# 3 Earth Fill Levees

Earth fill levees rather than sandbag dikes are the preferred type of emergency flood barrier for large scale flood fights, and their construction should be directed by experienced flood fight workers.

## *3.1 Foundation Preparation*

Prepare levee footprint as follows prior to placing fill. Remove snow from ground surface and place snow on riverside of levee to eliminate ponding of water behind levee when 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 stripped of topsoil and surface humus. *NOTE: 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 tough surface for bond with the embankment. If stripping is possible, the material should be pushed landward of the toe of levee and windrowed.

Every effort should be made to remove all ice or frozen ground. 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; however, on thawing, soil strength may be reduced sufficiently for cracking or development of slides. It also forms an impervious barrier to prevent seepage. This may result in a considerable build up in pressure under the soils landward of the levee, and, upon thawing, pressure may be sufficient to cause sudden failure of the foundation material resulting in piping , slides, and boils. If the ground is frozen, it must be monitored, and one must be prepared to act quickly if sliding or boiling starts.

## *3.2 Levee Fill*

Earth fill materials for emergency levees will come from local borrow areas. An attempt should be made to use materials that are compatible with the foundation materials as explained below. However, due to time limitations, any local materials may be used if reasonable construction procedures are followed. The materials should not contain large frozen pieces of earth.

**1. Clay Fill.** The majority of earth fill levees erected in recent floods consisted of clay or predominantly clay materials. Clay is preferred because the cross-section width can be made smaller with steeper side slopes. Also, clay is relatively impervious 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. Another disadvantage is that if the clay is wet, subfreezing temperatures may cause the material to freeze in the borrow pit and in the hauling equipment. Cold and wet weather could cause delays and should definitely be considered in the overall construction effort.

**2. Sand Fill.** If sand is used, the cross-section of the levee should comply as closely as possible with recommendations described in the following design section. Flat slopes are important, as steep slopes without poly coverage will allow seepage through the levee to outcrop high on the landward slope and may cause slumping of the slope and eventual failure.

**3. Silt.** Material that is primarily silt should be avoided, and, if it must be used, poly sheeting must always be applied to the river slope. Silt, upon wetting, tends to collapse under its own weight and is very susceptible to erosion.

### *3.3 Levee Design Section*

The dimensions of the levee design section are 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 should be requested and considered, if available from local officials or engineers. The three foundation conditions and the levee design sections described below are classical and idealized, and assume a sand foundation, a clay foundation, or a thin clay layer over sand foundation. Actual field conditions generally depart from the ideals to various degrees. However, the described levee design sections for each foundation should be used as a guide to reduce the likelihood of serious flood fight problems during high water. In determining the top width of any type of section, consideration should be given to whether a revised flood level forecast will require additional fill to be placed. A top width adequate for construction equipment will facilitate raising the levee.

Finally, actual levee construction will, in many cases, depend on available time, materials, and right-of-way access.

**1. Sand Foundation.** Pervious and permeable (readily allowing water to pass through).

a. ***Sand Section.*** Use a ratio of 1V (Vertical) to 3H (Horizontal) on the riverside slopes, and a ratio of 1V to 5H on the landward slope, with a 10-foot top width.

b. ***Clay Section.*** Use a ratio of 1V to 2-1/2H for both the riverside and landside slopes. The bottom width of the levee section should comply with creep ratio criterion; 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 criterion can be met by using berms consisting of material placed on either the landward or riverward side of a levee that extends beyond the normal levee foot print. These berms are placed to control or relieve uplift pressures and lengthen the seepage path, although they will not significantly reduce the volume of seepage. Berms are not as high as the levee itself, and thickness should be 3 feet or greater.

**2. Clay Foundations.** Impervious (does not allow water to pass through)

a. ***Sand Section.*** Same as paragraph 1.a. above.

b. ***Clay Section.*** Use a ratio of 1V to 2-1/2H for both the riverside and landside slopes.

### 3. Clay Layer over Sand Foundation

a. ***Sand Section.*** Use the same design as paragraph 1.a. above. In addition, a landside berm of sufficient thickness may be necessary to prevent rupture of the clay layer. The berm may be composed of sand, gravel, or clay material. Standard design of berms requires considerable information and detailed analysis of soil conditions.

However, prior technical assistance may reduce berm construction requirements in any emergency situation.

b. ***Clay Section.*** Use the same design as paragraph 1.b. above, "Clay Section, over Sand Foundation." A berm to prevent rupture may also be necessary as described above. Proper compaction of the emergency levee is critical to stability. Use of standard compaction equipment such as a sheepsfoot roller, may not be feasible during emergency operations because of time constraints or limited equipment availability. It is expected that in most cases the only compaction available will be from hauling and spreading equipment, such as dump trucks and dozers.

## *3.4 Scour Protection for Emergency Levees*

Scour protection may be required for the emergency levees. Factors that influence whether or not additional scour protection is required include levee material (clay levees tend to be much more resistant to scour than sand levees), channel velocities, presence of ice and /or debris in channel, wave action, and seepage. Methods of protecting levee slopes are numerous and varied.
However, during a flood emergency, time, availability of materials, cost, and construction capability may limit the use of certain 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 that prove highly effective in an emergency. Resourcefulness on the part of the field personnel may be necessary for success. The following is a brief summary of some of the options for providing emergency scour protection for levees.

**1. Polyethylene and sandbags.** A combination of polyethylene (poly) and sandbags has proven to be one of the most expedient, effective and economical methods of combating slope attack 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 before water has reach to toe of the levee – "in the dry." However, many cases of unexpected slope attack will occur during high water, and a method for placement "in the wet" is covered below. ***Plate 2*** and ***Plate 3*** display suggested methods of laying poly and sandbags in

the dry and in the wet, respectively. Because each flood fight project is unique (river, personnel available, materials, etc.), specific details of placement and materials handling will not be covered. Field personnel must be aware of resources available when using poly and sandbags.

Anchoring the poly along the riverward toe is important for a successful job. It may be done in three different ways. The most successful is as follows: (1) Poly is placed flat on the ground surface away from the levee toe and one or more rows of sandbags placed over the flap. The poly is then unrolled over this bottom row of sandbags, and up the slope and over the top enough to allow for anchoring with sandbags. This method was shown on ***Figure 5*** in the previous section, and is illustrated on ***Plate 4***.

Additional ways to anchor poly at the toe are (2) Poly is placed flat on the ground surface away from the levee toe, and sandbags are placed over the flap (***Figure 6*** and ***Plate 4***) and (3) A trench is excavated along the toe of the levee, poly is placed in the trench, and the trench is backfilled (***Figure 7*** and ***Plate 2***). Poly should always be placed from downstream to upstream along the slopes and the next sheet upstream overlapped by at least three feet (***Figure 8***). Overlapping in this direction prevents the current from flowing under the overlap and tearing the poly loose. Once the poly is placed, additional sandbags are needed on top of the poly to anchor the poly in place.

It is mandatory that poly placed on levee slopes be held down. Unless extremely high velocities, heavy debris, or a large amount of ice is anticipated, an effective method of anchoring poly is a grid system of sandbags, as shown in ***Plate 2***. 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, 2 by 4 lumber held down by attached bags, and rows of bags held by a continuous rope tied to each bag (***Plate 3***). For extreme conditions such as high velocity, excess seepage, ice or debris in the water or wave action, a solid blanket of bags over the poly should be used.

Counterweights consisting of two or more sandbags connected by a length of ¼-inch rope can also be used to hold the poly down, and this is more suitable for placement under wet conditions, as shown on ***Plate 3.*** The rope is saddled over the levee crown with a bag on each slope. The number and spacing of counterweights will depend on the uniformity of the levee slope and current velocity. For the more extreme conditions mentioned previously, a solid blanket of bags over the poly should be used. Sandbag anchors can also be formed at the bottom edge of the poly by bunching the poly around a fistful of sand or rock and tying a sandbag to each fist-sized ball. Wet placement may also be required to replace or maintain damaged poly or poly displaced by the action of the current.

Efficient placement of the poly requires that a sufficient number of the rope and sandbag counterweights be prepared prior to the placement of each poly sheet. Placement consists of first casting out the poly sheet from the top of the levee with the bottom weights in place, and then adding counterweights to slowly sink the poly sheet into place. In most cases the poly will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added quickly to ensure 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. While the implementation of poly with sandbags is an effective remedy, it can be overused or misused. For example:

- On well-compacted clay embankments in areas of relatively low velocities, use of poly would be excessive, as compacted clay is unlikely to be scoured out.

- Placement of poly on landward slopes to prevent seepage must **never** be done. This will only force seepage to another exit that may prove more detrimental.

A critical analysis of each 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.

**2. Placement of Riprap** is a positive means of providing slope protection and has been used in a few cases where erosive forces (caused by current, waves, or debris) were too large to effectively control by other means. Objections to using riprap when flood fighting are: (1) the relatively high cost, (2) a large amount may be necessary to protect a given area, (3) limited availability, and (4) little control over placement, particularly in the wet.

**3. Small groins** extending 10 feet or more into the channel can be effective in deflecting current away from the levees. Groins can be constructed using sandbags, snow fence, rock, compacted earth or any other substantial materials 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; generally
snow fence anchored to a tree beyond the toe of levee is used, but junk car bodies can be tied together to act as anchors.

**4. Log booms** have been used to protect levee slopes from debris or ice attack. Logs are cabled together and anchored in the levee with a device referred to as a "dead man," often consisting of a concrete block with reinforcing bar, or another heavy anchor. The anchor should be of sufficient size and weight to hold the log boom in place. The log boom is
floated out into the current and, depending on the log size, will deflect floating objects and protect the levee.

**5. Miscellaneous Measures.** Other available methods of slope protection include placement of straw bales pegged into the slope and spreading straw on the slope and overlaying with snow fencing. Both have been successful against wave action.

## *3.5 Flashboard and Box Levee Barriers*

In addition to earth fill and sandbag levees, two additional types of flood barriers are flashboard and box levees. The construction of flashboards and box levees requires significant time and expense to complete, so they are not very practical for emergency situations unless constructed well in advance of a flood event. However, they may be suitable under certain circumstances. Both are constructed using lumber and earth fill, and they may be used for capping a levee or as a barrier in highly constricted areas. Construction details for these barriers are shown on ***Plate 5***.

# 4 Interior Drainage Treatment

## 4.1 General

High river stages often disrupt the normal drainage of sanitary and storm sewer systems, render sewage treatment plants inoperative, and cause untreated sewage to back up within the system into homes and businesses, and eventually directly into river. When the river recedes, some of the sewage and natural storm water runoff may be trapped in low-lying pockets behind the constructed levees, causing the ponded area and soils to become contaminated. Hastily constructed dikes intended to keep out river waters may also seal off normal outlet channels for local runoff, creating large ponds on the landward side of the dikes. As the ponded runoff level increases, the levee now becomes vulnerable from both sides, nullifying the protection provided even if the dike is not overtopped. In these cases the ponded runoff will need to pumped over the dike to the river side. Storm water sewers may also back up because of this ponding.

## 4.2 Preliminary Work

To arrive at a reasonable plan for interior drainage treatment, field personnel must obtain several items of information:

a. Size of drainage area.

b. Pumping capacity and/or ponding required. If data are 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 (both abandoned and 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 and in use.

## *4.3 Pumps: Types, Sizes and Capacities*

***Tables 4.1*** through ***4.7*** included below, provide information on specific pump capacities.

**1. Storm Sewer Pumps.** ***Table 4.1*** indicates the size of pump needed to handle the full flow discharge from sewer pipes up to 24 inches in diameter. ***Table 4.2*** shows sizes and capacities of agricultural type pumps that may be useful in ponding areas or in low areas adjacent to the flood barrier where a sump hole could be excavated. ***Table 4.3*** lists full flow discharge capacities for clay sewer pipes laid on slopes of 0.001 and 0.005 feet per foot. Generally, the smaller pipes are laid on steeper slopes than are the larger pipes. ***Table 4.4*** and ***Table 4.5*** show sizes and capacities of Crisafulli and Flygt centrifugal pumps, respectively.

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

### 3. Table 4.1 – *Matching Sewer Pipe Size to Pump Size*

| Sewer Pipe Diameter | 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 |
| 24-inch | 10- to 12-inch |

## 4. Table 4.2 – *Typical Pump Discharge Capacities for Ag. Pumps used in ponded areas.*

### 16-inch Regular Pump @ 540 rpm

| Total Dynamic Head in Feet | Capacity Gallons per Minute | Brake Horsepower |
|---|---|---|
| 0 | 13,500 | 100 |
| 5 | 12,000 | 95 |
| 10 | 10,600 | 91 |
| 15 | 8,900 | 85 |
| 20 | 7,100 | 78 |
| 25 | 5,300 | 70 |
| 30 | 3,300 | 60 |
| 35 | 1,400 | 47 |
| 38.3 | 0 | 36.5 |

### 12-inch Regular Pump @ 540 rpm

| Total Dynamic Head in Feet | Capacity Gallons per Minute | Brake Horsepower |
|---|---|---|
| 0 | 5,525 | 42 |
| 5 | 5,100 | 40 |
| 10 | 4,600 | 38 |
| 15 | 3,900 | 35 |
| 20 | 2,900 | 30 |
| 24.8 | 0 | 15.6 |

## 5. Table 4.3 – *Flow Capacity of Clay Sewer Pipe on two different slopes (S)*

| | \|--- S = 0.001 ---\| | | \|--- S = 0.005 ---\| | |
|---|---|---|---|---|
| Pipe Diameter | cfs | gpm | cfs | gpm |
| 6-inch | 0.19 | 85 | 0.35 | 156 |
| 8-inch | 0.35 | 156 | 0.76 | 340 |
| 10-inch | 0.65 | 292 | 1.60 | 720 |
| 12-inch | 1.20 | 540 | 2.50 | 1,120 |
| 15-inch | 2.1 | 945 | 4.5 | 2,020 |
| 18-inch | 3.4 | 1,520 | 7.3 | 3,260 |
| 21-inch | 5.0 | 2,230 | 11.2 | 5,000 |
| 24-inch | 8.2 | 3,660 | 15.2 | 6,800 |

### 6. Table 4.4 – *Crisafulli Pumps -- Model CP 2-inch to 24-inch Tractor driven*

| 10-foot Head | | | |
|---|---|---|---|
| Pump Size | gpm | Elec. HP | Gas or Diesel HP |
| 2-inch | 150 | 1 | |
| 4-inch | 500 | 7.5 | 15 |
| 6-inch | 1,000 | 10 | 20 |
| 8-inch | 3,000 | 15 | 25 |
| 12-inch | 5,000 | 25 | 40 |
| 16-inch | 9,500 | 40 | 65 |
| 24-inch | 25,000 | 75 | 140 |

| 20-foot Head | | | |
|---|---|---|---|
| Pump Size | gpm | Elec. HP | Gas or Diesel HP |
| 2-inch | 130 | 1 | |
| 4-inch | 490 | 10 | 20 |
| 6-inch | 850 | 15 | 25 |
| 8-inch | 2,450 | 20 | 35 |
| 12-inch | 3,750 | 30 | 50 |
| 16-inch | 8,000 | 45 | 85 |
| 24-inch | 19,000 | 100 | 190 |

| 30-foot Head | | | |
|---|---|---|---|
| Pump Size | gpm | Elec. HP | Gas or Diesel HP |
| 2-inch | 120 | 1 | |
| 4-inch | 475 | 12 | 25 |
| 6-inch | 795 | 20 | 35 |
| 8-inch | 2,150 | 25 | 45 |
| 12-inch | 3,450 | 35 | 70 |
| 16-inch | 7,100 | 60 | 125 |
| 24-inch | 16,600 | 125 | 250 |

NOTE: Use high head pumps for heads over 20 feet.

### 7. Table 4.5 -- *Flygt Centrifugal Pumps (Submersible)*

| Pump Size | Capacity* | Horsepower |
|---|---|---|
| 3-inch | 90 - 150 gpm | 1.3 - 2.0 HP |
| 4-inch | 100 - 250 gpm | 2.7 - 3.5 HP |
| 6-inch | 1,150 gpm | 30.0 HP |
| 8-inch | 2,300 gpm | 29.0 HP |
| 10-inch | 3,300 gpm | 62.0 HP |

* (at 25-foot head)

**8. Pump Discharge Piping.** The Crisafulli pumps are generally supplied with 50-foot lengths of butyl rubber hose. Care should be taken to prevent damage to the hose. Irrigation pipe or small diameter culverts can also serve as discharge piping. The outlet of a pump discharge line should extend riverward far enough off the toe of the levee so that discharges do not erode the levee slope. The discharge end should be tied down or otherwise fixed to prevent its movement. These pumps must not be operated on slopes greater than 20 degrees from horizontal.

**9. Sanitary Sewage Pumping.** During high water, increased infiltration into sanitary sewers 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: $$\frac{5000 \ persons \ x \ 100 \ gal / person / day}{24 \ hrs / day \ x \ 60 \ minutes / hr} = 347 \ GPM$$

Infiltration: $$\frac{15000 \ gal / minute / day \ x \ 30 \ min}{24 \ hrs / day \ x \ 60 \ minutes / hr} = 312 \ GPM$$

Thus, required pumping capacity: 659 GPM

If using a Flygt centrifugal pump from *Table 4.7*, use one 6-inch or three 4-inch pumps.

## 4.4 Metal Culverts

Pumping of ponded water is usually preferable to draining the water through a culvert since the tail 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 flap gate at the outlet end may be desirable to minimize backup. If a culvert is desired to pass water from a creek through a levee an engineering-based computation of the drainage basin is required to determine pipe size.

## 4.5 Preventing Backflow in Sewer Lines

Watertight sluice gates, or flap gates can be used to prevent backflow. 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. ***Plate 6*** and ***Plate 7*** show examples of prefabricated pipe stoppers that can be placed in the pipe to block flows. ***Plate 8*** and ***Plate 9*** illustrate methods of sealing off the outlet openings of a manhole with standard materials that are normally available so that the manhole may be used as an emergency pumping station.

# 5 Flood Fight Problems

## 5.1 General

The problems that can arise during a flood fight are varied and innumerable. The problems covered below and in the prior section on Interior Drainage Treatment are those that are considered most critical to the integrity of the flood barrier system. It would be impossible to enumerate all the categories of problems, such as supplies, personnel, communication, etc., that field personnel must handle. The most valuable asset of field personnel under emergency conditions is their common sense. Many problems can be solved quickly and efficiently through the application of good common sense and sensitivity to human relations. Physical problems with the levees, dikes and related infrastructure can be identified early if a well organized levee patrol team with a good communication system exists. Finally, solutions to problems must take into account whether high water is present on the levee slopes.

## 5.2 Overtopping

Overtopping of a levee occurs when the water level exceeds the crest elevation of a levee and flows into the protected area. Since most emergency levees are in urban areas, overtopping should be prevented at any cost. Overtopping will generally be caused by (1) unusual hydrologic phenomena that cause a much higher stage than anticipated, e.g. heavy rainfall or an ice dam in the channel, (2) insufficient time in which to complete the flood barrier, or (3) unexpected settlement or failure of the barrier. Generally, emergency barriers are built two feet above the predicted water level. If the crest prediction is raised during construction, additional height must be added to the barrier. On an existing or completed barrier, predictions of increases to water levels or settlement of the barrier will call for some form of capping to raise the barrier. Capping should be done with earth fill or sandbags using normal construction procedures. Section 5.8 presents additional information and illustrations regarding overtopping and the possible consequences.

## 5.3 Seepage

Seepage is percolation of water through or under a levee and generally first appears at the landside toe. Seepage through the levee is likely to occur only in 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 that causes severe sand boils and piping is covered in the following Section 5.4.

Seepage is almost impossible to eliminate and any attempt to do so may create a much more severe condition. Pumping of seepage should be held to a minimum, based on the maximum ponding elevation that can be tolerated without damages. In the past, attempts to keep low areas pumped dry resulted in sand boils, and additional time and effort were then expended in trying to
control these sand boils caused by pumping. Therefore, seepage should be permitted if no apparent ill effects are observed and if adequate pumping capacity is available. If seepage causes saturation and sloughing of the landward slope, the section should be flattened to a 1V to 4H Flood-Fight Handbook -
ratio or flatter. Material for flattening should be at least as pervious as the existing embankment material to avoid a pressure build up. Do not place clay over sand to flatten a slope.

## *5.4 Sand Boils*

**1. Description.** A sand boil 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 flood water, 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 a seep occurs, a
stream of water bursts through the ground surface carrying with it sand or silt that is distributed around the hole in the shape of a cone. Depending on the magnitude of pressure and the size of the boil, it may eventually discharge relatively clear water or it may continue to carry quantities of sand and silt. Sand boils usually occur within 10 to 300 feet from the landside toe of the levee, but in some instances, have occurred up to
1,000 feet away.

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

a. ***Piping Flow.*** Piping is the active erosion of subsurface material as a result of substratum pressure and concentration of seepage in a localized channel. 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.

b. ***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 unravel the landside toe, resulting in sloughing of the landward slope.

c. ***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 by itself, the group of boils may cause saturation and flotation ("quickness") of the soil. This can reduce the shear strength of the material at the levee toe to such an extent that failure of the slope through sliding may result.

**3. Combating Sand Boils.** 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 that 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 sand boil 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. ***Plate 10*** illustrates and describes the techniques for ringing a boil with sandbags. Actual conditions at each sand boil will determine the exact dimensions of the boil and the flow of water from it, and the required sandbag ring.

In general, the following considerations should control construction of the sandbag ring: (1) the base width of the sandbag section on each side of the ring should be no less than 1-1/2 times the contemplated height, (2) weak soils near the boil should be included within the ring, thereby preventing a break through later, and (3) the ring should be 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 in the water, and not so high as to completely eliminate seepage. The practice of raising the ring to the river elevation is not necessary and may be dangerous in high stages. If seepage flow is completely stopped, a new boil will likely develop beyond the ring. This boil could erupt suddenly and cause considerable damage. Where many boils are found to exist in a given 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.

In the case of smaller sand boils, large diameter metal or concrete pipe can be placed around the boil to reduce the flow of soil material from the boil. In such cases, take care not to stop the water flow from the boil, only the material flow. It may be necessary to cut a hole in the side of the pipe to allow water to exit.

## *5.5 Erosion*

Erosion of the riverside slope is one of the most severe problems that will be encountered during a flood fight. Emergency operations to control erosion include the use of polyethylene sheeting and sandbag anchors. Poly placement along the riverward face of the dike is discussed at length in Section 3.4, Scour Protection for Emergency Levees.

## *5.6 Storm Sewers and Sanitary Sewers*

**1. 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, or old or abandoned sewer locations that were not found during pre-flood preparations. Any of these conditions can cause high pressures in parts of the sewer system and lead to collapse of the lines at weak points and manhole covers blowing off.

**2. 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 other 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 contained by some other method, such as concrete culverts with a sandbag base that allows the water to rise up above the top of the manhole. Some leakage may occur that will require safe disposal.

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. Doing so 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 any leakage that occurs.

Directly weighing down manhole covers with sandbags or other items is not recommended where high heads are possible as this will not work. A 10-foot head on a manhole cover 2 feet in diameter would exert a force of 2,060 pounds. Thus, a counterweight of more than one ton would have to be placed directly on the cover.

## *5.7 Closures*

Closures consist of gaps in the flood barrier system that are to be left open until flood stage reaches a critical elevation, at which point they are blocked and become part of the flood barrier. The critical elevation must be based on the time required to activate the work crew and reach the site, get materials to the site, and complete the construction, along with how fast the river is expected to rise.

Typical examples of closures include roadways and railroad tracks where traffic is allowed to continue to cross the flood barrier until the water level reaches an elevation where the risk of flooding becomes unacceptable. The size and number of closures should be kept to an absolute minimum. Although the means of blocking closures can typically be implemented fairly quickly, unanticipated problems occurring at a critical time when closure activities are underway could result in resources being reallocated elsewhere. This could result in a hole in the line of protection. If water rises faster than expected, sealing the closure can become difficult.

## *5.8 Causes of Levee Failure*

In addition to the problems covered above, the following conditions could contribute to failure:

- o Joining of an earth levee to a solid wall, such as concrete or piling.
- o Structures projecting from the riverside of levee.
- o A utility line crossing or a drain pipe crossing through the levee fill.
- o The elevation of the tops of "stoplogs" on roads or railroad tracks are at a lower elevation than the top of the levee.
- o Relying on railroad embankments as levees. Material comprising a railroad embankment may not be suitable as levee fill. Furthermore, the railroad embankment section often has a narrow top width and steep side slopes.
- o Allowing pump discharge lines to discharge directly on the riverward levee slope. When discharge lines are allowed to discharge on the levee slope, severe erosion can occur, thus threatening the levee stability. Insure that outlets for pump discharge lines are placed riverward beyond the levee toe, and appropriately anchored to prevent movement.

To assist in presenting a consistent message, definitions and illustrations of specific types of levee failures are provide below, and illustrated on Figures 9 through 12.

- **Levee:** An earth embankment, floodwall, or structure along a water course whose purpose is flood damage reduction or water conveyance.

- **Overtopping**: Water levels that exceed the crest elevation of a levee and flow into protected areas

- **Breach:** A rupture, break, or gap in a levee system whose cause has not been determined

- **Overtopping Breach:** A breach whose cause is known to be a result of overtopping (system exceeded)

• **Failure Breach:** A breach in a levee system for which a cause of failure is both known and occurred without overtopping. Usually requires an investigation to determine cause.

The chart below (***Figure 9***) further defines the appropriate flooding descriptions that should used to correspond to the levee responses to rising water.

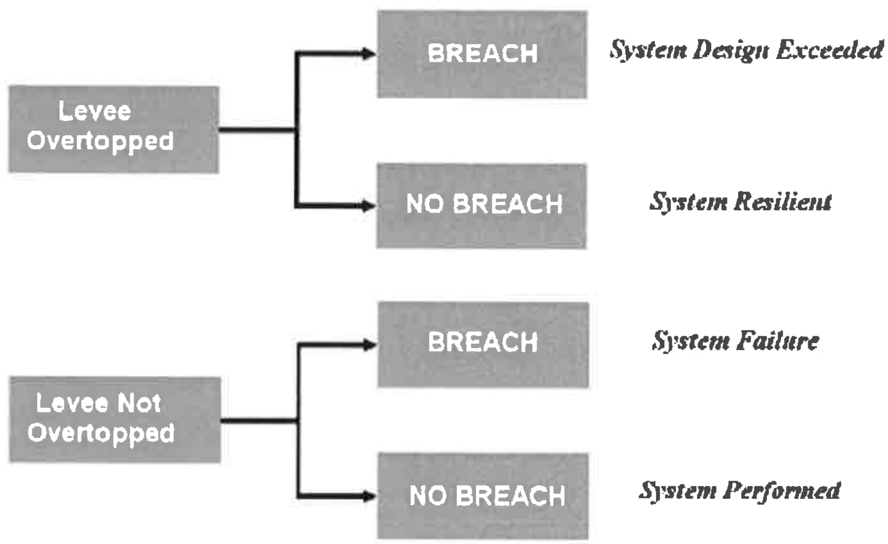



**Figure 9 - Appropriate flooding descriptions corresponding to the levee responses to rising water.**

The diagrams that follow further illustrate different categories of levee failures and breaches versus performing as designed.

**Levee Overtopped** (***Figure 10***) – When the flood excesses the level height of the levee, the levee will be overtopped. Water will flow over the top of the levee into the protected area. When this occurs the levee may be breached.

A breach occurs during overtopping due to damages caused by the water flowing over the top of the levee. Once breached the levee must be repaired to function during the next flood event.

In some cases, a levee may be overtopped without breaching (Non-Breach). In these cases the water does not erode the levee structure and the levee is still functional for the next event.

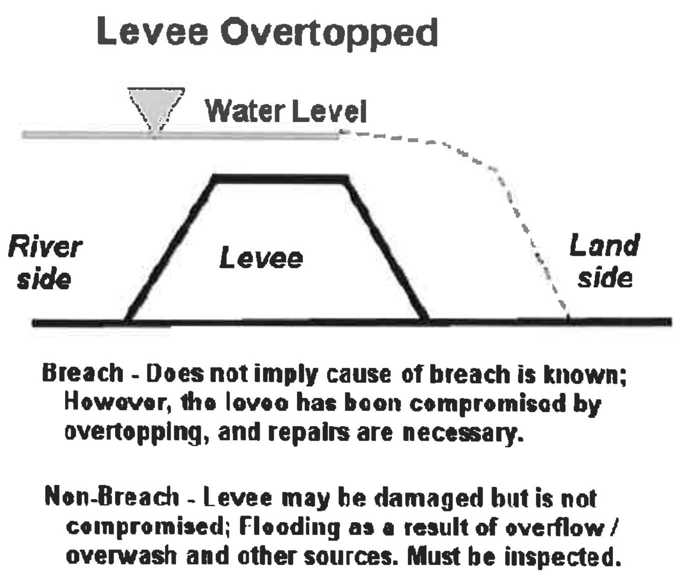
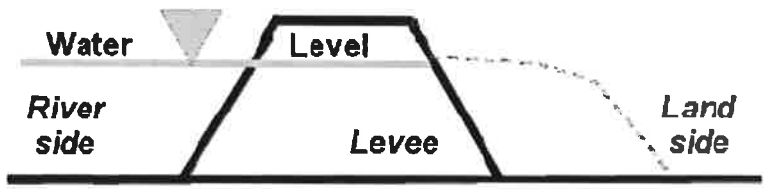



**Figure 10 – Possible results when levee is overtopped.**

A **levee failure** (***Figure 11***) occurs without overtopping when a breach occurs due to a failure of the embankment of the levee at a level below the top of the levee. Generally in this case, the cause of the failure and breach is known.

**Levee Failure**
**without Overtopping**




**Failure without Overtopping - Implies the cause of breach is known to be a result of poor levee performance and occurred without overtopping. This designation should only be applied where studies and investigations have revealed the cause of the breach with little uncertainty.**

**Figure 11 – Levee failure without overtopping.**

Even when the levee performs as designed (***Figure 12***), interior flooding can occur. Some of the causes of interior flooding can be:

1. Seepage and Sand Boils – flow of water through the foundation below the levee and up into in the interior.
2. Interior Drainage – rain fall run off from behind the levee cannot get to the river and ponds, resulting in interior flooding.
3. Levee Penetrations – drainage conduits design to drain the interior area during low flows do not close properly during the flood event and allow water to flow from the river side to the interior side.
4. Pump Station Failures – pump stations designed to pump interior drainage over the levee can fail during an event due to pump failures loss of power.

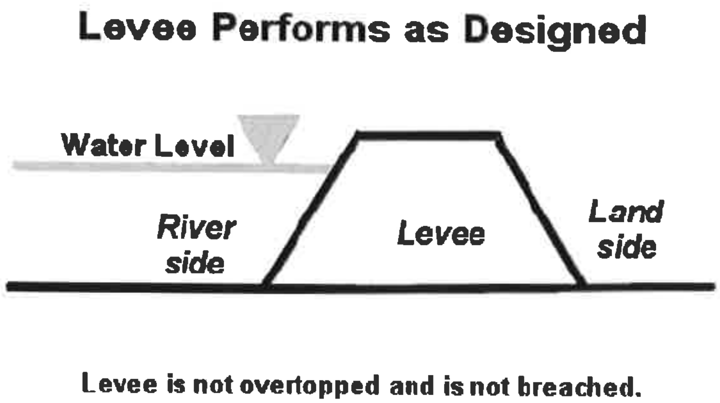



Figure 12 – Levee performs as designed.

## 6 List of Resources and Hyperlinks

**North Dakota State University,** Extension Service, Flood Disaster Education website at: http://www.ag.ndsu.edu/disaster/flood.html

**North Dakota State University**, Extension Service, Coping With Floods website at: http://www.ag.ndsu.edu/disaster/flood.html

**American Red Cross**, Disaster Event Preparedness webpage at: http://www.redcross.org/en/prepare/events provides links to flood, hurricane and other information.

**Pet Evacuation Guidelines** from FEMA:
http://www.fema.gov/plan/prepare/animals.shtm

**Livestock Evacuation Guidelines** from FEMA:
http://www.fema.gov/plan/prepare/livestock.shtm

**U.S. Army Corps of Engineers, St. Paul District:**
http://www.mvp.usace.army.mil/