completion of this study.

I. INTRODUCTION

5. Maintenance of adequate channel depths for passage of commercial and private vessels which utilize the coastal harbors and waterways of South Carolina is a precondition for the continued success and growth of three of the state's most important industries: recreation, commercial fishing and the import-export trade. These industries also depend to varying degrees on the continuing viability of one of the state's most valuable natural resources, the coastal wetlands.

6. The wetlands of South Carolina comprise about 788 square miles. Most of this area (about 678 square miles) is made up of tidal saltmarsh. The remainder consists of marsh which has been impounded for wildlife and other management purposes (Tiner, 1977). Marshland serves several important functions including the maintenance of (1) habitats which serve as nursery areas for fin and shellfish; (2) buffer zones which absorb energy and runoff from coastal storms; (3) natural filters which trap sediments and pollutants which run off from upland areas; and (4) natural and aesthetically pleasing environments important for recreational and educational pursuits. Most of these functions can and do impinge directly or indirectly on the state's major coastal industries.

7. The necessity of channel maintenance and the equally important need for marshland preservation represent conflicting goals that are necessary to maintain waterborne commerce in coastal areas. These conflicts arise because channel maintenance requires frequent dredging and usually the only sites available for disposal of dredged material are tidal saltmarshes. Disposal areas, that are located in the vicinity of saltmarshes, are easily recognized by at least one prominent feature common to such sites. This feature is the presence of dikes which surround each of the sites. These dikes prevent runback of dredged material into channels.

8. Diked disposal sites unfortunately do not have a completely desirable impact on the environment. When the confined dredged material (a mixture of sand, silt and clay particles with water) gradually dries, a series of successional seres are produced (Carlson, 1972; Ezell, 1976).

These seres are characterized by physical changes in the substrate which can also be associated with a concurrent plant successional pattern. All of these successional stages are also associated with production of arthropods, including some pest species. The nuisance potential of these insects is not limited to the immediate vicinity of their breeding sites but extends into nearby residential areas and other human population centers. There is also a public health risk factor associated with this problem because some species, especially mosquitoes, may serve as vectors of arthropod-borne encephalitis.

9. At the present time, there are no feasible alternative methods for the disposal of dredged material which could circumvent the need for diked disposal areas. Even if operationally and economically feasible alternatives were developed in the near future (an unlikely possibility), the present mosquito nuisance problem associated with existing diked disposal areas in South Carolina and other U.S. coastal areas would persist for many years (Askey, 1974). Thus, the only remaining alternative is to attempt to control noxious insects produced in dredged material disposal areas.

10. Temporary (insecticidal) control of mosquito breeding in dredged material disposal habitats is currently the only practical method available to mosquito abatement programs in South Carolina. Source reduction (permanent control by physical manipulation for elimination of breeding habitats) is rarely used at the present time because of a paucity of detailed knowledge about mosquito breeding habitats within dredged material disposal sites. The development of source reduction techniques, which could be integrated with temporary control measures in a pest management program, is however highly desirable because the need for insecticidal control would be reduced resulting in a cost reduction both in environmental and economic terms. Because source reduction appears to offer an extremely useful means of reducing mosquito-related problems within diked dredged material disposal sites, this study was undertaken to assess the potential of this approach and provide the necessary data needed for developing methods for its implementation.

II. BIOLOGY OF MOSQUITO SPECIES

OCCURRING IN COASTAL AREAS

11. More than 50 species of Culicidae occur in South Carolina. Based on records of the Charleston County Mosquito Abatement Program, 48 mosquito species occur in coastal sections of the state (Askey, 1977). Less than ten of these species are found in association with saltmarsh habitats. However, these saltmarsh species are responsible for the major portion of the nuisance associated with mosquitoes in the coastal zone.

Floodwater Mosquitoes

12. The most important mosquito pests in South Carolina coastal areas are species which breed in saltmarsh habitats that are intermittently flooded by tidal flow and/or rain. The two major species in this category are the common saltmarsh mosquito, *A. sollicitans* (Walker) and the black saltmarsh mosquito, *A. tritaeniorhynchus* (Wiedemann). Both species are common along most of the Atlantic and Gulf Coasts of the United States. Further details about the distribution and taxonomic position of these two species are given by Carpenter and La Casse (1955), Carpenter (1968; 1970) and Knight and Stone (1977). The summary of the biology and life history of these two species which follows has been taken from King et.al. (1960).

13. Several factors contribute to the importance of *A. sollicitans* and *A. tritaeniorhynchus* as pests of man. The most significant are the habits of the adults. The females of both species are fierce biters and strong fliers. They readily feed on warm-blooded hosts including man and they commonly migrate inland from the vicinity of their breeding habitats. Individuals may disperse more than 30 miles from the breeding site, but the average flight range is probably much less. Nevertheless, great influxes of both species into populated areas of the coastal plain are a common occurrence. At the end of such migrations, adults settle in grass, shrubbery and other types of available vegetation which offer some protection from the elements. From such positions, they will readily attack any passing persons or warmblooded animals. A significant

behavioral aspect of these mosquitoes, which adds to their nuisance potential, is that biting activity is not necessarily restricted to the crepuscular periods. *A. sollicitans* and to a lesser extent, *A. taeniorhynchus* will attack at anytime of day or night—even in fully sunlit areas!

14. Breeding habits: Mosquitoes of the floodwater group are similiar in many respects and they share the common habit of depositing their eggs on moist soil slightly above the prevailing water level. In the saltmarsh habitat, this soil zone is represented by that portion of the marsh which is irregularly flooded by monthly spring tides (high marsh) but not the daily action of tidal ebb and flow (low marsh). The lower limit of the high marsh zone is usually delineated by a transition from cordgrass, *Spartina alterniflora*, to other halophytic species. Further details of saltmarsh vegetational patterns in relation to community structure and zonation are given by Adams (1963). The relationship of vegetational communities to insect species composition and diversity in saltmarshes has been described by Davis and Gray (1966).

15. The crucial factor which determines floodwater mosquito distribution is related to the characteristics of substrates which are chosen for egg laying sites. Several substrate characteristics have been studied in efforts to determine what factor exerts the greatest influence on oviposition site selection. Knight and Baker (1962) found that the moisture content of artificial substrates significantly influences oviposition site selection by laboratory reared *A. sollicitans* and *A. taeniorhynchus*. Most eggs were laid on substrates with a high moisture level (70 percent or more of the saturation moisture content of the substrate). Knight (1965) reported that the larvae of the saltmarsh mosquitoes *A. sollicitans*, *A. taeniorhynchus* and *Anopheles bradleyi* were always found in areas that resulted from the flooding of habitats where soil exhibited a total soluble salt content of 1,644 ppm or more. However, Petersen and Chapman (1970) found that both *A. sollicitans* and *A. taeniorhynchus* would breed on substrates with an extremely wide range of salinity and concluded that salinity may not be the only factor restricting the distribution of these species. Petersen (1969) examined the oviposition responses of several saltmarsh *A. taeniorhynchus* spp. to seven different inorganic salts and found evidence that salinity may be more

important as a repelling factor than an attracting factor. Thus the exact role of physical and chemical factors in mosquito oviposition site selection remains unclear. No definitive studies have been conducted on the ovipositional requirements of mosquitoes developing within dredged material disposal sites. Despite the absence of good microhabitat features at the present time, saltmarsh mosquito breeding sites can be identified on the basis of *macrohabitat* features, especially vegetational features. Travis and Bradley (1943) demonstrated that the distribution of *Aedes* mosquito eggs on saltmarshes was correlated with vegetational type.

16. Once laid, eggs require a few days for embryonic development and conditioning. During this period, eggs will not hatch under any conditions. Once this conditioning period is completed, *most* eggs usually will hatch if inundated by water. Factors which prevent hatching include high dissolved oxygen levels in the water (deoxygenated water induces hatching), embryonic diapause (the physiological conditioning of eggs which prevents hatching during seasons which are unfavorable to successful development) and secondary conditioning factors. This latter factor refers to the fact that a small percentage of eggs requires one or more floodings to properly condition them for hatching. The details of this specialized mechanism remain unclear. A thorough review of available information about this unusual habit has been provided by Horsfall et al. (1973).

17. Following hatching, larvae feed on microplankton including algae, rotifers, protozoa, bacteria, and to some extent on detritus although the exact importance of non-living organic food is not known (Clements, 1963). Adult eclosion may occur in as few as six days following egg hatch under optimum conditions, but development to the adult stage usually requires 10-12 days—the developmental time is highly dependent on water temperature. Floodwater mosquito broods are usually closely synchronized and emergence of all adults in a brood is usually completed in a 2- to 3-day period once adult eclosion begins. Males usually emerge before females and remain near the breeding site in surrounding vegetation. Once a sufficient number of females have emerged and dried sufficiently, mating begins. Mating occurs in nuptial flights. During the period preceeding the onset of these mating flights, the females do not feed on blood and restrict their diet to nectar from flowering plants. Nectar apparently provides a carbohydrate energy source for

flight, while blood is used as a protein source to produce eggs. Males feed only on nectar as their mouthparts are not morphologically adapted for the blood sucking habit. Migration of females occurs shortly after the peak of the mating period. More detailed information about mosquito life history has been provided by Clements (1963), Edman (1971) and Nayar and Sauerman (1975 a,b,c).

Non-Floodwater Mosquitoes

18. Several species of mosquitoes deposit eggs directly on the surface of brackish or saline water associated with saltmarsh habitats. None of these species are as great a source of nuisance as saltmarsh *Aedes* because they usually do not occur in as great abundance and they apparently have a more restricted flight range. Nevertheless, localized outbreaks of some of these species can be bothersome. Two species of *Anopheles* (*A. atropos* Dyar and Knab and *A. brullei* King) frequently occur in saltmarshes. *A. atropos* is apparently best adapted to pools with a 1-12 percent salinity range. *A. atropos* larvae occasionally occur with those of *brullei* but *brullei* larvae usually occur in water with a lower salt concentration according to King et al., (1960). However, Chapman (1959) reported *brullei* from New Jersey saltmarsh sites with a salinity above 50 percent. *A. brullei* is most frequently associated with locations having emergent vegetation. Adult females of both species attack man. *A. atropos* is apparently active even during daylight hours. The behavior of *brullei* is difficult to document because it lacks characteristics which distinguish it from those of *A. crucians* and *A. gambiae*. Host preferences of *Anopheles* spp. have been described by Edman (1971).

19. One species of *Aedes* is frequently associated with saltmarsh habitats. In the Carolinas, *Aedes salinarius* Coquillett is usually found near the upland perimeter of high saltmarsh vegetation, especially in grassy pools where *Spartina patens* is dominant. This species apparently breeds in both fresh and brackish water and occurs in the Midwestern States as well as along the Atlantic and Gulf Coasts. The females attack man and disperse rather widely from their breeding habitats but are less important as pests in the south than in more northerly areas according to

King et al. (1960). Edman (1974) reviewed literature about the feeding habits of *C. salinarius* throughout its range and reported results of studies from Florida. This species feeds on many types of warm-blooded hosts, taking blood about as often from birds as from mammals. Crans (1968) reported similar results from host preference studies in New Jersey.

Medical Importance of Saltmarsh Mosquitoes

20. The involvement of saltmarsh mosquitoes as vectors of human disease has been documented in a number of studies. The most important diseases transmitted by saltmarsh mosquitoes in the United States are the encephalitide viruses. Major outbreaks of encephalitis in man, horses and pheasants have been attributed to five groups of virus: Eastern Equine Encephalitis (EEE): Western Equine Encephalitis (WEE): St. Louis Encephalitis (SLE): Venezuelan Encephalitis (VEE): and California Encephalitis (CE). The mosquito-virus relationships of these encephalitides have been reviewed by McIntock (1978). Eastern encephalitis is most significant because it has severe effects on the central nervous system. Although human outbreaks have thus far demonstrated low numbers of cases with clinical symptoms, approximately two-thirds of clinical cases have resulted in death (Crans, 1968). EEE has a more restricted distribution than some other forms of encephalitis and appears to be localized along the eastern seaboard and the Gulf of Mexico. The incidence of this disease closely parallels the distribution of *A. sollicitans* and a considerable body of evidence from laboratory and field studies has strongly implicated this species as a principal vector of human infection (Crans, 1962; 1964; 1968). *A. sollicitans* also has a demonstrated capability to carry Western and California Encephalitis. The frequency of these two infections is much lower than that for EEE in the eastern sections of the country. However, recent evidence indicates that both forms may be advancing eastward (Altman et al., 1967; Crans, 1968; Pratt, 1977). *A. taeniorhynchus* and *C. salinarius* also have a demonstrated ability to carry EEE and

WEE. In addition, SLE has been isolated from *A. taeniorhynchus*.

21. Evidence of involvement of saltmarsh anophelines in the cycling of encephalitis is sparse. Only one study has implicated *A. bradleyi* as a possible vector of encephalitis (Buescher et al., 1970). Both *bradleyi* and *atropos* have been infected with malaria parasites in laboratory studies but no evidence indicates that either of these species are important natural vectors (King et al., 1960).

III. MOSQUITO CONTROL IN COASTAL AREAS

22. An organized effort to control mosquitoes associated with saltmarshes was first developed in New Jersey. This pioneering effort was based on the studies and recommendations of Smith (1904) which advocated source reduction techniques by means of proper water management. Source reduction has been achieved primarily by the construction of ditches which promote drainage and/or improve circulation of tidal water in mosquito breeding habitats. Thus, either standing water is eliminated or free flow of water into such habitats is achieved. In the latter case, free circulation permits larvivorous fish to reach the major foci of mosquito breeding and devour the larvae before they can affect man. In some circumstances, water impoundments have been used to eliminate breeding sites by flooding and managing water depth at a level which exceeds the shallow depths required for the development of mosquitoes.

23. Similar efforts were initiated in other coastal regions of the country in the 1930's, particularly in Florida, where most of the coastal counties established mosquito abatement programs. However, control methods shifted dramatically in the 1940's when DDT was introduced as an insecticide. During the two decades which followed, much reliance was placed on DDT because the compound was inexpensive and reliable ground and aerial application methods had been developed which provided a means for thoroughly treating vast acreage in short periods of time (King et al., 1960).

24. More recently, strict reliance on insecticidal control has waned because of the development of resistant strains of mosquitoes and the adverse effects to non-target wildlife. At the present time, many mosquito abatement districts are emphasizing the integration of a variety of procedures into their programs. Although this approach may add to the operating costs of a program, researchers and district supervisors are gradually recognizing that added costs are frequently offset by having the most economical tool available to control different types of mosquito problems. The components of such an *integrated control* program include public education, preventive planning and surveillance as well as the more traditional concepts of water management, larviciding

and adulticiding (Provost, 1976). In addition, the latter three categories have undergone many refinements in the past two decades. Persistent insecticides such as DDT have been phased out in favor of short-lived compounds such as the organophosphate chemicals. Thus, the buildup of toxic compounds in the environment is reduced. Also, in many areas, greater emphasis is now given to the chemical control of mosquito larvae rather than the control of adults. Larval control offers at least two important advantages: (1) mosquitoes are eliminated before they ever have an opportunity to attack man; (2) much less insecticide is required to control mosquitoes in their aquatic habitats when compared with the amount needed to control adults once they have dispersed into human population centers.

25. The improvement of water management procedures has perhaps been as dramatic as changes in insecticidal control methods. Efforts to improve water management methods were accelerated following many critical reports of such procedures (Daiber, 1972). These studies indicated that ditching solely designed to eliminate mosquito breeding could have severe negative effects on other saltmarsh fauna. Ditching efforts intended for the achievement of drainage of marshes were reported to cause changes in the water table which then elicited changes in salt-marsh plant communities. The net effects of such changes reportedly resulted in drastic declines in various invertebrates such as molluscs and crustaceans followed by a decline in populations of waterfowl and wading birds which feed on the invertebrates. Impoundments generally had less severe or even positive effects on wildlife, but the difficulty of proper maintenance of impoundments was cited as a drawback and the need for additional studies on the impact of impoundments on microfauna was emphasized. Poor management of such areas was described as frequently eliciting a transition in mosquito species composition from floodwater to permanent water species, but not complete elimination of breeding.

26. These and other criticisms of early mosquito control water management procedures threatened to establish a permanent conflict between persons charged with mosquito control responsibilities and those affiliated with wildlife conservation (see Glasgow, 1938; for a discussion of the origins of these conflicting interests). However, an important step toward an equitable resolution of these differences occurred when

MacNamara (1952) proposed that a cooperative research program be initiated to develop ways of coordinating mosquito control efforts with beneficial wildlife management practices. The results of the research effort which followed have been reviewed by Clark (1977) and Provost (1977). A summary of these results has been provided in the remainder of this section. Since the proposal of MacNamara (1952), many studies (including Chapman and Ferrigno, 1956; Franz and Ruber, 1962; Franz, 1963; Mangold, 1962; Shoemaker, 1964; Florschutz, 1959; and Provost, 1959; 1968) have demonstrated that water impoundments in coastal areas can be successfully managed to achieve the dual purpose of eliminating mosquito breeding and encouraging wildlife, especially waterfowl and muskrats.

27. More recent studies have shown that marshes may even be ditched with much less disruption than was previously thought possible if indiscriminate parallel ditching is avoided. A procedure for constructing ditches and ponds for both the elimination of mosquito breeding depressions and the creation of habitats attractive to wildlife has been described by Ferrigno and Jobbins (1968), Ferrigno, et al. (1969) and Ferrigno (1970). This method, referred to as Open Marsh Water Management (OMWM), emphasizes detailed surveys to locate mosquito breeding sites so that a proposal for elimination of breeding sites can be developed for advance review. Before a project is implemented, areas are marked where ditches and/or ponds are to be constructed. During implementation, maximum emphasis is given to proper sod disposal so that natural marsh elevations are maintained—a key element of this management approach. This is achieved by using trained personnel and specialized equipment (Ferrigno et al., 1975). Amphibious rotary ditching equipment falls into the latter category. Equipment of this type cuts a ditch with a rotating cutting head. As the marsh sod is removed, it is shredded and scattered over a broad swath. The resulting spoil deposit never exceeds more than a few inches in depth and consequently, marsh vegetation within the swath is able to recover quickly and no change in species composition is produced. When properly carried out, an overall increase in productivity of marsh subjected to OMWM is observed (Shisler and Jobbins 1977). Another significant aspect of this type of sod disposal is that it avoids the risk of creating new mosquito breeding habitats around hummocks resulting from piles of disposed sod. This method also

has the added advantage of being faster than most other techniques currently available.

IV. PHYSICAL FEATURES OF DIKED

DREDGED MATERIAL DISPOSAL SITES

28. The general subject of navigation dredging and the environmental impacts associated with it have been reviewed by Clark (1977), LaRoe (1977) and Jeane and Pine (1975). However, few references are available which describe mosquito problems related to dredging activities, and since only one comprehensive review of this subject is currently available (Ezell, 1978) a summary of some of the more salient features of this topic have been provided in this report. That dredging activities are a potential source of mosquito production has been known for more than 75 years. One of the earliest such records is provided by William Crawford Gorgas (1915), Chief Sanitary Officer during the construction of the Panama Canal:

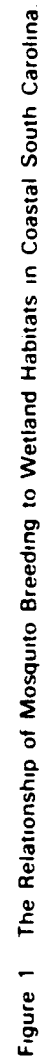
Occasionally, at a station where we had controlled mosquitoes for several years, a great swarm would appear for reasons which we could not explain. These swarms would not remain for a long period of time, and usually they were not made up of anopheles. While they lasted, we used the method of catching infected mosquitoes for the protection of our force. On one occasion, however, we had a large flight of anopheles. They swarmed everywhere about the station, and we could not account for them, or discover where they came from. The sanitary inspectors' department devoted all its spare force to investigating this point, and for a considerable period Mr. Joseph Le Prince who had supervised field operations for the yellow fever eradication program in Havana in 1901 and had a similar responsibility in Panama, devoted all his time to the subject. He finally located the breeding area in a small swamp about a mile from the town. The swamp had existed there during the preceding years when Gatun had been comparatively free from mosquitoes. At this particular time when the anopheles were so troublesome, the engineers had begun to pump silt from the channel of the Canal into this swamp. This silt was carried by salt water, which made the water of the swamp brackish. This brackish water apparently favored development of the anopheles,

and they were produced in enormous numbers. The engineers were requested to pump sea water into the swamp area for a few days. This soon made the water of the swamp too salty for the anopheles, and in a few days the mosquitoes disappeared from the town.

29. A few reports indicate that deposition of dredged material may not always have negative side effects with respect to mosquito breeding. One study (Darsie, et al., 1953) suggests that hydraulic fills for maintenance of the Delaware and Chesapeake Canal eliminated some breeding of the freshwater species *Culiseta inornata*. However, most studies indicate otherwise. Reports by Brooks (1939), Vannote (1945), Helm (1959) in New Jersey; Kinsey (1958) in New York; Ruth (1952) in Virginia; Fehn (1957) in South Carolina; and the Chatham County Mosquito Control Commission (1969) in Georgia represent some of the many documented cases of mosquito breeding in association with hydraulic dredged disposal sites along the Atlantic Coast.

30. Except for a section between Little River and Winyah Bay, most of the AIWW in South Carolina is contiguous with low saltmarsh (i.e., *Spartina alterniflora* and/or *Juncus roemerianus* marsh). Most diked disposal areas are located on low marsh because marshes were deemed to be of little value when these disposal areas were designated. Although further diking of low marsh appears unlikely in view of recent legislation designed to protect wetlands, some areas already diked may be subject to periodic use for many years. Even when dredged material has not been pumped into diked areas, dikes alone produce approximately the same effect as raising the elevation of low marsh. Deposition of dredged material merely accentuates the effect.

31. The relationship of marsh elevation to floodwater mosquito breeding is illustrated in Figure 1. Diked dredged material disposal areas correspond to the category of "unmanaged, impounded marsh" in the illustration. Mosquito breeding associated with diked disposal sites is usually confined to a number of identifiable subhabitats within and immediately outside the dikes. These subhabitats are illustrated in Figure 2 and described in the following paragraphs. More detailed



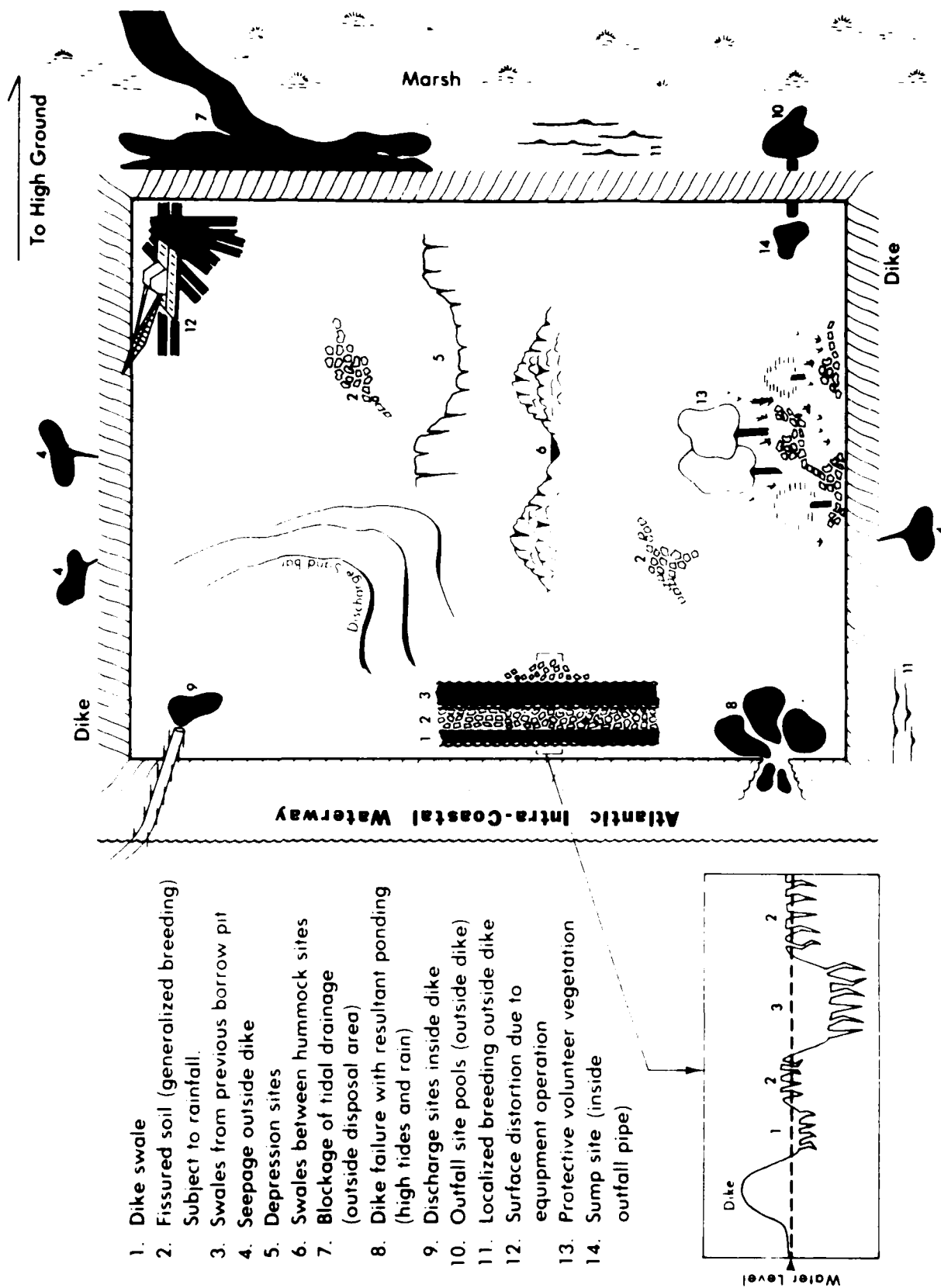


Figure 2 Composite Diagram of Possible Mosquito Breeding Habitats Associated with Dredged Material Disposal Areas (after Ezell 1978)

summaries of these subhabitats with respect to their occurrence and characteristics in parts of the country outside South Carolina have been provided by Ezell (1978).

Structural Features

32. Several mosquito producing subhabitats are usually created when construction of a new disposal site is underway or when dikes of previously existing sites are reinforced. The most significant aspect of these mosquito breeding foci is that some breeding commences almost immediately after the construction work has been completed—the deposition of dredged material is not a prerequisite for initiation of mosquito production, although breeding is usually much more intense after a pumping operation. Since sites are usually constructed or modified far in advance of the time they are needed (to allow sufficient time for dike settling and consolidation) the conditions described below may prevail for several years. Asterisks denote those conditions which may produce mosquitoes both before and after a site is pumped.

33. Dike swales* (item 1, Figure 2): These are areas located between borrow pit swales and dikes. The dike swale consists of a shallow depression bounded on one side by the dike and on the other side by a ridge of soil which usually is only a few inches above the prevailing contour. This ridge is created when soil spills from the dragline bucket as the dragline begins its pivot from the borrow pit to the dike. This area may be continuous around the entire inside perimeter of a site or it may be divided into a series of shallow depressions. The exact depth and conformation of this subhabitat is primarily dependent on the consistency of the borrow pit substrate and the habits of the dragline operator. Dike swales are extremely prone to intermittent flooding and drying and thus, to floodwater mosquito breeding (see also paragraph 45). The adjacent dike is a primary factor in the flooding of the dike swale because the extreme slope of the dike acts as an excellent watershed directing runoff from rainfall into the swale.

34. Borrow pits* (item 3, Figure 2): These areas are created

when fill is removed to provide material for dike construction. In South Carolina, as in most areas of the country, material for dike construction is usually removed from inside the disposal site, 10-15 meters from the dike in most instances. This procedure, called incremental dike construction (Murphy and Ziegler, 1974), results in a pit 1-3 meters deep. This borrow area may be either a continuous pit encircling the site or a series of unconnected pits depending upon the preferences of the dragline operator. Since most disposal sites are constructed in areas where water tables are very close to the surface, borrow pits usually flood immediately after they are excavated. These areas usually remain flooded until dredged material is pumped into a site. Flooded borrow pits usually acquire a minnow population soon after they are flooded. Thus, in most instances the borrow pit is not a significant source of mosquito production prior to the disposal operation. However, occasionally only a small amount of fill is required for the dikes, resulting in a very shallow borrow pit. This type of borrow area is prone to intermittent flooding usually caused by rainfall and it is conducive to mosquito production. Nevertheless, even when these conditions prevail, mosquito production is usually less severe than in dike swales.

35. Double diking* (not illustrated): This is a less frequently employed method of dike construction referred to as the "interior dike" method by Murphy and Ziegler (1974). This method employs a system of new dikes that are added around a disposal area always to the inside of the previous dike. This method does not appear to be in common practice at the present time in South Carolina. However, this description has been included because depressions between successive dikes in the series provide excellent conditions for heavy mosquito production.

36. Blockage of tidal drainage* (item 7, Figure 2): This condition results when dredged material disposal sites are interposed within natural tidal drainage patterns. This results in the interruption and/or redirection of small tidal creeks which drain the marsh. If redirection is complete, no mosquito breeding problem is produced. However, partial or complete interruption of drainage patterns results in the creation of a shallow pond or large puddle at the periphery of the disposal perimeter.

of disposal areas. Such habitats serve as an excellent breeding areas for some mosquito species.

37. Localized breeding outside disposal areas* (item 11, Figure 2): This situation may occur in natural habitats similar to that described in the previous paragraph. Localized breeding habitats differ in one major respect. They usually result from the entrapment of runoff from rainfall in pockets occurring along the outside perimeter of the dike rather than from interruption and entrapment of tidewater. These depressions are excellent floodwater mosquito habitats.

38. Surface distortion* (item 12, Figure 2): This category includes mosquito breeding habitats that are attributable to the operation of mechanical equipment used in the construction and maintenance of disposal sites. This includes ruts created by movement of mechanical equipment and depressions resulting from mats used to support equipment on the extremely unstable marsh substrate. These habitats may take the form of shallow, temporary potholes or larger, deeper, long-lasting depressions. The integrity of these habitats in relation to the overall conformation of the disposal site substrate is frequently retained even after deposition of dredged material. Thus they are likely to produce mosquitoes both before the pumping operation and following the operation once the material begins to consolidate. Flooding of these habitats usually results from rainfall and/or tidal flow.

Features Developing

After Disposal of Dredged Material

39. Most of the subhabitats described in the preceeding section continue to produce mosquitoes after they have been covered by dredged material, although breeding may be briefly interrupted immediately following the pumping operation (see Section V for more details about temporal effects on mosquito production). A more important fact is that the mosquito breeding potential of these subhabitats tends to be increased by deposition of dredged material. As a result larger broods of mosquitoes are produced more frequently. In addition, several subhabitats are

directly associated with dredged material and do not appear until after a site has been used at least once for a disposal operation. Descriptions of these subhabitats are provided in the remaining portion of this section. The modifications to some of the previously described subhabitats which result from deposition of dredged material, are also summarized.

40. Fissured soil: This represents a generalized habitat which occurs in most of the subhabitats that occur inside disposal areas after the disposed material has begun to dry and consolidate. The presence of fissures or cracks in the substrate (see profile diagram, Figure 2; see also paragraphs 63-70) is the best, single, preliminary indication that the substrate will support mosquito production. The composition of the substrate material, the depth of fissures, the effect of aging, weathering and filling of fissures and the density of vegetational stands which become established on the substrate are secondary factors which influence the degree and type of mosquito breeding on fissured substrates. The influence of these factors is described in greater detail in Part V.

41. Seepage (item 4, Figure 2): Following a disposal operation, surface water gradually percolates into the substrate. In some disposal sites, subsurface horizons of the dredged material substrate apparently are nearly impervious to surface water. This situation results in a perched water table. As a result, horizontal percolation of water occurs which is manifested by seepage at the base of the dike around the outside perimeter of the disposal area. Other factors may also influence this effect (e.g., the close proximity of the borrow pit to the dike and improper dike construction) and the relative importance of each of these factors has not yet been established (see Part V for a more detailed discussion of dredged material substrate characteristics). Such seepage may result in the formation of pools along the outer perimeter of the dike, which represent a frequent source of mosquito production. Formation of such breeding areas is especially enhanced if the dike interrupts the natural marsh drainage pattern and/or is juxtaposed with upland areas.

42. Depression and hummock sites* (items 5 and 6, Figure 2): These conditions result when depressions associated with the natural

contours of a disposal site are covered and filled by dredged material. The conformation of these depression areas is reestablished during drying of the dredged material because the depressions initially trap a larger deposit of dredged material than that deposited on surrounding higher substrate contours. This heavier deposit undergoes greater shrinkage from consolidation which results in deeper fissures that enhance the mosquito breeding potential of these subhabitats. A significant aspect of these situations is that their presence and distribution is not readily detected during ground inspections because they are not associated with any prominent landmarks (such as dikes). Thus, they are easily overlooked. For this reason, the heavy mosquito breeding they are capable of supporting may go unabated during control efforts implemented by ground crews.

43. Dike failures (item 8, Figure 2): This situation may result when seepage at the base of a dike (paragraph 41) undermines some portion of the dike around a disposal site. Erosion caused by runoff from rainfall and by the effect of wave and tidal action which occurs in the AIWW, may also result in dike failure. Wave and tidal effects can be magnified by situating the disposal site too close to the AIWW. Dike failure may eventually occur even when several meters of marsh or other substrate are situated between the Waterway and a disposal site if the energy of wave and tidal action is sufficient to gradually erode the substrate which was previously acting as a buffer. An important aspect influencing this effect is the force of waves created by the wakes of passing boats (this problem is particularly acute for disposal sites located in the vicinity of McClellanville, South Carolina; see individual site descriptions for additional details). When a dike is breached in the manner described above, the disposal site frequently becomes prone to flooding caused by spring and storm tides, but not to the flooding caused by the ebb and flow of daily tides. Thus, the site is easily flooded, but not flushed by tidal action. As a result, dike failure provides an excellent means for flooding some of the mosquito breeding subhabitats described in this section. Thus, dike failures tend to enhance and augment mosquito breeding conditions that are already present.

44. Discharge sites (item 9, Figure 2): These sites are

produced when sediments are pumped from a channel under high pressure and this material pours into a disposal area from a single outlet which is usually suspended one meter or less above the substrate. The combined effects of the quantity of material discharged, the pressure or force behind the discharged material and gravity result in the scouring of the substrate at the point of impact on the surface (illustrated in Figure 3). This effect can be avoided if a splash pad is used to absorb the energy of the discharged material. This action of the discharged material results in the formation of a deep depression or crater (about 1.5 meters in depth), which usually persists long after the disposal operation has ceased (at least several years). The bottom of depressions created in this manner usually occur below the prevailing water table. Therefore, they tend to remain partially flooded except during periods of very dry weather. The semipermanent water present in these subhabitats tends to support several species of aquatic and semiaquatic predators that attack mosquito larvae. These predators usually provide effective, natural biological control in the discharge site. However, extremely dry conditions may eliminate populations of predators and transform the depression into an efficient mosquito breeding habitat which is manifested at the beginning of the next period of wet weather.

45. Borrow area and dike swales (Items 1 and 3; Figure 2):

These two subhabitats were previously described in the first part of this section (paragraphs 33 and 34). Additional descriptive information is also provided here because deposition of fresh dredged material dramatically intensifies mosquito breeding in these two subhabitats. The relative mosquito breeding intensity of these two subhabitats also changes after a disposal operation. Prior to disposal of dredged material, mosquito breeding is usually more intense in dike swales. Afterward, more intense mosquito production is usually observed in borrow area swales. Since the borrow pit is nearly always the lowest portion of a disposal site, fresh dredged material fills it before any other part of the disposal area. Therefore, the heaviest deposit of dredged material occurs in the borrow area. As a result, the drying effects of shrinkage consolidation and fissure formation are greatest in the borrow area, making it one of the most suitable—as well as the most extensive—mosquito breeding areas in



Figure 3 Discharge of Dredged Material from a Pipe supported Above the Substrate (top) and from an Unsupported Pipe (bottom). Both Methods Result in the formation of a large mound.

a disposal site. Mosquito breeding conditions in the borrow area are usually further enhanced if a series of borrow holes are created during dike construction instead of a single continuous borrow ditch around the inside perimeter of a disposal area. A series of borrow holes results in a series of depressions following the dredging operation. During wet conditions each of these depressions normally floods, but the floodwater in each depression will not be joined with water in adjacent depressions. Therefore, if small fish or other predatory organisms were to become established in only one of these depressions the effect of their biological control function would remain isolated. In contrast, predators gaining access at a single point of a continuous borrow ditch swale are free to disperse throughout its entirety.

46. Dike swales also tend to concentrate a heavier deposit of fresh dredged material than most other portions of a disposal site. Although the deposit is always less than that occurring in borrow areas, the dike swale deposit is usually sufficient to undergo the shrinkage and fissuring processes which ultimately result in an excellent mosquito producing substrate. One of the most significant aspects of the dike swale subhabitat is that its conformation is reestablished when the deposit of fresh dredged material begins to dry. Therefore, an effective barrier persists between a flooded dike swale and a flooded borrow area swale. Thus, should mosquito predators gain access to either subhabitat, they usually cannot disperse into the other subhabitat. Observations described in the subsequent sections of this report indicate that even when predators gain access to the borrow area swale, mosquito breeding persists in the dike swale.

47. Outfall and sump sites (items 10 and 14, Figure 2): Most disposal sites are provided with drainage weirs, which are installed in the dike. As excess water from a disposal operation (or runoff from heavy rainfall) spills from the outfall pipe of the weir into the marsh, a depression is created by the scouring effect of the water. These depressions usually remain flooded either by water draining from a site, or in some instances by tidal action. Therefore, they usually are not a significant source of mosquito production. However, occasional breeding in these

depressions may occur following periods of unusually dry weather, unusually low tides or rarely when larvae are flushed out by drainage from inside the disposal area and become trapped in the depression. A similar type of entrapment of larvae may also occur within the coffer of the weir in rare instances.

48. The sump area represents a depression which forms immediately behind the weir inside a disposal site. It is often joined to or continuous with the borrow area swale. This depression is apparently the result of the increasing velocity of water draining from a disposal site which occurs near the weir. The velocity of the current apparently reduces the sedimentation rate of particulate matter suspended in the draining water as it approaches the weir. Thus, less material is deposited in the immediate vicinity of the weir than at points more distant from the weir. This effect is of course manifested as a depression. The sump habitat is probably subjected to the greatest amount of drying and wetting fluctuations of any points within a disposal area because it is always one of the lowest spots within a site. Therefore, it is often the most consistent and frequent source of mosquito production found in disposal areas.

49. Protective vegetation* (item 13, Figure 2): Diked disposal areas frequently include ridges of high ground which support upland vegetation including tall trees. Such areas usually result from diking around areas which had previously been used as undiked disposal sites. The vegetation in these areas is important to mosquito development and survival because it provides newly emerged mosquitoes with a means of protecting themselves from the elements. The vegetation in these areas always includes large stands of herbaceous flowering plants. Thus, these areas probably fulfill another important requirement of the adult mosquito life cycle by providing flower nectar as a source of carbohydrates.

50. The ridges of high ground usually possess an irregular surface. Thus, this surface will trap dredged material and establish mosquito breeding depressions if material pumped into an area overflows onto these ridges. Such an overflow frequently kills all vegetation. However, since these ridges supported upland vegetation prior to the kill, they also act as an excellent seed source. Thus, they are important for promoting rapid regrowth of pioneer vegetation which promotes more

rapid reestablishment of mosquito breeding conditions. Biological interactions influencing mosquito production are discussed more thoroughly in the section which follows.

V. CHEMICAL AND BIOLOGICAL FEATURES OF DREDGED MATERIAL DISPOSAL SITES

Introduction

51. The presence or absence and extent of mosquito breeding associated with dredged material disposal areas and other coastal habitats can be easily established from gross field observations. The results of such descriptive surveys are valuable in the applied sense for implementing effective mosquito control measures and a synthesis of such data was presented in the preceeding section of this report. Empirical data and more extensive descriptive data were also collected during this study so that factors influencing mosquito production could be firmly established and better defined. The purpose of this effort was to provide more specific and more accurate information that would (1) improve predictive capabilities for applied control; (2) provide the basis for new and more effective control efforts and (3) establish new directions in basic research which might yield better solutions for mosquito-related problems at some later date.

Dredged Soil Chemistry

52. The important, but yet unclear relationships between the physical and chemical properties of marsh soils and the selection of breeding sites by female saltmarsh mosquitoes about to lay eggs have been reviewed in a previous section of this report (see paragraphs 13-14). Because of this presumed importance of soil factors, several chemical characteristics of dredged material were analyzed in selected sites in South Carolina. The purpose of this effort was primarily descriptive, but the authors also believed that results might provide a more definitive, chemical characterization of known mosquito breeding microhabitats in the field than is currently available.

Literature Review

53. The vast majority of analytical soil studies have been directed toward the characterization of soil suitable for agricultural production. Few attempts have been made to develop a classification system for tidal marsh soils. One of the most significant of these efforts has been provided by Hill and Shearin (1970). In this system, three primary factors were utilized to classify the tidal marshes of Connecticut and Rhode Island: (1) thickness of the surface organic layer; (2) texture of the underlying mineral layer and (3) salinity. This system is particularly useful because all three parameters can be identified in the field if plants are used to estimate salinity. Studies of dredged material substrates appear to be even less common than those for saltmarsh soils. Ezell (1978) has reviewed this small body of literature and has provided data for dredged material substrates in the vicinity of Charleston Harbor, South Carolina.

54. Properties of sediments: The physical and chemical conditions present in sediments before and after they are deposited at the bottom of water bodies are of interest to the study reported herein, because they reflect some of the conditions which prevail in dredged material immediately after a disposal operation. Sediments in coastal areas such as those deposited on the bottom of navigational channels and eventually removed by dredging, often contain a large organic component. Saltmarshes are an important source of such organic material in the form of detritus. Organics within a bottom deposit are decomposed primarily by bacteria. A thin layer near the surface of the sediments usually contains sufficient oxygen, which diffuses into the sediments from overlying water, to support aerobic bacteria. Below this microzone, highly anaerobic conditions prevail. In the anaerobic region, bacterial decomposition of organics usually shifts from a reliance on oxygen to a reliance on sulfate as a hydrogen acceptor. As a result, sulfate is reduced and sulfides are produced in the anaerobic layer. These sulfides react with available iron in the sediments to form hydrous iron sulfide (hydrotroillite) which produces the characteristic black coloration of subsurface marsh

and benthic sediments (Hill and Shearin, 1970). When the rate of deposition of organics is high, as it often is in coastal areas, free sulfides produced by sulfate reduction may exceed the level of available iron. When this occurs, free sulfides build up within a deposit (Bella, 1977). When present, high sulfide concentrations in sediments have an important influence on the nature of substrates produced by dredging operations.

55. As Hill and Shearin (1970) have emphasized, acidity is a useful parameter because it provides a means of distinguishing between marsh sediments that have been permeated with fresh water and those permeated by salt water. Acidity also provides an indication of the relative degree of drying that has occurred in drained sediments such as those resulting from deposition of dredged material on dry land.

56. Sediments exposed to seawater generally exhibit a neutral or slightly alkaline pH which reflects the high pH (approximately 8.0) of seawater. Brackish and freshwater marsh sediments usually are more acid because seawater alkalinity is not available to neutralize organic acids produced by anaerobic decomposition of plant matter. Drying of drained marsh or benthic sediments that have been pumped to the surface is usually associated with an increase in acidity. This process, referred to as sulfur acidity (Flemming and Alexander, 1961), results from the exposure of sulfide-rich sediments to atmospheric oxygen. On exposure to air-drying, the sulfides oxidize to sulfate by chemical and biochemical reactions. If there are not enough alkaline earth carbonates present, sulfuric acid is formed and high acidity results. These soils are similar to problem soils which occur in Holland where they are called Katteklei (cat's clay) soils.

Materials and Methods

57. A total of six disposal sites were selected for the chemical characterization of the dredged soil habitat including four sites on the AIWW, S-10, S-11, G-10 and G-7 and one site in the vicinity of Charleston Harbor adjacent to the campus of the Citadel. One other

site was located on a disposal area in the Maryville section of Georgetown on the south bank of the Sampit River approximately one mile from its confluence with Winyah Bay. This site was selected because it supported a dense stand of reeds (*Phragmites communis*), a plant that is common in many other coastal areas of the United States, but was only recently found in South Carolina (Stalter, 1975). Other criteria, in addition to vegetation also influenced the selection of soil sampling sites. An effort was made to select disposal areas which represented a cross-section of substrate conditions with respect to the length of the time interval since the last disposal operation on the site. Once sites were selected, an effort was also made to remove the soil samples from the highest and lowest points within the area. In some instances, however, relative elevational differences could not be distinguished. The temporal data for the disposal areas included in the soil survey are provided in Table 1.

58. Three fundamental characteristics of the dredged material substrate were chemically analyzed: the acidity or alkalinity (as pH); conductivity (as micromhos/cm) and soil particle size (as percent sand, silt and clay). Samples were collected with a core sampler (5.1 cm, i.d.). Surface samples were isolated by removing the topmost 5.1 cm (two inches) of soil from a core. Subsurface samples were isolated by removing the fraction of a core between 12.7 and 17.8 cm from the surface. The analytical procedures were the same as those used by Ezell (1978).

Table 1. Age of disposal site substrates (computed from the time of the last disposal operation) included in the soil sampling survey.

Disposal Area	Elapsed time since last disposal operation
G-10*	1 year
Citadel*	1 year
G-7*	1 year
S-10	1-5 years

Table 1. (continued)

S-11	1-5 years
Maryville	5 years

*Designates those disposal areas in which relative elevational differences could be distinguished.

Results and Discussion

59. Results of the soil survey have been tabulated in Tables 2-7. The tables have been arranged in approximate order of the age of the substrate beginning with the most recently pumped sites.

60. Acidity and conductivity: Both of these parameters exhibited variations which appeared to be closely associated with the age of the substrate of each disposal area sampled. As expected, an inverse relationship was observed between conductivity values and increasing time following deposition of dredged material. This effect is illustrated graphically in Figure 4. The values shown in the histogram of Figure 4 represent the averages of all surface and all subsurface conductiveness (reported in Tables 2-7) recorded for each disposal area sampled. A similar time-related decline in conductivity was reported by Ezell (1978) for disposal areas in the vicinity of Charleston Harbor. The results of the Ezell (1978) study were combined with the results reported in Tables 2-7. These data were used to construct a histogram for the average conductivity of dredged soil less than one year old, one-five years old and more than five years old (Figure 5). Much of the observed conductivity apparently results from seawater salts deposited in disposal sites as dissolved salts in the mixture of particulate matter and water which makes up dredged material. Conductivity values for some sampling sites exceeded that of seawater which probably represents the precipitation and concentration of salts at the substrate surface as surface water evaporated following a disposal operation. The decline in the salinity of older substrates apparently reflects the translocation of surface salts to deeper strata

Table 2. Summary of physio-chemical factors affecting dredged material habitats on disposal area G-10, Atlantic Intra-Coastal Waterway (mouth of the Waccamaw River).

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s (low)	6.4	85,200	47.0	13.0	40.0
2s (low)	6.6	81,600	43.5	20.5	36.0
Avg. (low)	6.5	83,400	45.2	16.8	38.0
3s (high)	6.2	61,000	57.8	11.8	30.4
4s (high)	5.3	46,000	64.6	6.2	29.2
Avg. (high)	5.7	53,500	61.2	9.0	29.8
1ss (low)	6.3	44,000	65.0	11.0	24.0
2ss (low)	---	-----	----	----	----
3ss (high)	6.4	33,500	78.8	6.8	14.4
4ss (high)	---	-----	----	----	----

s: surface sample ss: subsurface sample

Table 3. Summary of physio-chemical factors affecting dredged material habitats on The Citadel disposal area (Ashley River, vicinity of Charleston Harbor).

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s (low)	6.2	32,000	10.0	31.3	58.7
2s (low)	6.4	45,000	8.6	31.9	59.5
Avg. (low)	6.3	38,500	9.3	31.6	59.1
3s (high)	6.2	30,000	6.1	32.8	61.1
4s (high)	6.5	70,000	3.1	48.6	48.3
Avg. (high)	6.4	50,000	4.6	40.7	54.7
1ss (low)	6.5	36,000	3.5	29.8	66.7
2ss (low)	6.4	40,000	5.3	68.0	26.7
Avg. (low)	6.5	38,000	4.4	48.9	46.7
3ss (high)	7.0	40,000	45.9	31.4	22.7
4ss (high)	6.6	61,000	4.2	49.9	45.9
Avg. (high)	6.8	50,500	25.1	40.7	34.3

s: surface sample ss: subsurface sample

Table 4. Summary of physio-chemical factors affecting dredged material habitats on G-7, Atlantic Intra-Coastal Waterway, Isterville.

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s (low)	6.0	11,760	46.9	21.5	31.6
2s (low)	5.9	38,400	68.4	22.8	8.8
Avg. (low)	5.9	25,080	57.7	22.2	20.2
3s (high)	5.8	25,000	48.1	25.2	26.4
4s (high)	6.0	12,100	78.5	20.7	0.8
Avg. (high)	5.9	18,550	63.3	23.0	13.6
1ss (low)	6.6	31,200	59.4	26.9	13.2
2ss (low)	5.0	30,750	41.9	25.3	32.8
Avg. (low)	6.3	30,975	50.9	26.1	23.0
3ss (high)	5.4	21,000	63.9	17.7	18.4
4ss (high)	6.2	8,800	44.1	14.1	41.8
Avg. (high)	5.8	14,900	54.0	19.4	26.6

s: surface sample ss: sub-surface sample

Table 5. Summary of physio-chemical factors affecting dredged material habitats on S-10, Atlantic Intra-Coastal Waterway at Watt Cut (between North and South Edisto Rivers).

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s	4.5	15,600	42.8	17.0	40.2
2s	4.0	18,400	61.2	17.6	21.2
3s	4.8	17,500	47.2	17.6	35.2
4s	4.7	39,000	29.1	14.5	56.4
Avg.	4.5	22,625	45.1	17.7	37.2
1ss	5.1	17,500	26.3	39.3	34.4
2ss	4.7	19,500	18.3	39.9	41.8
3ss	4.9	12,500	59.9	26.5	19.7
4ss	5.9	41,000	48.9	16.7	34.4
Avg.	5.1	22,700	37.9	31.9	30.2

s: surface sample ss: sub-surface sample

Table 6. Summary of physio-chemical factors affecting dredged material habitats on disposal area S-11, Atlantic Intra-Coastal Waterway at Watts Cut (between North and South Frio Rivers).

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s	---	-----	30.7	22.5	46.8
2s	4.7	11,500	28.7	24.1	47.2
3s	4.7	8,800	31.8	25.4	42.8
4s	---	-----	31.1	26.1	42.8
Avg.	4.7	10,150	30.6	24.5	44.9
1ss	---	-----	47.7	21.5	30.8
2ss	4.6	15,750	64.6	20.6	14.8
3ss	---	-----	33.1	21.5	44.4
4ss	4.3	8,710	16.5	37.1	46.4
Avg.	4.4	12,233	40.7	25.2	34.1
s1: surface sample			ss1: subsurface sample		

Table 7. Summary of physio-chemical factors affecting dredged material habitats on Maryville disposal area (Georgetown County).

Sample No.	pH	Conductivity (Micromhos/cm)	Percent		
			Sand	Silt	Clay
1s (high)*	6.3	12,400	74.4	12.4	13.2
2s (high)	5.7	14,200	73.7	17.5	8.8
Avg. (high)	6.0	13,300	74.1	15.0	11.0
1ss (high)	7.0	8,150	74.00	15.6	10.4
2ss (high)	7.1	6,000	71.7	14.3	14.0
Avg. (high)	7.1	7,075	72.9	15.0	12.2

* Samples not collected from the low point on the site because extremely dense vegetative cover made identification of the low point impossible.

s1: surface sample ss1: subsurface sample

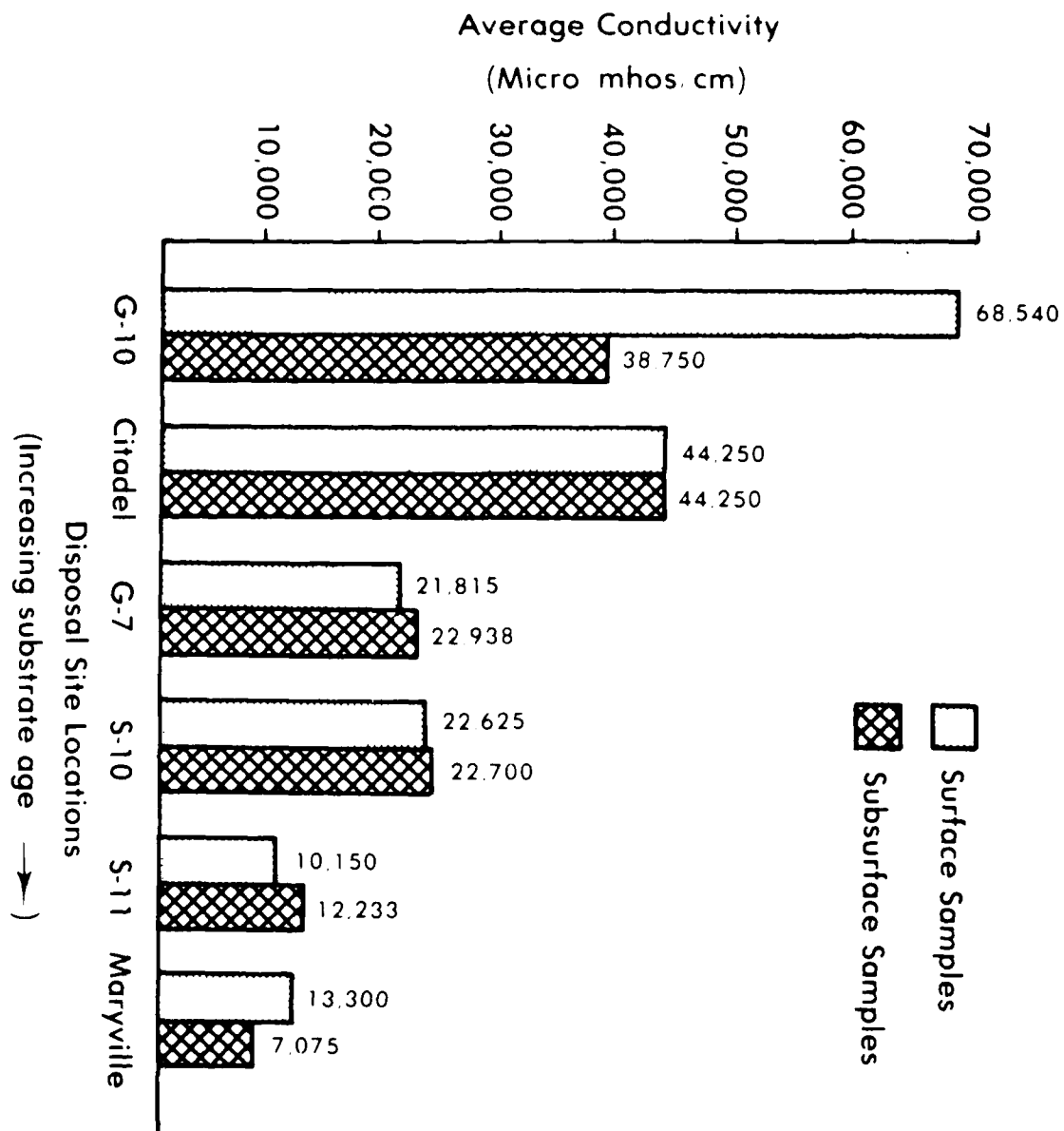


Figure 4 The Average Surface and Subsurface Conductivity of Dredged Soil from Six South Carolina Disposal Areas

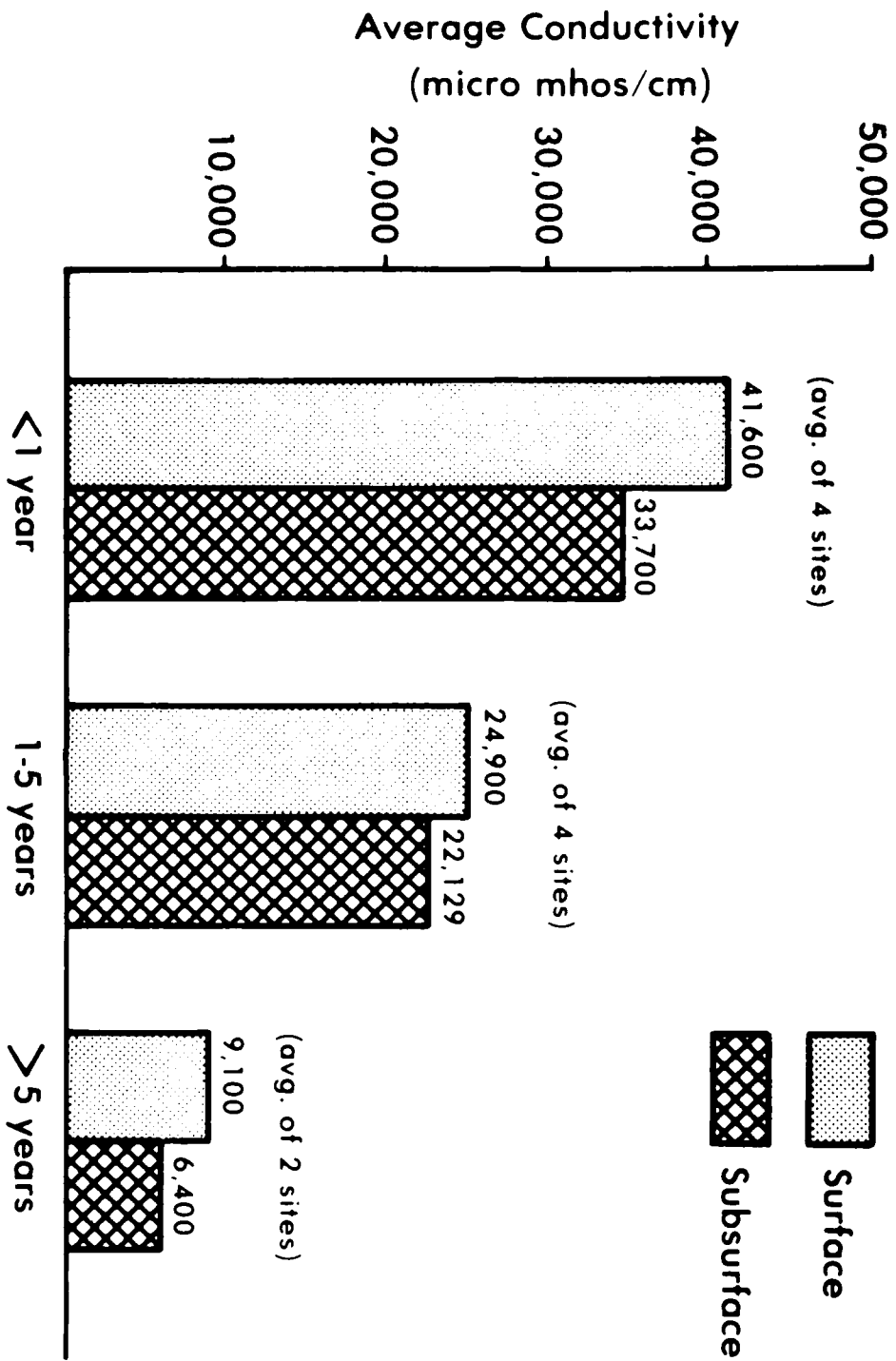


Figure 5. The Average Surface and Subsurface Conductivity of Dredged Soil Less Than 1 Year Old, 1-5 Years Old and More Than 5 Years Old (after Ezeil, 1978, in part)

caused by the leaching effect of water deposited from rainfall.

61. The pH tended to be near neutrality in samples from sites which had recently been filled with dredged material. These sites (G-10, Citadel and G-7) exhibited a pH range of 5.8-6.8. In contrast, sites with a one to five-year-old dredged material substrate (S-10 and S-11) exhibited more acid conditions with a pH range of 4.0-5.9. These results are consistent with the effect of sulfur acidity because an interval of time is required for the slow drying and oxidation processes associated with the formation of sulfur acidity. The development of surface fissures in the substrate is associated with drying and undoubtedly enhances the process by increasing the amount of surface area which is exposed to the atmosphere. The pH of the Maryville site ranged between 5.7 and 7.1 which suggests that sulfur acidity produced during the drying process of dredged material may eventually be partially neutralized either by leaching, plant-substrate interactions or some other process as yet unknown. However, the results obtained from this disposal site probably should not be regarded as conclusive because samples were only recovered from the highest elevation of the site. This substrate may have been influenced by the neutralizing effect of a deposit of marl which occurred in the immediate vicinity of the discharge site. Results provided by Ezell (1978) from Charleston Harbor sites tend to support the view that pH values tend to drop and then regress back toward neutrality during a period of several years after a site is pumped. All disposal areas sampled in the Charleston Harbor study (Ezell, 1978) however, exhibited higher pH values than these for sites sampled for the present report, although relative differences between substrates of different ages appeared to be approximately the same. The more alkaline conditions in the Charleston Harbor sites appear to reflect the influence of a higher concentration of seawater (pH about 8.0) in the dredged material slurry deposited on these sites. A higher seawater concentration would be expected because the Charleston Harbor sites are closer to the Atlantic ocean than the AIKW sites that were sampled.

62. Sand, silt and clay: The composition of the substrate with respect to particle size appeared to influence the extent of substrate

fissure formation and the duration of the fissured soil stage in the aging process of dredged material. Ezell (1978) has provided detailed descriptions of stages in the drying cycle of dredged material with respect to mosquito breeding, and these stages have been summarized in a subsequent section of the present report (paragraphs 63-70). Fissures usually form within the first year following a disposal operation and their presence is nearly always associated with mosquito breeding. These fissures normally exhibit a weathering and filling pattern with increasing age (1-5 years following disposal of dredged material). Sites less than one year old (listed in Tables 2-4) followed the expected pattern, but in the case of the Esterville (G-7) disposal area, the pattern appeared to be greatly accelerated. Within a period of one year, the substrate dried, fissures formed, weathered, and were completely filled. In reviewing the data for the three sites less than one year old, the two areas (G-10 and The Citadel) with the highest clay content in the surface layer (range between 29.8 and 61.7 percent) exhibited a slower aging pattern (longer retention of surface fissures) than the Esterville site (range of the surface clay content between 13.6 and 31.6 percent). Explanations of this observation based on other factors such as sand and silt content appear less useful in explaining the differences. For example, the sand content at the Esterville site was high (48.1-63.3 percent), but it was also high at the (G-10) site (43.5-64.6 percent) where fissures were retained much longer. Ezell (1978) has noted that the establishment of vegetation on fissured dredged soil appears to slow the weathering and filling of fissures. This observation was believed to result from the formation of a root mat which physically held together the clods of the dredged material mosaic between the fissures. Results from the present study suggest a second factor. Electrostatic forces between clay particles when present in sufficient concentration in the surface layer apparently have an important role in the formation and retention of surface fissures. The establishment of a root mat by pioneering forbs and grasses probably slows the rate of translocation of the surface fines (clay particles required for fissure retention) to deeper strata. Other factors may also be important. For example, the amount of organic material

present in the substrate (which was not measured for this study) may influence fissure formation and retention. Further studies encompassing additional variables would probably be useful in characterizing more elaborate substrate interactions influencing fissure formation.

Comparative Survey of Mosquito Breeding in
Coastal Habitats of South Carolina

63. That the presence of fissures in dredged material disposal areas is probably the best single indicator of mosquito breeding was previously mentioned in this report. The fissured stage and conditions prior to and following fissure formation have been classified according to physical substrate characteristics and the floral and faunal species composition inhabiting the substrate (Ezell, 1978). This classification system is especially useful for applied mosquito control operators because the stages are easily identified in the field and the stages most likely to support mosquito production have been described. A total of eight stages bearing the abbreviation DM (for dredged material) were identified by Ezell (1978). A descriptive summary of these stages follows. A summary diagram of these stages is provided in Figure 6.

64. DM-1 (supernatant liquid): This initial stage of the disposal site habitat begins as soon as deposition of dredged material on the surface of a site ceases. It is marked by the partitioning and sedimentation of particulate matter suspended in the slurry of dredged material. Many species of aquatic insects invade the overlaying layer of supernatant water that marks this stage. They usually inhabit the site until the supernatant water is lost by evaporation and percolation. This process is usually complete in six months or less but the duration is, of course, influenced by seasonal and daily weather patterns. Mosquitoes are not usually associated with this stage.

65. DM-2 (bare mud): This is a transitional stage characterized by an unbroken mud flat. It is not significant as a mosquito producer. This stage precedes the formation of mosquito producing stages by about six-eight weeks. Thus, it is a good indicator of the approximate time of onset of mosquito breeding within a site.

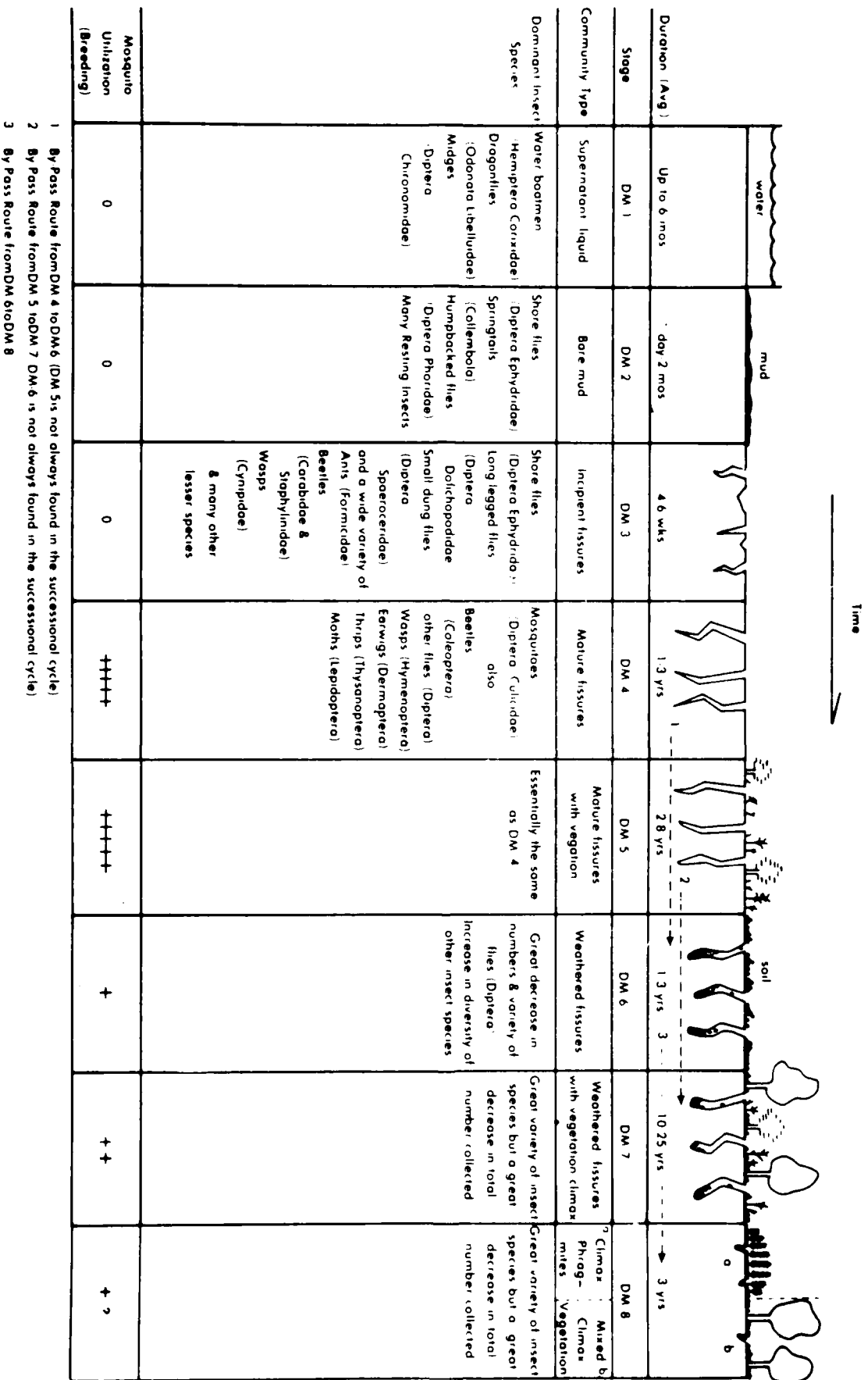


Figure 6 Summary Diagram of Insect Habitats Based upon Dredged Soil Weathering Conditions (after Ezell, 1978)

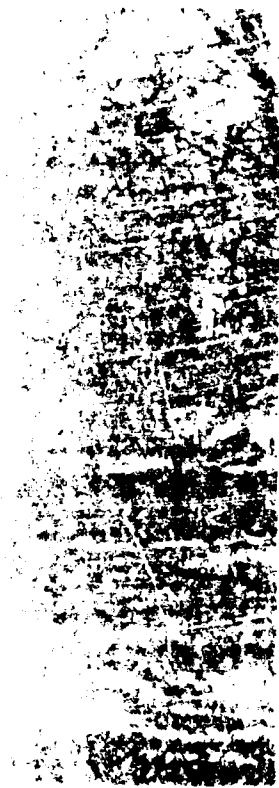
66. DM-3 (incipient fissure formation): This is also a transitional stage resulting from further drying of the mud flat characteristic of DM-2. It is always marked by the presence of shallow, tenuous fissures. It may also be marked by the presence of the white, siliceous remains of diatoms stranded on the surface of the mud when supernatant water evaporated. These deposits frequently persist through subsequent stages. This stage rarely lasts longer than six weeks and no mosquito breeding is associated with it. However, Ezell (1978) found that overall arthropod diversity was highest in this stage.

67. DM-4 (mature fissures): In this stage, the differential rate of drying at surface and subsurface strata is manifested by a greater rate of shrinkage near the surface. As dehydration continues, deep fissures form (10-60cm and occasionally more in depth). When viewed from above, the fissured surface of dredged material appears as a mosaic of blocks (see Figure 7). Such fissures form ideal mosquito breeding microhabitats because rainfall is trapped at the bottom of them. The duration of this stage is approximately 1-3 years. If the duration is short, fissures may fill before pioneering vegetation has had sufficient time to become established. In this case, the DM-4 stage advances directly to the DM-6 stage.

68. DM-5 (vegetated fissures): When the DM-4 stage persists for more than a year and/or when seed sources are in close proximity to or inside a disposal site, a dense stand of vegetation may become established on the fissured surface (see Figure 8). *This condition appears to be the most favorable situation for mosquito production on a fly ash site* (and perhaps anywhere in the coastal environment). The vegetative layer has several roles in relation to mosquito production: (1) it reduces air circulation and insolation within the fissures and this reduces evaporation of water within fissures. This stabilizes the mosquito breeding microhabitat. The extent of the possible offsetting effect of transpiration is not known. (2) It provides a more protected habitat which provides for greater survival of adult mosquitoes—especially for emerging adults. (3) It contributes to the fulfillment of the energy needs of adult mosquitoes by providing



Figure 1. (top) Micrograph of the material with siliceous deposit (see caption for DM 4 Stage (bottom))



a source of carbohydrate in the form of flower nectar.

69. DM-6 (weathered fissures) and DM-7 (weathered fissures with vegetation): DM-6 conditions normally follow the DM-4 stage if weathering of fissures is rapid. DM-7 conditions result when weathering of fissures is slow and is further retarded by the tendency of vegetation to maintain the fissured substrate. The DM-4 to DM-5 to DM-7 sequence usually represents a series of conditions which support heavy and sometimes nearly continuous mosquito breeding for many years. The DM-4 to DM-6 succession usually results in less intense mosquito production which is maintained for a shorter duration of time. Nevertheless, even in this latter case, mosquito breeding is nearly always sufficiently severe to require control measures.

70. DM-8 (climax stage): This stage is represented by the development of tall woody shrubs and trees with a closed canopy. Although usually less intense, mosquito breeding may persist during this stage especially if the DM-4 to DM-5 to DM-7 successional sequence has preceded it. Another type of climax stand is the grassy monoculture produced by *Scirpus americanus*. This condition is a climax in the loosest sense of the term because no other vegetational species are usually observed to precede its development. Once the monoculture of *S. americanus* is established, it appears to persist indefinitely. This species is probably most accurately viewed as a persistent ruderal. When a new dredging operation results in destruction of a phragmites stand, this species is able to rapidly reestablish itself by the production of new stems which penetrate through the new layer of overlaying dredged material.

71. Although the presence and extent of mosquito breeding has been described for the stages listed in the preceding paragraphs, no thorough study of the species composition of mosquitoes occurring in the dredged disposal areas of South Carolina is currently available. Also, little or no information is currently available about the relative intensity of mosquito breeding in dredged disposal areas when compared with other coastal habitats of the state. Therefore, the following study was made to provide data about mosquito species composition and breeding intensity.

Materials and Methods

72. Three types of habitats were surveyed with emergence traps to characterize mosquito production. The habitats studied included dredged disposal areas, waterfowl management impoundments (commonly referred to as duck ponds and henceforth this vernacular terminology will be used in this report) and natural high marsh (see Figure 1 for the relative position of high marsh in South Carolina coastal areas) associated with barrier beach islands. Twenty-five wooden frame emergence traps covered with nylon screen were used to sample mosquito production. Each trap covered one square meter of substrate. The collecting containers for the traps were fashioned from one-quart polyethylene ice cream containers by cutting a hole in the bottom of each container and glueing a polyethylene funnel (in the inverted position) over the hole. A trap and collecting container are illustrated in Figure 9. Fifteen sampling stations were located in dredged disposal areas: six on dredged substrates which had aged less than one year; six on substrates 1-5 years old; three on sites more than five years old. Five sampling stations were also established on each of the other two habitat types studied. However, two of the duck pond sites were later dropped from the survey because of a logistical problem with collecting samples. An effort was made to establish at least one sampling location representing each type of habitat studied in each of the three geographical areas included in the survey: Charleston, Georgetown and Beaufort-Colleton counties. Traps were collected once or twice per week from 30 June-28 September 1977. Traps were relocated each week to sample a previously unsampled portion of the same substrate type within each study location. A record of rainfall and surface water depth was maintained for each sampling location.

Results and Discussion

73. Six different species of mosquitoes were collected during the survey. Most specimens collected were either *Aedes taeniorhynchus* or *A. sollicitans*. The level of mosquito breeding observed in coastal



Figure 9

Figure 9

South Carolina during the summer months of 1977 was lower than had been anticipated. This apparently resulted from extremely dry conditions throughout the period. For example, the site (N-21) which received the most rainfall, received only 12.5 inches during the entire 3-month period of the survey. Total rainfall in excess of ten inches during the 3-month span was recorded at only three of the other 24 locations sampled.

74. Records of mosquito emergence at each of the sampling sites have been tabulated in Table 8. Most of the mosquito production indicated in Table 8 occurred at the end of the summer when more rainfall was recorded than at the beginning of the survey. The two locations producing the most mosquitoes were at N-7 and Bear Island, a dredged material disposal site and a duck pond, respectively. These results tend to support the view that the artificial, man-made habitats are responsible for more mosquito production than high, natural saltmarsh. When weekly emergence trap records were reviewed, a pattern of nearly constant emergence of small numbers of mosquitoes in the range of 10-20 per square meter of sampling area was noted for the natural marsh sites. In contrast, mosquito emergence from the modified habitats (i.e., dredged disposal sites and duck ponds) occurred in the form of fewer but very large broods. The production of these broods was closely associated with periods of heavy rainfall. These results indicate that normal tidal fluctuations have little influence on mosquito breeding in the modified habitats. However, tidal action is apparently the dominant factor influencing mosquito production in natural saltmarsh habitats. Whether or not this factor would remain dominant during years with heavier rainfall is not known. Nevertheless, the tidal influence on mosquito breeding clearly is a more important factor in natural marsh locations than in modified habitats.

75. The dominant species recorded for the summer of 1977 was *A. triseriatus*. *A. albopictus* was present as a second dominant but was exceeded by *A. triseriatus* by a ratio of more than 6-1. Askey (1977) has suggested that during some years, *A. albopictus* appears to be more prevalent than *A. triseriatus* in South Carolina and that the relative abundance of these two species may fluctuate according to some as yet unclarified cycle. Results from the present study are not

Table 8. Mosquito emergence at 25 saltmarsh locations in South Carolina during the summer of 1977.

LOCATION OF SITE	SPECIES COLLECTED ¹				
	<u>taken</u>	<u>Aedes solli</u>	<u>An. tritaeniorhynchus</u>	<u>Ps. ciliatus</u>	Unidentified TOTAL
<u>Georgetown</u>					
<u>County</u>					
<u>Disposal Sites:</u>					
G-7 [*]	1	11	2		14
Maryville ^{**}					0
G-10 [*]	6	6	10		22
<u>Charleston</u>					
<u>County</u>					
<u>Duck Ponds:</u>					
Murphy I. (#1)	4				4
Murphy I. (#2)	22		1		23
Santee Gun Club ⁺					0

Table 8. (continued)

LOCATION OF SITE	SPECIES COLLECTED ¹				
	<i>Aedes taen</i>	<i>Aedes sol</i>	<i>An. trita</i>	<i>Culex sal</i>	<i>Ps. colu</i> Unidentified TOTAL
<u>Charleston</u>					
<u>County</u>					
<u>Barrier</u>					
<u>Beach Sites:</u>					
Long I. (#1) 336	3		6	2	347
Long I. (#2)					0
Morris I.					0
<u>Charleston</u>					
<u>County</u>					
<u>Disposal</u>					
<u>Sites:</u>					
Citadel [*]	96	297	4		397
N-21 [*]					0
N-16 (#1)					0
N-16 (#2)					0
N-14 (#1)					0
N-14 (#2)					0
N-7	18,570	2,620		10	21,200
S-8					0
N. Drum I. ^{**}					0
S. Drum I. ^{**}	2	1			3

Table 8. (continued)

LOCATION OF SITE	SPECIES COLLECTED ¹					
	<i>Aedes</i> <i>tenu</i>	<i>Aedes</i> <i>solt</i>	<i>mite</i>	<i>An</i> <i>brui</i>	<i>Culex</i> <i>sal</i>	<i>Ps</i> <i>colu</i>
					Unidentified	TOTAL
<u>Beaufort/</u>						
<u>Colleton</u>						
<u>County</u>						
<u>Disposal</u>						
<u>Sites:</u>						
S-15*	48	34		117	21	251
S-21*		4				0
<u>Beaufort/</u>						
<u>Colleton</u>						
<u>County</u>						
<u>Barrier</u>						
<u>Beach Sites:</u>						
Hunting I. (#1)						0
Hunting I. (#2)	525	27	2			554
<u>Beaufort/</u>						
<u>Colleton</u>						
<u>County</u>						
<u>Duck Ponds:</u>						
Bear I.	3,767	750		31	13	4,561

Table 8. (concluded)

LOCATION OF SITE	SPECIES COLLECTED ¹					TOTAL		
	<i>Aedes taen</i>	<i>Aedes soll</i>	<i>An nite</i>	<i>Culex brad</i>	<i>Ps colu</i>			
TOTALS FOR ALL SITES:	23,351	3,779	8	165	54	2	21	27,380

¹ Abbreviations: *An*, *Anopheles*; *Ps*, *Psorophora*; *taen*, *taeniorhynchus*; *soll*, *sollittans*; *nite*, *nitellae*; *brad*, *bradleyi*; *sal*, *salinarius*; *colu*, *columbiae*.

- * Dredged substrate less than one year old.
- ** Dredged substrate more than five years old.
- + Sampled during July, 1977 only.

N.B.: All disposal sites not otherwise designated had a dredged substrate between one and five years old.

sufficient to either confirm or refute this view. However, if such a cycle does occur, the results of the 1977 survey indicate that *A. taeniorhynchus* is possibly a more successful species than *A. sollicitans* when abnormally dry conditions prevail. A seasonal cycle in the relative abundance of these two species could also account for the observed results. Evidence for such a cycle has been observed in North Carolina disposal sites (Scotton, 1977). This study indicated that the abundance of *A. sollicitans* eggs was much lower during the mid-summer months than during the fall.

76. Closer analysis of the different types of dredged material sites sampled for this study indicates that additional factors probably influenced the differences in abundance of the two dominant aedine species. Disposal areas with a substrate less than one year old had a more even distribution of these two species than sites with older substrates (1-5 years old; cf. results from The Citadel and S-15 sites with those from N-7). Possible explanations for these differences include (1) the presence or absence of vegetation; (2) substrate salinity and (3) substrate acidity.

77. Vegetation: The N-7 site, where *A. taeniorhynchus* was more prevalent, had a well-developed layer of herbaceous plant growth (substrate stage late DM-5 or early DM-7). The S-15 and Citadel sites, where *A. sollicitans* was more prevalent, supported no vascular flora (substrate stage DM-4). Therefore, *A. sollicitans* may be better adapted to non-vegetated dredged material substrates while *A. taeniorhynchus* may have a dependence on some aspect(s) of vegetation. Evidence that vegetation may have an important role in oviposition site selection has been found in North Carolina. Scotton (1977) reported that significantly higher numbers of eggs were found in association with the exposed surface roots of live *Aster subulatus* than with any of the other habitats sampled. However, this association was manifested for both *A. taeniorhynchus* and *A. sollicitans* and the fall *A. sollicitans* peak was postulated as being influenced by the flowering season of *A. subulatus*. Inflorescences were thought to provide nectar which resulted in increased production of *sollicitans* eggs.

78. Results of soil conductivity measurements of disposal site substrates exhibiting different degrees of aging suggest an obvious correlation between declining salinity and colonization by aedine mosquitoes. These results indicate that *A. sollicitans* may tolerate higher substrate salinities than *A. taeniorhynchus*. The mechanism of this response is unclear, however, especially since previous studies have yielded conflicting results. Petersen (1969) has discussed earlier studies which suggest a direct correlation with substrate salinity. However, results of Petersen's 1969 study conflict with this view and suggest that salinity may be more important as a repelling factor rather than as an attracting factor. A negative response, such as this, nevertheless, could still account for the observed differences in abundance observed in the survey results reported here. Such a postulated inhibitory role of salinity implies that the two aedine species would have different thresholds of sensitivity to substrate salts with *A. sollicitans* being less inhibited by higher salinity levels than *A. taeniorhynchus*.

79. Acidity: Increasing substrate age within dredged material disposal sites was also correlated with a decline in the pH of the substrate (an effect apparently caused by the production of sulfur acidity). Thus, colonization of sites by *A. taeniorhynchus* and *A. sollicitans* may have been governed by a response to pH rather than salinity. Support for this view in previous laboratory studies is more convincing than for the salinity theory. McGaughey (1968) observed that laboratory-reared *A. taeniorhynchus* exhibited a negative response to sodium chloride salinity. However, unlike the Petersen (1969) interpretation, sulfate salinity appeared to elicit a positive response in *A. taeniorhynchus*. This result was interpreted as more likely being a response to the production of sulfur acidity rather than a direct response to sulfate ions. Further support for this argument was provided by the fact that the repellent effect of sodium chloride could be removed if sulfuric acid was also added to the oviposition substrate. The acidity parameter also appears to explain the response of *A. sollicitans* to oviposition substrates. As McGaughey (1968) has emphasized, *A. sollicitans* breeding in inland habitats has been associated with the acid tailings of mining operations. Thus substrate activity

generated by sulfate reactions appears to provide a better explanation which is consistent with the observed response of saltmarsh *Aedes* spp. to potential oviposition substrates. Field data from the present study are consistent with this interpretation. However, further field investigations are needed to corroborate this theory of oviposition site selection and elucidate possible interactions with other substrate chemistry factors. Such studies would undoubtedly yield a more precise definition of the oviposition niche of saltmarsh mosquitoes.

Summary and Conclusions

80. Data about the chemical and physical composition of dredged material disposal sites was presented. The possible relationship between these factors and mosquito breeding habitats was discussed. Mosquito breeding in South Carolina saltmarshes in 1977 was monitored with emergence traps. The relative abundance of mosquitoes in natural marsh habitats, dredged material disposal sites and duck ponds was compared. Some possible areas for further research emphasis were suggested.

81. Results of the study provided the basis for the following conclusions:

82. *Aedes taeniorhynchus* was the dominant mosquito species breeding in South Carolina saltmarsh habitats in 1977.

83. *Aedes sollicitans* was the second dominant species.

84. The abundance of the two dominant species appeared to be more nearly equal in disposal sites with substrates supporting little or no vegetation (newer disposal areas).

85. As dredged material aged, substrate conductivity declined and substrate acidity increased. The increase in acidity appeared to be followed by a period of decline in the oldest disposal sites sampled.

86. Substrate acidity appeared to be a better parameter than conductivity for explaining the utilization of dredged material as a breeding site by saltmarsh spp. However, an interaction between these two parameters could also be an important determining factor and this possibility was not explored.

87. Percent clay in the surface substrate layer of dredged material appeared to be the most important factor influencing fissure development and retention.

VI. INVENTORY OF DIKED DREDGED MATERIAL
DISPOSAL SITES USED FOR MAINTENANCE OF
THE AIWW IN SOUTH CAROLINA

88. During the course of this study a survey was made of all diked disposal sites used for the maintenance dredging of the AIWW in South Carolina. Results of these ground and aerial inspections follow. The major purpose of this survey was to assess the mosquito producing capabilities of each site. Emphasis was placed on assessing the extent of mosquito breeding occurring on each site, determining and describing the exact locations within a site which were producing mosquitoes, identifying the species present and making an assessment of whether or not breeding intensity was likely to change as the site aged. A system was devised for evaluating each site. Inspections were made to determine if specific structural features and subhabitats frequently associated with disposal sites were present or absent (see paragraphs 32-50 for a detailed description of these structural features and subhabitats). A determination of the mosquito breeding capability of each subhabitat present in a site was made by sampling with a one-pint dipper and by observing whether or not the substrate condition (e.g., presence or absence of fissures) was conducive to mosquito production (see paragraphs 63-71 for a detailed description of the successional stages associated with the aging and drying processes of disposed dredged material). The results of inspections were tabulated and used to estimate the overall mosquito breeding potential of each site. The breeding potential was described with a scale of 0-5 with the highest value being indicative of the most intense mosquito breeding possible.

89. A descriptive summary of each level of intensity follows:
(0) no mosquito production; (1) capable of occasional, low density mosquito breeding comparable to or less than the breeding intensity found in natural, low (*Spartina alterniflora*) saltmarsh (rarely or never a source of nuisance level, adult mosquito populations); (2) capable of producing occasional mosquito broods which exceed nuisance level; (3) capable of producing mosquito broods which exceed nuisance levels at frequent but indefinite intervals (broods usually correlated with

rainfall only); (4) capable of producing mosquito broods which exceed nuisance levels at frequent definite intervals (mosquito broods correlated with both rainfall and spring tides); (5) capable of constant, sustained mosquito breeding (populations in excess of nuisance levels constantly emerging). The extremes of the scale (0 and 5) are essentially hypothetical situations which never or very rarely occur. Except for a few areas such as those with a pure sand substrate, no area can be described as completely incapable of producing mosquitoes. Constant, heavy mosquito production is equally unlikely because such a situation obviously would require permanently flooded breeding sites--a situation which would also be conducive for the production of small fish and other predators which would limit the size of mosquito populations. Therefore, all disposal sites described in this study have a mosquito breeding potential which is greater than zero and less than five.

90. The disposal site evaluations described in the remainder of this report are grouped according to the counties the sites are located in with a brief introductory comment about general conditions occurring in each county. Aerial views of most of the major sites surveyed have been provided. These plates represent enlargements made from negatives photographed at a scale of 1:20,000. Since the size of disposal areas in the Charleston District varies from less than ten to well over 100 acres, it was necessary to vary the scale of the enlargements to produce reproductions that illustrated each site with adequate detail. Most of the plates represent enlargements to a scale within the range of 1:2,500 to 1:8,000. Acreage estimates were made directly from the original 1:20,000 negatives using a compensating polar planimeter.

91. Designations for each site evaluated have been listed according to the system used by the Charleston CE District and also according to a separate system used during this study. The CE system involves the use of station numbers as they appear on the official aerial maps of the AIWW in the Charleston District. The system used in this study involves a prefix (H or G) for the Horry and Georgetown County sites, followed by a number. Numbers for sites in Horry County have been ascribed in ascending order when proceeding from north to south on the AIWW. Numbers for sites in Georgetown County have been ascribed

in ascending order from south to north on the AIWW. Thus, G-7 is north of G-6 but H-7 is south of H-6. The remaining sites are designated with a prefix N or S depending upon whether they are north or south of Charleston Harbor. This system of notation is the same as that used by personnel of the Charleston County Mosquito Abatement Program. In the inventory of sites, which follows, the CE designation is given first and is followed by the notation used during this study in parentheses.

Section 1: Horry County

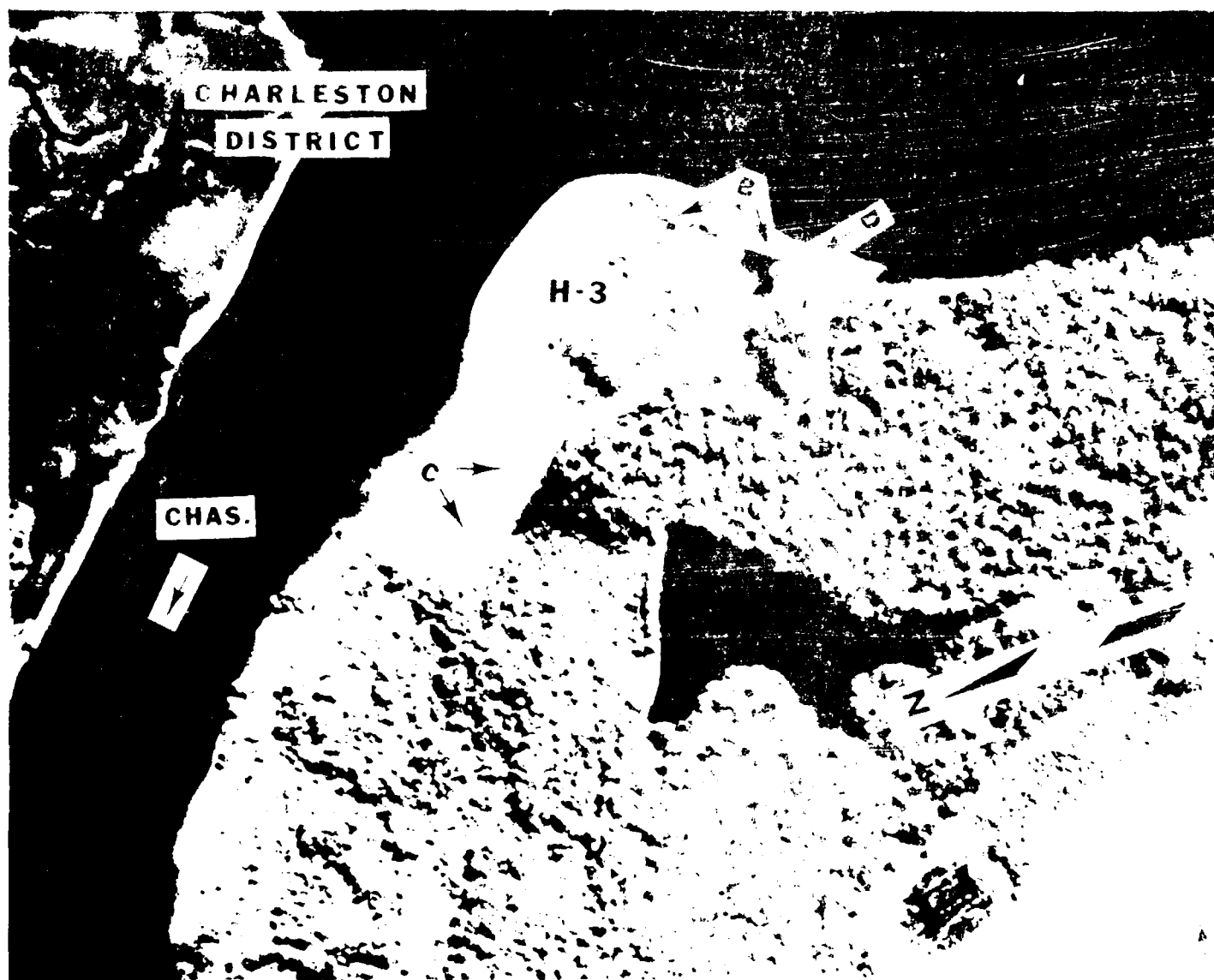
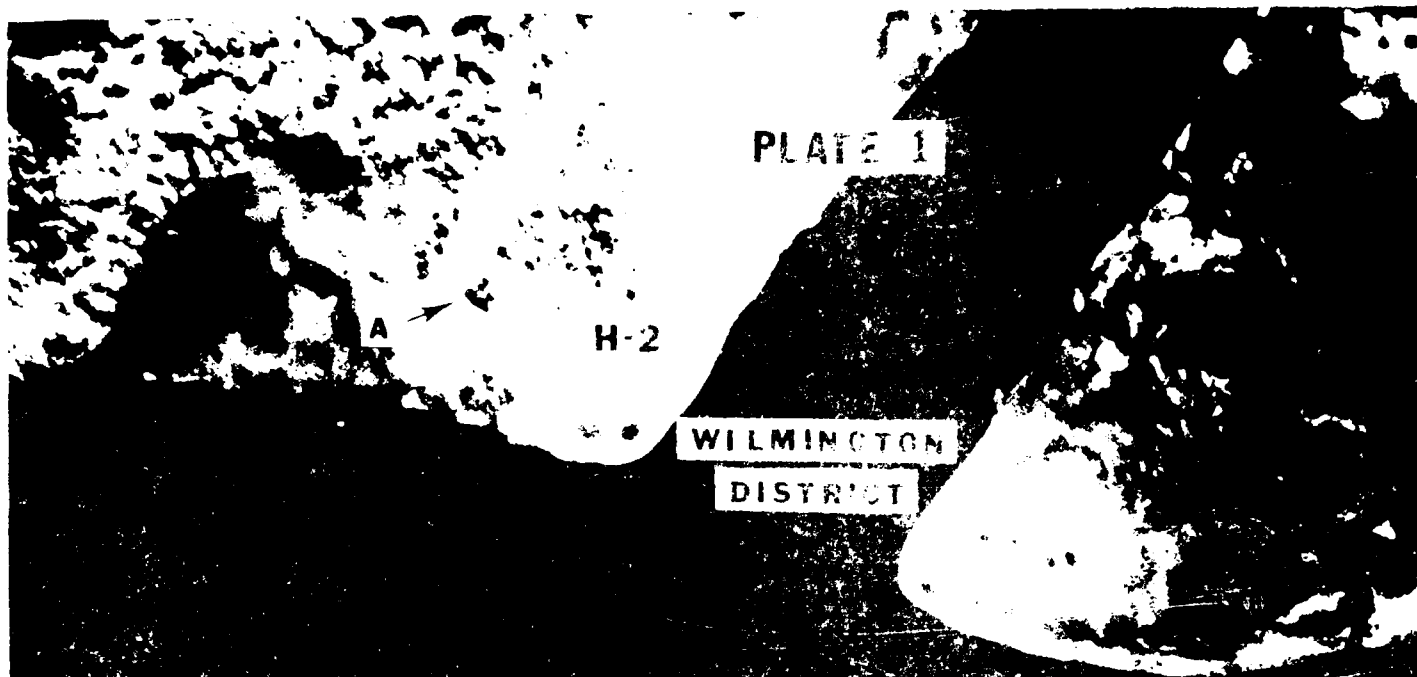
92. Dredged material disposal sites in Horry County are limited to a section of the AIWW north of statute mile 345 (the extreme north end of the county). Two of the sites (H-1 and H-2) are located north of the north boundary of the Charleston District. A portion of H-1 is located in North Carolina. All of the sites are located in the vicinity of the town of Little River or in the vicinity of the confluence of Calabash Creek and Little River. Some of the sites were well-drained and represent only minor mosquito breeding sources. One site, H-4, possesses what was believed to be all the best design characteristics which minimize mosquito breeding. Thus, it could serve as a model for future construction and modification of disposal areas.

SITE DESIGNATION: STA. #59 L-W (H-1); STA. #92 L-W (H-2)

Summary

93. Only a summary is provided here for these two sites because they are located beyond the north boundary of the Charleston District. The brief description which follows is provided because both sites are significant sources of mosquito production. H-2 was primarily sandy on the north end. However, a long borrow swale extended northward and westward from the south corner (Plate 1:A). The substrate was in the late DM-4 stage and represented an excellent breeding habitat for *Aedes taeniorhynchus* and *A. sollicitans*. One inspection of this site revealed the presence of large numbers of cast pupal skins of these two major saltmarsh species. Thus, this site was clearly an active mosquito producer. The estimated breeding potential was 3.

94. The H-1 site (not pictured) was at least two or three times larger than H-2. Substrate conditions at H-1 represented the early DM-4 stage. More than 50 percent of the surface was either fissured or possessed a substrate which was likely to become fissured before the 1978 mosquito breeding season. The estimated breeding potential was 3-4. Conditions conducive to heavy mosquito breeding are likely to prevail at these two sites for at least several years.



SITE DESIGNATION: STA. #110 L-W (H-3)

Physical Features

95. Estimated acreage: 9.4.

96. Substrate evaluation: The soil within the site contained a high amount of sand. No soil fissures were observed at this site. The south corner (Plate 1:B) exhibited a higher organic content than that of the soil in the central portion of the site. The substrate in the west corner appeared to contain less sand and more silt than soil in the central area.

97. Drainage characteristics: More than half of the surface area exhibited excellent drainage that resulted from the high sand content of the soil. Only a few shallow depressions were observed in the central portion of the site. These depressions are probably never flooded. The lowest elevation occurred at the south corner (Plate 1:B). This area is a permanently flooded freshwater marsh. Another low area occurred at the west corner (Plate 1:C). This area is probably intermittently flooded by heavy rainfall. The site is not flushed by tides.

Biological Features

98. Vegetation: The highest elevation (central portion) of the site supported a wide variety of forbs, especially composites such as *Aster* spp. and *Helianthus* spp. The freshwater marsh is dominated by *Spartina* spp. and *Phragmites* spp. Although small, this marsh appeared to be an excellent waterfowl habitat because of the food source available from fruiting bodies of the rushes. A low area in the west corner (Plate 1:C) supported a pure stand of *Spartina patens*. The remainder of the site supported a mixed stand of shrubs, pines and a few hardwoods. Some of this vegetation is dead but it was still standing at the time of the site inspection. This kill undoubtedly resulted from the accretion of dredged material around the vegetation. The effects of this kill may have had some positive side benefits to wildlife since white ibis utilize the dead vegetation as a roosting site and possibly as a nesting site.

99. Mosquito breeding: The freshwater marsh represented an ideal situation for a variety of permanent water mosquitoes. However, the habitat supported a well-developed complex of mosquito predators. Therefore, the potential for producing nuisance level adult mosquito populations appeared minimal. The low area supporting *Phragmites communis* appeared to be suitable for production of saltmarsh floodwater species. However, dry conditions during 1977 made evaluation of this area difficult. A small area along the outside of the dike (Plate 1:D) also appeared suitable for low-level saltmarsh mosquito production.

100. Mosquito species composition: *Anopheles* spp., *Culex* spp., *Wyeomyia punctipennis*, *Pedophilus* spp., *Aedes sollicitans* and *A. triseriatus*.

101. Mosquito breeding potential: 1-2.

102. Site prognosis: No change in mosquito production is likely to occur unless the site is altered by further dredging.

SITE DESIGNATION: STA. #177 L-W (H-4); STA. #200 L-W (H-5);
STA. #210 L-W (H-6)

103. These three sites are situated in close proximity of each other. Because they exhibit similar features, they are described here in a single summary. All three sites are pictured in Plate 2.

Physical Features

104. Estimated acreage: H-4, 9.1; H-5, 9.6; H-6, 22.7.

105. Substrate evaluation: Disposed dredged material consisted primarily of sand in all three sites. H-5 contained the heaviest deposit of dredged material. Sites H-4 and H-6 contained only a small deposit (Plate 2:A and B).

106. Drainage characteristics: The sandy deposits of dredged material were well-drained on all three sites. The undisturbed marsh substrate of H-4 and H-6 was also well-drained because weep holes have been provided in the dikes of each of these sites (Plate 2:C and D). Three hummock areas, resulting from disposal operations conducted before the dike was built, were present in H-6. The two hummock ridges at the extreme east and west ends partially interrupted the drainage pattern of the site. This resulted in two areas where drainage is reduced, but not entirely stopped (Plate 2:E and F). The hummock did not affect drainage on H-4 because of the close proximity of the weep hole. Both H-4 and H-6 also exhibited excellent drainage features outside the dike because the marsh in this area was drained by several tidal creeks. Both sites are internally flushed by daily tides. H-5 is not flushed by tides. The construction of the H-5 dike has resulted in tidal blockage of marsh outside the dike at the southwest end (Plate 2:G).

Biological Features

107. Vegetation: The high ground of the hummock sites supported a mixture of shrubs and stunted trees including *Myrica carolinensis*, *Juniperus communis*, red cedar and black cherry. Disposed material deposited since dike construction supported a sparsely distributed stand of forbs



and a few shrubs. The marshy portions of H-4 and H-6 supported *Juncus roemerianus* and *Spartina alterniflora*.

108. Mosquito breeding: None of the three sites surveyed exhibited any significant sources of mosquito production. Good conditions for low level saltmarsh mosquito production were observed at points E, F and G shown in Plate 2.

109. Mosquito species composition: *A. taeniorhynchus*, *A. taeniorhynchus* and *Anopheles bradleyi*.

110. Mosquito breeding potential: H-4 = 0-1. H-5 = 1;
H-6 = 1-2.

111. Site prognosis: No increase or reduction in mosquito activity is likely at any of the sites unless they are altered by further dredging. There is a slight possibility that tidal drainage at H-4 and H-6 could be interrupted by natural siltation processes or dike erosion in the vicinity of the weep holes. Such an occurrence probably would increase the breeding activity within these two sites. However, alteration of drainage in these sites by new dredging activities is probably more likely to occur before natural processes result in such changes.

SITE DESIGNATION: STA. vic. #248 L-W (H-7); STA. vic. #280
L-W (H-8); STA. vic. #300 L-W (H-9)

112. These sites are not listed on the updated (in 1975) version of the 1963 Charleston District AIWW CE survey map. A summary is provided however, because all three sites exhibit mosquito producing potential.

113. The H-7 site was located between Sta. #250 and statute mile 345, almost directly opposite Brainard Landing (see Plate 3). A comparison of the 1963 AIWW map photograph with Plate 3 indicated that the marsh behind H-7 (Plate 3:A) may have been impounded and flooded sometime between 1963 and 1977 when the Plate 3 photograph was produced. The highest elevation of H-7 was represented by sandy disposal material (Plate 3:B). The internal portions of H-7 were not flushed by tides. Tidal access to a section of marsh between H-7 and the flooded area (Plate 3:C) has been cut off. This area produced saltmarsh mosquitoes. The estimated breeding potential is 2-3.

114. Site H-8 was located between statute mile 345 and Sta. #300. H-9 was directly opposite Sta. #300. Both sites were enclosed by make-shift dikes on three sides. The high ground of the upland formed a barrier along the remaining (south) side of each site (see Plate 4). Habitats conducive to mosquito production in H-8 are indicated in Plate 4:A. The estimated mosquito breeding potential was 2-3. Habitats conducive to mosquito production in H-9 are indicated in Plate 4:B. This area contained a shallow, silty deposit of dredged material in the DM-4 stage. Tidal creeks entered the west side of H-8 and the east side of H-9 (Plate 4:C). A considerable portion of the west perimeter of both sites was located above MHW (Plate 4:A and B). Therefore, monthly spring tides were an important factor influencing mosquito breeding in both of these sites. The estimated breeding potential for both sites is 3-4.

PLATE 3

A

C

B

H 7

CHAS.

CHANNARD

NEG.



PLATE 4

H 8

H 9

CHAS.

1

Section 2: Georgetown County

115. All dredged material disposal sites used for the maintenance of the AIWW in Georgetown County are located south of the Waccamaw River. That portion of the AIWW which runs north of Winyah Bay to the vicinity of Little River in Horry County exhibits little or no shoaling problems. This results from a geographical peculiarity which occurs in this portion of South Carolina. The coastline from North Island to the North Carolina state line fronts directly on the Atlantic Ocean. There are no barrier islands and few saltmarshes along this portion of the South Carolina coast. Thus, the AIWW runs through high, stable land where sedimentation and shoaling are not significant problems.

SITE DESIGNATION: STA. #1025N W-C (G-1)

Physical Features

116. Estimated acreage: 90.1.

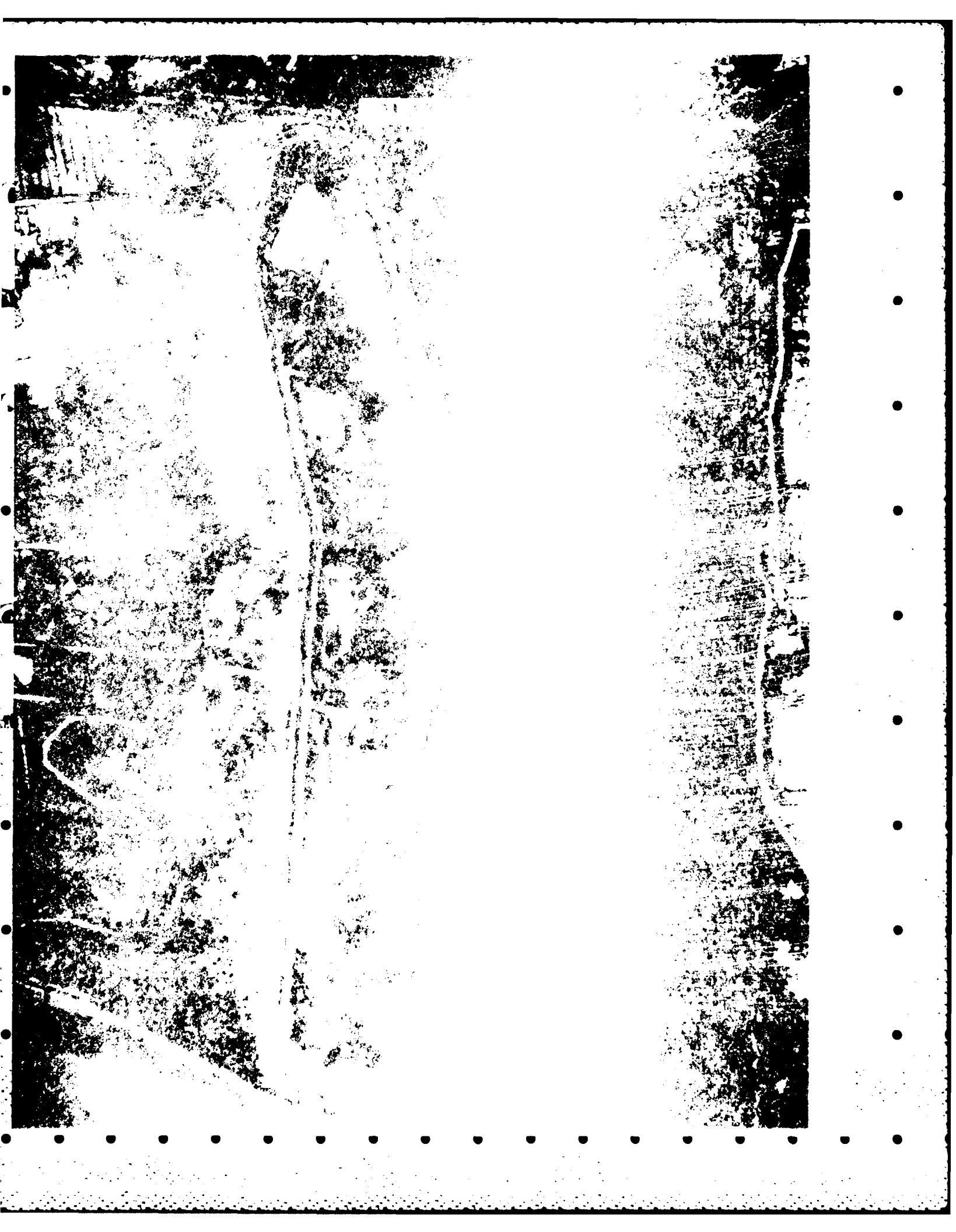
117. Substrate evaluation: Approximately 90 percent of the surface of this site was covered by a substrate with a high silt content. The discharge area, located at the southeast corner, was sandy. This discharge area (Plate 5:A) represented the highest elevation within the site and apparently resulted from accretion from disposal operations conducted since the dike was constructed. Another area of high ground, which appeared to be the result of a disposal operation which was conducted before dikes were built, was situated near the center of the site (Plate 5:B). The substrate condition was variable ranging between late DM-4 to DM-6.

118. Drainage characteristics: The central portion of the site was fairly well-drained, although a number of depression and hummock areas occur in this portion of the site. The borrow area swale extended around the entire inside perimeter of the site except for a small section in the vicinity of the discharge area. Portions of the borrow area swale remained flooded at all times. Poorest drainage was associated with the dike swale, especially that portion along the west perimeter of the site. The site was not flushed by tides.

Biological Features

119. Vegetation: The highest area near the center of the site (Plate 5:B) supported some tall woody growth. Otherwise, vegetation was sparsely distributed, consisting of a few grasses and forbs. At least half of the surface did not support vegetation.

120. Mosquito breeding: The dike swale was a major source of mosquito production because it is subjected to regular flooding by rainfall. The borrow area swale retained a sufficient amount of water to maintain aquatic predators that reduce mosquito populations. Depressions in the central portion of the site were subject to flooding by rainfall. Thus, they were capable of floodwater mosquito production. However, these



depressions were not as extensive as the breeding sites in the dike swale portion of the site.

121. Mosquito species composition: *Aedes sollicitans* and *A. taeniorhynchus*.

122. Mosquito breeding potential: 3.

123. Site prognosis: No major shift in mosquito breeding activity is likely if the site is not subjected to further dredging operations. A slight increase could occur if the borrow area swale is invaded by emergent aquatic vegetation. Such a development would provide a suitable breeding situation for *Anopheles tritaeniorhynchus*.

SITE DESIGNATION: STA. #1152N W-C (G-2)

Summary

124. This site was not listed on the 1975 Charleston District survey map. It appeared that the site may have been constructed since the map was last updated. The site is located between station 1175 and 1136. It possessed an entirely sandy substrate and it supported no vegetation. Therefore, is exhibited no potential for mosquito production. Two pools of water, one on the east and one on the west end, were located in the site. These areas were being utilized by gulls, terns and a few wading birds at the time the site was inspected. Bird utilization has resulted in an accumulation of bird droppings in these areas. This deposit may provide sufficient nutrients for invasion of the site by submergent and/or emergent aquatic vegetation. Such a modification could result in conditions suitable for mosquito breeding.

SITE DESIGNATION: STA. #1190N W-C (G-3): STA. #1229N W-C (G-4)

Physical Features

125. Estimated acreage: G-3, 70.6; G-4, 19.8.

126. Substrate evaluation: Most of the G-3 substrate consisted of a silt-clay mixture except for a few isolated sandy locations on the south end of the site. The south end represented the highest elevation of the site (Plate 6:A). Substrate characteristics of G-4 were similar to those of G-3. The lowest portion of G-4 was located at the east corner (Plate 6:B). The substrate condition was represented by late DM-4 or early DM-6 stages. The DM-5 stage was represented to a limited extent in areas where dredged material has filled around previously existing vegetation.

127. Drainage characteristics: Both sites were poorly drained. A small portion of the borrow area swale near the low end of each site remained flooded. More than half of the borrow area swale in each site was prone to frequent drying and reflooding cycles caused by rainfall. Similar conditions prevailed in the dike swales of each site. Both sites also possessed a number of depression and hummock sites which are capable of producing mosquitoes.

Biological Features

128. Vegetation: More than half of the surface of G-3 was bare. Most of the existing vegetation resulted from upland shrub and tree growth that developed on piles of dredged material left by operations on the site before it was diked. The G-4 site exhibited similar vegetational characteristics except that proportionately more of the surface was vegetated. The vegetation on G-4 was primarily composed of woody shrubs.

129. Mosquito breeding: The dike swale, borrow area swale and depression sites all supported heavy, frequent mosquito breeding.

130. Mosquito species composition: *A. tritaeniorhynchus*, *A. albopictus*.

PLATE

G 4

8

CHAS.

1

G 3

131. Mosquito breeding potential: G-3 = 3-4; G-4 = 3-4.

132. Site prognosis; The current level of mosquito production should continue for several years. The dominant species may shift from *A. sollicitans* to *A. triseriatus* if aging processes continue. *Anopheles bradleyi* will probably begin breeding on the site if emergent aquatic vegetation develops in the borrow area swales. Further deposition of dredged material on either site would interrupt mosquito breeding for six months to a year when conditions similar to present conditions could again be expected to develop.

SITE DESIGNATION: STA. #1370N W-C (G-5); STA. #1421N W-C (G-6);
STA. #1450N W-C (G-7)

Physical Features

133. Estimated acreage: G-5, 66.5; G-6, 21.5; G-7, 24.2.

134. Substrate evaluation: All three of these sites contained a substrate which has a high silt content. A discharge area was located at the north end of G-5 (Plate 7:A). This northeast corner was separated by a secondary dike from the remaining portion of the site (Plate 7:B). Most of the site exhibited an even contour. The lowest area was represented by a borrow area swale which runs along the entire length of the west side (Plate 7:C). The substrate condition was in the early DM-7 stage except for the borrow area swale which exhibited late DM-4 conditions.

135. The G-7 site was the last of these three sites to receive a deposit of fresh dredged material. As described in a previous section of this report, the substrate weathered very rapidly to the DM-6 stage. Both G-5 and G-6 appeared to contain soil which was similar to that found in G-7. Thus, substrate weathering patterns following disposal operations were probably similar in all three sites. The G-7 site was rediked during early 1977. This has left a series of deep borrow pits around the perimeter of this site (see Plate 8). These borrow pits represent the lowest elevation within the site. No discharge site was apparent in this site.

136. The G-6 site exhibited characteristics found in both G-5 and G-7. The central portion exhibited substrate stage DM-6. This area has been modified mechanically by plowing. This resulted from a deliberate attempt to cultivate corn on the site—perhaps to attract ducks and other game birds. It was impossible to determine if the substrate would have weathered as rapidly to the DM-6 stage if the area had not been plowed. The lowest portion of G-6 occurred in the borrow area swale along the west side. The substrate in this area was in the DM-4 stage. The highest elevation occurred near the southeast corner (Plate 8:A) and apparently resulted from the production of high land

PLATE 7

B

A

C

G 5

CHAMBER

by dredging operations conducted before the area was diked. Substrate in this area was in the DM-8 stage.

137. Drainage characteristics: The central portions of all three sites were well-drained. Poorest drainage was associated with the borrow area swale along the west perimeter of G-5 and G-6 where water levels fluctuated according to weather cycles. These borrow areas may dry out completely during extremely dry weather because rainfall is the only source of flooding—no tidal flushing occurred in either G-5 or G-6. The deep borrow pits of G-7 maintained water to a depth of several feet in places and appeared to be influenced by the high water table as well as by weather conditions. During the extremely dry weather period of 1977, these areas remained flooded. Drainage in G-7 was not influenced by tides.

Biological Features

138. Vegetation: The G-7 site was almost entirely bare except for a few stands of polkweed. The G-6 site exhibited better developed layer of primarily herbaceous vegetation. The most common plant in the central portions of the site was polkweed. Near the perimeter of the east dike, grasses, forbs and woody shrubs formed a dense substrate cover. The high area (Plate 8:A) had a similar vegetational structure, but with the addition of hackberry trees (to 10 meters). Semiaquatic vegetation appeared to be gradually encroaching along the borrow area swale on the west side of both G-6 and G-5. Thus, a shift from DM-4 to DM-5 substrate conditions appeared to be in progress. The remainder of the G-5 site supported a mixture of grasses and forbs.

139. Mosquito breeding: G-7 was one of the sites monitored for the emergence trap survey (See Table 8 for results; see Plate 8:B for trap location). Mosquito breeding in G-7 was less extensive than that occurring in G-5 and G-6 probably because of the permanent nature of the water in G-7. The borrow area swales of G-5 and G-6 were the major foci of breeding in those sites. In addition, G-6 exhibited heavy breeding in a sump area near the northwest corner (Plate 8:C).

140. Mosquito species composition: *Aedes sollicitans*,

ERRY

A. taeniorhynchus and *Anopheles bradleyi*.

141. Mosquito breeding potential: G-5 = 3; G-6 = 3; G-7 = 2.

142. Site prognosis: Mosquito activity in G-7 may increase slightly if or when vegetation develops in the site. Deposition of dredged material in the area will probably result in the production of borrow area swales conducive to more extensive breeding than now occurs. Conditions in G-6 and G-5 are not likely to change for at least several years if the sites are not altered by further dredging operations.

SITE DESIGNATION: STA. #1505N W-C (G-8); STA. #1511N W-C (G-9)

Physical Features

143. Estimated acreage: G-8, 22.7; G-9, 44.0.

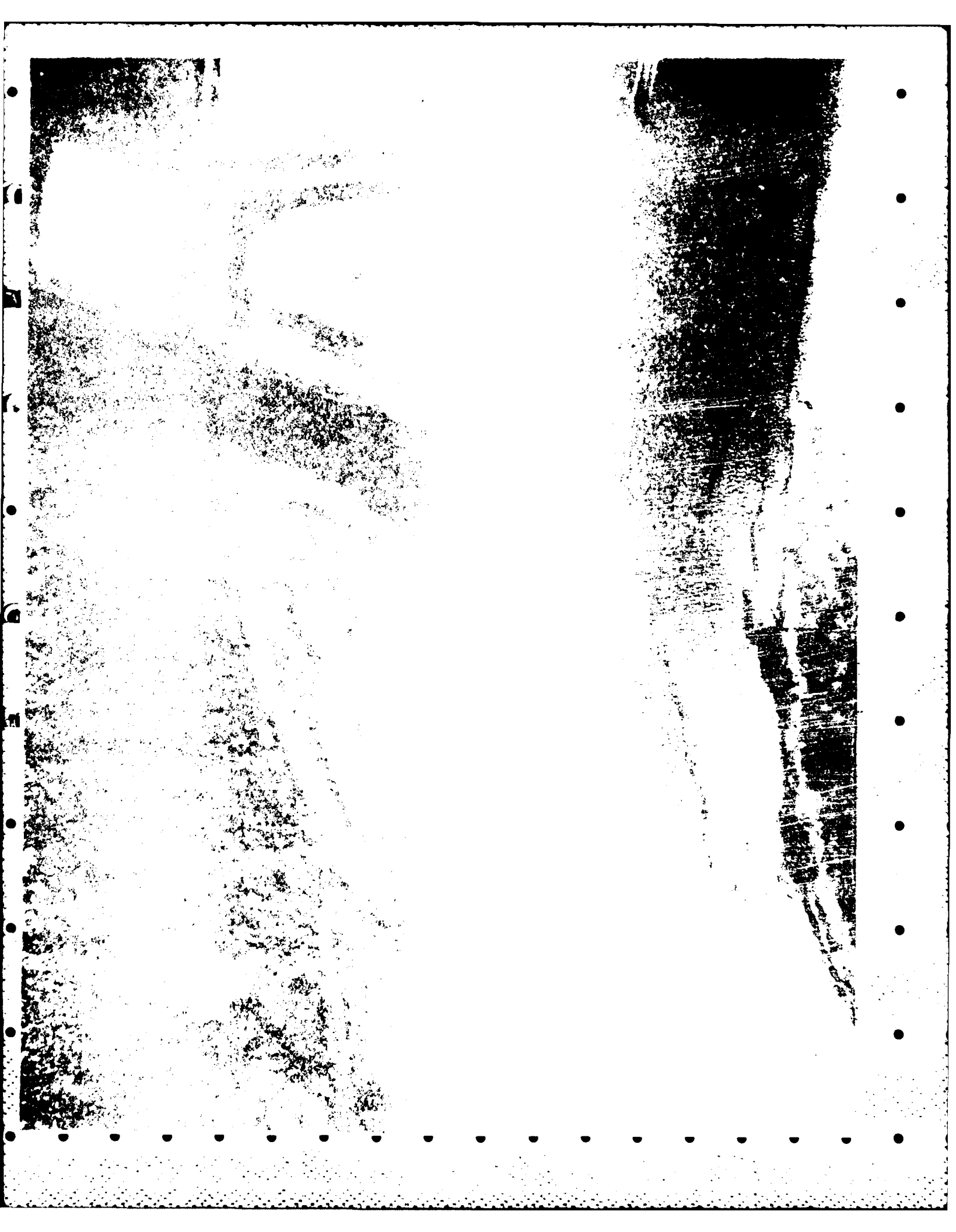
144. Substrate evaluation: G-8 was recently diked but no evidence that dredged material deposition was observed. Deep borrow areas were located around most of the perimeter of the site. G-9 appeared to be a much older site and has been utilized for dredged material disposal many times. The highest elevation located in the site is indicated in Plate 9:A. Lowest areas were represented by borrow area swales (Plate 9:B and C). The substrate condition was in the late DM-5 or early DM-7 stage.

145. Drainage characteristics: G-8 was well-drained in the central portions. Perimeter borrow pits were permanently flooded. The site was not flushed by tides. G-9 was poorly drained throughout most of its extent. Portions of the borrow area swale and dike swale (Plate 9:B and C) were irregularly flooded by rain. No evidence of tidal flushing could be found in the site.

Biological Features

146. Vegetation: The central portions of G-8 supported a mixture of grasses. This area has previously been used as a pasture for grazing domestic cattle. G-9 supported a variety of woody shrubs which dominated the dike swale. *baschardis halimifolia* was most common. A mixture of primarily freshwater vegetation occurred in the borrow area swale. Cattails, sedges and rushes were most common. Giant cord grass (*Spartina cynosuroides*) also occurred in this area. The south perimeter and southwest corner supported a stand of pines and a few hardwoods. Many of these trees apparently were killed by dredged material deposited on the site, but remained standing.

147. Mosquito breeding: Low level mosquito breeding was associated with borrow pit areas in G-8. Borrow area swales and dike swales were major foci for mosquito breeding on G-9.



148. Mosquito species composition: G-8, *Culex* spp. and *Anopheles* spp. G-9, *Aedes sollicitans*, *A. triseriatus* and *Anopheles bradleyi*.

149. Mosquito breeding potential: G-8 = 1-2; G-9 = 3.

150. Site prognosis: G-8 conditions are likely to show a slight tendency toward more favorable conditions for mosquito production as semi-aquatic vegetation invades the edges of borrow pits. Disposal of dredged material on this site would probably establish a borrow area swale producing a significant increase in mosquito activity. G-9 breeding conditions are likely to prevail for at least several years if the site is not further altered by dredging.

SITE DESIGNATION: WACCAMAW NECK (G-10)

Summary

151. This site was not shown on the Charleston District survey map. The site is located at the mouth of the Waccamaw River and it was unclear from inspections whether it used for AIWW or Winyah Bay maintenance. The substrate represented a DM-4 or DM-8 stage. Most of the site had a fissured soil habitat. More than half of the substrate supported *Phragmites communis*. Mosquito production at this site was monitored with an emergence trap (see Table 8). Emergence at this site during 1977 appeared light and lack of rain was undoubtedly a factor influencing this result. But the homogenous nature of the substrate in this site suggested that the emergence trap results were representative of the mosquito production of the entire surface of the site. Therefore, even apparant light breeding was significant in this case when multiplied by the total area of the site. This reasoning provided a basis for estimating the mosquito breeding potential of the site at 3. The nuisance produced by this site is magnified by its geographical position which is immediately adjacent to the major population center of the city of Georgetown.

Section 3: Charleston County

152. The majority of diked dredged material disposal sites which occur in South Carolina are found along the AIWW in Charleston County. More than half of these (28) occur north of Charleston Harbor and many are characterized by excellent mosquito producing conditions. Some of the sites in the vicinity of McClellanville, South Carolina were among the heaviest mosquito producers encountered during this survey. Fewer sites (13) are found along the AIWW south of Charleston. This apparently results because the course of the AIWW south of Charleston Harbor follows the main channel of several major river systems, the Stono, Wadmalaw and Dawho Rivers, where the effects of currents reduce shoaling problems. This effect is emphasized by the fact that the major disposal sites (S-7, S-8, S-9, S-10, S-11 and S-12) to the south of Charleston all occur along a man-made cut (Watts Cut) which connects the AIWW between the Dawho and South Edisto Rivers.

SITE DESIGNATION: STA. #774N W-C (N-1)

Physical Features

153. Estimated acreage: Not available.

154. Substrate evaluation: This site was rediked in 1977 resulting in deep borrow pits which surround the site. A major feature of the substrate was a number of deep ruts resulting from the movement of heavy equipment on the site during the rediking operation.

155. Drainage characteristics: The deep borrow areas usually remain flooded although they are subject to fluctuation according to weather cycles. The ruts which cover many portions of the surface are subjected to irregular flooding. The site was not flushed by tides.

Biological Features

156. Vegetation: The borrow area was completely bare and supported no vegetation. The center of the site supported a stand of pines which has become established on an old disposal area created before the site was diked (hummock area).

157. Mosquito breeding: The major source of mosquitoes from this site was the depressions which resulted from heavy equipment.

158. Mosquito breeding potential: 2-3.

159. Mosquito species composition: *Aedes sollicitans*, *A. triseriatus* and *Culex* spp.

160. Site prognosis: Depression sites should continue to breed unless the site is altered. Borrow pits probably will begin producing mosquitoes as vegetation develops around the edges of these sites. If the site is filled, the development of borrow area swales should contribute to increased mosquito production.

SITE DESIGNATION: STA. #716N W-C (N-1A); STA. #697N W-C (N-1B)

Physical Features

161. Estimated acreage: N-1A, not available; N-1B, 26.2.

162. Substrate evaluation: N-1A and N-1B exhibited identical conditions. Both sites were constructed during 1977 by diking previously undiked disposal areas (see Plate 10 for a comparison of conditions before and after diking). The substrate of each site consisted of high ground in the center. The lowest areas were the borrow pits (Plate 10:A) along the inside perimeter of each site. A number of depressions have also been created within the site by movement of heavy equipment.

163. Drainage characteristics: The borrow pits of each site usually remained flooded, but the water depth was subject to fluctuation. Depressions resulting from ruts left by heavy equipment were irregularly flooded. Neither site was influenced by normal tidal action.

Biological Features

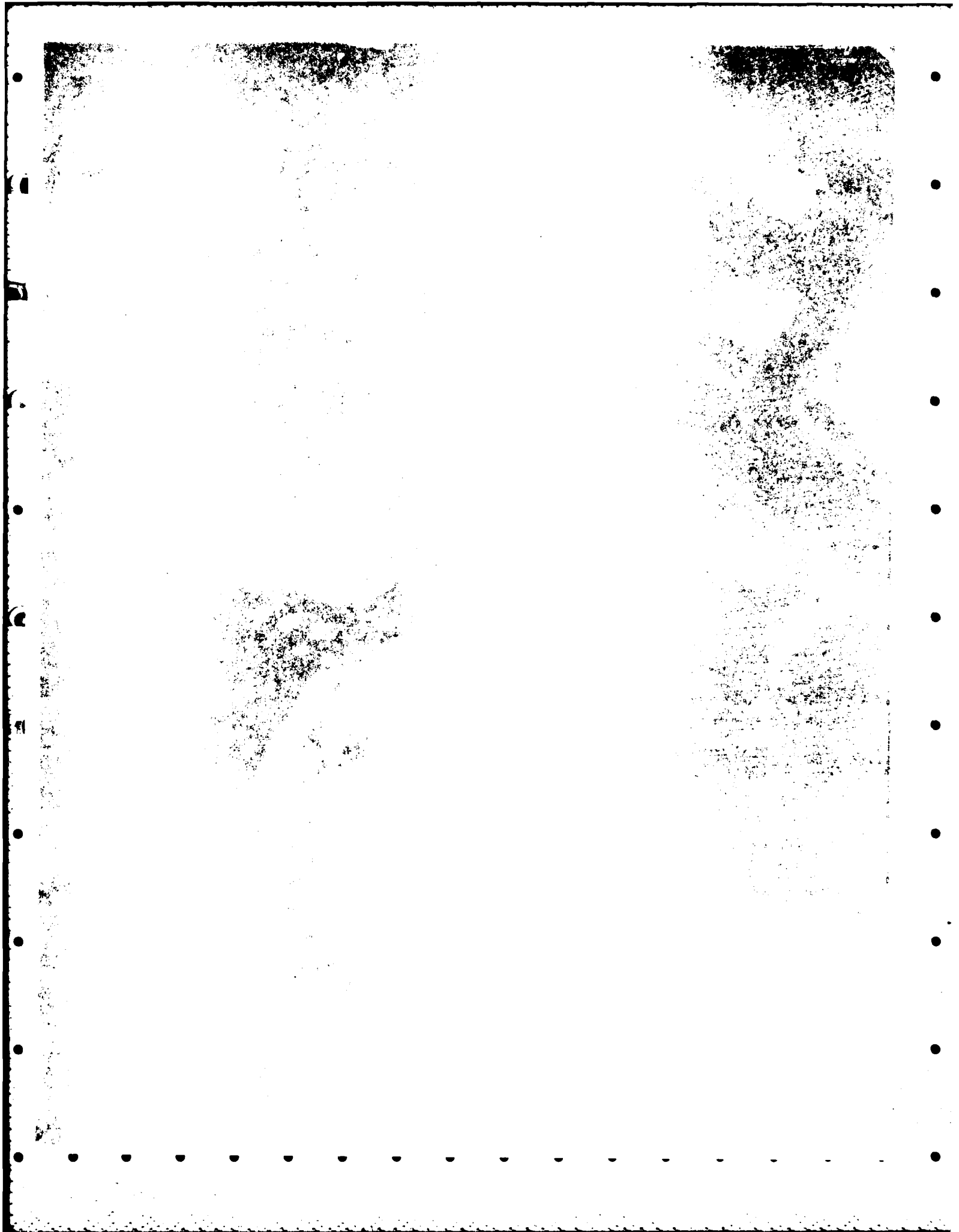
164. Vegetation: Both sites support a well-developed pine forest (hummocks) to ten meters or more. The perimeter areas were stripped of vegetation by the diking operation.

165. Mosquito production: Low-level mosquito production by permanent water species was found in the borrow pits. Slightly more intense breeding by floodwater species occurred in shallow depression sites.

166. Mosquito species composition: *Culex* spp., *Aedes sollicitans* and *A. triseriatus*.

167. Mosquito breeding potential: N-1A = 2; N-1B = 2.

168. Site prognosis: Depression sites should continue to breed unless the site is altered. Borrow pit breeding probably will intensify as aquatic vegetation develops in and around these sites. If the sites are filled, the development of borrow area swales should intensify floodwater mosquito breeding.



AD-A152 155

INVESTIGATION OF COMPARATIVE MOSQUITO BREEDING IN
DREDGED MATERIAL DISPOS. (U) CITADEL CHARLESTON SC DEPT
OF BIOLOGY J VORGETTS ET AL. 1978 IVB-CONTRIB-78-04
DACM60-76-C-0032

2/2

UNCLASSIFIED

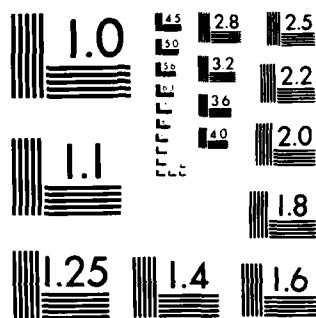
F/G 6/6

NL

END

FORMED

END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

SITE DESIGNATION: STA. #598N W-C (N-2)

Physical Features

169. Estimated acreage: 73.8.

170. Substrate evaluation: The lowest area was found to be associated with the borrow pit at the north corner (Plate 11:A). Another low portion occurred in a borrow swale along the southeast face (Plate 11:B). The substrate along the southeast face was in the late DM-5 or early DM-7 stage.

171. Drainage characteristics: The borrow area along the entire northwest and southeast perimeter of the site was found to be irregularly flooded by rainfall. The site was not flushed by normal tidal action.

Biological Features

172. Vegetation: The borrow area along the northwest side of the site was generally free of emergent and aquatic vegetation. The borrow area swale along the southeast side supported several species of composites, sedge rushes and cattails. The central portion of the site supported a pine forest (hummock area) with trees to ten meters.

173. Mosquito breeding: The borrow area swale along the southeast perimeter was a major source of mosquito production.

174. Mosquito species composition: *Anopheles sollicitans*, *A. tritaeniorhynchus* and *Culex* spp.

175. Site prognosis: No change in mosquito breeding activity is likely unless the site is altered. Further augmentation of the dredged material deposit may briefly interrupt breeding but a return to present conditions would probably occur in less than a year after a new disposal operation.

PLATE 11

A

CHAS.

N 2

↑
B
↓

N

SITE DESIGNATION: STA. #507N W-C (N-4); STA. #508N W-C (N-4A)

Physical Features

- 177. Estimated acreage: N-4, no estimate; N-4A, 20.4.
- 178. Substrate evaluation: Both sites were sandy throughout.
- 179. Drainage characteristics: Neither site was affected by normal tidal action. Both were well-drained.

Biological Features

- 180. Mosquito breeding potential: N-4 = 0-1; N-4A = 0-1.
- 181. Site prognosis: N-4 appeared to be unsuitable for further filling unless dikes are raised, and no change in the mosquito breeding potential of this site is likely. No change is likely in N-4A unless the site is altered by further dredging activities.

SITE DESIGNATION: STA. #460N W-C (N-5)

Physical Features

182. Estimated acreage: 52.1.

183. Substrate evaluation: The site was recently rediked.

Thus, the lowest elevation occurring in the site was associated with the borrow pit. The borrow area extended around most of the inside perimeter of the site. Two areas of high ground representing discharge points interrupted the borrow area (Plate 12A and B). The discharge areas were sandy. The surface of the site also retained numerous depressions created by movement of heavy equipment. That portion of the substrate which was not disturbed by the rediking operation was in the late DM-5 or early DM-6 stage.

184. Drainage characteristics: The borrow area usually remained flooded, but the water level was subject to fluctuations. Depression sites were irregularly flooded. Normal tidal action was not influencing flooding in the site.

Biological Features

185. Vegetation: The site was almost completely devoid of vegetation.

186. Mosquito breeding: Mosquito breeding was associated with the borrow area, especially on the north side. However, the major source of mosquito production was the depression sites.

187. Mosquito species composition: *Aedes sollicitans* and *A. triseriatus*.

188. Mosquito breeding potential: 2-3.

189. Site prognosis: Some increase in borrow area breeding is likely to accompany development of aquatic vegetation. Deposition of dredged material would result in a borrow area swale which would increase the mosquito breeding capabilities of the site.



SITE DESIGNATION: STA.#402N W-16 (N-6); STA. #340N W-C (N-7);
STA.#308N W-C (N-8); STA. #204N W-C (N-9)

Physical Features

190. Estimated acreage: N-6, 48.1; N-7, 86.5; N-8, 34.7;
N-9, not available.

191. Substrate evaluation: The lowest portion of N-6 was associated with borrow area swales along the southeast side and northeast corner (Plate 13:A and B). Highest elevations were in the center and at the extreme ends of the site (Plate 13: C, D and E). The substrate in the low areas of the site was in the late DM-5 or early DM-7 stage. N-7 was rediked in 1977. This resulted in many shallow depressions, especially at the southwest end (Plate 14: A). The substrate was in the late DM-5 or early DM-7 stage except in borrow pits where the rediking operation destroyed prevailing vegetation. N-8 has been rediked and also enlarged (Plate 15; irregular broken line surrounds addition). The lowest areas were represented by borrow pits resulting from rediking which surrounded the inside perimeter of the site. The substrate was in the late DM-5 or early DM-7 stage. The highest area occurred on the southwest end (Plate 15: A). The lowest portion of N-9 occurred in the borrow area along the southeast side and northwest side. The substrate was in the late DM-5 or early DM-7 stage.

192. Drainage characteristics: The N-6 borrow area swale has been subjected to frequent drying and reflooding cycles. The site was not influenced by normal tidal action, however. Most of the site was low and poorly drained. N-7 drainage was influenced by tidal flow on the southeast and southwest sides. However, borrow area and dike swales along the northwest side of the site (Plate 14: B) were not influenced by this tidal action. They were irregularly flooded by rainfall. Depression sites (Plate 14: A) were also irregularly flooded by rainfall. N-8 was well-drained on the north end because a weep hole was constructed at the northwest corner (Plate 15: B). A series of shallow depressions were associated with the dike swale on the south half of this site. These depressions are irregularly flooded by rainfall. The borrow area of N-9 was flushed by tides on the southeast and

PLATE

18

AS

M 6

PLATE 14

N 7

A



PLATE 15

B

N 8

CHAS.



southwest sides. The dike swale of most of this site was irregularly flooded by rainfall.

Biological Features

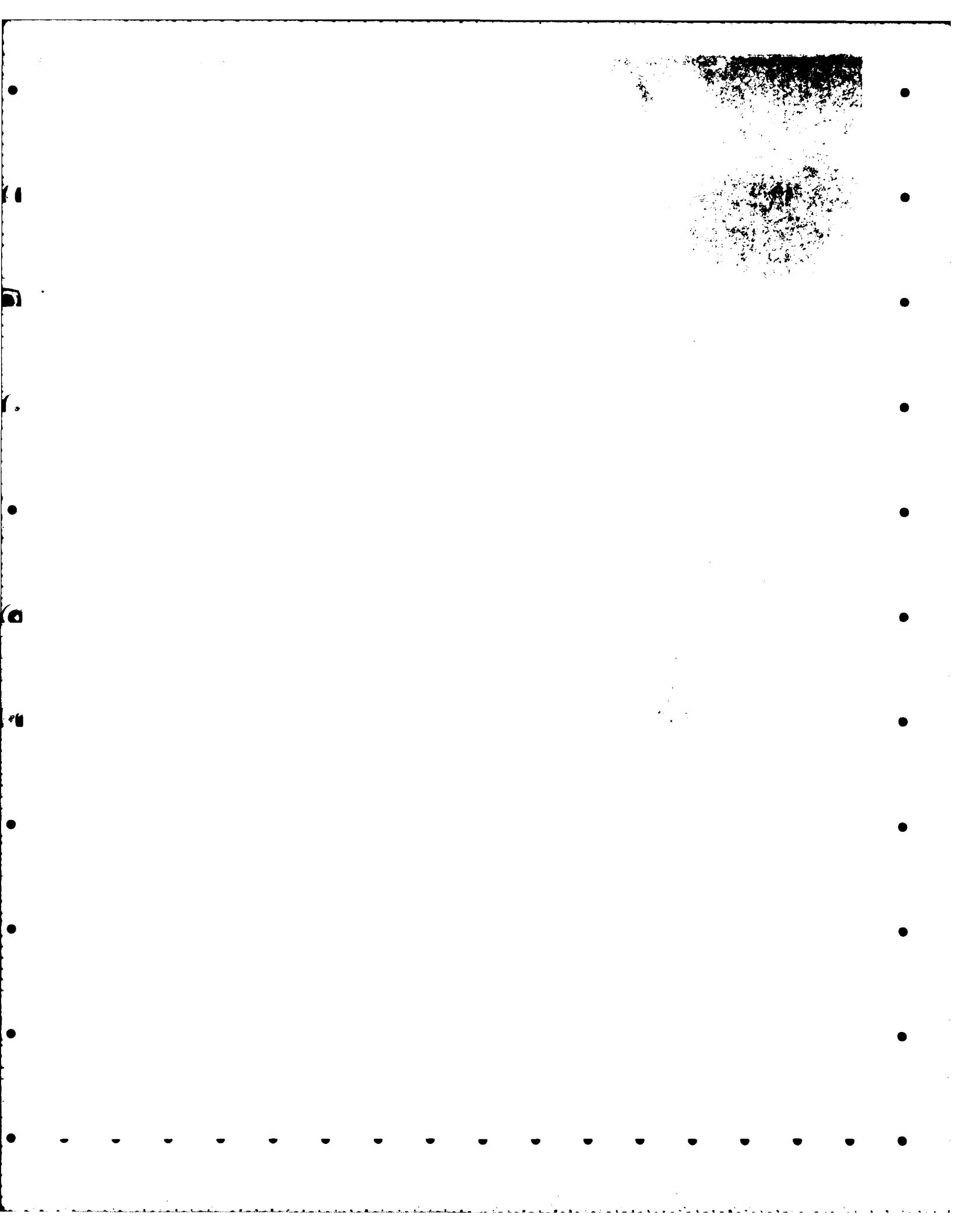
193. Vegetation: The vegetation pattern of all four sites was approximately the same. The lowest, wettest areas supported a mixture of rushes and *Spartina cynosuroides*. Slightly higher elevations supported a mixture of forbs dominated by composites. The higher central portions of each site supported more woody shrub growth with *Baccharis bracteolata* predominating.

194. Mosquito breeding: Major mosquito breeding areas on N-6 were associated with borrow area swales on the southeast side (Plate 13: A and B). At the time the site was inspected, outfall pipes in the vicinity of these depressions were slightly too high to permit tidal flushing. A minor adjustment of the weirs would permit flushing and allow predatory mosquito fish to gain access to these breeding areas. The dike swale and depression sites (Plate 14: A and B) were major sources of mosquito production on N-7. Drainage through the weep hole on the north end of N-8 has significantly reduced mosquito breeding in this portion of the site. Depressions associated with the dike swale produced large mosquito broods on the south half of N-8. Tidal flushing through outfall pipes on the southeast side of N-9 (Plate 16: A and B) were effective in reducing mosquito production in the borrow area swale. However, the effects of tidal flushing did not reach the dike swale areas where breeding continued to be heavy.

194. Mosquito species composition: *Anopheles tritaeniorhynchus*, *A. sollicitans* and *Anopheles bradleyi*.

195. Mosquito breeding potential: N-6 = 3-4; N-7 = 3-4; N-8 = 3; N-9 = 3.

197. Site prognosis: No change is likely to occur in the mosquito breeding capabilities of these four sites unless modifications specifically designed to control mosquitoes are implemented.



SITE DESIGNATION: STA. #78N W-C (N-10)

Physical Features

198. Estimated acreage: Not available.
199. Substrate evaluation: The highest portion of the site occurred on the northwest side. The substrate was in the late DM-7 or early DM-8 stage on the northwest half of the site. DM-6 conditions prevailed on the opposite side of the site.
200. Drainage characteristics: Drainage was excellent because a continuously declining elevation gradient promoted drainage from the highest elevation into the marsh on the undiked southeast side of the site.

Biological Features

201. Vegetation: The site was dominated by a mature stand of *Spartina patens*.
202. Mosquito breeding: Little or no mosquito breeding occurred on the site.
203. Mosquito breeding potential: 0-1.
204. Site prognosis: The site should remain unchanged with respect to mosquito production if the undiked portion of the site is not enclosed by dikes.

SITE DESIGNATION: STA. #40N W-C (N-11)

Physical Features

205. Estimated acreage: 59.5 acres.

206. Substrate evaluation: The substrate was primarily silt throughout except for a small sand flat at the northeast corner. Most of the substrate has aged beyond the fissured soil stages except in the vicinity of several depressions (described below). Fissures associated with the depressions are deep (up to 2 feet) and represent substrate condition DM-5.

207. Drainage characteristics: The highest elevation within the site occurred at the north end and apparently resulted from accretion of dredged material which was discharged during past disposal operations. Although no discharge hole was located at this end during inspections, the presence of a sandy substrate appeared to verify the observation. The lowest elevation was located at the opposite end of the site near the southeast corner. However, the site did not possess a continuous elevation gradient from highest to lowest points because a secondary dike perpendicular to the long axis of the site between the southwest and northeast ends interrupts the gradient (Plate 17: A). Depressions located along the base of the secondary dike (Plate 17: B and C) were a major drainage feature that acted as reservoirs for surface runoff. These depressions are intermittently flooded. The frequency and extent of flooding was wholly dependent on weather conditions. Flooding also occurred in borrow area depressions near the dike at the north and southwest corners (Plate 17: D and E). No portion of the site was flushed by tidal action.

Biological Features

208. Vegetation: Highest elevations within the site supported a mixture of woody vegetation including pines and shrubs (*Baccharis halimifolia*, *Myrica carolinensis*). In some sections shrubs formed dense thickets which were nearly impenetrable. The northeast side of the site

PLATE 17

CHAS.

Y

D

B

A

A

C

E

N



supported a mixture of grasses, forbs and low shrubs. Vegetation is sparse and gradually disappeared completely on the sand flat at the extreme northeast corner.

209. Mosquito breeding: A major source of mosquito breeding occurred in the site in swales associated with the secondary dike which divided the site. These swales are located on both sides of the secondary dike and apparently were the result of borrow areas left after construction of the secondary dike. Borrow area swales associated with the primary dike at the north and southwest corners of the site also supported mosquito breeding (see Plate 17: B, C, D, and E). Mosquito production in all depressions was sporadic and was correlated closely with heavy rainfall. Populations were frequently produced which exceeded nuisance levels.

210. Mosquito species composition: *Aedes triseriatus* and *A. albopictus*.

211. Mosquito breeding potential: 3.

212. Site prognosis: Mosquito breeding potential is likely to remain at the level present when the site was inspected if the surface is not disturbed by new dredged material disposal operations. Depression fissures which are an important indicator of the mosquito breeding potential are not likely to fill because standing vegetation currently impedes weathering processes.

SITE DESIGNATION: STA. #19N W-C (N-12); STA. #14N W-C (N-13)
STA. #41S W-C (N-14)

Physical Features

213. Estimated acreage: N-12, 19.8; N-13, 39.5; N-14, 89.7.

214. Substrate characteristics: The N-12 substrate consisted of a borrow area swale around the perimeter of the site. This was the lowest area in the site. The substrate stage was DM-5 or early DM-7. Two areas of high ground near the central portion of the site represented the highest elevation. The lowest areas in N-13 occurred in borrow area swales along the south and southeast sides of the site. The substrate stage was DM-5 or early DM-7. Two discharge sites also represented low depressions (Plate 18: A). The lowest portion of N-14 occurred along the southeast side and especially in the extreme south corner (Plate 19: A). Several discharge sites located along the north-west face (Plate 19: B) were also low. The substrate was in the DM-4 stage along the southeast side. Several areas of high ground were situated along the central axis of N-14.

215. Drainage characteristics: Surface water conditions on both N-12 and N-13 were influenced by normal tidal action. Tidewater entered N-12 through an outfall pipe on the east corner of the site (Plate 18: B). Seepage produced by tides extended around the entire site. The tides entered N-13 on the south side (Plate 18: C). Tides flushed the borrow area swale along the south and east perimeters of N-13, but the dike swale usually was not affected. Tides also entered N-14 at the extreme southeast corner but this usually only occurred a few times during each month. No daily flushing was observed at N-14. A number of depression sites at the southeast end of N-14 were created during the last rediking operation. These depressions were irregularly flooded by rainfall. All three sites were prone to flooding by rainfall, particularly in dike swales along the perimeter of each site.

PLATE 12

N 12

N 12

A

Biological Features

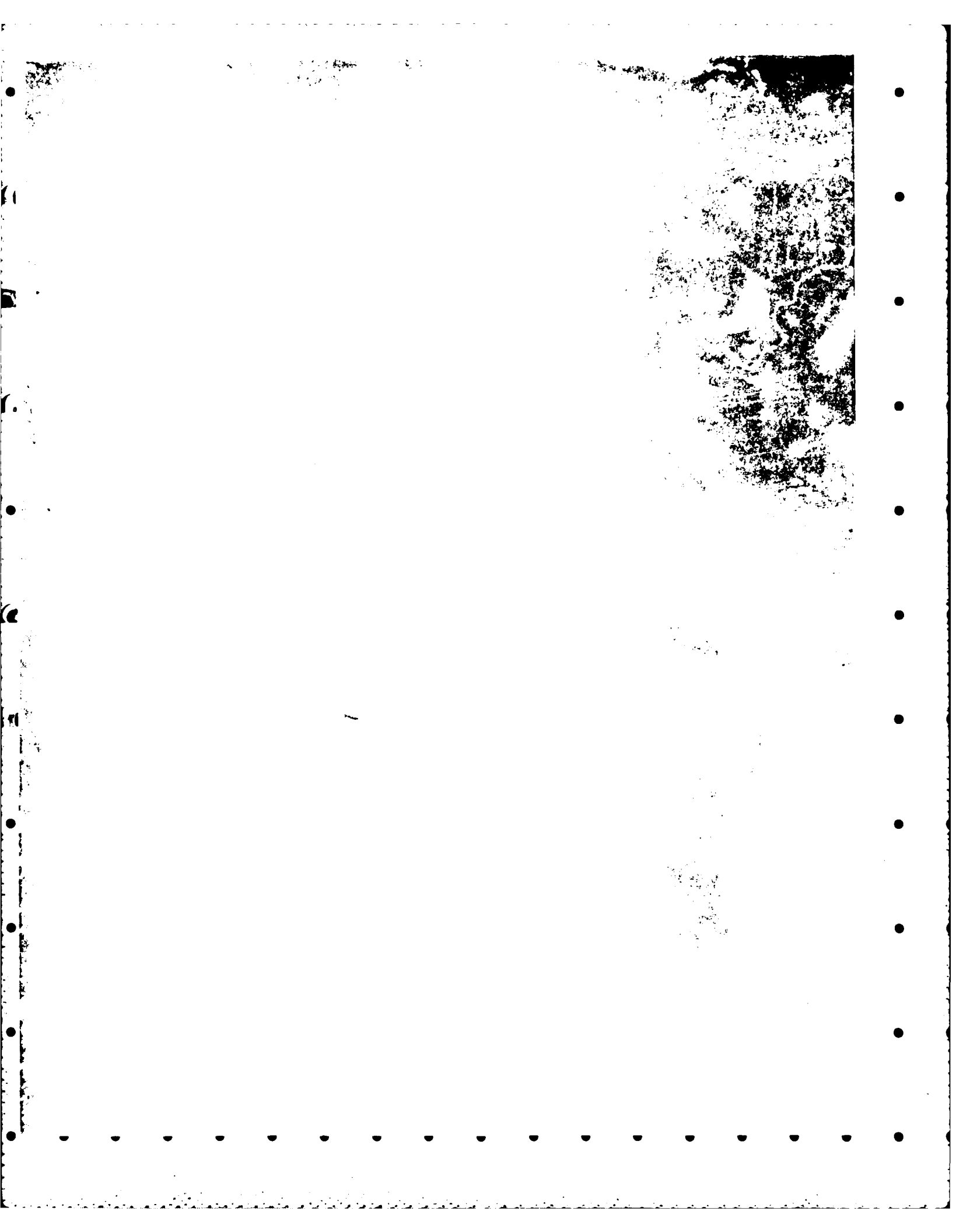
216. Vegetation: The hummock area of N-11, produced by disposal operations conducted before the site was diked supported a mature pine forest surrounded by a dense stand of shrubs. A band of grasses and forbs occurred along the southeast side of the upland areas. The remainder of the area between herbaceous growth and the southeast dike was barren, fissured soil. Similar but less extensive areas of mature pine were found on N-12 and N-13. The substrate between these areas and the dike was entirely covered by a herbaceous layer of vegetation. Species observed included *Eleocharis acicularis*, *Spartina patens*, *Distichlis spicata*, *Salicornia* spp. in the tidally influenced areas. Other species included *Eleocharis* spp., *Spartina patens*, *Distichlis* spp., *Salicornia* spp., *Distichlis* spp. and *Eleocharis* spp.

217. Mosquito breeding: The higher reaches of the borrow area swale on N-12 and N-13 were flooded only by the monthly spring tides. These areas, such as area D shown in Plate 18, supported heavy mosquito production. Similar conditions were found on N-13 (Plate 18:E). The dike swale which runs parallel to the borrow area along this section of N-13 also produced mosquitoes. Mosquito production on N-14 was associated with soil fissures and depression sites at the south corner (Plate 19: A).

218. Mosquito species composition: *Anopheles albopictus*, *A. tritaeniorhynchus*, *Anopheles bradleyi* and *Culiseta* spp.

219. Mosquito breeding potential: N-12 = 4; N-13 = 4; N-14 = 2-3.

220. Site prognosis: No change in mosquito activity at N-12 and N-13 is likely unless the sites are specifically altered to improve drainage for elimination of mosquitoes. N-14 breeding conditions are likely to be further enhanced by the gradual development of vegetation at the south end of the site.



SITE DESIGNATION: STA. #6095S W-C (N-15); STA. #6455S W-C
(N-16)

Physical Features

221. Estimated acreage: N-15, 29.6; N-16, 31.5.

222. Substrate evaluation: The N-15 area has been diked for several years, but no dredged material has been deposited in the site since it was diked. Thus, the major surface feature was a deep, permanently flooded borrow pit which surrounded most of the inside perimeter of the site. N-16 has been used for at least one disposal operation. The highest elevation and the discharge site were located at the south corner (Plate 20: A). A few shallow borrow area depressions (substrate stage DM-6) extended northeast from this point. The lowest portions of the site occurred at the north end. The substrate was in the late DM-5 or early DM-6 stage. A number of depression sites have been created in this site during recent rediking operations.

223. Drainage characteristics: N-15 was well-drained except for some shallow dike swale depressions which are most extensive at the south corner of the site. These areas were flooded by heavy rainfall. The central portions of the site were generally higher in elevation than the perimeter areas. Thus, runoff from the center was diverted into the permanently flooded borrow area. Shallow depressions of the borrow area swale and the dike swale on the southeast corner of the site were occasionally flooded by rainfall. Most runoff, however, followed the declining elevation gradient to the north end of the site. The north end of N-16 was flushed by tidewater which entered through a weep hole in the dike at the extreme north corner (Plate 20: B). In August, 1977, this opening was closed during rediking operations. Since then, the low, north end of N-16 has been poorly drained.

Biological Features

224. Vegetation: N-15 included a few patches of scrubby upland



vegetation which developed on dredged material deposited before the site was diked. The remainder of the site supported saltmarsh vegetation. Species observed included *Spartina alterniflora*, *S. patens*, *Distichlis spicata*, *Salicornia* spp., *Eleocharis acicularis*, *Scirpus americanus* and *Juncus roemerianus*. N-16 exhibited a similar species composition at the low north end. A number of forbs including *Aster* sp. and *Claytonia* sp. have become established on the south end of the site. A few stands of tall, upland, woody growth occurred in the more centrally located sections of the site.

225. Mosquito breeding: The only significant mosquito breeding areas on N-15 occurred along the dike swale at the south end. The permanent water in the borrow area adequately maintained a complex of predators which minimized mosquito production in that subhabitat. Mosquito production at N-16 was restricted to the north end until the weep hole at the south end was closed by rediking. Within a week of the elimination of tidal flushing, mosquito breeding was observed in borrow area swales and depression sites.

226. Mosquito species composition: *Anopheles tritaeniorhynchus*, *A. walkeri*, *Culiseta inornata* and *Aedes* spp.

227. Mosquito breeding potential: N-15 = 2; N-16 = 3.

228. Site prognosis: Current N-15 conditions are likely to prevail unless the site is altered by new dredging operations. The breeding intensity at N-16 is currently increasing. This trend can be expected to continue unless the dike at the south end is reopened to tidal flushing.

SITE DESIGNATION: (N-17, N-17A, N-18 AND N-19)

Summary

229. These sites are not listed on the current Charleston District survey map and are not part of CE system of disposal sites designated for AIWW maintenance. N-17A, N-18, and N-19 are located in the vicinity of Sta. #950 and exhibited little or no mosquito production at the time of inspection. N-18 and N-19 have been filled with sand. N-17A has a weep hole in the dike at the southwest end which promotes drainage. This drainage outlet has eliminated most mosquito breeding. A few depressions at the south end were occasionally flooded by unusually high tides. This resulted in some minor floodwater mosquito production. The mosquito breeding potential of N-19 = 0-1; N-18 = 0-1; N-17A = 1.

230. The N-17 site is located immediately south of N-16 near Sta. #700. This site was very similar to the N-16 disposal area. The prominent feature of N-17 was a dike failure which has occurred along the southeast face of this site. Therefore, this side of N-17 is subject to occasional flooding by abnormally high tides resulting from storms. Floodwater mosquito breeding follows such events. The opposite side of the site was flushed by normal tidal action entering through a breach in the dike. This side of N-17 was less likely to breed mosquitoes. The mosquito breeding potential of N-17 was rated at 2.

SITE DESIGNATION: STA. #970S W-C (N-19A)

Physical Features

231. Estimated acreage: 25.9.

232. Substrate evaluation: The highest elevations within the site were associated with hummocks which apparently resulted from dredged material deposits pumped on the site before it was diked (Plate 21: A and B). Another ridge divided the site near its center (Plate 21: C). The lowest point, a sump site, occurred near the west corner (Plate 21: D). Deep depressions were associated with discharge sites, where the only sandy substrate of the site was located (Plate 21: E and F). A series of shallower borrow area depressions occurred along the north perimeter of the site between points D and C, Plate 21. With the exception of those limited areas of high ground and the two discharge points described above, the entire substrate of the site was in the DM-4 stage.

233. Drainage characteristics: The entire site was poorly drained. Tidal flushing occurred through an outfall pipe at the west corner (Plate 21: D). As a result, the borrow area swale along the southwest side remained permanently flooded. The shallow depressions along the north perimeter were flooded by monthly spring tides and/or rainfall. Swales occurring along the fringes of the higher elevation of the site were flooded by rainfall. Drainage was also poor along the outside of the dike which interrupted tidal drainage, especially at the southwest end (Plate 21: G).

Biological Features

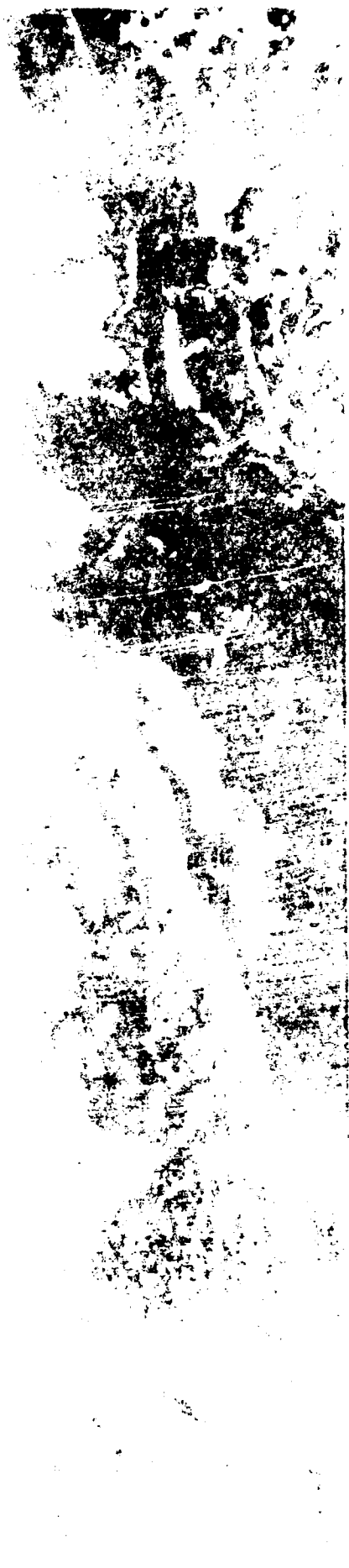
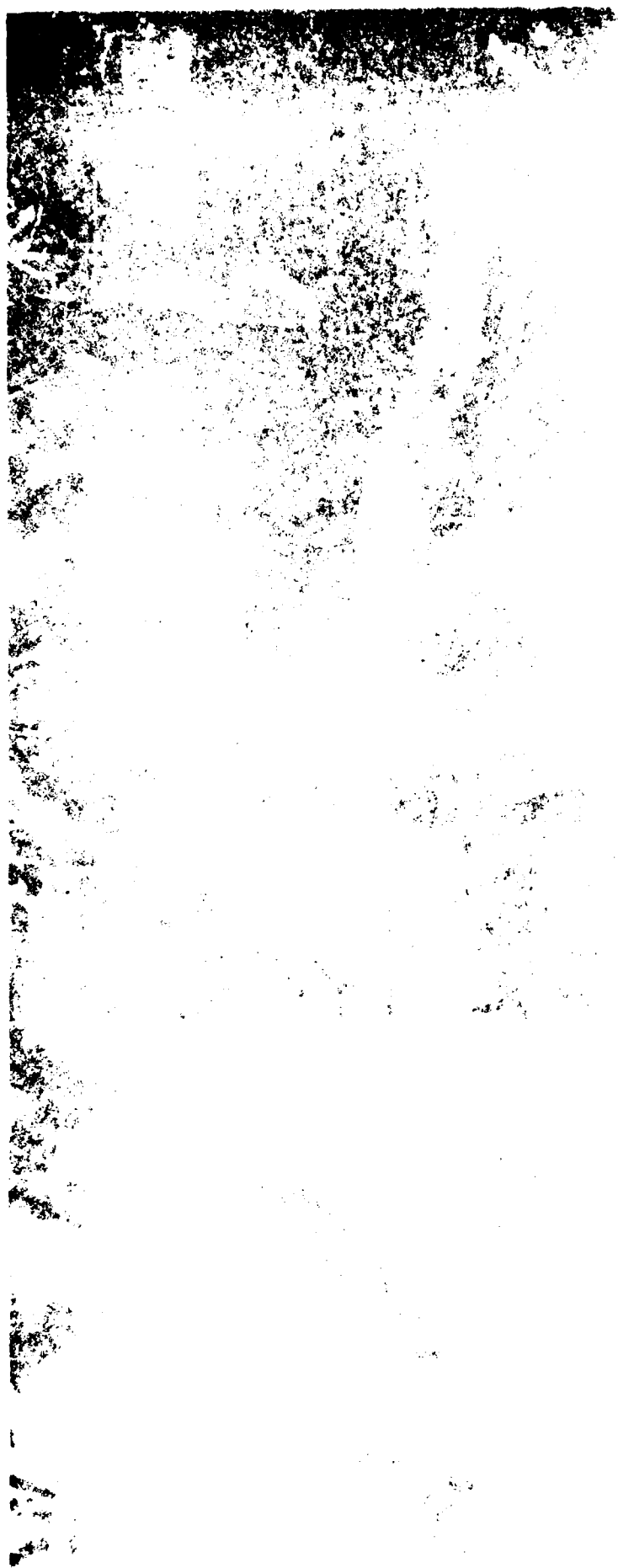
234. Vegetation: Very little vegetation occurred on the site except for pines and shrubs growing on the hummock sites.

235. Mosquito breeding: Adequate drainage occurred in the borrow area swale along the southwest side of N-19A. All other areas described, except hummock and discharge sites, favor mosquito production. The entire fissured portion of the substrate supported mosquito breeding when runoff was trapped in fissures. Areas outside the dike, where tidal drainage was blocked, also produced mosquitoes.

236. Mosquito species composition: *Aedes albopictus*, *A. taeniorhynchus* and *Anopheles crucians*.

237. Mosquito breeding potential: 4-5.

238. Site prognosis: The present level of mosquito breeding in N-19A is likely to persist for at least several years unless the site is altered by further dredging.



SITE DESIGNATION: STA. #1006S W-C (N-20): STA. #1056S W-C
(N-21)

Physical Features

239. Estimated acreage: N-20, 61.2; N-21, 47.6.

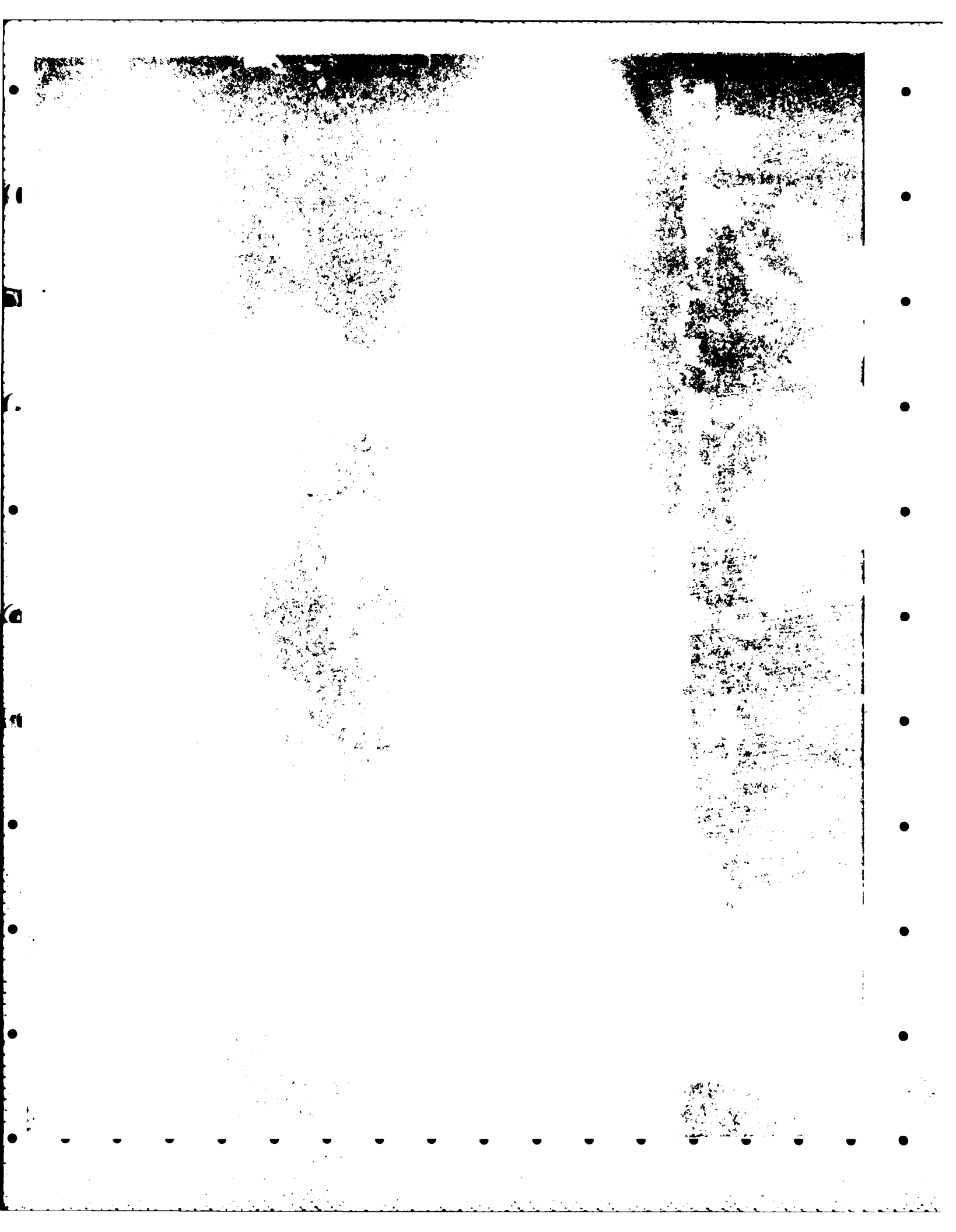
240. Substrate evaluation: The highest elevations of N-20 were associated with several hummock sites distributed along the central axis. Only two hummock areas occurred on N-21. The lowest elevations were found along the west perimeter of N-20 (Plate 22: A) in borrow areas and at the north corner of N-21 (Plate 23: A). A discharge point occurred at the east corner of N-20 (Plate 22: B) and at the south corner of N-21 (Plate 23: B). The substrate of N-20 was in the DM-4 or DM-6 stage. The N-21 substrate was in the DM-4 stage.

241. Drainage characteristics: The general direction of drainage in N-20 was from east to west. Drainage was poorest in fissured portions of the substrate, in depressions around fringe areas of hummock sites and in depressions associated with borrow area and dike swales. A portion of the borrow area on the north side of the site was flushed by tides (Plate 22: C). Most of N-21 was poorly drained because of the preponderance of fissured soil in the site. Borrow area and dike swales on the north and south faces exhibited poorest drainage. The best drainage occurred in the extreme north corner, which was flushed by normal tidal action (Plate 23: A).

Biological Features

242. Vegetation: The only vegetation present on the low elevations of N-21 occurred at the extreme north corner. This area supported a small stand of rushes (Plate 23: A). The low elevations of N-20 supported more vegetation than N-21, especially at the west end of the site near or in the borrow area swale (Plate 22: A). Herbaceous growth, especially *Cyperus* and *Eleocharis* spp. were most prevalent. The hummock sites of N-20 and N-21 were similar and supported a mixed stand of small pines, red cedar, wax myrtle and palmetto.

243. Mosquito breeding: The borrow area swales along the south



and west sides of N-20 were major mosquito breeding habitats. The entire borrow area swale of N-21 had recently reached the DM-4 stage at the time the site was inspected and low level mosquito breeding was evident. Fissured areas near the center of the site were also suitable mosquito breeding habitats.

244. Mosquito species composition: N-20 and N-21: *Aedes sollicitans*, *A. taeniorhynchus* and *Anopheles trairorai*.

245. Mosquito breeding potential: N-20 = 2-3; N-21 = 1-2.

246. Site prognosis: Conditions at N-20 are likely to persist unchanged unless the site is altered by further dredging activities. Mosquito breeding intensity at N-21 is likely to increase as the substrate continues to age. The establishment of herbaceous vegetation may slow this process and increase the mosquito breeding intensity.

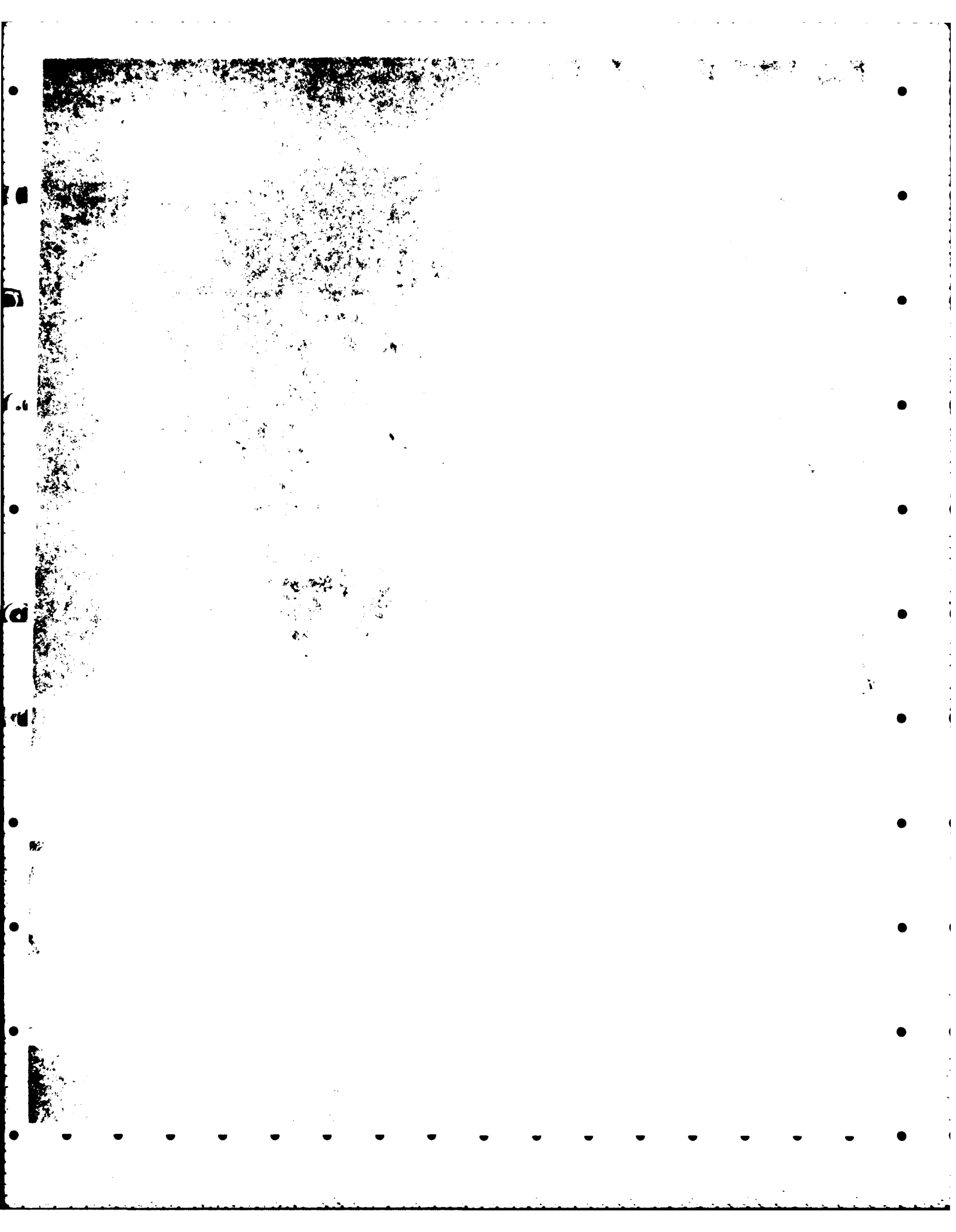
SITE DESIGNATION: STA. #1089S W-C (N-22)

Physical Features

247. Estimated acreage: 88.2

248. Substrate characteristics: A major feature influencing substrate conditions within this site was a center dike which divides it in half (Plate 24: A). The west half of the site has been further modified by a weep hole in the dike. The lowest elevations occurred in the borrow area swale along the entire south perimeter both east and west of the center dike. The borrow area along the north side was slightly higher. The highest elevations occurred along the east-west center axis in the form of hummocks produced by undiked disposal operations. The substrate stage on both the east and west ends was late DM-5 or early DM-7. The substrate was primarily silty.

249. Drainage characteristics: The drainage pattern within the site was from the central portion to the perimeter. The central area exhibited good drainage features. A few depression sites that were flooded after heavy rains represented the only poorly drained locations in the center area of the site. Therefore, most runoff flowed to the perimeter. With respect to the perimeter alone, flow in the borrow area swale on both ends of the site was directed to points on either side of the center dike along the south face of the site (Plate 24: B and C). Runoff, which reaches the point just west of the center dike (Plate 24: B), was flushed out through the weep hole in the main dike at low tide. Runoff, which reaches the point just east of the center dike (Plate 24: C) was trapped in a depression which exhibited a fluctuating water level, because the main dike at this point did not contain a weep hole. The borrow area on the west end of the site (Plate 24: D) exhibited a somewhat erratic elevational gradient which has resulted in a series of potholes that are irregularly flooded by rainfall. Similar conditions prevailed in the borrow area swale along the south and east face of the main dike east of the center dike. The borrow area along the south face of the main dike west of the center dike (Plate 24: E) was flushed by tidewater entering through the weep hole (Plate 24: B).



Depressions outside the dike at the east and west ends of the site were also irregularly flooded (Plate 24: F and G). Flooding of these depressions usually resulted from rainfall, but abnormally high tides also influenced these sites.

Biological Features

250. Vegetation: Both divisions of this site had a well-developed layer of herbaceous and short woody vegetation including *Aster* spp., *Callitriche* spp., *Borreria frutescens* and *Myrica caroliniana*. The vegetation has encroached along the periphery of the entire borrow swale and at times of heavy rain may be partially submerged. Hummock sites were typically composed of trees and tall shrubs including pines, wax myrtle, red cedar and cabbage palmetto.

251. Mosquito breeding: Mosquito production was most intense in the borrow area swale east of the internal center dike. Inspections consistently resulted in the collection of larvae at a rate of 25-50 per dip. Small fish have gained access to the borrow area swale west of the center dike through the weep hole in the main dike. Thus, this portion of the borrow area swale was not a source of significant mosquito breeding. Depressions at the west end in the borrow area and sites outside the dike were significant foci of mosquito activity, but the breeding intensity was not as severe as the borrow area swale along the south face of the dike east of the center dike.

252. Mosquito species composition: *Aedes albopictus*, *A. triseriatus*, *Anopheles walkeri* and *Culex quinquefasciatus*.

253. Mosquito breeding potential: East division = 3-4; west division = 2.

254. Site prognosis: No major changes in the mosquito breeding intensity are likely to occur unless the site is altered by further dredging activities.

SITE DESIGNATION: STA. #1207S W-C (N-23)

Physical Features

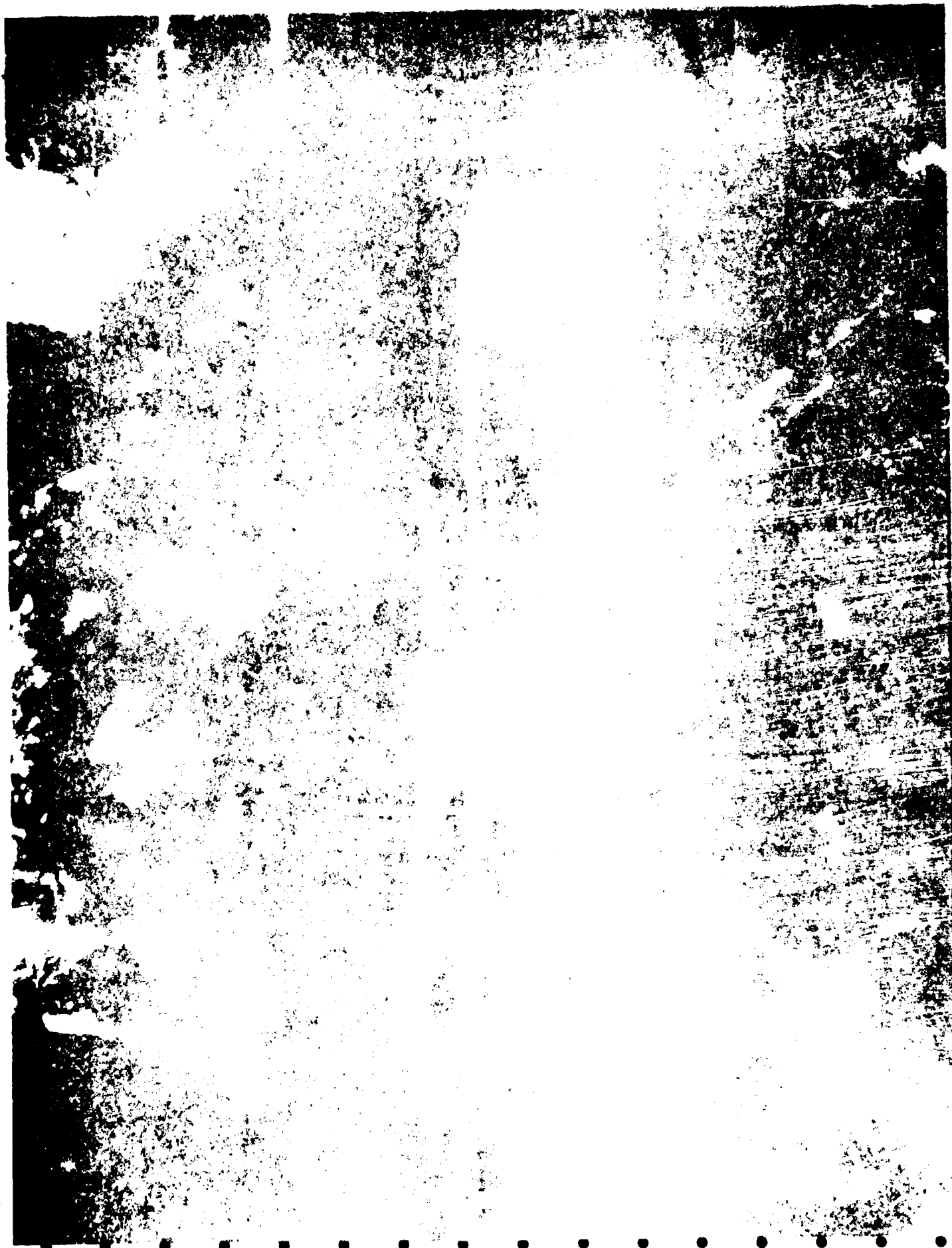
255. Estimated acreage: 34.4

256. Substrate evaluation: The highest elevation in the site was situated at the extreme east corner (Plate 25: A). This end was characterized by a deep discharge hole. A fairly constant, declining elevation gradient extended from the east to the west corner. The lowest point occurred in the borrow area swale at the west end (Plate 25: B). A hummock area was also situated at the west end (Plate 25: C). The substrate in the hummock area and near the discharge point was sandy. One other sandy area (Plate 25: D) was located near the center of the site and may represent a second discharge point. However, no discharge hole could be located in this vicinity to verify this observation. The remaining low surfaces were composed of a silty substrate. Most of the substrate was in the late DM-5 or early DM-7 stage.

257. Drainage characteristics: The sandy nature of the higher elevations together with the uninterrupted elevational gradient provided adequate drainage into the borrow area swale at the west end. This portion of the borrow area was flushed by tidewater entering through outflow pipes and was permanently flooded as a result. Irregular or intermittent flooded occurred only in the discharge hole (Plate 25: A) and in the borrow area swale along the north face of the site midway between the east and west ends (Plate 25: E).

Biological Features

258. Vegetation: Vegetation was sparse and mainly herbaceous in form in the vicinity of the sandy high spots, except for the hummock area at the west end where trees including hardwoods prevailed. Dense shrubby vegetation was prevalent along both sides of the borrow area swale on the south face of the site (Plate 25: F). The dominant species was *Brachyura halimifolia*. Emergent rushes and cattails occurred in the



borrow area swale along the north face (Plate 25: F).

259. Mosquito breeding: Mosquito production was confined to the discharge hole at the east end (Plate 25: A) and the borrow area along the north face (Plate 25: E). Larvae did not normally exceed ten per dip in these areas. Fish provided satisfactory control of mosquitoes in the other portions of the borrow area.

260. Mosquito species composition: *Aedes albopictus*, *A. triseriatus*, *Anopheles crucians* and *Culiseta inornata*.

261. Mosquito breeding potential: 1-2.

262. Site prognosis: No change in mosquito production within this site is likely if it is not disrupted by further dredging activities.

SITE DESIGNATION: STA. #104 C-P (S-1A); STA. #400 C-P
(S-1); STA. #475 C-P (S-2); STA. #540
C-P (S-3)

Summary

263. These four disposal areas were small (less than 15 acres each), sandy locations which provided little or no habitats suitable for mosquito production. S-1A is located immediately south of Charleston Harbor in the vicinity of Elliott Cut. S-1, S-2 and S-3 were located on the Stono River in the vicinity of or just east of Limehouse Bridge. Conditions on these sites are not likely to change to those favoring mosquito production even if they are used for further dredging activities unless the composition of dredged material changes from sand to a more silty material.

SITE DESIGNATION: STA. #532 C-P (S-4); STA. #580 C-P
(S-5)

Physical Features

264. Estimated acreage: S-4, 61.9; S-5, not available.

265. Substrate evaluation: Dredged material which was deposited on both of these sites was composed of sand. Only a small amount of material has been deposited on S-4 since the site was diked (Plate 26: A). Similar conditions prevailed on S-5. Approximately half of the substrate within each site consisted of unmodified saltmarsh. Hummocks resulting from disposal operations conducted prior to diking were also present (Plate 26: B and C).

266. Drainage characteristics: The borrow area of S-4 remained flooded throughout its entirety at all times. Fluctuating water levels occurred in a few depression sites located along the fringe areas of hummock sites in both S-4 and S-5. Flooding of the borrow area of S-5 was similar to that of S-4, but tidal flushing appeared to influence conditions on S-4 to a greater extent than on S-5.

Biological Features

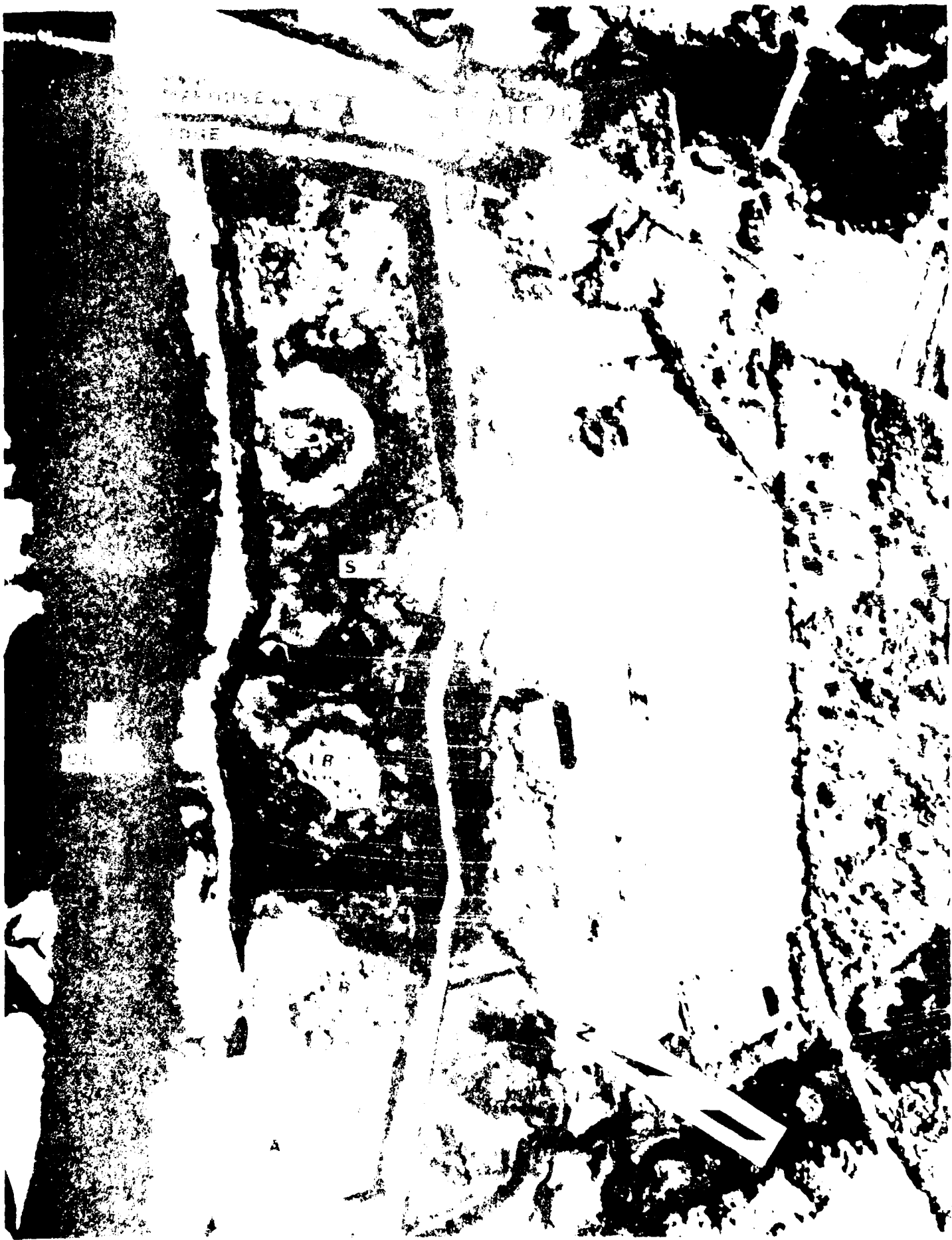
267. Vegetation: The lowest portions of both sites supported typical saltmarsh vegetation including *Spartina alterniflora*, *S. patens*, *Juncus roemerianus*, etc. S-5 supported some freshwater emergent species.

268. Mosquito breeding: Conditions similar to those which prevail in natural saltmarshes were found in both sites. Mosquito production was confined to a few small depressions which occurred near the center of the site and the fringe areas surrounding hummocks.

269. Mosquito species composition: *Aedes albopictus*, *A. triseriatus*, *Anopheles knabii* and *Culex salinarius*.

270. Mosquito breeding potential: S-4 = 1-2; S-5 = 1-2.

271. Site prognosis: No change is likely to occur in the intensity of mosquito breeding within these two sites. Further dredging activities probably will not influence any increase in mosquito breeding if disposed dredged material continues to be sandy.



SITE DESIGNATION: STA. #1595 C-P (S-6); STA. #1663 C-P (S-7)

Physical Features

272. Estimated acreage: S-6, not available; S-7, 38.1

273. Substrate evaluation: Approximately one-third of both S-6 and S-7 was predominantly sand. The north and east perimeters of S-6 exhibited muddy surfaces with little or no vegetation. Most of the perimeter of S-7 was surrounded by a deep borrow area. Shallower depressions occurred along the north face of S-7 (Plate 27: A). The east end of the site was higher in elevation and represents the discharge area (Plate 27: B). The west end was low and resembled low saltmarsh. Fissured surfaces were of minor significance on both sites.

274. Drainage characteristics: Flooding on S-6 was primarily under tidal influence. Tidewater enters the site through two outflow pipes on the north side during every high tide. S-7 was also under the influence of tidal action. However, runoff from rainfall was responsible for flooding of depressions on the north side which were associated with the dike and borrow area swales.

Biological Features

275. Vegetation: Less than half of the surface of S-6 and S-7 has been disturbed by dredging activities. Therefore, these sites have retained a vegetative cover typical of high or low saltmarsh.

276. Mosquito breeding: The influence of the tide was effective in providing a means of access for fish to most of the flooded portions of both sites. A small area at the east end of S-6 was irregularly flooded and a source of low level mosquito production. Depressions along the dike and borrow area swale especially on the north side were occasional sources of heavy mosquito production.

277. Mosquito species composition: *Anopheles triseriatus*, *A. albopictus*, *Culiseta inornata*, *C. quinquefasciata*, and *Aedes albopictus*.

278. Mosquito breeding potential: S-6 = 1; S-7 = 2.

279. Site prognosis: Present levels of mosquito activity on



PLATE 22

37

PAWHO
PLATE

both sites are likely to continue unchanged unless the sites are altered by further dredging activities. If sediments in the vicinity of these sites continue to yield sandy dredged material, the deposition of such material on the breeding sites described above could reduce or eliminate production within these sites.

SITE DESIGNATION: STA. #1717 C-P (S-8); STA #1743 C-P (S-9);
STA. #1789 C-P (S-10)

Physical Features

280. Estimated acreage: S-8, 58.5; S-9, 117.6; S-10, 49.3

281. Substrate evaluation: All three sites have been utilized extensively for several disposal operations. Thus, all three sites have extensive areas of high ground resulting from the accretion of dredged material. The highest point on S-8 was at the discharge point near the east corner (Plate 28: A). The lowest sections were located in borrow area swales at the west end (Plate 28: B) and near the north corner (Plate 28: C). The highest elevation of S-9 occurred at the east corner (Plate 29: A). The dike at this corner has eroded and collapsed. The borrow area was deep around the entire perimeter and represented the lowest portion of the site. S-10 was lowest in the borrow area swale at the south corner (Plate 30: A). Another low area occurred at the east corner (Plate 30: B). The perimeter along the north face of the site was characterized by a series of shallow depressions which occurred in the borrow area and dike swales (Plate 30: C). The highest elevation occurred on a hummock site, which apparently was produced by undiked disposal operations. The substrate of all three sites was composed almost entirely of silty material. The substrate condition at the three sites was in the late DM-5 stage.

282. Drainage characteristics: Drainage on all three sites was poor. All three areas exhibited a well-developed dike and borrow area swale. Drainage in the swales as well as in more centrally located portions of these sites was further impeded by a predominance of fissured substrate conditions. The borrow area of S-8 on the west side of the site was apparently permanently flooded. The extent to which this condition was influenced by tidal action could not be determined. Swales on the east half were irregularly flooded and were under the influence of runoff from rainfall. S-9 was under greater tidal influence than S-8 because the breach in the dike at the east corner (Plate 29: A) provided an access point for flooding during

PLATE

US 5

PLATE

A

CHAS.

S 9

2

spring tides. As a result, most of the borrow area remained permanently flooded. Shallow depressions along the north face of S-10 (Plate 30: B and C) and the extensive areas of fissured substrate in the central portions of the site were flooded by rainfall. The borrow area in the vicinity of the south corner (Plate 30: A) was influenced by tidal action and remained permanently flooded.

Biological Features

283. Vegetation: Conditions on all three sites were greatly influenced by vegetation. S-8 and S-9 supported large expanses of giant cord grass (*Spartina patens*). S-9 was almost completely covered by this species. Sections of S-8 along the north face of the site supported a mixture of cattails, sedges and rushes in addition to giant cord grass. The north face of S-10 (Plate 30: C) supported woody shrubs, primarily *Proelia hirsuta*. A small stand of mixed rushes and sedges which at times of heavy rainfall was partially submerged, occurred at the east corner (Plate 30: B). The remainder of the site, except for the hummock area (Plate 30: D) was about equally divided between barren non-vegetated fissured substrate and areas supporting marsh grasses. These vegetated areas appeared to result from marsh grasses which were overlaid by dredged material. The depth of the dredged material was apparently shallow enough to permit the original marsh vegetation to survive and penetrate through to the new surface. Vegetation on all three sites had a significant role in maintaining soil fissures in a partially filled condition.

284. Mosquito breeding: More than half of the S-8 and S-10 areas exhibited excellent mosquito breeding conditions. S-8 was especially significant as one of the most uniformly conducive breeding habitats of all areas surveyed during this study. Larval dip counts consistently approached 100 per dip when dike and borrow area swales were flooded after significant rainfall. Fissured areas in the central locations of the site also consistently produced mosquitoes. Conditions on S-10 were similar to but less extensive than those of S-8. A major focus of mosquito production occurred in depressions along the north face



(Plate 30: B and C). Fissured areas on the south half of the site were also significant. The intensity of breeding on S-9 was somewhat less than that of S-8 and S-10 because of the firm access at the east corner.

285. Mosquito species composition: *Anopheles walkeri*, *A. saltator*, *Anopheles bradleyi* and *Anopheles punctipennis*.

286. Mosquito breeding potential: S-8 = 4; S-9 = 2-3; S-10 = 3.

287. Site prognosis: Present conditions on all three sites can be expected to persist even if they are used for further dredging operations. Deposition of new dredged material can be expected to interrupt breeding for only a brief period (less than one year).

SITE DESIGNATION: STA. #1820 C-P (S-11); STA. #1836 C-P (S-12)

Physical Features

288. Estimated acreage: S-11, 21.3; S-12, 43.7

289. Substrate evaluation: Conditions of S-11 resembled those of S-8 however, the substrate has undergone more extensive weathering which has resulted in the filling of most fissures. The lowest areas were located in the borrow area along the south face of the dike (Plate 31: A) and in the northwest corner (Plate 31: B). The highest area was a hummock site on the east side (Plate 31: C). The substrate throughout most of the site was in the late DM-5 or early DM-7 stage. The lowest portion of S-12 occurred in the borrow area swale which runs along the entire inside perimeter of the site. A large hummock represents the highest elevation and extends along the entire east-west axis of the site (Plate 31: D). This area exhibited a dense vegetational cover which was thought to be an indication that the site has not been disturbed by dredging operations for many years. Most dredged material which has been pumped into the site has settled in the borrow area along the north face (Plate 31: E). The substrate was in the late DM-4 or early DM-5 stage.

290. Drainage characteristics: Drainage on S-11 was poorest in the swales along the south face and in the northwest corner (Plate 31: A and B). These areas were subjected to a fluctuating water level which was dependent on rainfall. No tidal flushing occurred in this site. Drainage in the entire borrow area swale of S-12 was very poor and the water level was dependent on rainfall. Tidal action was of minor importance and appeared to influence the borrow area only at the southwest corner (Plate 31: F).

Biological Features

291. Vegetation: More than half of S-11 supported a mature stand of *Baccharis halimifolia*. A portion of the northwest corner was overgrown with *Spartina cynosuroides* (light area of S-11 in Plate 31). A transition to freshwater species such as cattails, sedges and rushes occurred in the extreme northwest corner (Plate 31: B). Little



or no vegetation grew in the borrow area swale along the north face of S-12. The hummock area supported a mature stand of trees including pines, cedar, wax myrtle and hardwoods. Proceeding down the elevation gradient from the hummock to the south face, a transition to *Spartina patens*, *Distichlis spicata* and finally saltmarsh grasses was observed (Plate 31: G). A small area along the west side of the site supported cattails, sedges and rushes.

292. Mosquito breeding: Most mosquito breeding on S-11 was confined to the borrow area on the south face and the northwest corner (Plate 31: A and B). The breeding intensity on S-12 was greater than that of S-11 and occurred throughout the entire borrow area swale. The dike swale along the north face was also a favorable mosquito breeding habitat.

293. Mosquito species composition: *Culex tarsalis*, *A. triseriatus*, *Anopheles punctipennis*, *A. albopictus* and *A. triseriatus*.

294. Mosquito breeding potential: S-11 = 2-3; S-12 = 3-4.

295. Site prognosis: Present conditions on S-11 are likely to prevail indefinitely unless the site is further altered by dredging activities. Breeding intensity on S-12 will probably increase in the borrow and dike swales along the north face especially if a herbaceous layer of vegetation becomes established and impedes fissure weathering.

Section 4: Colleton-Beaufort Counties

296. Only a small section of the AIWW in Beaufort County is within the boundary of the Charleston District. Little or no shoaling occurs along this short stretch north of Port Royal Sound and as a result no diked disposal sites have been constructed along it at the time of the writing of this report. The AIWW in Colleton County is similar to the portion of the Waterway in south Charleston County in that most of it passes through rivers (the South Edisto, Ashepoo and Coosaw) which have naturally deep channels. As a result, little dredging is required for maintenance of the AIWW in Colleton County. Most of the six diked disposal sites in Colleton County are associated with man-made cuts which connect the AIWW between the above mentioned rivers. These cuts include those at Fenwick and Ashe Island.

SITE DESIGNATION: STA. #2157 C-P (S-15); STA. #2234 C-P (S-16)

Physical Features

297. Estimated acreage: S-15, 32.1; S-16, 5.5

298. Substrate features: S-16 was small and of minor significance from the standpoint of mosquito control. Most of the site was sandy throughout except for a hummock area in the center. The dike at the north end was eroded and has collapsed. As a result, tidewater entered a small portion of the site and the substrate at this point contained a few shallow fissures in the late DM-4 stage. S-15 has been filled and the entire surface has been covered with silty dredged material. A small portion near the east corner (Plate 32: A) was covered with sandy material and this area represented the discharge location. Except for this discharge point, the entire surface was fissured and was in the DM-4 stage. Fissures were deep, especially in the borrow area swale where depths approached one-half meter.

299. Drainage characteristics: S-16 was well-drained. Drainage in S-15 was poor. Runoff from rainfall was trapped in fissures. Borrow area and dike swales encircled the entire perimeter of the site and were especially prone to flooding because they represent the lowest areas in the site. The lowest portion of the borrow area occurred along the west side of the site (Plate 32: B). On some occasions, heavy rainfall resulted in water depths which approached one-half meter in this area. S-15 was not influenced by tides. S-16 was subjected to a minor tidal influence as described in the preceeding paragraph.

300. Vegetation: S-16 supported little vegetation except for plant growth on the hummock area which supported mature trees. S-15 was completely devoid of vegetation.

301. Mosquito breeding: S-16 exhibited no significant mosquito breeding habitats except for occasional light breeding near the breach in the dike. The fissured substrate of S-15 represented excellent conditions for mosquito production, especially in the dike and borrow area swales.

302. Mosquito species composition: S-15 and S-16: *A. sollicitans*



and *A. taeniorhynchus*.

303. Mosquito breeding potential: S-16 = 1; S-15, 2-3.

304. Site prognosis: No change is likely in S-16 conditions unless the site is altered by further dredging. Mosquito breeding intensity at S-15 is likely to increase as the surface ages. This effect will be further enhanced if a layer of herbaceous vegetation becomes established before weathering of fissures is complete.

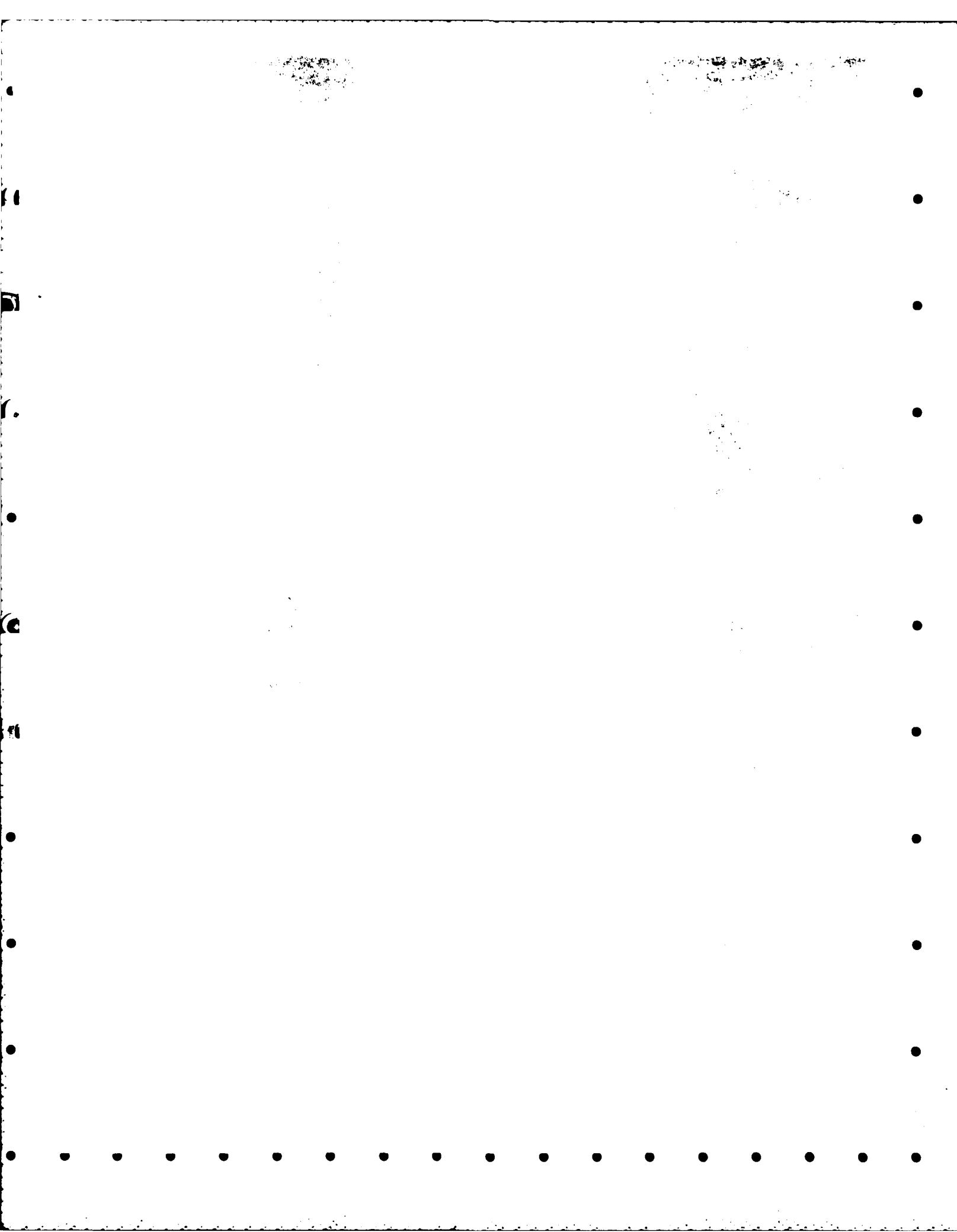
SITE DESIGNATION: STA. #2461 C-P (S-17); STA. #2508 C-P
(S-18); STA. #2536 C-P (S-19); STA. #2564
C-P (S-21)

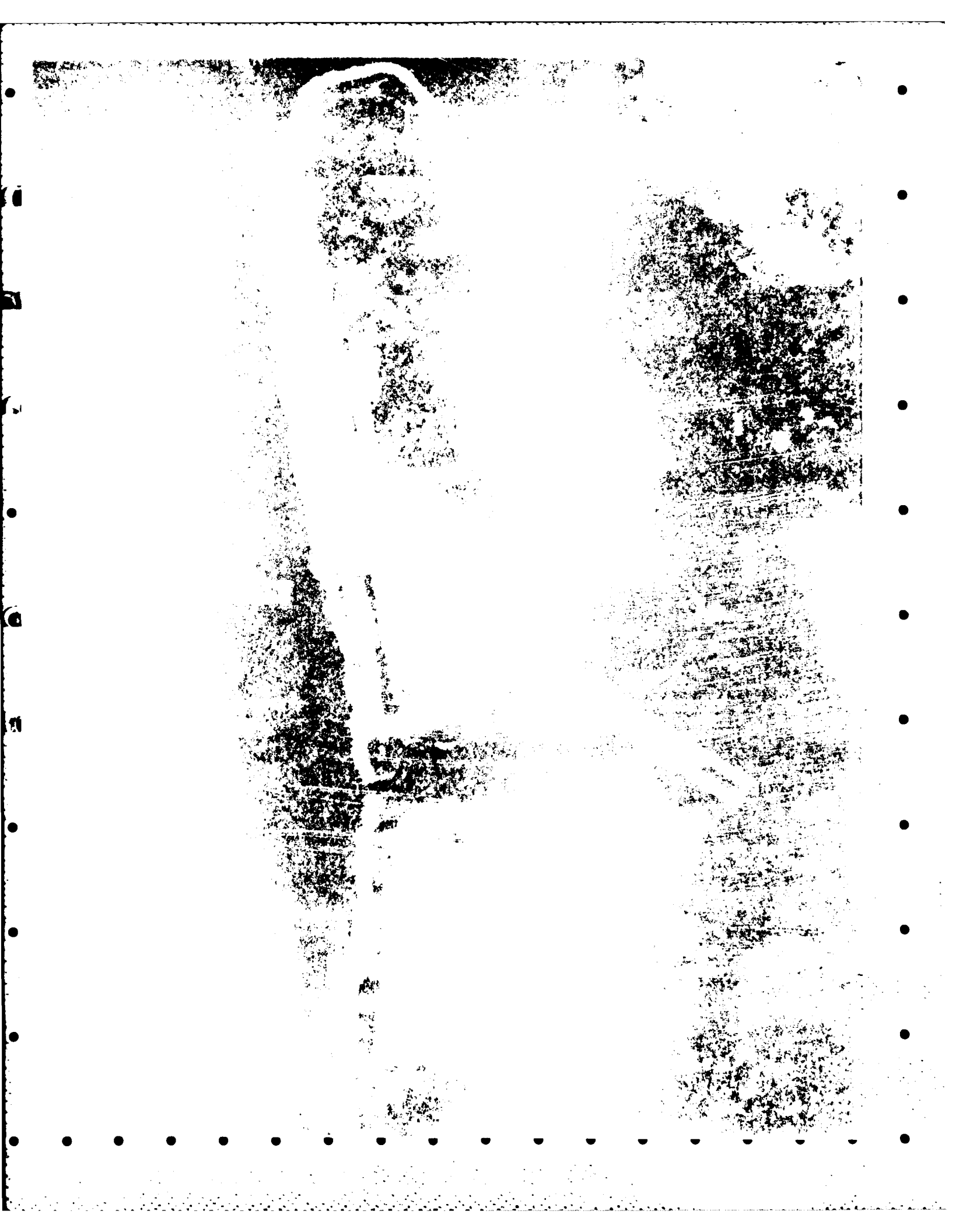
Physical Features

305. Estimated acreage: S-17, 72.3; S-18, 45.7; S-19, 19.3;
S-21, 29.6

306. Substrate evaluation: All four sites were basically similar (S-20 was not diked when this report was prepared). They all have been filled and the deposited dredged material is silty. S-17 and S-18 each have a large, high hummock area which occupied approximately one-half of the surface area (Plate 33: A; Plate 34: A). The remaining half was low and completely covered with dredged material. The substrate stage was early DM-4. Both sites were encircled by a deep borrow area swale and a dike swale. A discharge area was a prominent feature of S-17 (Plate 33: B), but the discharge point on S-18 could not be located during inspections of the site. Sump sites were located on the east end of S-17 (Plate 33: C) and the south end of S-18 (Plate 34: B). The highest areas on S-19 and S-21 were small hummock sites (Plate 34: C and Plate 35: A). Most of the surface of both sites was composed of silty dredged material except for sandy deposits in the vicinity of the discharge points (Plate 34: D and Plate 34: B). Most of the surface in both areas was fissured and represented the DM-4 substrate stage. Sump areas represented the lowest elevation in both sites (Plate 34: E and Plate 35: C).

307. Drainage characteristics: Irregular flooding occurred in all four sites and this resulted primarily from runoff from rainfall. None of the sites were influenced by tidal action. However, several depression sites located outside the dike of S-21 were flooded by abnormally high tides as well as by rainfall (Plate 35: D). All the low areas within S-17, S-18, S-19 and S-21 exhibited a tendency to flood, including discharge holes, dike and borrow area swales and sump sites.







Biological Features

308. Vegetation: Except for trees and shrubs occurring in the hummock areas, most of the surface of these sites was devoid of vegetation. One section of S-21, adjacent to the hummock area, was beginning to revegetate rapidly (Plate 35: E). This area was overlaid by a shallow layer of dredged material which covered *Spartina patens*. The depth of the dredged material deposit was not sufficient to kill the stand of *Spartina* and a dense stand of new sprouts was emerging when the site was inspected. This will probably impede weathering of fissures in the portion of the site where the *Spartina* is developing.

309. Mosquito breeding: All four sites exhibited excellent mosquito breeding habitats throughout most of their extent. All low areas including discharge holes, dike and borrow area swales, sump sites and the entire fissured surface of each site was capable of heavy mosquito production.

310. Mosquito species composition: S-17, S-18, S-19 and S-21: *Anopheles walkeri* and *A. triseriatus*.

311. Mosquito breeding potential: S-17 = 3; S-18 = 3; S-19 = 2-3; S-21 = 3-4.

312. Site prognosis: Mosquito breeding intensity on all sites will probably increase slightly as vegetation begins to develop on the barren surfaces. This effect will be enhanced if revegetation is rapid enough to impede weathering of fissures. Such an effect is already occurring on S-21. Further deposition of dredged material probably will not have any lasting effect on the mosquito producing capabilities of these sites.

VII. CONCLUSIONS AND RECOMMENDATIONS

313. Experimental data about the generalized physical, chemical and biological conditions found on dredged material disposal sites in the Charleston CE District have been presented. Detailed summaries of existing conditions on each disposal area associated with the maintenance dredging of the AIWW within the Charleston District have also been presented. The major conclusions relating to the information presented in the preceding sections of this report are reviewed in this section together with recommendations for reducing or eliminating mosquito breeding associated with the disposal of dredged material. Many of these recommendations relate to working methods used for mosquito abatement in other types of saltmarsh habitats, but they have not been adequately studied and refined to maximize their effectiveness in diked dredged material disposal site situations. Therefore, many of the recommendations presented in the remainder of this section *should not* be regarded as practicable methods for implementing control measures at this time. They should instead be interpreted as suggestions for initiating experimental pilot studies. This may be regarded as the initial recommendation of this section, (i.e., to conduct further studies of the feasibility of augmenting and supplanting insecticidal control methods with cultural practices in a defined pest management program).

Interagency Communication

314. Ezell (1978) has provided an excellent report of the attitudes of persons associated with different government agencies concerned with harbor and channel maintenance and with mosquito abatement. Results of this study indicated that personnel within each of these agencies had differing and sometimes conflicting perspectives of the role, function and responsibility of the other agency. Thus, the improvement of communication among different agencies should contribute to an improvement in the achievement of the goals of all concerned interests. It is therefore, recommended that some mechanism be established for interagency communication. The structure of such a mechanism should be devised in

a manner that will best accomodate the existing organizational structure of the different agencies concerned. Since organizational structures vary in different areas and since the scope of problems may encompass different amounts of area (i.e., county, regional, state, etc.), no single standard for developing channels of communication is applicable in all cases. In some instances, the establishment of a position for a commissioner representing a given interest group or agency on the board of commissioners of a mosquito abatement district may suffice. In other instances, a state commission organized under the aegis of an appropriate department such as environmental protection or public health may be necessary. A somewhat novel and extremely effective approach to stimulating interagency communication has been developed in New Jersey. The Associated Executives of Mosquito Control in New Jersey is an organization of supervisory personnel which meets monthly to review problems within their purview, establish policy and develop cooperative, regional projects. Policy decisions are formulated only after members of agencies with a possible interest in such policy have represented their views before this organization. The range of possible organizational approaches is of course virtually limitless and any structure which is functional and amenable to all interested parties can be considered to be a satisfactory means of solving communication problems.

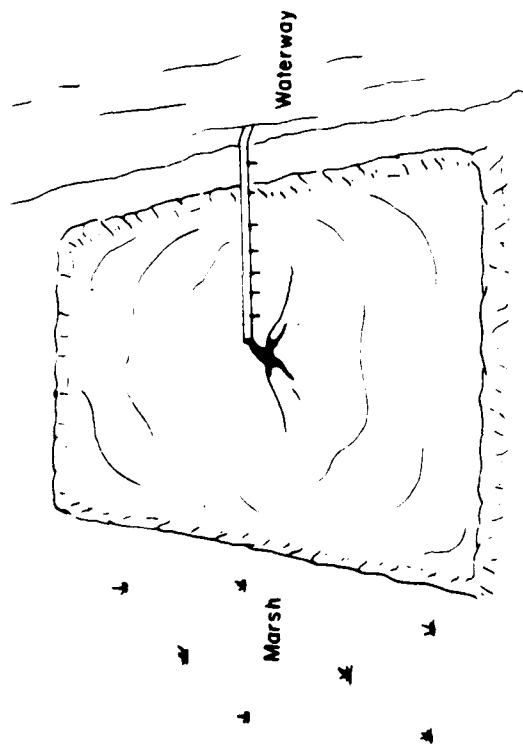
Cultural Practices

315. Results already discussed in this report demonstrate that most mosquito-related problems associated with diked dredged material disposal areas in South Carolina are attributable to floodwater mosquitoes. Therefore, the application of an appropriate water management scheme within disposal areas would provide an excellent means of implementing permanent control. As previously described, water management for mosquito control in saltmarsh habitats can be implemented in one of two basic ways: by means of permanent water impoundments; by means of a water drainage and circulation schemes (Open Marsh Water Management). The latter approach appears to be the most suitable one for diked disposal areas because it complements the need for dewatering sites which is necessary before sites can be reused. Results from the review of the

generalized physical, chemical and biological features of disposal areas indicated that drainage is a feasible approach. The implementation of this type of management scheme would involve modifications to practices currently used in disposal site construction and to the manner in which dredged material is pumped into sites. Additional site modifications might also be required after the disposal operations are completed. Such modifications might also entirely replace the need for changes to sites prior to the pumping operation in some instances.

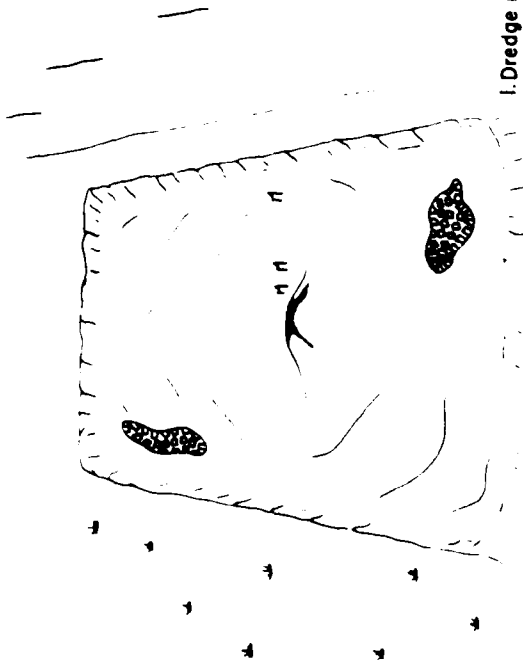
316. Rim ditching: One approach to drainage has been discussed in detail by Ezell (1978). This method, which is illustrated in Figure 10, involves the establishment of an elevation gradient with the highest point at the center of the disposal site. The perimeter area, which is the lowest portion of the site, is then excavated to provide material for reinforcing the dike and to produce a deep rim ditch. The rim ditch acts as a sink receiving runoff from the higher, central portions of the site. This sink can be connected with tidewater by weep holes in the dike which will permit larvivoracious fish to enter the site and devour any mosquitoes before they reach the adult stage. The success of this technique is dependent on two factors: a continuous elevation gradient with a surface that is even and does not trap water; the action of tidal flushing resulting when a weep hole or access pipe is installed in the dike. Under some circumstances, such as disposal areas which have been used for many disposal operations, it may be impossible to excavate a rim ditch which is deep enough to be flooded by daily tidal action. In such situations, rim ditches would still be effective if they were carefully constructed with sufficient slope to provide drainage to an outlet (weep hole or access pipe in the dike). Extra care would be necessary in such instances to avoid any irregularities in the slope of ditches of this kind—irregularities could result in potholes conducive to mosquito breeding if drainage patterns are not carefully designed and constructed.

317. Radial ditches and minnow reservoirs: Mosquito breeding in many disposal sites may not be completely eliminated by rim ditch construction alone because of naturally occurring irregular contours and the shape and size of sites. During the preliminary phase of developing



A

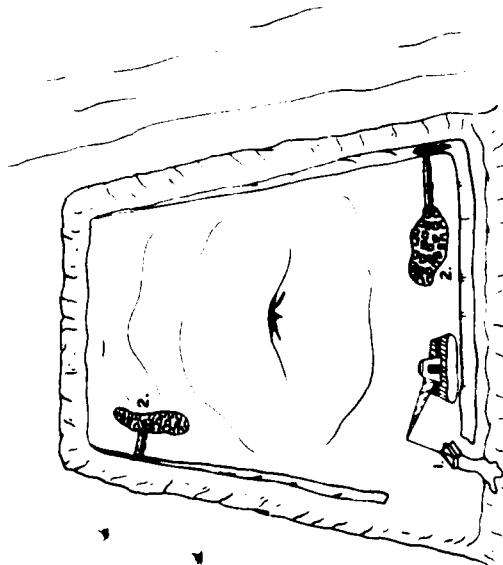
Initial Operation : Discharge Pipe near center of disposal area



B

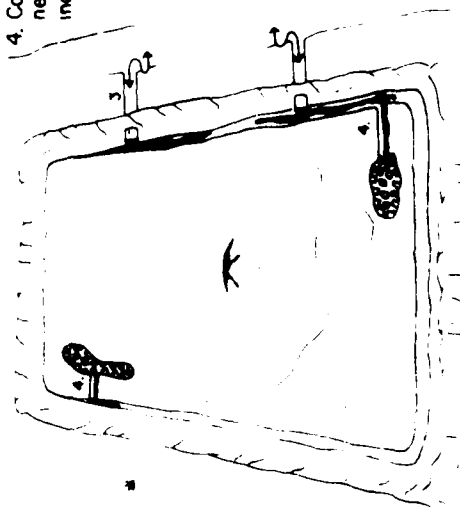
Consolidation : with Hydraulic Gradient
(center to periphery)

1. Dredge material from RIM ditch is used to reinforce original dike
2. Specific breeding locations must be isolated
3. Culverts and/or tide gates established to insure tidal flow
4. Collateral ditches may be needed to drain specific individual breeding locations



C

RIM Ditch Operation



D

RIM Ditch Complete

Figure 10 Artist's Conception of RIM Ditching Pattern for Control of Dredge Material Disposal Area Mosquitoes (after Ezell, 1978)

a plan for implementing permanent control measures, an on-site inspection should be conducted to locate potential trouble spots. A decision can then be made to either excavate such potential breeding sites to a depth sufficient to maintain permanent water (ponding) or to connect the site to the rim ditch with a secondary or radial ditch. Where small ponds would eliminate the mosquito breeding habitats, the possibility of using high explosives in place of heavy equipment should be studied.

318. External drainage: Augmentation of drainage patterns surrounding the outside perimeter of many disposal areas may be necessary to eliminate mosquito breeding sites created by blockage of natural tidal drainage patterns and other localized breeding situations which develop along the base of dikes outside disposal areas. The need for such control procedures could be determined during the on-site inspection made to plan the internal drainage scheme. In some situations, the creation or modification of external drainage may be necessary to make the internal drainage scheme function properly.

319. Specialized equipment: Modifications described in the previous paragraphs are difficult and expensive to implement with standard construction equipment. Consideration should be given to the use of more maneuverable amphibious equipment whenever possible (this would have the added advantage of eliminating breeding habitats created by mats used to support non-amphibious equipment). Consideration should also be given to the use of specialized equipment designed specifically for soft terrain and mosquito problems. Since equipment in this category, such as the rotary marsh ditcher and the riverine utility craft (RUC), has had few trials in diked dredged material disposal sites, it should be considered for inclusion in a pilot study.

320. Surface modification: In some localities of the country, harrowing the surface of dredged material with a disc or spring tooth harrow has proved to be an effective means of abating associated mosquito problems (Ezell, 1978). This approach to control in the South Carolina coastal area unfortunately does not appear to be feasible for most disposal areas because climatic conditions and sediment compositions in this region of the country tend to produce a dredged material substrate which remains unstable for long periods of time. As a result, mosquito breeding substrate stages frequently develop before the

substrate is firm enough to support equipment used for harrowing. The possible use of this technique in older disposal areas, which are no longer used for disposal of dredged material, should not be ruled out however.

321. Other means of surface modification should receive further study. Preliminary investigations (Ezell, 1978) have indicated that soil fissuring can be retarded or eliminated by the application of materials over the dredged material surface which reduce the rate of moisture loss. Soil chemistry profiles reported in this study do not rule out the possibility of chemically altering the substrate composition in a manner which makes the substrate unattractive as an oviposition site for floodwater mosquitoes. These two potential control approaches should therefore be emphasized in future basic research studies.

Chemical Control Procedures

322. No review of the effectiveness of current chemical control methods was provided in this report because this was not part of the intended purpose of this study. However, it is possible that even the best designed permanent control efforts will not always provide 100 percent control of mosquitoes. Therefore, efforts should be made to review and study chemicals and formulations available at the present time because many new, safer compounds have recently been developed and placed on the market.

LITERATURE CITED

- Adams, D. A. 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. *Ecology* 44(3): 445-456.
- Altman, R., M. Goldfield and O. Sussman. 1967. The impact of vector-borne diseases in the Middle Atlantic States. *Med. Clin. of N. Amer.*, 51(3): 661-671.
- Askey, M. M. 1974. The thirteenth annual report of the Charleston County Mosquito Abatement Program. Charleston Co., Charleston, S. C. 12pp.
- Askey, M. M. 1977. The sixteenth annual report of the Charleston County Mosquito Abatement Program. Charleston Co., Charleston, S. C. 17pp.
- Bella, D. A. 1977. Hydrogen sulfide gas. Pages 643-645 in J. R. Clark, Coastal ecosystem management. John Wiley & Sons, Inc., New York. 928 pp.
- Brooks, J. E. 1939. Interference with mosquito control works resulting from hydraulic filling. *Proc. N. J. Mosq. Exterm. Assoc.* 26: 166-167.
- Buescher, E. L., R. J. Byrne, G. C. Clark, D. J. Gould, P. K. Russell, F. G. Scheider and T. M. Yuill. 1970. Cache Valley virus in the Del Mar Va Peninsula. 1. Virologic and serologic evidence of infection. *Am. J. of Trop. Med. Hyg.*, 19:493-502.
- Carlson, P. R. 1972. Patterns of succession on spoil islands: a summary report. NSF Tech. Studies Rep. GY-9170. New College, Sarasota, Fla. 113pp.
- Carpenter, S. J. and W. J. LaCasse. 1955. Mosquitoes of North America (North of Mexico). University of Calif. Press, Berkeley, Los Angeles, London. 487 pp.
- Carpenter, S. J. 1968. Review of recent literature on mosquitoes of North America. *Calif. Vector Views.* 15(8): 72-98.
- Carpenter, S. J. 1970. Review of recent literature on mosquitoes of North America - Supplement I. *Calif. Vector Views.* 17 (6): 39-66.

- Chapman, H. C. and F. Ferrigno. 1956. A three-year study of mosquito breeding in natural and impounded salt-marsh areas in New Jersey. *Proc. N. J. Mosq. Exterm. Assoc.* 43:48-64.
- Chapman, H. C. 1959. Observations on the salinity of natural and impounded salt-marsh areas in New Jersey in relation to vegetation, mosquitoes and predators. *Mosq. News*, 19:148-150.
- Chatham County Mosquito Control Commission. 1969. Special report: mosquito breeding problems associated with the dredging of Savannah Harbor. Savannah, Ga. 10 pp.
- Clark, J. R. 1977. Coastal ecosystem management. John Wiley & Sons, Inc. N.Y., London, Sydney. 928 pp.
- Clements, A. N. 1963. The physiology of mosquitoes. The MacMillan Co., New York. 393 pp.
- Crans, W. J. 1962. Blood meal preference studies with New Jersey mosquitoes. *Proc. N.J. Mosq. Exterm. Assoc.* 49:120-125.
- Crans, W. J. 1964. Continued host preference studies with New Jersey mosquitoes. *Proc. N. J. Mosq. Exterm. Assoc.* 51:50-58.
- Crans, W. J. 1968. Mosquito incidence and feeding patterns in four encephalitis reservoir areas in New Jersey. Ph.D. thesis. Rutgers University, New Brunswick, N. J. 133pp.
- Daiber, F. C. 1972. Tide marsh ecology and wildlife: salt marsh plants and future coastal salt marshes in relation to animals. 1971-1972 Ann. Pittman-Robertson Rpt. to Div. Fish Wildlife, Delaware Dept. Nat. Res. Env. Con. 80 pp.
- Darsie, R. F., D. MacCreary and L. A. Stearns. 1953. Analysis of mosquito trap collections at Delaware City and Lewes, Delaware, for the twenty-year period, 1932-1951. *Proc. N. J. Mosq. Exterm. Assoc.* 40:169-190.
- Davis, L. V. and I. E. Gray. 1966. Zonal and seasonal distribution of insects in North Carolina salt marshes. *Ecol. Monographs* 36(3):275-295.

- Edman, J. D. 1971. Host-feeding patterns of Florida mosquitoes.
I. *Aedes*, *Anopheles*, *Coquillettidia*, *Mansonia* and *Psorophora*.
J. of Medical Entomol., 8(6): 687-695.
- Edman, J. D. 1974. Host-feeding patterns of Florida mosquitoes.
III. *Culex* (*Culex*) and *Culex* (*Neoculex*). J. of Medical
Entomol., 11(1): 95-104.
- Ezell, W. B., Jr. 1976. Dredged spoils. Pages 412-413 in R. O.
Hayes (Moderator) Water resources projects in relation to
mosquito production and control. Mosq. News 36(4): 412-415.
- Ezell, W. B., Jr. Gen. ed. 1978. An investigation of physical
chemical and/or biological control of mosquitoes in dredged
material disposal areas. Contract Rep. DACW 39-75-C-0122.
U. S. Army Engineer Waterways Expt. Sta., Vicksburg, Miss.
266 pp.
- Fehn, C. F. 1957. Study of mosquito problems in Charleston County,
South Carolina. USPHS. Communicable Diseases Lab., Savannah,
Ga. 14pp.
- Ferrigno, F. and D. M. Jobbins. 1968. Open marsh water
management. Proc. N. J. Mosq. Exterm. Assoc. 55:104-115.
- Ferrigno, F., L. G. Mac Namara and D. M. Jobbins. 1969.
Ecological approach for improved management of coastal
meadowlands. Proc. N. J. Mosq. Exterm. Assoc. 56:188-202.
- Ferrigno, F. 1970. Preliminary effects of open marsh water
management on the vegetation and organisms of the salt
marsh. Proc. N. J. Mosq. Exterm. Assoc. 57:79-94.
- Ferrigno, F., P. Slavin and D. M. Jobbins. 1975. Saltmarsh water
management for mosquito control. Proc. N. J. Mosq. Control
Assoc. 62:30-38.
- Fleming, J. F. and L. T. Alexander. 1961. Sulfur acidity in
South Carolina tidal marsh soils. Soil Sci. Soc. Amer.
Proc. 25:94-95.
- Florschutz, O., Jr. 1959. Mosquito production and wildlife usage
in impounded, ditched and unditched tidal marshes at Assawoman
Wildlife Area, Delaware, 1957-1958. Proc. N. J. Mosq.
Exterm. Assoc. 55:103-111.

- Franz, D. R. and E. Ruber. 1962. Some effects of salt marsh impoundment on micro-crustacean and mosquito productivity. Proc. N. J. Mosq. Exterm. Assoc. 49:126-136.
- Franz, D. R. 1963. Production and distribution of mosquito larvae on some New Jersey salt marsh impoundments. Proc. N. J. Mosq. Exterm. Assoc. 50:279-285.
- Glasgow, R. D. 1938. Mosquitoes and wild life as interrelated problems in human ecology. New York State Museum Bull. 316:7-20.
- Gorgas, W. C. 1915. Sanitation in Panama. D. Appleton and Co. N. Y. and London. 298 pp.
- Helm, R. W. 1959. Disappearing meadowland in Union County. Proc. N. J. Mosq. Exterm. Assoc. 46:74-77.
- Hill, D. E. and A. E. Shearin. 1970. Tidal marshes of Connecticut and Rhode Island. The Connecticut Agr. Exp. Sta. Bull. 709. 34 pp.
- Horsfall, W. R., H. W. Fowler, Jr., L. J. Morretti and J. R. Larsen. 1973. Bionomics and embryology of the inland floodwater mosquito. Univ. of Illinois Press. 211pp.
- Jeane, G. S., II, and R. E. Pine. 1975. Environmental effects of dredging and spoil disposal. J. Water Pollution Control Federation 47:553-561.
- King, W. V., G. H. Bradley, C. N. Smith and W. C. McDuffie. 1960. A handbook of the mosquitoes of the southeastern United States. U.S.D.A. Agricultural Research Service. Agricultural Handbook. No. 173. 188pp.
- Kinsey, L. 1958. Salt marsh reclamation in Nassau County and its effect upon mosquito control. Proc. N. J. Mosq. Exterm. Assoc. 45:179-184.
- Knight, K. L. and T. E. Baker. 1962. The role of the substrate moisture content in the selection of oviposition sites by *Anopheles punctipennis* (Wied.) and *A. triseriatus* (Walk.). Mosq. News 22(3):247-254.

- Knight, K. L. 1965. Some physical and chemical characteristics of coastal soils underlying mosquito breeding areas. *Mosq. News* 25 (2):154-159.
- Knight, K. L. and A. Stone. 1977. A catalogue of the mosquitoes of the world (Diptera: Culicidae). 2nd Ed. The Thomas Say Foundation. Volume VI. 611 pp.
- LaRoe, E. T. 1977. Dredging - ecological impacts. Pages 610-614 in J. R. Clark, Coastal ecosystem management. John Wiley & Sons, Inc., New York.
- MacNamara, L. G. 1952. Needs for additional research on mosquito control from the standpoint of fish and game management. *Proc. N. J. Mosq. Exterm. Assoc.* 39:111-116.
- Mangold, R. E. 1962. The role of low-level dike salt impoundments in mosquito control and wildlife utilization. *Proc. N. J. Mosq. Exterm. Assoc.* 49:117-120.
- McGaughey, W. H. 1968. Role of salts in oviposition site selection by the black salt-marsh mosquito, *Aedes triseriatus* (Wiedemann). *Mosq. News* 28(2):207-217.
- McLintock, J. 1978. Mosquito-virus relationships of American encephalitides. *Ann. Rev. Entomol.* 23:17-37.
- Murphy, W. L. and T. W. Zeigler. 1974. Practices and problems in the confinement of dredged material in Corps of Engineers projects. Technical Rep. D-74-2. U. S. Army Engineer Waterways Expt. Sta., Vicksburg, Miss. 136 pp.
- Nayar, J. K. and D. M. Sauerman, Jr. 1975a. The effects of nutrition on survival and fecundity in Florida mosquitoes. Part 1. Utilization of sugar for survival. *J. of Medical Entomol.*, 12(1): 92-98.
- Nayar, J. K. and D. M. Sauerman, Jr. 1975b. The effects of nutrition on survival and fecundity in Florida mosquitoes. Part 2. Utilization of a bloodmeal for survival. *J. of Medical Entomol.*, 12(1): 99-103.

- Nayar, J. K. and D. M. Sauermann, Jr. 1975c. The effects of nutrition on survival and fecundity in Florida mosquitoes. Part 3. Utilization of blood and sugar for fecundity. J. of Medical Entomol., 12(2): 220-225.
- Petersen, J. J. 1969. Oviposition response of *Aedes sollicitans*, *Aedes taeniorhynchus*, and *Psorophora confinnis* to seven inorganic salts. Mosq. News 29(3):472-483.
- Petersen, J. J. and H. C. Chapman. 1970. Chemical characteristics of habitats producing larvae of *Aedes sollicitans*, *Aedes taeniorhynchus*, and *Psorophora confinnis* in Louisiana. Mosq. News, 30(2): 156-161.
- Pratt, H. 1977. Current status of the major vector borne diseases. (unpub. paper) Presented at the fifth annual meeting of the South Carolina Mosq. Control Assoc., Charleston, S. C.
- Provost, M. W. 1959. Impounding salt marshes for mosquito control and its effects on bird life. Fla. Nat. 32(4):163-170.
- Provost, M. W. 1968. Managing impounded salt marsh for mosquito control and estuarine resource conservation in LSU Marsh and Estuary Symposium. 1967. pp. 163-171.
- Provost, M. W. 1976. Source reduction in mosquito control. (unpub. paper) Presented at the first annual meeting of the Mid-Atlantic Mosquito Control Assoc., Savannah, Ga.
- Provost, M. W. 1977. Mosquito control. Pages 666-671 in J. R. Clark, Coastal ecosystem management. John Wiley & Sons, N. Y. 928 pp.
- Ruth, P. W. 1952. Mosquito control on soft fills. Proc. N. J. Mosq. Control Assoc. 39:160-162.
- Scotton, G. L. 1977. Mosquito oviposition (*Aedes taeniorhynchus* and *Aedes sollicitans*) on coastal dredge spoil. M. S. Thesis N. C. State Univ.
- Shisler, J. K. and D. M. Jobbins. 1977. Salt marsh productivity as affected by the selective ditching technique, Open Marsh Water Management. Mosq. News 37(4):631-636.
- Shoemaker, W. E. 1964. A biological control for *Aedes sollicitans* and the resulting effect upon wildlife. Proc. N. J. Mosq. Exterm. Assoc. 51:93-97.

Smith, J. B. 1904. Report of the New Jersey Agricultural Experiment Station upon the mosquitoes occurring within the state, their habits, life history, etc. Trenton, N. J. MacCrellish & Quigley, 482pp.

Stalter, R. 1975. *Phragmites communis* in South Carolina. Rhodora 77:159.

Tiner, Jr., R. W. 1977. An inventory of South Carolina's coastal marshes. South Carolina Marine Resources Center Technical Report No. 23. 33pp.

Travis, B. V. and G. H. Bradley. 1943. The distribution of *Aedes* mosquito eggs on salt marshes in Florida. J. of Econ. Entomol., 36(1); 45-50.

Vannote, H. G. 1945. Some mosquito control operations in Monmouth County, New Jersey. Mosq. News 5(4):142-143.

END

FILMED

4-85

DTIC

