HANDBOOK FOR EMERGENCY FLOOD PROTECTION

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

FORWARD

Since it is often impossible to place well experienced people in all supervisory capacities during highwater emergencies, this manual has been prepared with a view to suggesting the best methods of providing advance protection during floods, and of effecting emergency repairs efficiently, economically, and in the shortest practicable time.

The types of construction outlined herein are considered standard and should, therefore, be followed as closely as possible. It is not intended that personal initiative be destroyed in dealing with unusual emergencies. On the contrary, if danger occurs along a levee line, immediate action is demanded using the materials and labor at hand. However, since an emergency is not a time in which to experiment, these proven methods should be employed wherever possible.

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PREFACE

AUTHORITY. Public Law 84-99 authorizes the Corps of Engineers to provide temporary and supplemental assistance to local and State Governments during flood emergencies.

Except for sections of this law pertaining to droughts and contaminated source of drinking water*, all emergencies eligible for Corps assistance must be flood related. Corps assistance for non-flood emergencies must usually follow a Presidential disaster declaration and then only as directed by the Federal Emergency Management Agency (FEMA).

GENERAL. While it is the Corps desire to provide maximum assistance within the limits of its authority, we must keep in mind that the primary responsibility for flood fighting rests with the local community. It is not the intent of the law for the Corps to assume this responsibility. Communities must commit all their available resources and seek aid from county and state governments prior to requesting Corps assistance.

TYPES OF ASSISTANCE

In the event of imminent or actual flooding, Corps assistance may include technical advice, loan, or issue of equipment and supplies, construction of temporary protective works, and post-flood assistance.

*These types of assistance are not covered herein. See "Disaster Activities Plan" for information.

TECHNICAL ASSISTANCE. Technical assistance is normally provided upon request from community officials, assuming it is within the limits of the District's manpower and funding constraints.

EQUIPMENT AND SUPPLIES. Equipment and supplies (sandbags, pumps, etc.) will be loaned or issued to communities by the Emergency Operations Center provided the community has exhausted its own supplies, and sought additional aid from county and state officials. As with other types of Corps assistance, supplies and equipment can only be issued when a flood is imminent or is actually occurring. Also, it is expected that all loaned equipment and unused supplies will be returned to the District as soon as practical after flooding has ceased. Consumed supplies may, at the discretion of the District Engineer, be replaced in kind or paid for by local interests.

CONSTRUCTION OF TEMPORARY PROTECTIVE WORKS. As stated earlier, it is required that a community first commit all its available resources and seek aid from the county and State, before protective type works will be considered by the Corps. In addition, any proposed Federal undertaking must be considered in light of the following:

Cost Effectiveness. The cost of the project must be weighted against the possible damages prevented. How detailed an evaluation is made is dependent on the time available.

Engineering Feasibility. The proposed project must have a reasonable assurance of success.

Timely Completion. The proposed project must be able to be effectively completed to meet the present threat.

Environmentally Acceptable. Coordination, consistent with the time available, will be made with State and Federal environmental agencies, to assure no permanent environmental damage.

Best Interest of the General Public. A segment of the general public should benefit from the proposed project.

Local Assurances. Before the proposed project can commence, it is necessary that the community officials sign an assurance agreement providing the following at no cost to the Corps of Engineers:

1. Indemnification of the Federal Government.

2. Rights-of-way or entry. (Borrow is provided)

3. Removal of the temporary works.

4. A clear understanding of the proposed project and respective responsibilities of each concerned party should be established, especially concerning restoration of the project, borrow, and disposal sites.

ASSISTANCE AFTER THE FLOOD. Post-flood assistance, under this authority, is limited to the rehabilitation of eligible flood control works or Federally authorized and constructed shore protection structure, damaged by the flood.

Post flood assistance for projects to prevent loss of life and property is available. This assistance is limited to a 10-day period. Specific request from the Governor is required.

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1. INTRODUCTION.

1. FLOOD FIGHTING can be defined as those emergency operations that are taken in advance of and during a flood to prevent or minimize damages to public and private property. As defined herein, flood fighting includes the hasty construction of emergency levees; the overbuilding of existing levees or natural river banks; ring and U-shaped levees constructed around facilities or areas of high property value; preservation of vital facilities including water treatment plants and wells; power and communication facilities; protection of sanitary and storm sewer systems; and provisions for interior drainage treatment during flood stages. Flood fighting plans should acknowledge that it may not be feasible to protect entire communities based on economic or time and equipment considerations; therefore, evacuation of certain areas may be a necessary facet of an emergency operation.

2. RECOMMENDED LOCAL ORGANIZATION. Each community with a flood history should establish an organization and written plans for the purpose of conducting flood fighting operations. These plans should include identification of flood-prone areas and previous high water marks; flood fighting or evacuation plans; delegation of responsibilities; lists of important suppliers of materials and special equipment; lists of local contractors; and establishment of earth borrow sites, etc. The plan should further provide for the establishment of an emergency operation center and list various assistance programs available, either through the State or Federal government. The plan should also address procedures for maintaining records of equipment, manpower, supplies used during the flood fight. The records are key items for obtaining assistance for flood and post flood activities. Further assistance

in developing these plans can be provided by the State or local County Emergency Management Director in the area.

II. FLOOD BARRIER CONSTRUCTION.

1. <u>INTRODUCTION</u>. The two basic features of an emergency levee system include the flood barrier, generally constructed of earth fill, and the related interior drainage treatment. It is desirable that individuals assigned to a flood-fight situation have prior knowledge of flood barrier construction, interior drainage, and related flood-fight problems which they may encounter. They should also be acquainted with the past flood emergency efforts, historical flood stages, and forecasted stages for the community. The following information will provide personnel with guidelines based on actual experience. However, it cannot be over emphasized that individual resourcefulness is a key element in a successful flood fight.

2. <u>PRELIMINARY WORK</u>.

A. <u>Alignment</u>. A complete alignment for the barrier should be established promptly in cooperation with State or local floodplain management officials. The alignment should be the shortest practical route, provide the maximum practical protection, and take advantage of any high ground. Sharp bends should be avoided. Topographic, plat, or city street maps may be useful in selecting alignments. In choosing the alignment, consideration should be give as to whether sufficient time remains to complete construction before the flood crest arrival. Potentially unstable river banks should be avoided. The levee should be kept as far landward of the river as possible to provide maximum overbank.

Keep as many trees and brush between the levee and river as possible to help deflect current, ice, and debris. However, in constricted areas of the river, 5 feet, and preferable 10 feet, should be allowed between the levee toe and vertical obstructions such as trees. Right-of-way considerations may also influence the final alignment. Generally, the city or county engineer will assist in laying out the line and grade for the barrier, or a professional surveyor may be available. However, if help is not available, a hand-level along with a known elevation can be used to lay out rough grade. As soon as the alignment is firm, quantities of earthwork should be estimated for establishing equipment and borrow requirements.

b. <u>Drainage</u>. In laying out a flood barrier, the problem of interior drainage from snowmelt, rain, or sewer backup should be considered. A certain amount of ponding, if valuable property will not be damaged, is not detrimental and may be allowed. the excess interior water can be pumped out over the levee if pumps are available. The ponding also helps prevent the build-up of hydrostatic pressure from the flood waters, which may lead to undermining of the levee.

c. <u>Borrow Area and Haul Road</u>. The two prime requisites for a borrow area are that adequate material be available and that the site be accessible at all times. The quantity estimate plus an additional 50 percent should provide the basis for the area requirement. The area must be located so that it will not become isolated from the project by high water. The borrow area should also be located where the present water table, if known, and the water table levels caused by high water will not hinder or stop its use. If possible, a borrow area should be selected which will provide suitable materials for levee construction as covered below. Local contractors and local officials are the best source of information on available borrow areas. If undeveloped, the area should be cleared of brush, trees, and debris, with topsoil and surface humus being stripped. In early spring, it will probably be necessary to rip the area to remove frozen material. An effort should be made to borrow from the area in such a manner that the area will be relatively smooth and free-draining when the operation is complete. The haul road may be an existing road or street, or it may have to be constructed. To mitigate damages it is highly desirable to use unpaved trails and roads, or to construct a road if the haul distance is short. In any case, the road should be maintained to avoid unnecessary traffic delays. The use of flagmen and warning signs is mandatory at major crossings such as highways, near schools, and at major pedestrian crossings. A borrow area, or source of sand for sandbags, should also be located promptly. This can become a critical item of supply in some areas due to long haul, project isolation, etc. It may become necessary to stockpile material near anticipated trouble areas.

d. Equipment. One of the important considerations in earthwork construction is the selection of proper equipment to do the work. Under emergency conditions, obtaining normally specified earthwork equipment will be difficult and the work will generally be done with locally available equipment. It may be wise to call for technical assistance in the early contract stage to insure that proper and efficient equipment use is proposed. If possible, compaction equipment should be used in flood-barrier construction. This may involve sheepsfoot, rubber-tired, or vibratory rollers. Scrapers should be used for hauling when possible because of speed (on short haul) and large capacity. Truck haul, however, has been the most widely used. A ripper is almost essential for opening borrow areas in the early spring. A bulldozer of some size is mandatory on the job to help spread dumped fill and provide some compaction.

e. <u>Construction Contract</u>. The initiation of a construction contract under emergency conditions require emergencies contract procedures. Field personnel, therefore must be somewhat knowledgeable in construction in that it delineates what equipment must be accounted for on the project and what is available for construction. During construction, if it becomes obvious that the equipment provided by the initial contract is inadequate to provide reasonably good construction or timely completion, a new or supplemental contract may be required. Procedures are the same as in the initial contract. Flexibility may be built into the original contract if it can be foreseen that additional pieces of equipment will ultimately be used.

f. <u>Supplies</u>. Early anticipation of floodfight problems will aid greatly in providing necessary and sufficient supplies on hand. These include sandbags, polyethylene, pumps, etc. The importance of initiative, resourcefulness, and foresight of the individual on the project cannot be over emphasized. Technical assistance may be invaluable in locating potential problem areas which, with proper materials at hand, could be alleviated early.

3. <u>EARTH FILL LEVEES</u>.

a. <u>Foundation Preparation</u>. Prior to embankment construction, the foundation area along the levee alignment should be prepared. This is particularly important if the levee is to left in place. During spring flooding, the first item of work will probably be snow removal. The snow should be pushed riverward so as to decrease ponding when the snow melts. Trees should be cut and the stumps removed. All obstructions above the ground surface should be removed, if possible. This will include brush, structures, snags, and similar debris. The foundation should then be (Clearing and grubbing, structure removal, and stripping should be performed only if time permits.) Stripping may be impossible if the ground is frozen. In this case, the foundation should be ripped or scarified, if possible, to provide a rough surface for bond with the embankment. Every effort should be made to remove all ice or soil containing many ice lenses. Frost or frozen ground can give a false sense of security in the early stages of a flood fight. It can act as a rigid boundary and support the levee; but on thawing, soil strength may be reduced sufficiently for cracks or slides to develop. It also forms an impervious barrier to prevent seepage. This may result in a considerable buildup in pressures under the soils landward of the levee, and upon thawing pressure may be sufficient to cause sudden blowouts. If this condition exists it must be monitored, and one must be prepared to act quickly if sliding or boiling starts. If stripping is possible, the material should be pushed landward and riverward of the toe of levee and windrowed.

After the flood, this material may be spread on the slopes and provide topsoil for vegetation.

b. Materials. Earth fill materials for emergency levees will usually come from local borrow areas. An attempt should be made to utilize materials which are compatible with the foundation materials. Due to time limitations, however, any local materials may be used if reasonable construction procedures are followed. The material should not contain large frozen pieces of earth.

(1) Clay. The majority of earth fill levees erected during floods consisted of clay or predominantly clayey materials. Clay is preferred because the section can be made smaller (steeper side slopes). Clay is also relatively impervious (will not readily permit passing of water) and has relatively high resistance to erosion in a compacted state. A disadvantage in using clay is that adequate compaction is difficult to obtain without proper equipment and when the material is wet. Another disadvantage is if the clay is wet and sub-freezing temperatures occur, this may cause the material to freeze in the borrow pit and hauling equipment. Weather could cause delays and should definitely be considered in the overall construction effort.

(2) Sand. If sand is used, the section should comply as closely as possible with recommendations in paragraph c(3) below. Flat slopes are important, as steep slopes without poly coverage will cause seepage through the levee to outcrop high on the landward slope, and may cause slumping of the slope.

(3) Silt. Material which is primarily silt should be avoided. If used, poly facing must be applied to the river slope.

Silt upon wetting, tends to collapse under its own weight and cause severe problems.

c. Levee Section.

(1) General. In standard levee design the configuration of the levee is generally dictated by the foundation soils and the materials available for construction. Therefore, even under emergency conditions, an attempt should be made to make the embankment compatible with the foundation. Information on foundation soils may be available from local officials or engineers, and it should be utilized. The three foundation conditions and the levee sections cited below are classical and idealized, and usual field conditions depart from them to various degrees. However, if they are used as a guide, possible serious flood-fight problems could be lessened during high water. In determining the top width of any type of section, consideration should be given as to whether a revised forecast will require additional fill to be placed. A top width adequate for construction equipment will facilitate raising the levee. Finally, actual dike construction will in cases, depend on time, materials, and right-of-way available.

(2) Sand Foundation - Pervious-(Readily allowing water to pass through).

a. Sand Section. Use 1 V(Vertical) on 3 Horizontal) river slopes, 1 V on 5 H landward slope, and 10-foot top width.

b. Clay Section. Use 1 V on 2 1/2 H for both slopes. Bottom width should comply with creep ratio criteria; i.e., L (across bottom) should be equal to C x H; where c=9 for fine gravel and 15 for fine sand in the foundation, and H is levee height. This criteria can be met by using berms either landward or riverward of the levee. Berm thickness should be 3 feet or greater. Berms are used mainly to control or to relieve uplift pressures and will not reduce seepage significantly.

3. Clay Foundations.

a. Sand Section. Same as paragraph (a) above.

b. Clay Section. Use 1 V on 2 1/2 for both slopes.

4. Clay Layer Over Sand Foundation.

a. Sand Section. Use same design as paragraph (a) above. In addition, a landside berm of sufficient thickness may be necessary to prevent of rupture of the clay layer. The berm may be either sand, gravel or clay material. Standard design of berms requires considerable information and detailed analysis or soil conditions. However, proper technical assistance may facilitate berm construction in any emergency situation.

b. Clay Section. Use same design as paragraph (b) above, "Clay Section," except a berm to prevent rupture may be necessary.

c. Placement and Compaction. As stated above, obtaining proper compaction equipment for a given soil type will be difficult. It is expected in most cases that the only compaction will be from that due to the hauling and spreading equipment i.e., construction traffic routed over the fill. However, attention is is directed.

to Attachment 1, which specifies levee construction. Levee height should provide 2 feet of freeboard above forecast flood crest.

d. <u>Slope Protection</u>.

(1) <u>General</u>. Methods of protecting levee slopes from current scour, wave wash, seepage, and debris damage are numerous and varied. However, during a flood emergency, time, availability of materials, cost and construction capability preclude the use of most accepted methods of permanent slope protection. Field personnel must decide the type and extent of slope protection the emergency levee will need. Several methods of protection have been established which prove highly effective in an emergency. Again, resourcefulness on the part of the field personnel may be necessary for success.

(2) <u>Polyethylene and Sandbags</u>.

(3) <u>General</u>. Experience has shown that a combination of polyethylene poly and sandbags is one of the most expedient, effective, and economical methods of combating slope erosion in a flood situation. Poly and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. Ideally, poly and sandbag protection should be placed in the dry. However, many cases of unexpected slope erosion will occur during high water, and a method for placement in the wet is covered below. See plates 3 and 4 for suggested methods of laying poly and sandbags. Since each flood fight project is generally unique (river, personnel available, materials etc.), specific details of placement and materials handling will not be covered. Personnel must be aware of resources available when using poly and sandbags.

(4) Toe Anchorage and Poly Placement. Anchoring the poly along the riverward toe is important for a successful job. It may be done in three different ways 1) After completion of the levee, a trench excavated along the toe, poly placed in the trench, and the trench backfilled; 2) Poly placed flat-out away from the toe, and earth pushed over the flap; and 3) Poly placed flat-out from the toe and one or more rows of sandbags placed over the flap. The poly should then be unrolled up the slope and over the top enough to allow for anchoring with sandbags. Poly should be placed from downstream to upstream along the slopes and overlapped at least 2 feet. The poly is now read for the "hold-down" sandbags.

(5) Sloped Anchorage. It is mandatory that poly placed on levee slopes be held down. An effective method of anchoring poly is a grid system of sandbags, unless extremely high velocities, heavy debris, or a large amount of ice is anticipated. Then a solid blanket of bags over the poly should be used. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Various grid systems include vertical rows of lapped bags, two-by-four lumber held down by attached bags, and rows of bags held by a continuous rope tied to each bag. Poly has held down by a system using two bags tied with rope and the rope saddled over the levee crown with a bag on each slope.

(6) Placement in the Wet. In many situations during high water, poly and sandbags placed in the wet must provide the emergency protection. Wet placement may also be required to replace or maintain damaged poly or poly displaced by current action. Plate 4 shows a typical section of levee covered in the wet.

Sandbag anchors are formed at the bottom edge and ends of the poly by bunching the poly around a fistful of sand or rock and typing the sandbags to this fist-sized ball. Counter-weights consisting of two or more sandbags connected by a length of 1/4 inch rope are used to hold the center portion of the poly down. The number of counterweights will depend on the uniformity of the levee slope and current velocity. Placement of the poly consists of first casting out the poly sheet with the bottom weights and then adding counterweights to slowly sink the poly sheet into place. The poly, in most cases, will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added to insure that no air voids exist between the poly and the levee face and to keep the poly from flapping or being carried away in the current. for this reason, it is important to have enough counterweights prepared prior to the ring sufficient to check the velocity

(7) Overuse of Poly. In past floods there has been a tendency to overuse and in some cases misuse poly on slopes. For example, on well compacted clay embankments, in areas of relatively low velocities, use of poly would be unnecessary. Also, placement of poly on landward slopes to prevent seepage must not be done. It will only force seepage to another exit and may prove detrimental. A critical analysis of a situation should be made before poly and sandbags are used, with a view toward less waste and more efficient use of these materials and available manpower. However, if a situation is doubtful, poly should be used rather than risk a failure, with the critical areas receiving priority.

(8) Riprap. Riprap is a positive means of providing slope protection and has been used

in a few cases where erosive forces were too large to effectively control by other the Objections to using riprap when flood fighting are: 1) rather costly; 2) large amount necessary to protect a given area; 3) availability; and 4) little control over its placement, particularly in the wet.

(9) Groins. In the past, small groins extending 10 feet or more into the channel were effective in deflecting current away from the levees. Groins can be constructed by using sandbags, snow fence, rock, compacted earth, or any other substantial materials that are available. Preferably groins should be placed in the dry and at locations where severe scour may be anticipated. Consideration of the hydraulic aspects of placing groins should be given, because haphazard placement may be detrimental. Hydraulic technical assistance should be sought if doubts arise in the use of groins. Construction of groins during high water will be very difficult and results will generally be minimal. If something other than compacted fill is used, some form of anchorage or bonding should be provided. (For example, snow fence anchored to a tree beyond the toe of the levee.)

(10) Log Booms. Log booms have been used to protect levee slopes from debris or ice attack. Logs are cabled together and anchored with a dead man in the levee. The boom will float out in the current and, depending on log size, will deflect floating objects.

(11) Miscellaneous Measures. Several other methods of slope protection have been used. Straw bales pegged into the slope may be successful against wave action, as is straw spread on the slope and overlain with snow fence.

4. SANDBAG DIKES. The sandbag dike should not be considered as a primary flood barrier. The main objections to their use are that the materials (bags and sand) are quite costly; they require a tremendous amount of manpower; and are time consuming to construct. Sandbags dikes should be used where a very low and relatively short barrier is required and earth fill would not be practicable, such as in the freeboard range along an arterial street. They are very useful in constricted areas, such as around or very close to buildings, where right-of-way would preclude using earth fill. They are also useful where temporary closure is required, such as roads and railroad tracks. A polyethylene seepage barrier should be incorporated into the sandbag structure. The poly must be on the riverward slope and brought up immediately behind the outermost layer of bags. The poly should be keyed-in seepage causes sloughing of the landward best, lapped under the sandbags for anchorage. See plate 1 for recommended practices in sandbag dike construction. A few points to be aware of in sandbag construction are: 1) sand, or predominantly sandy or gravelly material should be used; 2) extremely fine, clean sand, such as washed mortar sand; should be avoided; 3) bags should be 1/2 full; 4) bags should be lapped when placing; 5) bags should be tamped lightly in place; and 6) the base width should be wide enough to resist the head at high water (3 to 1). Sandbagging is also practical for raising a narrow levee, or cannot be used. Sandbag raises should be limited to 3 feet, if possible.

5. MISCELLANEOUS FLOOD BARRIERS. In addition to earth fill and sandbag levees, two other types of flood barriers should be mentioned. They are the flashboard and the box levees, both of which are constructed using

lumber and earth fill (see plate 2). They may be used for capping a levee or as a barrier in highly constricted areas. Two disadvantages in using these barriers are the long construction time involved are very high cost. Therefore, these barriers are not recommended, unless a very unusual situation warrants their use.

III. EMERGENCY INTERIOR DRAINAGE TREATMENT.

1. GENERAL. High river stages often disrupt the normal drainage of sanitary and Many problems can be solved instantly and with sanitary and storm sewer systems, render sewage treatment plants inoperative, and cause backup in sewers and the discharge of untreated sewage directly into the river. When the river recedes, some of the sewage may be trapped in low lying pockets to remain as a possible source of contamination. Hastily constructed dikes intended to keep out river waters may also seal seal off normal outlet channels for local runoff, creating large ponds on the landward side of the dikes, making the levees vulnerable from both sides. If the ponding is excessive, it may nullify the protection afforded by the dikes even if they are not overtopped. Sewers may also back up because of this ponding.

2. PRELIMINARY WORK. In order to arrive at a reasonable plan for interior drainage treatment, several items of information must be obtained by field personnel. These are:

a. Size of drainage area.

b. Pumping capacity and/or ponding required. (If data is not available, can be estimated by hydraulic engineering personnel).

c. Basic plan for treatment.

d. Storm and sanitary sewer and water line maps, if available.

e. Location of sewer outfalls (abandoned or in use).

f. Inventory of available local pumping facilities.

g. Probable location of pumping equipment.

h. Whether additional ditching is necessary to drain surface runoff to ponding and/or pump locations.

i. Location of septic tanks and drain fields abandoned or in use.

3. PUMPS, TYPES, SIZES AND CAPACITIES.

a. Storm Sewer Pumps. Table 1 indicates the size of pump needed to handle the full flow discharge from sewer pipes up to 24" in diameter. Table 2 shows sizes and capacities or agricultural type pumps which may be useful in ponding areas or in low areas adjacent to the flood barrier where a sump hole could be excavated.

b. Fire Engine Pumps. The ordinary fire pumper has a 4-inch suction connection and a pumping capacity of about 750 gpm. Use only if absolutely necessary.

TABLE NO. 1

Matching Pipe Size to Pump Size

Sewer Pipe Size	Probable Required Pump Size
6 inch	2 inch
8 inch	2 to 3 inch
10 inch	3 to 4 inch
12 inch	4 to 6 inch
15 inch	6 to 8 inch
18 inch	6 to 10 inch
21 inch	8 to 10 inch
25 inch	10 to 12 inch

TABLE NO. 2

Crisafulli Pumps

Size	Gal. Per Min.	Head	Elec. H.P	Gas or Diesel H.P
2"	150		1	
4"	500		7.5	15
6"	1000		10	20
8"	3000	10'	15	25
12"	5000		25	40
16"	9500		40	65
24"	25000		75	140
2"	130		1	
4"	490		10	20
6"	850		15	25
8"	2450	20'	20	35
12"	3750		30	50
16"	8000		45	85
24"	19000		100	190

12" REGULAR PUMP

TOTAL DYNAMIC HEAD FEET	540 RPM CAPACITY GALLON PER MIN.	BRAKE HORSE POWER
0	5525	42
5	5100	40
10	4600	38
15	3900	35
20	2900	30
24.8	0	15.6

TABLE NO. 3

Flygt Centrifugal Pumps

Size	Capacity*	Horsepower
3"	90 - 150 gpm	1.3 - 2.0 hp
4"	100 - 250 gpm	2.7 - 3.5 hp
6"	1150 gpm	30.0 hp
8"	2300 gpm	29.0 hp
10"	3330 gpm	62.0 hp

* (at 25 foot head)

c. Pump Discharge Piping. The Crisafulli pumps are generally supplies with 50-foot lengths of butyl rubber hose. Care must be taken to prevent damage to the hose. Irrigation pipe or small diameter culverts will also serve as discharge piping. Care should be taken to extend pump discharge lines riverward far enough to not cause erosion of the levee. The discharge end should be ties down or anchored. On 12-inch or larger lines, substantial anchorage is required. These pumps must not be operated on slopes greater than 20 degrees from horizontal.

d. Sanitary Sewage Pumping. During high water, increased infiltration into sanitary sewage may necessitate increased pumping at the sewage treatment plant or at manholes at various locations to keep the system functioning. To estimate the quantity of sewage, allow 100 gallons per capita per day for sanitary sewage and an infiltration allowance of 15,000 gallons per mile of sewer per day. In some cases, it will be necessary to pump the entire amount of sewage, and in other cases only the added infiltration will have to be pumped to keep a system in operation.

Example: Estimate pumping capacity required at an emergency pumping station to be set up at the first manhole above the sewage treatment plant for a city of 5,000 population and approximately 30 miles of sewer (estimated from map of City). In this case, it is assumed that the treatment plant will not operate at all

Computation:

Sewage: $\frac{5000 \text{ per} \times 100 \text{ g/per/day}}{24 \text{ hrs} \times 60 \text{ min}} = 347 \text{ gpm}$

Infiltration: $\frac{15000 \text{ g/mi/day} \times 30 \text{ mi}}{24 \text{ hrs} \times 60 \text{ min}} = 312 \text{ gpm}$

Required pumping capacity: 659 gpm. From Table 3, use on 4 inch pump or its equivalent.

4. METAL CULVERTS

Pumping of ponded water is usually preferable to draining the water through a culvert since the flood water (drainage end of culvert) could increase in elevation to a point higher than the inlet, and water could back up into the area being protected. Installation of a flapgate at the outlet end may be desirable to minimize backup.

Table 4 shows the capacity of corrugated pipe culverts on a flat slope, with H factor (head) representing the difference between the headwater level and tailwater level, assuming the outlet is submerged. If the outlet is not submerged the head equals the difference in elevation between the headwater level and 0.6 of the diameter of the pipe measures from the bottom of the pipe upward. The capacity would change for smooth pipe, pipe laid on a slope, or if headwalls or wingwalls are used.

If a culvert is desired to pass water from a creek through a levee a computation of the drainage basin by an engineer is necessary to determine pipe size.

5. PREVENTING BACKFLOW IN SEWER LINES.

a. Watertight sluice gates or flap gates are one answer. Emergency stoppers may be constructed of lumber, sandbags, or other materials, using poly as a seal, preferably placed on the discharge end of the outfall pipe.

b. Plates 11 and 12 contain manufacturer's literature on prefabricated rubber pipe stoppers which can be placed in the outlet opening of a manhole.

c. Plates 6-10 illustrate methods of sealing off the outlet openings of a manhole with standard materials which are normally available so that the manhole may be used as an emergency pumping station.

TABLE 4

CAPACITY OF CORRUGATED METAL PIPE CULVERTS
Without Headwalls and With Outlet Submerged (outlet control-full flow)
(Circular)

DIA. IN INCHES		CUBIC FEET PER SECOND — Head on Pipe in Feet 0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 20 Feet	1.0	1.4	1.7	2.0	2.2	2.4	2.8	3.1	3.4	3.7	4.0	4.2	4.4	5.0	5.4	5.8	6.2
15		1.7	2.4	2.9	3.4	3.8	4.1	4.8	5.3	5.8	6.3	6.8	7.1	7.5	8.4	9.2	9.9	11
18		2.6	3.6	4.4	5.2	5.7	6.2	7.2	8.0	8.8	9.5	10	11	11	13	14	15	16
21		3.6	5.1	6.2	7.2	8.0	8.8	10	11	12	13	14	15	16	18	19	21	22
24		4.9	6.8	8.4	9.6	11	12	14	15	17	18	19	20	21	24	26	28	30
27		6.2	8.8	11	12	14	15	18	20	21	23	25	26	28	31	34	36	39
30		7.8	11	14	16	17	19	22	25	27	29	32	33	35	39	42	46	49
36		12	16	20	23	26	28	33	37	40	43	46	49	32	57	63	68	72
42		16	23	28	32	36	39	45	51	55	60	64	68	71	79	86	93	100
48		22	30	37	43	48	52	60	68	74	80	85	90	94	106	117	125	134
54		28	39	48	55	61	67	78	87	94	102	109	116	121	136	149	160	171
60		34	48	59	68	76	83	96	107	118	126	134	142	150	167	182	197	210

DIA. IN INCHES		CUBIC FEET PER SECOND — Head on Pipe in Feet 0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 40 Feet	0.8	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.0	3.2	3.4	3.6	4.0	4.4	4.8	5.1
15		1.4	1.9	2.4	2.7	3.1	3.4	3.9	4.3	4.8	5.2	5.5	5.9	6.2	6.9	7.6	8.2	8.8
18		2.1	3.0	3.7	4.3	4.8	5.2	6.0	6.8	7.4	8.0	8.6	9.0	9.6	11	12	13	14
21		3.0	4.3	5.3	6.1	6.8	7.4	8.6	9.6	11	12	12	13	14	15	17	18	19
24		4.2	5.9	7.2	8.4	9.4	10	12	13	15	16	17	18	19	21	23	25	27
27		5.5	7.8	9.6	11	12	14	16	17	19	21	22	23	25	28	30	33	35
30		7.0	9.8	12	14	16	17	20	22	24	26	28	30	31	35	36	42	44
36		10	15	18	21	24	26	30	33	36	39	42	45	47	53	58	62	66
42		15	21	26	30	33	36	42	47	51	55	59	62	66	74	80	88	93
48		20	28	35	40	45	49	56	63	69	74	80	84	89	99	109	118	127
54		26	36	45	51	57	63	72	81	89	96	103	109	115	128	140	152	163
60		32	45	55	64	72	78	90	100	110	120	128	136	143	160	175	190	202

DIA. IN INCHES		CUBIC FEET PER SECOND — Head on Pipe in Feet 0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 60 Feet	0.7	1.0	1.2	1.4	1.6	1.7	2.0	2.2	2.4	2.6	2.8	2.9	3.1	3.5	3.8	4.1	4.4
15		1.2	1.7	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.5	4.8	5.1	5.4	6.0	6.6	7.1	7.6
18		1.9	2.7	3.3	3.8	4.2	4.6	5.3	5.9	6.5	7.0	7.5	8.0	8.4	9.3	10	11	12
21		2.7	3.9	4.8	5.5	6.1	6.6	7.7	8.7	9.5	10	11	12	12	14	15	16	17
24		3.8	5.4	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	21	22	24
27		5.0	7.1	8.7	10	11	12	14	16	17	19	20	21	22	25	27	29	31
30		6.4	9.0	11	13	14	16	18	20	22	2.	25	27	28	32	35	37	40
36		9.7	14	17	19	22	24	27	31	33	36	38	41	43	48	52	56	60
42		14	19	24	28	31	34	39	44	48	51	55	58	61	68	74	80	86
48		19	27	32	38	42	46	53	59	64	69	74	78	82	92	100	108	116
54		24	34	42	48	54	59	68	77	83	90	96	102	108	120	131	142	152
60		31	43	53	61	68	74	86	97	105	113	120	128	135	150	166	178	190

IV. <u>FLOOD FIGHT PROBLEMS</u>.

1. <u>GENERAL</u>. Problem situations which arise during a flood fight are varied and innumerable. The problems covered below and in "Emergency Interior Drainage Treatment" are those which are considered most critical to the integrity of the flood barrier system. It would be impossible to enumerate all of the problems, such as supplies, personnel, communications, etc., which field personnel must handle. The most valuable asset of field personnel under emergency conditions is their common sense. Many problems can be solved instantly and with less effort through the relations. Problems, such as those below, can be identified early only if a well organized levee patrol system with a good communication system exists. The problems are presented with the assumption that high water is on the levee slopes.

2. <u>OVERTOPPING</u>. Overtopping of a levee is the flowing of water over the levee crown. Since most emergency levees are of an urban nature, overtopping should be prevented at any cost. Overtopping will generally be caused by: 1) unusual hydrologic phenomena which causes a much higher stage than anticipated; 2) insufficient time in which to complete the flood barrier; or 3) unexpected settlement of the barrier. Generally, the flood barriers are constructed 2 feet above the crest prediction. If the crest prediction is raised during construction, additional height must be added to the barrier. On an existing or completed barrier, increases predictions or settlement will call for some form of capping. Capping should be done with earth fill or sandbags, using normal construction procedures.

3. <u>SEEPAGE</u>. Seepage is percolation of water through or under a levee, generally appearing first at the landside toe. Seepage through the levee is applicable only to a relatively pervious section. Seepage, as such, is generally not a problem unless 1) the landward levee slope becomes saturated over a large area; 2) seepage water is carrying material from the levee; or 3) pumping capacity is exceeded. Seepage which causes severe sand boils and piping is covered below. Seepage is difficult to eliminate, and attempts to do so may create a much more severe condition. Pumping of seepage should be held to a minimum, bases on the maximum ponding elevation without damages. Seepage should be permitted if no apparent ill-effects are observed, and if adequate pumping capacity is available. If seepage causes sloughing of the landward slope, it should be flattened to a IV on 4H maximum. Material for flattening should be at least as pervious as the embankment material.

4. <u>SAND BOILS</u>.

a. <u>Description</u>. A sand boils is the rupture of the top foundation stratum landward of a levee caused by excess hydrostatic head in the substratum. Even when a levee is properly constructed and of such mass to resist the destructive action of floodwater, water may seep through a sand or gravel stratum under the levee and break through the ground surface on the landside in the form of bubbling springs. When such eruptions occur, a stream of water bursts through the ground surface, carrying with it a volume of sand or silt which is distributed around the hole. A sand boil may eventually discharge relatively clear water, or the discharge may contain quantities of silt, depending upon the magnitude of size of the boil. They usually occur within 10 to 300 feet from the landside toe of the levee, and in some instances have occurred up to 1,000 feet.

b. Destructive Action. Sand boils can produce three distinctly different effects on a levee, depending upon the condition of flow under the levee.

c. Piping Flow. Piping is the active erosion of subsurface material as a result of substratum pressure and concentration of seepage in the localized channels. The flow breaks out at the landside toe in the form of one or more large sand boils. Unless checked, this flow causes the development of a cavern under the levee, resulting in the subsidence of the levee and possible overtopping. This case can be easily recognized by the slumping of the levee crown.

d. Non-piping Flow. In this case, the water flows under pressure beneath the levee without following a defined path, as in the case above. This flow results in one or more boils outcropping at or near the landside toe. The flow from these boils tends to undercut and ravel the landside toe, resulting in sloughing of the landward slope. Evidence of this type of failure is found in undercutting and revelling at the landside toe.

e. Saturating Flow. In this case, numerous small boils, many of which are scarcely noticeable, outcrop at or near the landside toe. While no boil may appear to be dangerous in itself, the consequence of the group of boils may cause flotation ("quickness") of the soil, thereby reducing the shearing strength of the material at the toe, where maximum shearing stress occurs, to such an extent that failure of the slope through sliding may result.

f. <u>Combating Sand Boils</u>. All sand boils should be watched closely, especially those within 100 feet of the toe of the levee. All boils should be conspicuously marked with flagging so that patrols can locate them without difficulty and observe changes in their condition. A sand boil which discharges clear water in a steady flow is usually not dangerous to the safety of the levee. However, if the flow of water increases and the sandboil begins to discharge material, corrective action should be undertaken immediately. The accepted method of treating sand boils is to construct a ring of sandbags around the boil, building up a head of water within the ring sufficient to check the velocity of flow, thereby preventing further movement of sand and silt. See plate 5 for technique in ring a boil. Actual conditions at each sand boil will determine the exact dimensions of the ring. The diameter and height of the ring depends on the size of the boil and the flow of water from it. In general, the following considerations should control; 1) the base width of the sandbag section should be no less than 1 1/2 times the contemplated height; 2) include weak ground near the boil within the ring, thereby preventing a break though later; and 3) the ring should be of sufficient size to permit sacking operations to keep ahead of the flow of water. The height of the ring should only be that necessary to stop movement of soil, and not as high as to completely eliminate seepage. The practice of carrying the ring to the river elevation is not necessary any may be dangerous in high states. If seepage flow is completely stopped, a new boil will likely develop beyond the ring; this pressure and the boil could then suddenly erupt and cause considerable damage. Where many boils are found to exist in a give area, a ring levee of sandbags should be constructed around the entire area and, if necessary, water should be pumped into the area to provide sufficient weight to counterbalance the upward pressure.

5. EROSION. Erosion of the riverside slope is one of the most severe problems which will be encountered during a flood fight. Emergency operations to control erosion have been presented earlier under "Slope Protection."

6. STORM AND SANITARY SEWERS.

a. Problems. Existing sewers in the protected area may cause problems because of seepage into the lines, leakage through blocked outlets to the river, manhole pumps not spread throughout the sewer system, and old or abandoned sewer locations which were not found during preflood preparations. Any of these conditions can cause high pressures in parts of the sewer system and lead to the collapse of lines at weak points and blowing off of manhole covers.

b. Solutions. During the flood fight, continued surveillance of possible sewer problems is necessary. If the water level in a manhole approaches the top, additional pumps in manholes may alleviate the problem. In sanitary sewers, additional pumping may be required at various locations in the system to provide continued service to the homes in the protected area. When pumps are not available, manholes may have to be ringed with sandbags or by some other method which allows the water to head up above the top of the manhole. To eliminate the problem of disposing of this leakage from manholes, the ring dike would have to be raised above the river water surface elevation. This creates high pressures on the sewer and should not be done. As with sand boils, it is best to ring the manhole part way to reduce the head and dispose of what leakage occurs. Directly weighing down manhole covers with sandbags or other items it not recommended where high heads are possible. A 10-foot head on a manhole cover 2 feet in diameter would a force of 1960 lbs. Thus, a counterweight of a ton would have to be placed directly on the cover.

7. CAUSES OF LEVEE FAILURES. In addition to the problems covered above, the following conditions could contribute to failure

a. Joining of a levee to a solid wall, such as concrete or piling.

b. Structures projecting from the riverside of levee.

c. A utility line crossing or a drain pipe through the fill.

d. Tops of stoplogs on roads or railroad tracks at a lower elevation than the levee.

Attachment 1

SPECIFICATION FOR PLACING AND COMPACTING EARTH LEVEES

1. Placement. Layers shall be started out to the full width of the embankment base, and subsequent lifts shall be placed so that the tops are substantially horizontal. In general, the levee section should be homogeneous. However, where materials of varying permeability are encountered in the borrow area, the more pervious material should be placed on the land side of the embankment.

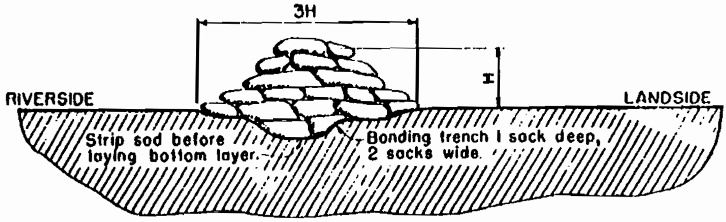
2. Compaction.

a. Pervious Fill. Material shall be placed in layers not more than 12 inches in thickness prior to compaction. (Each Layer shall be compacted by not less than three complete passes of a crawler-type tractor, or by two passes of a vibratory roller. As a minimum under emergency conditions, each layer shall be compacted by at least one pass of the hauling equipment.)

b. Impervious Fill. (Material shall be placed in layers not exceeding 9 inches prior to compaction and compacted with four to six complete passes of a tamping type roller or a rubber tired roller.) Fill shall be placed in layers not exceeding 9 inches prior to compaction and each layer shall receive at least one complete coverage of the track or wheel of the placing equipment or equivalent.

NOTE: Sentences in parenthesis are for use where time, cost, and availability of equipment will permit. Using these sentences will provide for a much safer structure. It is to be realized that even the minimum requirements may not be possible or feasible; and, if the situation demands, material should be placed and compacted in any way possible and the levee observed closely for signs of failure. The above should not be taken as a guarantee that a safe structure will be constructed.

CORPS OF ENGINEERS



SECTION

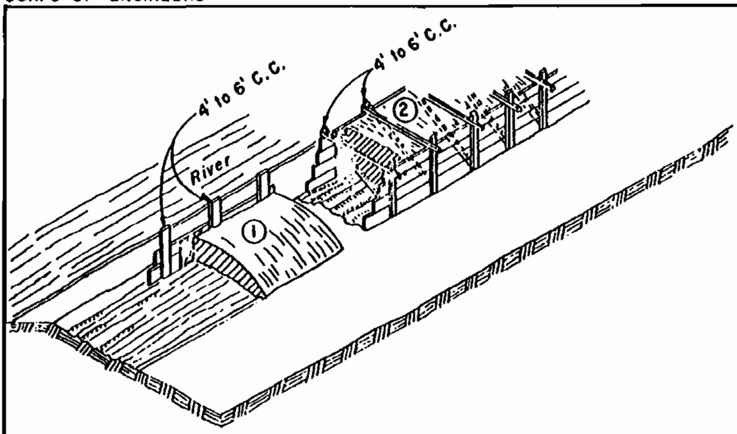
NOTE:
Alternate direction of sacks with bottom layer parallel to flow, next layer perpendicular to flow, etc.
Lap unfilled portion under next sack.
Tying or sewing sacks not necessary.
Tamp thoroughly in place.
Sacks should be approximately 1/2 full of sand.

Start Upstream

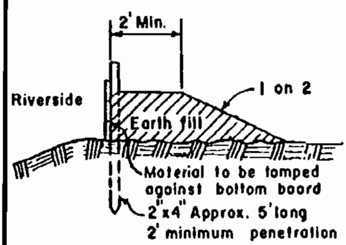
METHOD OF LAPPING SACKS

EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD
FOR
SANDBAG BARRIER
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA

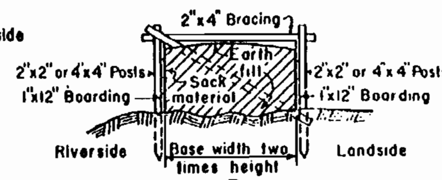
PLATE 1



TYPES OF WOOD AND EARTH LEVEES

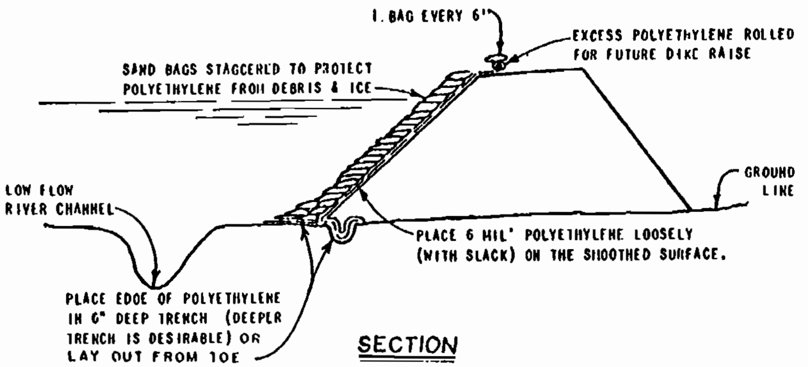


①
FLASH BOARD LEVEE

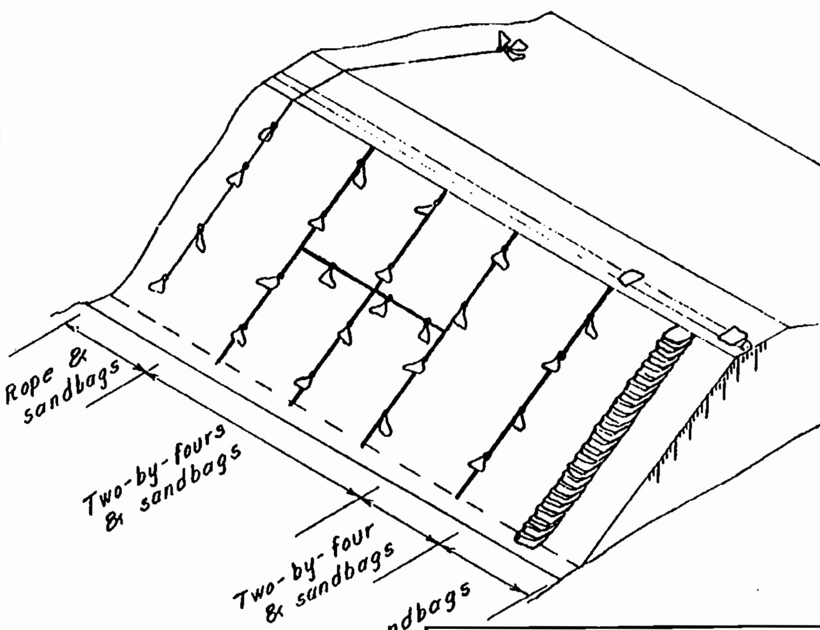


②
BOX LEVEE

EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD
FOR
FLASH BOARD & BOX LEVEES
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA



SECTION



METHODS OF ANCHORING POLYETHYLENE

*6 MIL BLACK POLYETHYLENE IS THE MOST DESIRABLE, 6 MIL CLEAR SECOND, 4 MIL BLACK THIRD, 4 MIL CLEAR FOURTH & 2 MIL POLYETHYLENE SHOULD ONLY BE USED AS A LAST RESORT.

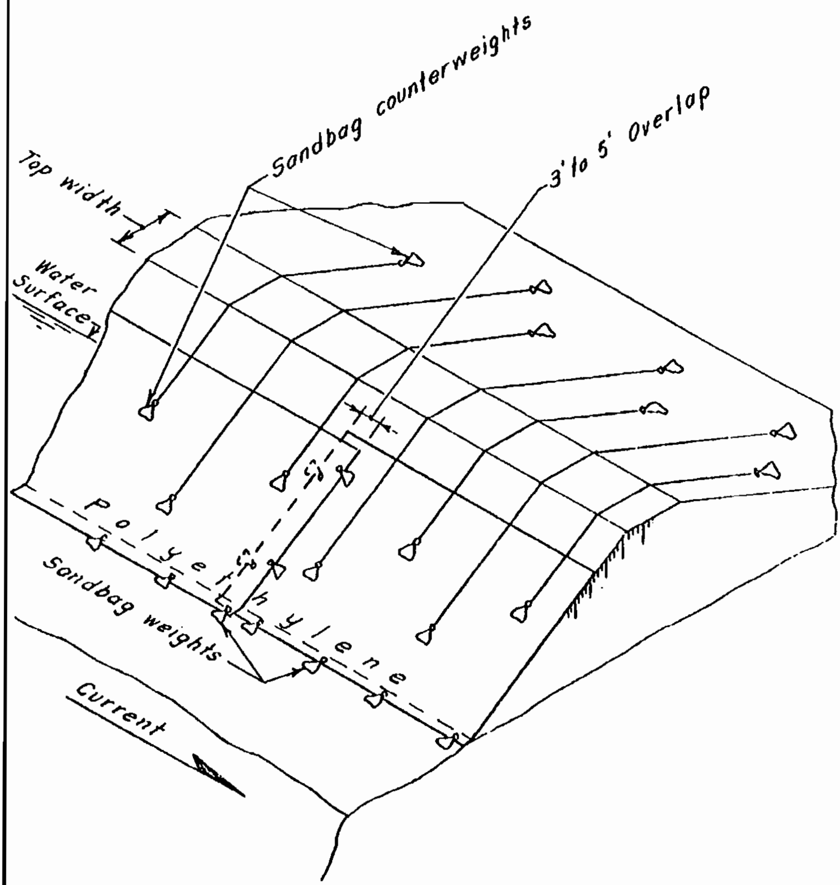
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD
FOR

PLACEMENT OF POLYETHYLENE SHEETING ON TEMPORARY LEVEES

OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA

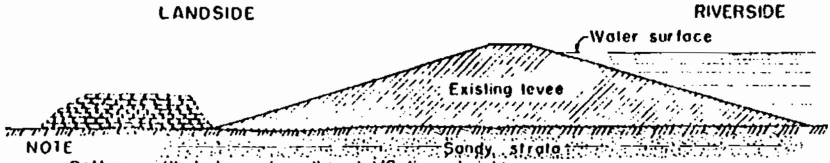
PLATE 3

CORPS OF ENGINEERS



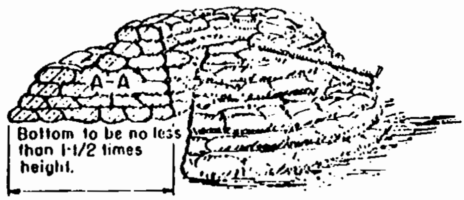
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD
FOR
PLACEMENT OF POLYETHYLENE
SHEETING IN THE WET
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL MINNESOTA

PLATE 4

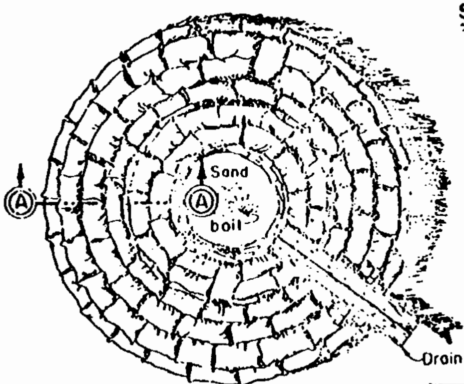


NOTE
Bottom width to be no less than 1-1/2 times height.
Tie into levee if boil is near toe

ELEVATION



SECTIONAL ELEVATION



NOTE
Entire base to be cleared of debris and scarified.
Loose earth to be used between all sacks.
All joints to be staggered.

PLAN

EMERGENCY FLOOD CONTROL ACTIVITIES

RECOMMENDED METHOD

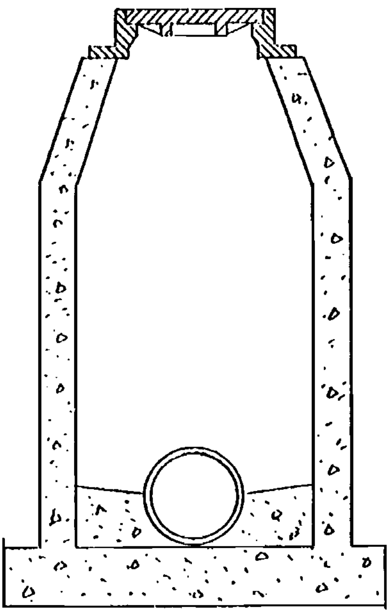
FOR

RINGING SAND BOILS

OFFICE OF THE DISTRICT ENGINEER

ST. PAUL MINNESOTA

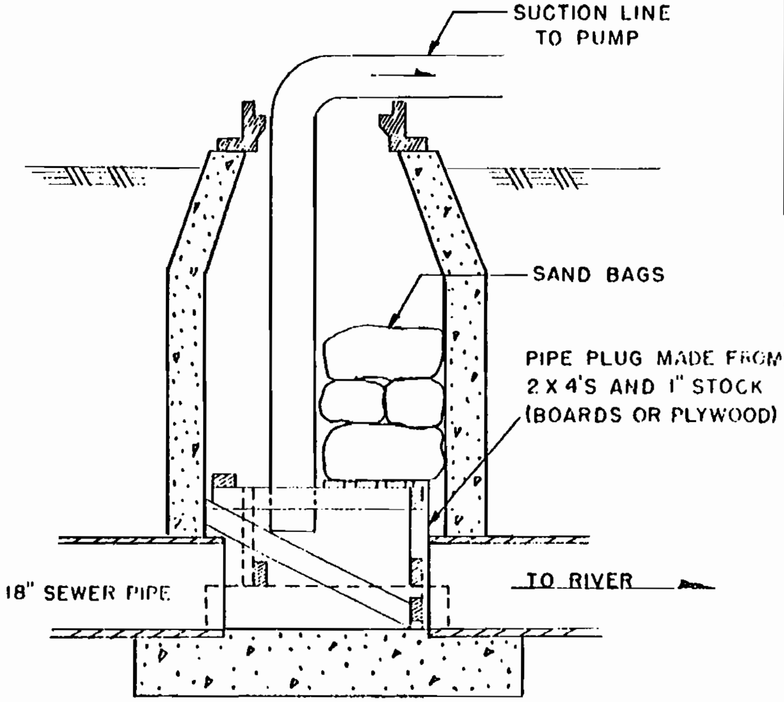
CORPS OF ENGINEERS



TYPICAL MANHOLE

EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
For
INTERIOR DRAINAGE TREATMENT
Corps of Engineers - St. Paul

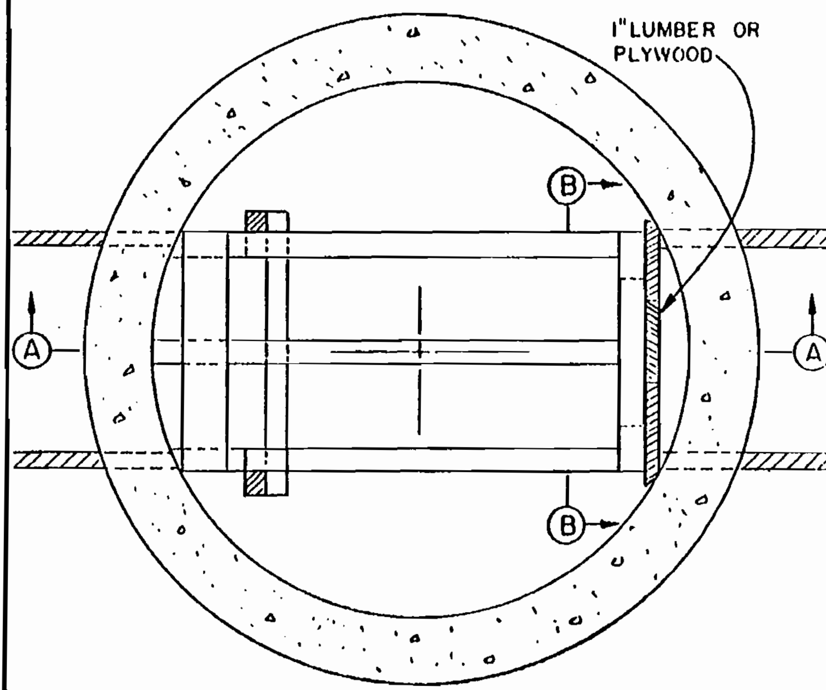
PLATE 6



ADAPTING MANHOLE FOR PUMPING
DURING FLOOD EMERGENCY

EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
For
INTERIOR DRAINAGE TREATMENT

Corps of Engineers - St. Paul



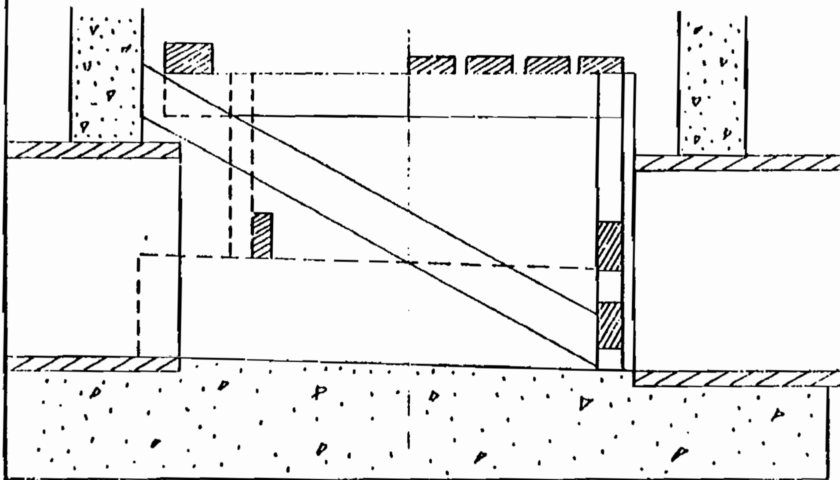
PLAN

Scale 3/32" = 1"

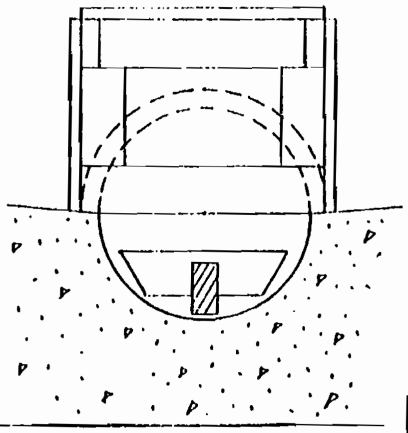
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD
For
INTERIOR DRAINAGE TREATMENT

Corps of Engineers - St. Paul

CORPS OF ENGINEERS



SECTION A-A

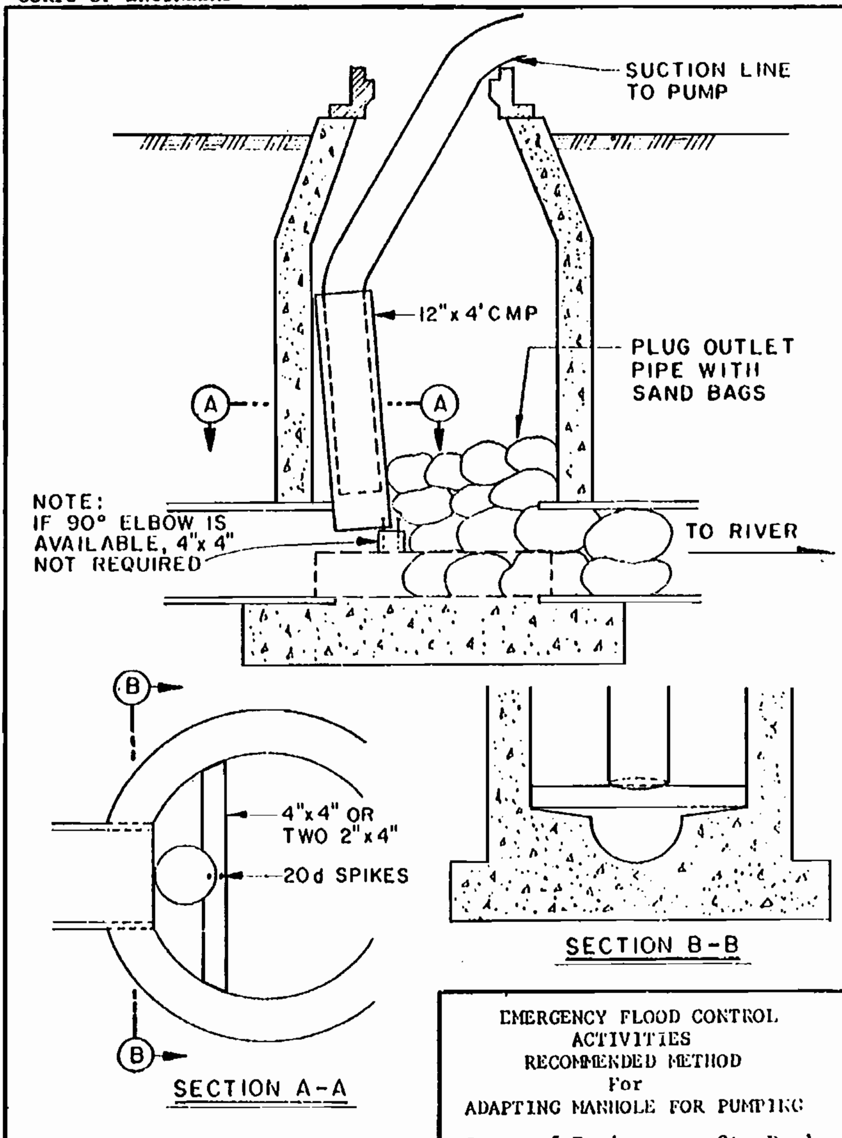


SECTION B--B

EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
For
INTERIOR DRAINAGE TREATMENT

Corps of Engineers - St. Paul

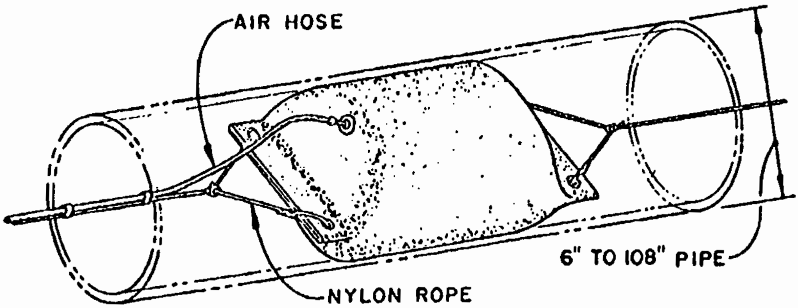
PLATE 9



EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
For
ADAPTING MANHOLE FOR PUMPING

Corps of Engineers - St. Paul

PLATE 10

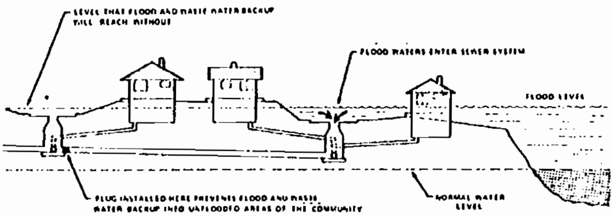


N.B. PRODUCTS PIPE STOPPER

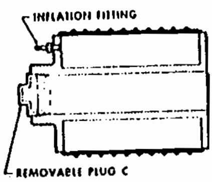
N.B. Products, Inc. Manufactures a rubberized pipe stopper in all standard pipe sizes from 6" to 108 ". N.B. Products maintains an inventory of all standard sizes for immediate shipment. The costs for these devices range from $220+ to $8,500+. Additional equipment required to install the pipe stopper are an air hose kit, air hose and nylon rope. A two-week shipping period is required. Manufacturing lead-time is presently required for sizes over 60 inches. Orders for these units can be placed to:

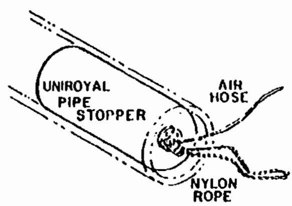
N.B. Products, Inc.
903 Sheehy Drive
Horsham, Pennsylvania 19044
215-674-8660

EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
for
INTERIOR DRAINAGE TREATMENT
Corps of Engineers - St. Paul



MUNI-BALL plug





CHERNE INDUSTRIAL PIPE STOPPERS

Immediate delivery of pipe plugs raning in sizes from 6 inches through 60 inches can be made locally. Cherne Inductrial, Inc. manufactures the Muni-Ball plug to fit standard pipe sizes from 6 inches through 60 inches. Special configurations are available such as a by-pass valuve for sewage pump connection to relive back-pressure.

Contact:

CHERNE INDUSTRIAL, INC.
5700 Lincoln Drive
Minneapolis, Minnesota 55436-1695
612-933-5501
Fax: 612-938-6601

EMERGENCY FLOOD CONTROL
ACTIVITIES
RECOMMENDED METHOD
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INTERIOR DRAINAGE TREATMENT
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