US Army Corps
Of Engineers
Albuquerque District

FLOOD EMERGENCY HANDBOOK



JULY 2020

(SUPERSEDES ALL PREVIOUS VERSIONS)

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For information on U.S. Army Corps of Engineers assistance or eligibility for assistance during flood emergencies, contact the U.S. Army Corps of Engineers Albuquerque District office at one of the following numbers:

Readiness & Contingency Operations	505-342-3686
Regulatory Division	505-342-3374
Levee Safety	505-342-3427
Flood Plain Management Services/ Flood Risk Management Program	505-342-3296

CHAPTER 1 – INTRODUCTION

1.1 OBJECTIVE

This booklet is intended for use by local officials as a source of U.S. Army Corps of Engineers (hereinafter "USACE") advice for flood emergency preparation and flood fight activities. USACE authority to assist local interests is also described. This booklet is also furnished to USACE employees for information and as an aid for coordination with local interests.

Disclaimer: This Flood Emergency Handbook outlines general and recommended flood fighting methods. Local officials and individuals must consider that some flood fighting methods require early planning and site specific solutions that may have not been covered in this handbook.

1.2 US ARMY CORPS OF ENGINEERS AUTHORITIES

a. USACE may provide emergency assistance under Public Law (PL) 84-99 Flood Control and Coastal Emergencies to save lives and protect properties (e.g. public facilities/services and residential/commercial developments) during or following a flood event. USACE emergency assistance will be undertaken only to supplement state, tribe, county, and local efforts. State, tribal and local interests must commit all available resources, e.g. work force, supplies, equipment, funds, National Guard assets, etc. as a general condition of USACE assistance.

USACE authorities consist of either technical assistance or direct assistance during flood response operations. Technical assistance consists of providing review and recommendations in support of state and local effort, and helping determine feasible solutions to uncommon situations. The following are examples of technical assistance:

- Guidance in flood fight techniques,
- Inspection of an existing flood control works project,
- Providing hydraulic and hydrologic analysis of the area, and
- Geotechnical evaluations of existing flood control works.

Direct assistance under PL 84-99 may include furnishing flood-fighting materials, e.g., sandbags, polyethylene sheeting, lumber, pumps, and applications of riprap revetment to stabilize eroding levees. As well as contract hiring of equipment and operators for flood fighting operations, construction of emergency flood control projects, removal of log or debris jams that are blocking stream flow and causing flooding of communities, etc. Direct assistance under PL 84-99 is limited to flood related emergencies only.

Advanced Measures, when directed by the Chief of Engineers, authorizes advance or "foresight" type measures under PL 84-99 to prevent damage resulting from forecasted imminent flooding. Emergency advance protective work must be requested by governor of state, justifiable from the engineering and economic aspects, feasible for timely completion, and of a temporary nature sufficient for the current emergency. Details of local assurances, cooperation of local assurances, and cooperation and participation will be obtained. Local requirements may be waived by the Chief of Engineers in isolated cases.

Local entities desiring assistance from USACE for flood fighting should first go to their emergency disaster agency or other state or tribal agencies who are authorized to act for the state or tribal governor in times of natural disaster. The state/tribal governor, or an authorized representative, will request assistance for the applicable program from USACE. Assistance under PL 84-99 cannot be provided directly to individuals.

A public sponsor can request flood emergency preparation assistance and rehabilitation of a flood control project threatened or destroyed by a flood. Public sponsors can be a legal subdivision of a state government, the state itself, a local unit of government, a state chartered organization or a qualified Indian tribe.

b. Section 404 of Public Law 92-500, "Clean Water Act of 1977" requires that a permit be obtained from USACE for the discharge of dredged or fill material in all waters of the United States including adjacent wetlands. These requirements should not delay work necessary to prevent loss of life or property during an actual emergency or flood fight. Normal maintenance of flood control structures is authorized by this law. However, construction of such structures prior to or after a flood will generally require a permit from the USACE. Local interests who are planning the construction of structures which require excavation or placement of fills in lakes, streams, or wetlands should inform the District Engineer of USACE of their plans at least 60 days prior to start of construction.

c. Section 408 provides that USACE may grant permission for another party to alter a Civil Works project upon a determination that the alteration proposed will not be injurious to the public interest and will not impair the usefulness of the Civil Works project. This requirement was established in Section 14 of the Rivers and Harbors Act of 1899, codified at 33 United States Code (USC) 408 (Section 408). Formal Section 408 permissions coordination is not required during times of emergency or flood fight. Current USACE guidance for Section 408 is EC 1165-2-220 and can be downloaded from the USACE publication page; https://www.publications.usace.army.mil/Portals/76/Users/227/19/2019/EC_1165-2-220.pdf?ver=2018-09-13-114714-120. Contact your local USACE District office for current guidance as updates occur periodically.

d. Section 14 of the 1946 Flood Control Act, as amended, allows the USACE to study, design and construct bank protection works in the interest of protecting public facilities (churches, roads, bridges, known cultural sites, public buildings, utilities, etc.). Erosion caused by the design or operation of the facility itself, by inadequate drainage, or due to lack of reasonable maintenance, is not eligible. In addition, repair of the facility itself is excluded.

e. Section 208 of the 1954 Flood Control Act provides authority for USACE for channel clearing and excavation, with limited embankment construction by the use of materials from the clearing operation to reduce nuisance flood damages caused by debris and minor shoaling of rivers.

f. Section 205 of the Flood Control Act of 1948, as amended, authorizes the USACE to study, design and construct small flood risk management projects. Projects are planned and designed under this authority to provide the same complete flood control project that would be provided under specific congressional authorizations.

g. Public Law 93-288 (Stafford Act), as amended, authorizes the Federal Emergency Management Agency (FEMA) to task USACE with disaster recovery missions under the Federal Response Plan.

For further information on the USACE assistance or eligibility for assistance during flood emergencies, contact your local USACE District office (USACE Albuquerque District - Readiness & Contingency Operations Phone # 505-342-3686).

CHAPTER 2 – FLOOD PREPAREDNESS AND OPERATIONS

USACE Albuquerque District's flood emergency preparedness program is of a continuing nature and consists of preparation procedures as authorized by Public Law 84-99.

2.1 PREPAREDNESS, TRAINING, AND COOPERATION WITH OTHERS

a. Preparation and updating of emergency manuals and standard operating procedures

b. Internal and external flood fight training exercises.

c. Periodic inspections of flood control works and provision of advice and/or recommendations as to their operations and maintenance. Continuing liaison with other Federal, State, and local agencies and the participation of ad hoc meeting dealing flood threats.

d. Inventory, maintenance and augmentation of sandbag and other special purpose flood emergency items.

e. Technical advice of State and local measures for adequate preparedness to act including operational planning.

CHAPTER 3 – SAFETY

Strict adherence to safety procedures are critical to flood fighting operations. Presented below are some important safety tips.

Tip #1	Use proper lifting techniques to avoid injury and fatigue. Lift with your legs and bend at the knees to save your back.
Tip #2	Sandbags are treated to prevent deterioration when stored. Use work gloves and avoid contact with your eyes and mouth.
Tip #3	Stay in eye contact with heavy equipment operator and keep alert for vehicle backup alarms.
Tip #4	Flood waters can be polluted. Use rubber gloves and appropriate clothing if contact with water is unavoidable.
Tip #5	Wear adequate clothing in layers and watertight boots. Reflective material on outer clothing is essential for night work.
Tip #6	Rotate team members frequently to avoid fatigue.

CHAPTER 4 – FLOOD FIGHTING METHODS

There is no set of rigid rules for flood fighting that is applicable to every condition that might develop during a flood emergency. Engineering judgment must be applied to determine the most appropriate solution. There are some general instructions described in this handbook which have been followed with good results. When there is doubt as to which procedures should to be taken, consult with experienced engineers and follow standard engineering practices in meeting the situation. Floods can happen at any time. Common causes include high river levels due to spring snow melt and heavy rain storms. There are many flood preparedness steps that can be taken to increase protection and reduce severity of impact on your home, business, and family.

4.1 GENERAL INSTRUCTIONS

This handbook describes engineering-related solutions to protect structures from flooding. It will help you determine what supplies and materiel to have on hand, as well as provide detailed guidance on implementing the different solutions. There are many excellent sources of information for other areas of preparedness (e.g. family emergency plans, protection of the interior/contents of a structure, and business continuity planning). When time permits, local interest should accomplish the following items:

a. Fill in holes or erosion voids in the levee crown and compact firmly based on applicable standard and guidance.

b. Repair gaps where road crossings or cattle trails have been worn down and the levee is below grade. Fill and compact firmly where needed. The compaction should follow applicable standard and guidance.

c. Clean out, repair, and close all flap and sluice gates as applicable on culverts before they are covered with flood waters.

d. Clean out bridges and culvert openings. Clean debris out of the channel. Remove channel vegetation that significantly restricts channel flow, especially trees. Section 404 permit consultation should be coordinated with this activity.

e. Expedite rodent control, if indicated. Removal of beavers and their dams, where necessary, should be done by State Game Officers or Conservation Officer.

f. Ascertain condition of all roads leading to and upon the levees, river channels, arroyos, culverts, stock ponds and bridges etc. (Improve, if required). Roads leading to levees may be soft or wetted by subsurface water.

g. Determine what will be needed and locate necessary tools and materials (rock including large riprap, sandbags, brush, lumber, lights, polyethylene sheeting, bentonite clay, gabions, etc.) and distribute as necessary. Local governments or flood control districts have the responsibility of maintaining a supply of sandbags and other supplies that are adequate to cover anticipated emergencies. USACE maintains a limited stockpile of sandbags and other flood fighting materials that are intended to be available to augment the stockpiles of local jurisdictions during actual flood emergency situations. USACE should not be considered as the supplier of first resort for sandbags and other supplies.

h. Make liaison arrangements with American Red Cross, Contractors Associations, State and Federal representatives, as appropriate.

i. Check for property and livestock within the levee that is subject to flood damage.

j. Investigate all drainage ditches on the land side of levees for slumps along banks, or other obstructing conditions. Inspect the levee on both sides before high water covers the riverside weak points. Repair these weak points before water becomes too high to allow repairs.

k. Erect stop logs in existing structures at applicable locations, (Local officials are in charge of this action).

l. Check stream side levee slope protection to determine if any scour has occurred at the toe. If toe scour has occurred, place additional slope protection at the toe of the levee. Monitor channel/arroyo conditions for erosion of banks if scour is occurring consider dumping riprap in the area and constructing bend way weirs to divert water away from the toe (see section 4.34 for additional information concerning bendway weirs).

m. Assign levee/river channel patrol responsibilities. Important to have ongoing inspections during high flow events. Monitor and assess levee conditions and document problems observed so they can be corrected either during or after the flood emergency as appropriate.

n. Notify local residents living next to levees/channels/arroyos about the likelihood of high water and enlist their aid to monitor and report conditions.

o. Maintain a stock pile of filled sandbags and riprap for quick deployment to problem areas.

p. Practice or conduct table top exercises related to potential flooding or levee failure to gain a perspective on what materials are lacking or where knowledge gaps exist.

4.2 EARTHEN LEVEES

An earthen levee is at risk whenever there is water against it. This risk can be considered directly proportional to the height of the water, the duration of the flood stage, and the intensity of either the current or wave action, or both. Faulty design, faulty construction, bad foundation conditions, lack of appropriate maintenance to the levee, negative effects to animal burrows, inadequately engineered or non-approved alterations may result in a levee failure. Foundation failures can result in sand boils. Poor construction methods and the use of unsatisfactory materials cause slides and sloughs. However, such threatened failure can be overcome if prompt action is taken and proper methods of treatment are used. Wave wash is to be expected whenever the levee is exposed to a wide stretch of open water and, if permitted to continue over a considerable length of time, will develop into a serious threat. Streams in mountainous and hilly areas tend to have very high velocity flood flows which can rapidly erode unprotected levees, stream, and arroyo/channel banks.

4.3 GENERAL APPLICATIONS OF SANDBAGS FOR FLOOD PROTECTION

A levee is an embankment, floodwall, or structure along a water course whose purpose is flood risk reduction or water conveyance. A properly built sandbag levee can reduce flood damage. Sandbag levees are labor-intensive, have more opportunities for error during construction, and require disposal procedures after the event. However, sandbag levees generally do not require heavy equipment and can be constructed by small groups of individuals. Sandbag levees should be used where a very low and relatively short barrier is required or where earth fill would not be practical, such as in the freeboard range along an arterial street. They are very useful where temporary closures are required, such as roads and railroad tracks. The sandbag size, fill material used, and method of placement all influence the effectiveness of the sandbag levee. This section describes and illustrates a number of suggested techniques for using sandbags and other materials to build temporary flood protection levees.

4.3.1 SANDBAG AND FILL MATERIAL

Bags must be filled and placed properly to give the best protection. Any available material can be used to fill sandbags, but dry sand is easiest to handle. Silt and clay will form a good levee but are more difficult to work with. Different size bags are available, but bags are easier to handle if weight is limited to between 35 and 40 pounds. This weight limit is particularly important when teenagers or older persons will be handling the bags and assisting with emergency operations and levee construction. Dry sand is much easier and lighter than wet sand to handle. Wet sand will add weight and make it much more difficult to fill, move and place sandbags.

Typically, sandbags are filled approximately half to two thirds full and do not need to be tied, although they may be tied loosely near the top. Sandbags can also be folded. It is desired that the sandbags lay flat when placed. Overfilled bags reduce the levee's effectiveness by leaving gaps between the bags, allowing water to seep through. Figure 1 and Figure 2 illustrate the correct and incorrect ways to prepare sandbags. Tying is not required for a correctly filled sandbag.

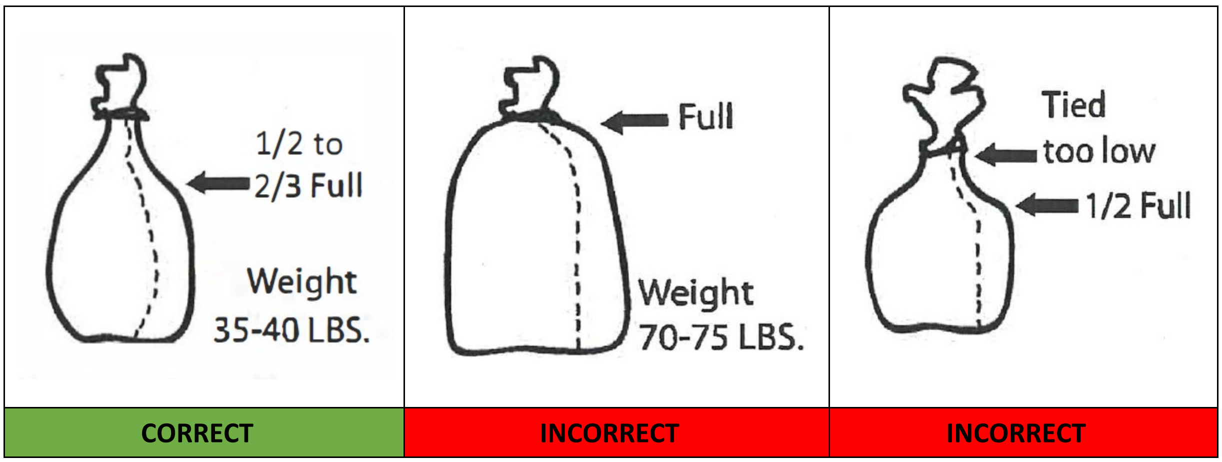


Figure 1. Sandbag filling and preparation.

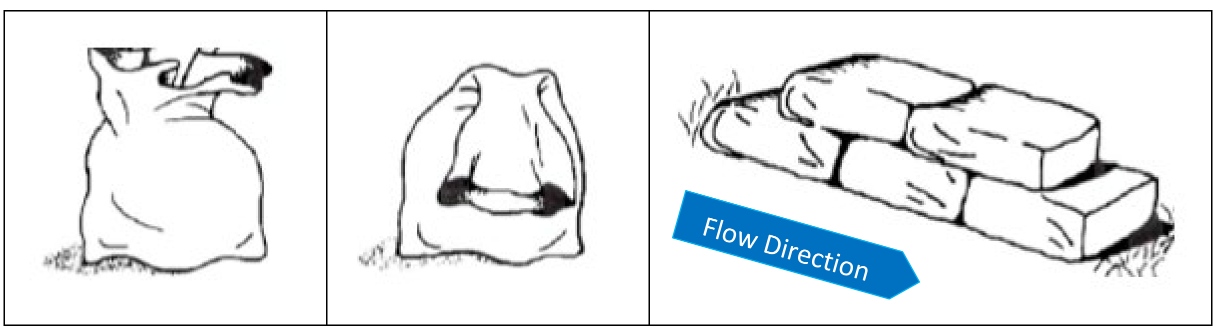


Figure 2. Sandbag filling and preparation: Folded Sandbag placement (source: San Diego County).

Ordinarily, filling sandbags is a three-person operation. One member of the team should place the bottom of the empty bag on the ground slightly in front of the person who is loading the sand. This person may also want to kneel or sit to avoid back strain from bending. The throat of the bag is folded outward about one and one-half inches to form a collar and held in that position to allow a second team member to empty a shovelful of material into the open end, until the bag is one-half to two-thirds full. The third team member stacks and stockpiles the filled sandbags. Gloves should be used to avoid injury, and safety goggles are desirable during dry and windy days. For larger operations some jurisdictions have sand bagging machines or you could use holding racks and funnels on the back of dump trucks, safety cones with the bottom third cut off on ladders and other power loading equipment can be used to expedite the filling operation. Contact your county emergency office for information on where to obtain sandbags.

4.3.2 SITE SELECTION AND PREPARATION

When selecting the location for a sandbag levee, consider the ground elevation, ground condition, obstructions, items or infrastructure to be protected by the sandbag levee, potential staging areas for equipment and material, and proposed alignment. For stability, the levee should be kept as short and low as possible. Avoid any obstructions that would weaken the levee, and do not build the levee against a building wall unless the wall has been designed to retain floodwaters. If possible, plan to leave at least 8 feet between the landward toe/base of the levee and any building or obstructions to allow for future levee raises, levee monitoring, construction equipment and vehicles, and to prevent damage to building walls and foundations.

If the sandbag levee will be more than 2-3 feet high, dig a bonding trench along the center line of the alignment to better anchor the levee in place, as shown in Figure 3.

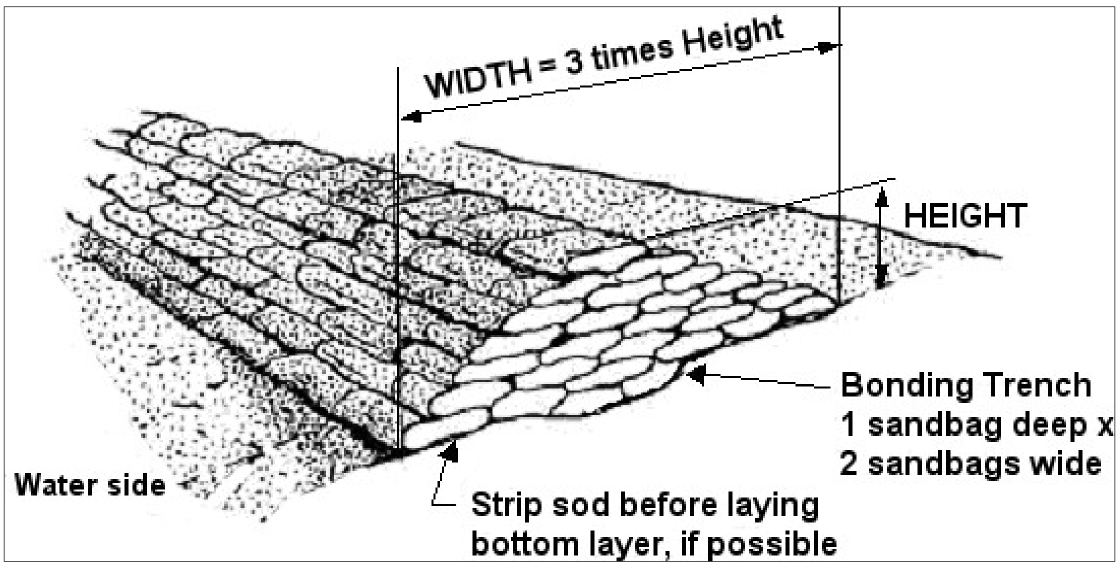


Figure 3. Proportions of sandbag levee showing bonding trench at base.

4.3.3 STACKING SANDBAGS TO FORM A LEVEE

Overlap the sandbags as shown in Figure 4, placing the first layer of bags lengthwise along the levee and lapping the bags so the filled portion of one bag lies on the unfilled portion of the previous bag.

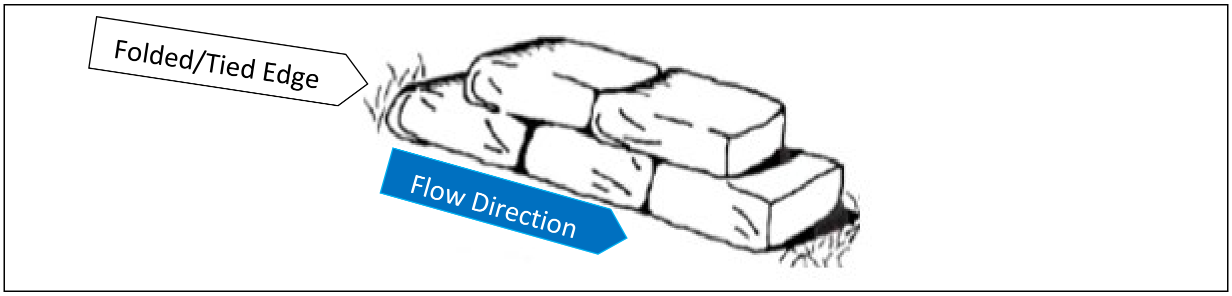


Figure 4. Sandbag placement (source: San Diego County).

The bags should be placed lengthwise and overlapped parallel to the direction of the river flow. The bonding trench shown in Figure 3 should be filled with a layer that is two sandbags wide by one sandbag high; the first full layer is then placed over this bonding trench. The base of the levee should be three times as wide as the levee is high.

The second layer of bags should be staggered perpendicular to the first layer and placed over the seams of the previous layer, with additional layers laid in alternating directions to the top of the levee, as shown in the "Correct" example in Figure 5. By alternating placement directions, the gaps and seams along the edges and corners in each layer below will be covered and filled in by a sandbag in the next overlying layer.

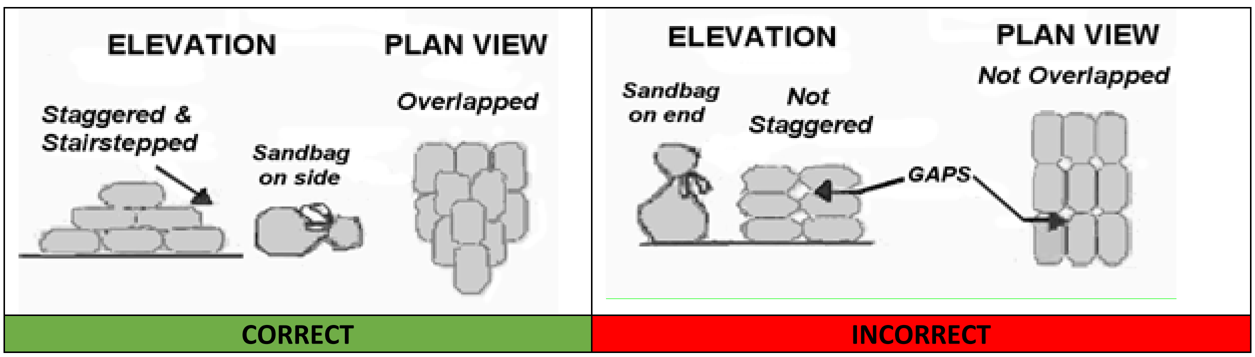


Figure 5. Correct and incorrect placement of staggered sandbag layers.

4.3.4 SEALING THE LEVEE

The finished levee can be sealed with a sheet of polyethylene plastic (poly) to improve water tightness. The poly sheeting should be about 6 mils thick, and is generally available in 20-foot-wide by 100-foot-long rolls from construction supply firms, lumberyards, and hardware/farm stores.

4.3.5 ANCHORING

The poly must always be anchored at the bottom edge and weighted along the top and slope to be effective. Three methods are recommended to anchor the poly on the river side face of a sandbag levee.

The most successful anchoring method is to place the poly flat on the ground surface extending away from the bottom row of sandbags, and then place one or more rows of sandbags over the flap. The poly should then be unrolled over the anchoring row of sandbags, anchored again, and then up the slope and over the top of the sandbag levee, far enough to allow for anchoring with additional sandbags. This method is illustrated in Figure 6**.**

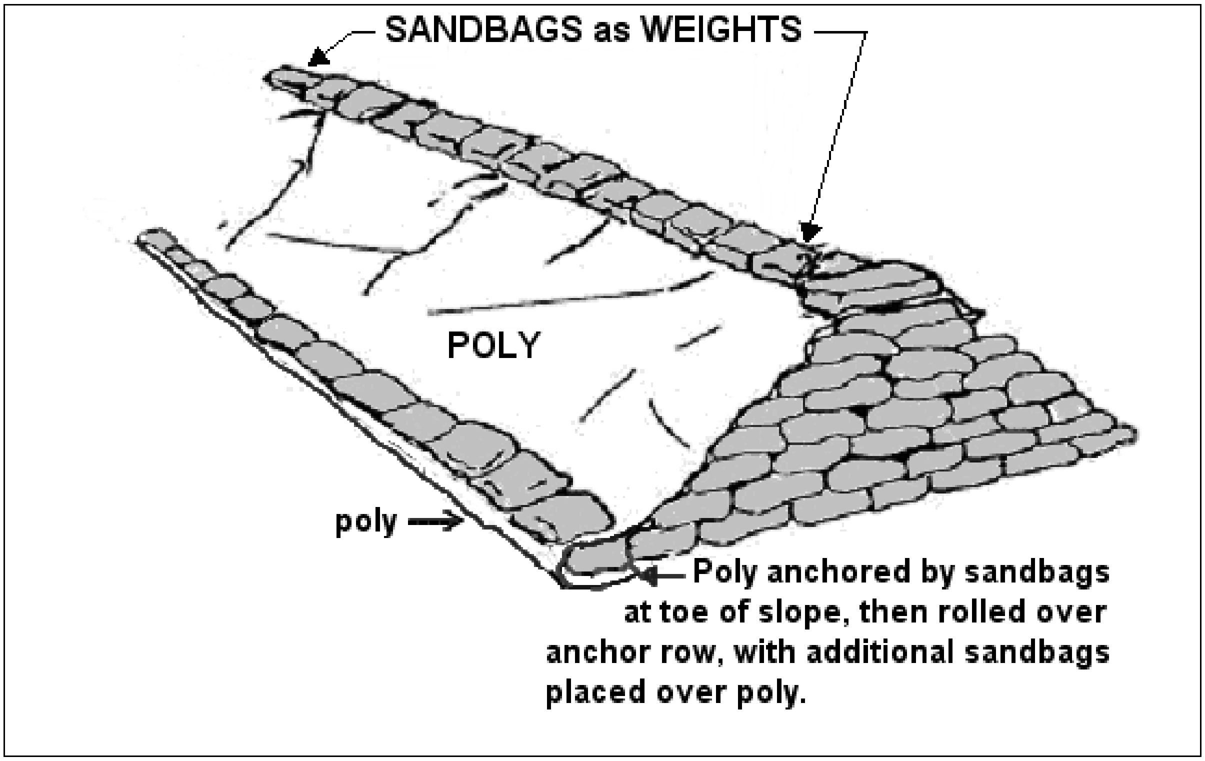


Figure 6. Preferred method of tucking and anchoring poly with two rows of sandbags.

An alternate method to anchor poly is to spread a layer of dirt or sand one inch deep and about one foot wide along the base of the levee on the water side, to create a uniform surface to anchor the poly. Lay the poly sheeting so the bottom edge extends one to two feet beyond the bottom edge of the sandbags over the loose dirt, and then place sandbags over the edge of the poly to anchor. This method is illustrated in Figure 7.

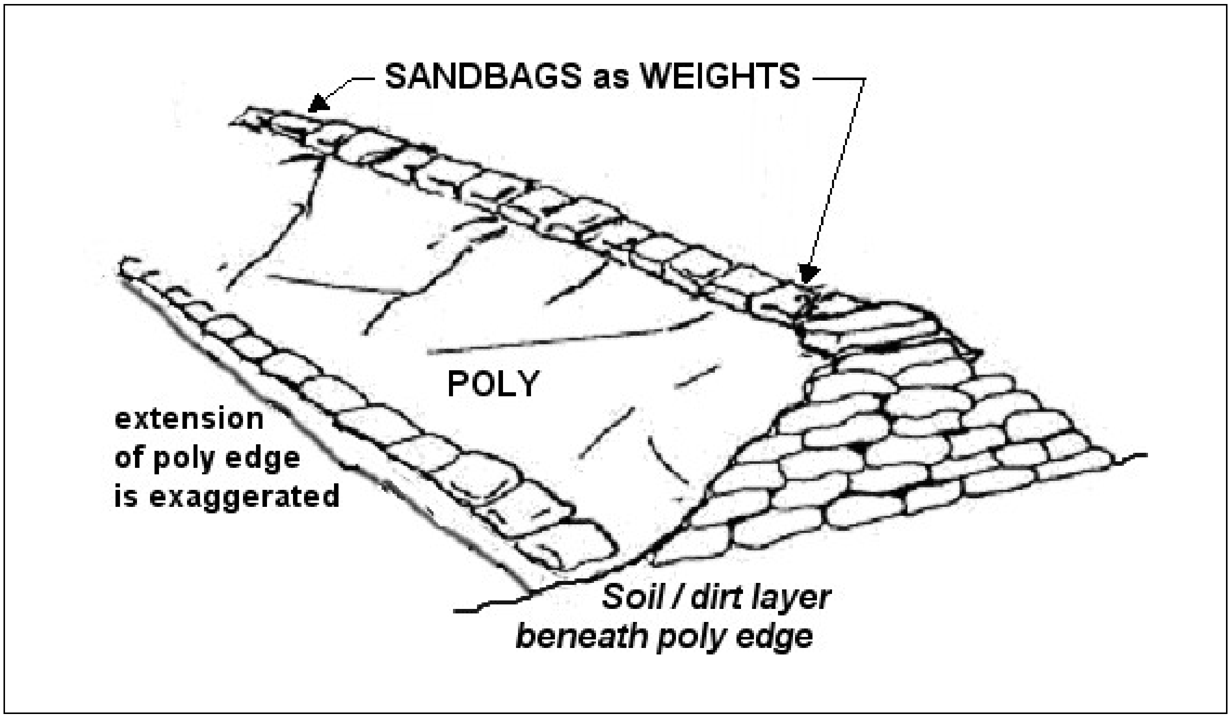


Figure 7. Poly edge placed over dirt and anchored with a row of sandbags.

A third method to anchor the poly is to excavate a 6-inch or deeper trench along the toe of the levee, place poly in the trench, and backfill the trench, compacting the backfill material or placing a row of sandbags over the trench to prevent loss of the backfill material. This method, illustrated in Figure 8**,** will be unsuitable if water levels have reached the sandbags at the toe of the levee.

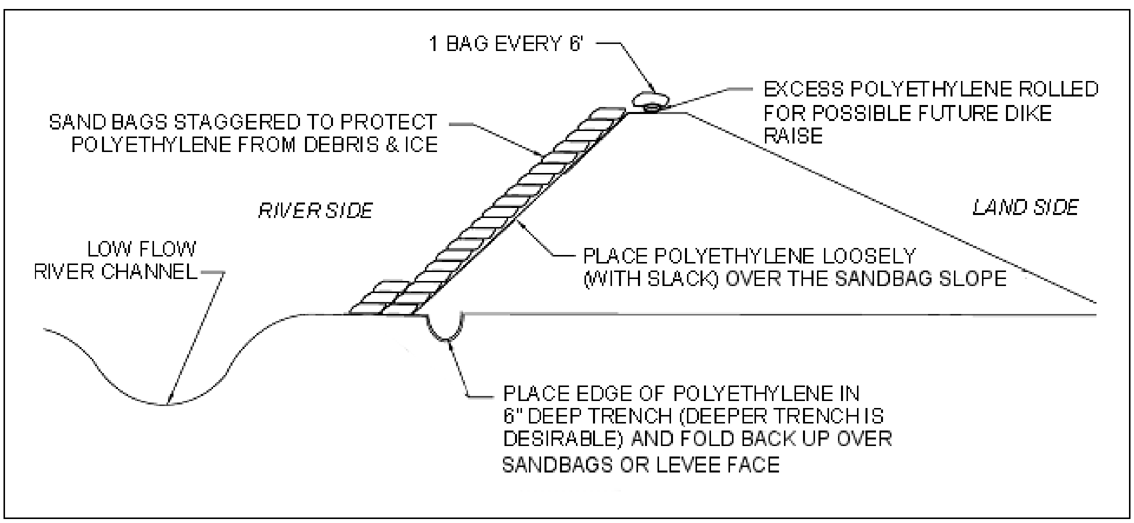


Figure 8. Poly anchored within a trench (placed under dry conditions).

4.3.6 PLACEMENT

Poly should be placed from downstream to upstream along the slopes and the next sheet upstream overlapped by at least 3 feet, as shown on Figure 9**.** Overlapping in this direction prevents the current from flowing under the overlap and tearing the poly loose. After the poly is anchored in place, it should be unrolled up the slope and over the top. Lay the poly sheeting down very loosely, as the pressure of the water will make the poly conform easily to the sandbag surface if the poly is loose. If the poly is stretched too tightly the force of the water could puncture the poly.

Once the poly is anchored and unrolled, additional sandbags, boards, and/or loose dirt should be used as weights along the top of the levee to keep the poly in place and prevent the wind or river current from disturbing it. These weights are not shown on the illustration. Avoid puncturing the poly with sharp objects or by walking on it.

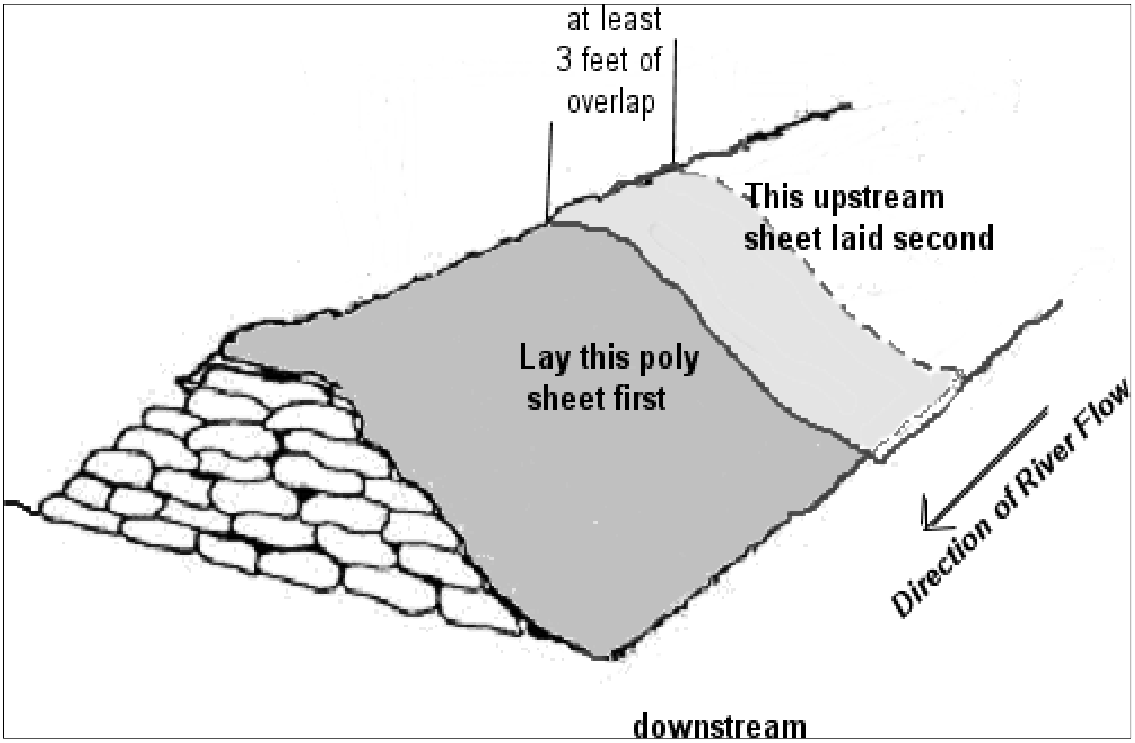


Figure 9. Poly placement from downstream to upstream with overlap shown.

4.3.7 NUMBER OF SANDBAGS NEEDED

The information in drawing below indicates the approximate number of sandbags that are needed for levees of various heights and lengths. Note that 4 feet high is the practical limit of a sandbag levee. If a higher sandbag levee is needed, alternative means of construction should be considered. The preferred height limit is 3 feet. Quantities of required sandbags are presented in Figure 10 and Table 1. In addition to the required quantities of sandbags, it is also important to consider the quantity of fill material.

PYRAMID PLACEMENT METHOD

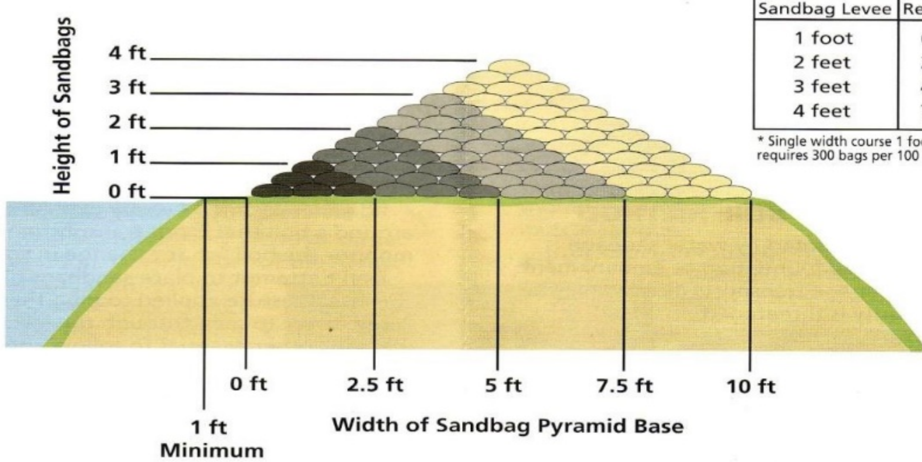
Use pyramid placement to increase the height of sandbag protection; however, use caution when raising the levee height. Determine the height of the sandbag raise by using the best available forecasts of flood conditions.

An example: When the water level is currently 1 foot below the top of the levee and is predicted to rise 3 more feet, construct a 2-1/2 foot sandbag operation which includes one-half foot of height as a safety factor.

It's important to compact each bag in place by walking on it, butting the ends of the sacks toether, maintaining a staggered joint placement and folding under all loose ends.

Watch for flooding elsewhere, and watch for boils on the landward side of the levee due to the increased water elevation.

TYPICAL PYRAMID SANDBAG PLACEMENT



Bags Required Per 100 Linear Feet of Levee	
Height of Sandbag Levee	Bags Required
1 foot	600*
2 feet	2100
3 feet	4500
4 feet	7800

* Single width course 1 foot high requires 300 bags per 100 linear feet.

The pyramid placement method issued to increase the height of sandbag protection.

Use this rule of thumb in determining dimensions of the pyramid:

- 1 bag in length equals about 1 foot
- 3 bags in width equals about 2-1/2 feet.
- 3 bags in height equals about 1 foot.

Place the sandbags by laying an equal number of horizontal rows on the bottom as there are vertical layers.

It's important to compact each bag in place by walking on it, butting the ends of the sacks together, maintaining a staggered joint placement and folding under loose ends.

Figure 10. Typical pyramid sandbag placement.

Table 1. Approximate number of sandbags required for length of levee.

LEVEE HEIGHT	NUMBER OF SANDBAGS REQUIRED FOR LENGTH OF LEVEE									
	50 FT	100 FT	175 FT	200 FT	250 FT	300 FT	350 FT	400 FT	450 FT	500 FT
1 Foot	300	600	1,050	1,200	1,500	1,800	2,100	2,400	2,700	3,000
2 Feet	1,050	2,100	3,675	4,200	5,250	6,300	7,350	8,400	9,450	10,500
3 Feet	2,250	4,500	7,875	9,000	11,250	13,500	15,750	18,000	20,250	22,500
4 Feet	3,900	7,800	13,650	15,600	19,500	23,400	27,300	31,200	35,100	39,000

4.3.8 NUMBER OF SANDBAGS NEEDED FOR A DOOR WAY

Sandbags should also be used in front of doorways/roller doors and brickwork vents. Most standard homes and buildings on a concrete slab can be protected with between 25-40 sandbags. However, consideration should be given to placing the closure in such a way as to allow for egress in case of emergency.

4.3.9 HOW MANY SANDBAGS WILL A YARD OF SAND FILL

Dry sand weighs 100 to 130 pounds per cubic foot, and depends on moisture content and packing. A cubic yard is 27 cubic feet. Each 14-inch by 24-inch bag will hold about 0.4 cubic feet if filled about one-half full. Based on volume, each cubic yard of sand will fill about 67 bags one-half full. Note that less bags will be filled if bags are 2/3 full. Dry sand is recommended since wet sand is much heavier and bags will be much harder to handle.

4.3.10 SANDBAG LIMITATIONS

a. Sandbags will not seal out water.
b. Sandbags deteriorate when exposed for several months to the sun or continued wetting and drying. If bags are placed too early, they may not be effective when needed.
c. Sandbags are basically for low-flow protection (up to 4 feet). Protection from high flow requires a permanent type of structure.
d. Sandbags are not always an effective measure in the event of flooding because water will eventually seep through the bags and finer materials like clay may leak out through the seams.

CHAPTER 5 – STANDARD METHODS FOR TREATING VARIOUS LEVEE PROBLEMS

5.1 GENERAL

If possible, levee patrols should be initiated before arrival of a predicted flood (i.e., major snowmelt runoff or post fire flood preparation). Access routes, travel time, bridge capacities, known problem areas should be examined. The methods of treating levee problems outlined in the following paragraphs have been used by the USACE and have proven to be effective.

5.2 DRAINAGE OF SLOPES

This work can be done economically while awaiting developments and will serve to make the levees more stable and efficient. Crews should be organized to cut seep drains at all places on the landside levee slope and berm where seepage appears. The drains should be V-shaped, no deeper than necessary, and never more than six inches deep. In all instances, drains should be cut straight down the levee slope or nearly so. Near the toe of the slope the small drains should be tied together and led into larger drains, which in general, should lead straight across the landslide berm into the landside pits or main lateral ditch. If the levee becomes saturated and sloughs occur, see Section 5.4.

5.3 SETBACK LEVEES

Setback levees are smaller levees built to the landside of the main levee for formation of pools to reduce the effective water pressure on the landside and thus inhibit the formation of sand boils and movement of foundation material. Nearby road or irrigation canal embankments may be at the proper position and grade to be temporarily incorporated into a setback levee arrangement. Immediately upon mobilization, siphons or pumps should be put into operation and kept running until each sub-levee basin is filled. The spillways should be kept free of obstructions so that when the basin is filled the surplus water can escape. The siphons, of course, need not be run if the basin fills of its own accord from normal seepage. If the spillways constructed in the setback levees do not have capacity sufficient to drain off the water to the level of the spillway crest, additional temporary spillways should be constructed. The crest of the spillways should not be raised, unless active sand boils begin to appear above the water level. The setback levee should be raised at once to a height sufficient to stop the active sand boil flow.

5.4 SAND BOILS

A sand boil is the rupture of the top foundation stratum landward of a levee caused by excess hydrostatic pressure in the lower layer (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 or further away.

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 the localized channels. The flow breaks out at the landside toe in the form of one or more 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 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 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 occur.

All sand boils should be monitored closely; however, if sediment is discharging (or if flow through sand boils is carrying soil particles), these danger spots are serious especially if within a distance of 100 feet from the toe of the levee. The common method of handling sand boils is by walling up a watertight sandbag ring dike around the boil until the water within the ring has attained sufficient pressure head to counteract the effective head causing the boil. In the event that several boils of sufficient force to displace sand are observed at points where sub-levees have not been provided, and if any considerable number of them are within 100 feet of the levee, a sandbag sub-levee should be built around the entire nest of boils rising to such a height that none of the boils will discharge with enough force to displace sand. If after being controlled by a ring dike or sub-levee, sand boils show signs of discharging with increasing force and indicate that considerable sand is being displaced, preparations must be made to raise the counter water level by increasing the height of the ring dike or sub-levee. Outlined below are items to consider when placing sandbags (sandbag rings) around sand boils:

a. The area should be cleared of any vegetation and debris prior to placing sandbags.
b. The inside base width of sandbag should be no less than $1^1/_2$ times the height.
c. All sandbag placements should be staggered.
d. Do not attempt to fill a sand boil with silt or clay material.
e. If sand boil appears close to the levee toe, sandbags can be placed in such a way that it's tied to the toe of the levee or a semi-circular dike can be built if the boil is on levee slope.
f. The ring should be sufficient in size to allow for the pepper placement of sandbags (i.e. the height of the ring should only be as high as necessary to stop movement of soil particles, and not so high as to completely stop seepage).
g. If seepage flow is completely stopped, a new boil will likely develop beyond the ring. Monitoring for new sand boils should be conducted constantly.
h. If several boils are found to exist within a given area, a ring levee of sandbags should be constructed around the entire area. This is done by building a berm/bench on the landside of the levee. This berm/bench is constructed by placing a geotextile fabric on the ground and then placing a 4 feet thick layer of aggregate on the fabric. This solution performs well when numerous sand boils develop within 20-30 feet of the levee toe.
i. It may be necessary to pump additional water into the ringed area in order to provide sufficient weight to counter balance the upward pressure.

Figure 11 illustrates the recommended sandbag application around sand boils. Also see photos below (Figure 12 to Figure 14) which show a large sand boil and some examples of sandbagging accomplished in the field. Figure 13 demonstrates how a sand boil ringed with sandbags can raise the water surface elevation to equalize hydrostatic pressure. This acts to slow flow through the sand boil and reduce the risk of piping erosion through a levee.

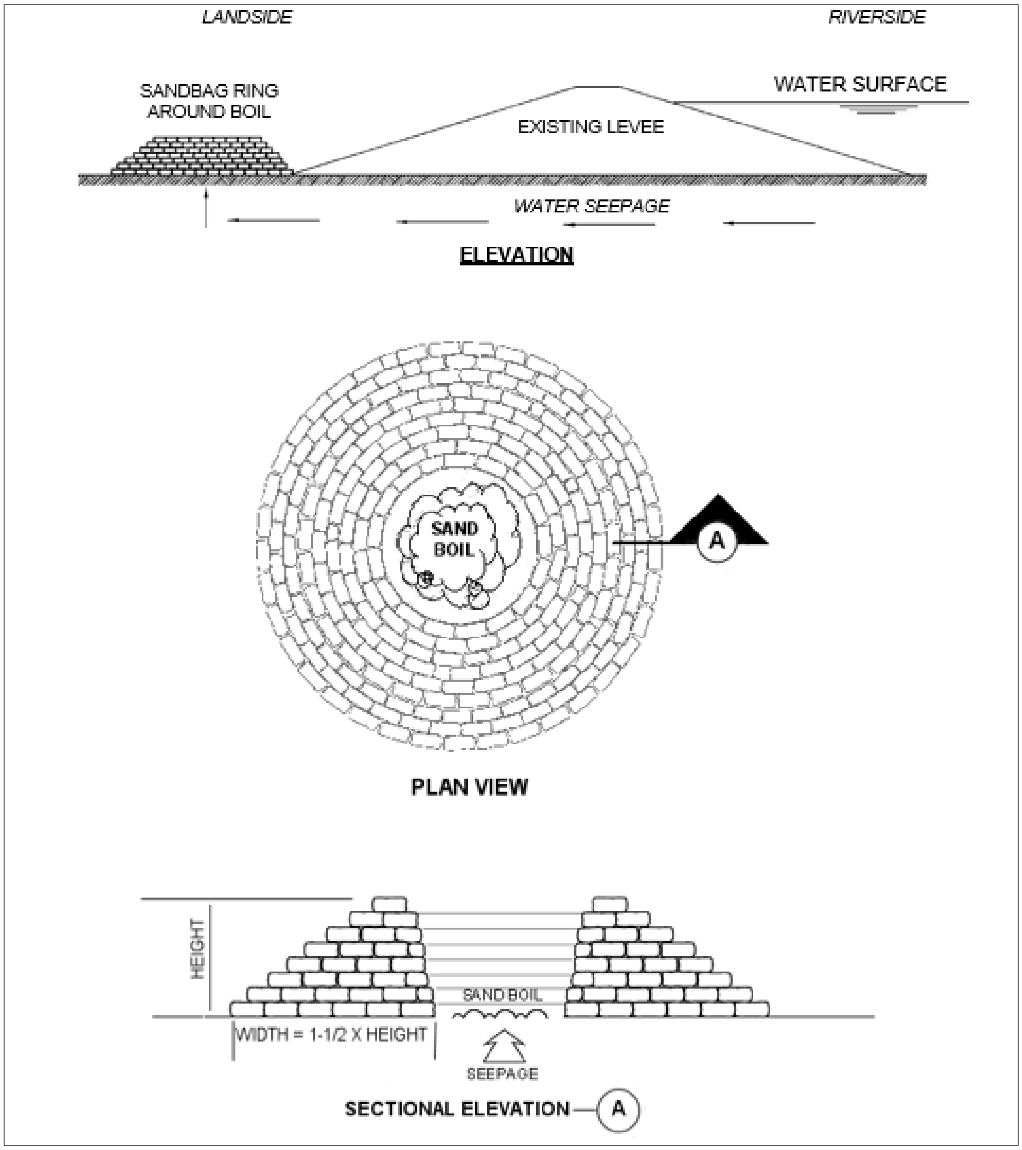


Figure 11. Recommended sandbag application around sand boils.

Figure 12. Sand boil under water within ringed dike of sandbags.

Figure 13. Sand boil ringed with sandbags.

Figure 14. Team of workers passing sandbags at sand boils near the Rio Grande in Presidio, TX.

5.5 SLOUGHING ALONG A LEVEE

There are a few reaches in the Albuquerque District where the material in the levee sections is of such a nature that prolonged high stages of the river may cause sloughing conditions on the back slopes.

Concerns that should be monitored typically relate to seepage either under or through levees and may result in sand boils being observed. This can result in sloughing to the riverside drain bank closest to the levee. This is of particular concern as this area could be considered an extension of the landside toe of the levee. If left unchecked for an extended period this seepage and sloughing could lead to levee failure resulting in a levee breach. The seepage and sloughing can grow progressively worse over time as high flow conditions continue. In extreme cases this sloughing may extend into or close enough to the landside levee face that communities are forced to take remedial action to repair the affected area and armor the bank of the riverside drain next to the levee. Any work in the riverside drain must be coordinated with the local conservancy district or other authority in charge of operation and maintenance.

Damages to the riverside drain embankment can start before flows exceed the active river channel capacity in many locations. Geotechnical issues start as seepage decreases soil strength parameters, causing tension cracks at bank crest, which may lead to sloughing of the bank slope. As river flows increase, causing greater pressure differential, sand boils form within the invert of the riverside drain, causing greater loss of material that previously constituted the levee. Flows in the riverside drain carry soil material downstream making measuring the amount of soil material moved difficult for several locations. Ongoing sloughing causes the seepage path to shorten thus setting up successive cycles of sloughing to occur at an accelerating rate.

Sloughing conditions on levees and berms on Rio Grande levees near Los Lunas, New Mexico, were successfully controlled in 1973 and 1975 by spreading a minimum of 18 inches of pit run coarse gravel over the sloughing locations. The gravel halts the displacement of material and allows the free flow of seepage water. Filter fabric placed between the levee and the gravel was found to be very helpful in extreme cases of sloughing during the 1979 spring snowmelt runoff. In 2019 during flood monitoring operations several locations required quick repairs to be conducted to prevent sloughing from progressing through the levee cross-section thus causing a breach. Those repairs included, in many cases, removing vegetation and installing large quantities of imported rock and soil to stabilize the slopes. Work crews from the Middle Rio Grande Conservancy District (MRGCD) performed repairs to the riverside drain. Without these on-going repairs, reduced run-off releases would likely have been required due to the deteriorating levee conditions. Repaired areas allowed for continued releases in 2019 but may not provide permanent risk reduction for future events. Figure 15 to Figure 17 illustrate sloughing conditions and repair effort. Figure 15 demonstrates sloughing due to seepage under or through levee. The photo was taken on 21 June 2019 on the spoil levee located on the east side of the Rio Grande south of Los Lunas and north of Belen, NM. The flow in the Rio Grande on this date was 5000 cubic feet per second (cfs) measured at the Albuquerque Gage.

Figure 15. Sloughing due to seepage under or through levee.

Figure 16. Riverside Drain (near Duran Open Space) sloughing due to seepage May 1, 2019.

Figure 17. Riverside Drain (near Duran Open Space) repaired condition May 29, 2019.

5.6 WAVE WASH

Engineers should study their areas beforehand for possibility of wave wash. Sandbags or brush should be placed over the washed areas. Some Districts have effectively used polyethylene sheeting weighted with concrete blocks to prevent wave wash.

5.7 LEVEE AND RIVER BANK EROSION (SCOUR)

Erosion (sometimes referred to as scour) protection may be required for earth fill levees. Factors that influence whether or not additional erosion protection is required include levee material (clay levees tend to be much more resistant to erosion 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 emergency slope protection the 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 erosion protection for levees.

Erosion at the toe is probably the most common cause of failure to a slope protected embankment. During high flows, the streambed is scoured by rapidly flowing water, undermining the slope protection, and leaving an unprotected area below the in place slope protection. Slope protection should be extended below the grade of streambed to prevent streambed scour from initiating levee erosion. Streams which have a history of degradation during major floods require extra protection at the riverside levee toe. The elevation of the levee toe on these streams will constantly move lower as the streambed degrades. These levees should be inspected after ever major flood.

Careful observations should be made of the riverside of the levee along all localities where a current of more than two feet per second is observed adjacent to the levee or where the river gradients have a slope of two feet per mile or greater. Trouble may be expected at the ends of old levee dikes, road-crossing ramps, and old stream channels. If any sign of levee erosion is observed, soundings should be taken to observe the amount and progress of the scour. A successfully used method of construction to check scour is to construct deflection dikes using rock, brush, treetops, and lumber. Two rows of stakes are driven, then wired together with wire fencing. The space between the rows is then filled with brush. Anchored rubber tires, cabled together and/or anchored trees are effective for stopping scour and bank caving but may be considered an eyesore when the flood recedes.

Sandbags can be used to check scour. Waves tend to wash fines out of course weave bags; this was evident during the 1979 spring snowmelt runoff where sandbags placed on Rio Grande levee banks did not survive. Dumped riprap was eventually used to control bank erosion for flows in excess of 3000 cfs.

Other methods of bank scour mitigation include the installation of riprap revetments (or streambank armoring with spurs. These type structures are generally preemptive in nature and built prior to the emergency; nonetheless, the following gives examples for installing a configuration of riprap revetment or river bank armoring and spurs along the vulnerable embankment slopes. These features will aid in maintaining the existing bank. Figure 18 shows a conceptual application of spurs and riprap revetment. The spacing, key length, and spur lengths were computed using the procedures outlined in the Federal

Highway Administration (FHWA) Publication No. FHWA-NHI-09-112, Hydraulic Engineering Circular No. 23, “Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition; Volume 2”.

a. The minimum recommended D_{50} rock size for these structures is 12 inches. However, rock size should be based on specific site conditions and flow velocity.

b. Appropriate angling of the bank spur features is crucial to ensuring the stability of the streambank. The upstream-most spur should be slightly tilted in a downstream direction while the lower three spurs should be at right angles to the stream bank. These spurs help push the thalweg (or active stream channel) away from the bank, and this configuration aids in stabilizing the stream bank and directing high velocity flow away from the stream bank.

c. Routine monitoring and maintenance of the bank spurs and riprap revetment will be required to maintain its stability and functionality.

d. Design and application should follow FHWA’s guidance: Publication No. FHWA-NHI-09-111, Publication No. FHWA-NHI-09-112, or other equivalent jurisdictional approved methods.

An alternative (but similar) approach which has proven effective is to construct “Bendway Weirs” which are built with the spurs directed in a 20 to 30 degree upstream configuration. They are built with the weir crest elevation set at roughly the 50% exceedance (2-year) water surface elevation. Rather than blocking and entirely diverting flow, the intent of bendway weirs are to reduce the flow velocities so sediment will drop out next to the bank line and thereby act to move the thalweg (or active river channel) further away from the scoured bank. Riprap revetment on the bank may also be required to add stability against future flows. Rock size for all features should be based on specific site conditions and flow velocity. Routine monitoring and maintenance of the bendway weirs and riprap revetment will be required to maintain its stability and functionality. Figure 19 shows revetment along an outside bend of the Rio Grande just downstream from Central Avenue in Albuquerque, NM. Bendway weirs were included in this installation but are below the water surface and do not show in the photo.

NOTE: It’s important to emphasize that the structures discussed above usually need Section 404 permit consultation prior to implementation.

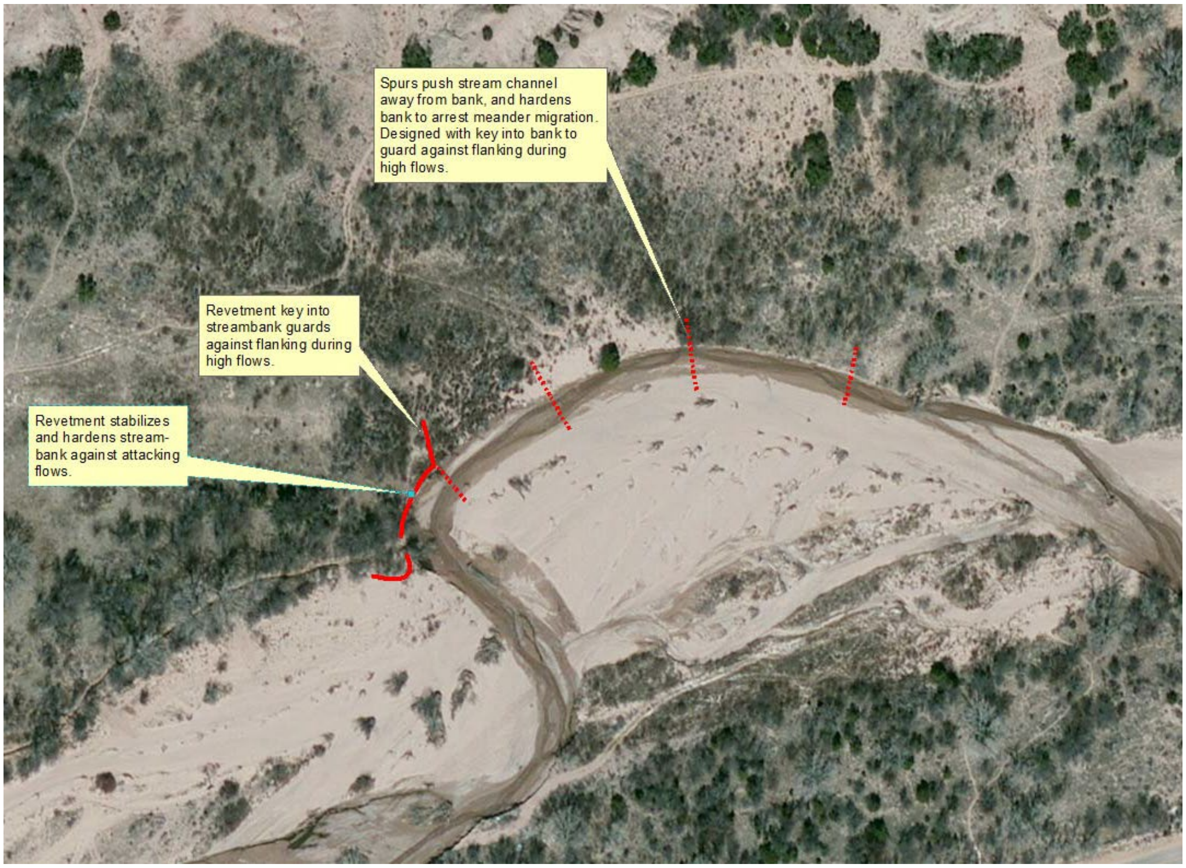


Figure 18. Streambank armoring and spurs (or bendway weirs) for vulnerable embankment slopes.

Figure 19. Riprap revetment (streambank armoring) on Rio Grande in Albuquerque, NM.

Bank cutting and erosion of land occurs in streams which are unimproved. This is a natural process and USACE assistance under PL 84-99 is not normally authorized. Temporary emergency work during a flood fight may be undertaken by USACE if the erosion threatens valuable improved public property or is a threat to life and the situation exceeds state and local capability. Once the flood fight is over, the existing statutory authority under Section 14 of the Flood Control Act approved 24 July 1946 (Emergency Bank Protection) may allow USACE to plan, design, and construct, permanent stream bank erosion control projects to protect public facilities. A letter of application to the District Engineer is required to initiate a preliminary investigation under these authorities.

5.8 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 erosion on earth fill levees.

Anchoring the poly along the riverside toe of the sandbag levee is important for a successful job. Anchoring methods for poly on sandbag levees, described in Section 4.3.5, should be used for earth fill levees as well.

Ideally, poly and sandbag protection should be placed before water has reached the toe of the levee. However, wet placement may be required due to rising river levels or to replace or maintain damaged poly or poly displaced by the action of the current. Placement of poly on earth fill levees is the same as placement on sandbag levees, as described in Section 4.3.5.

It is mandatory that poly placed on levee slopes be held down by weights. Unless extremely high velocities, heavy debris, or a large amount of ice is anticipated, an effective method of weighting poly is a grid system of sandbags, as shown on Figure 20. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Grid systems may include vertical rows of lapped bags or 2 ft by 4 ft boards held down by attached bags.

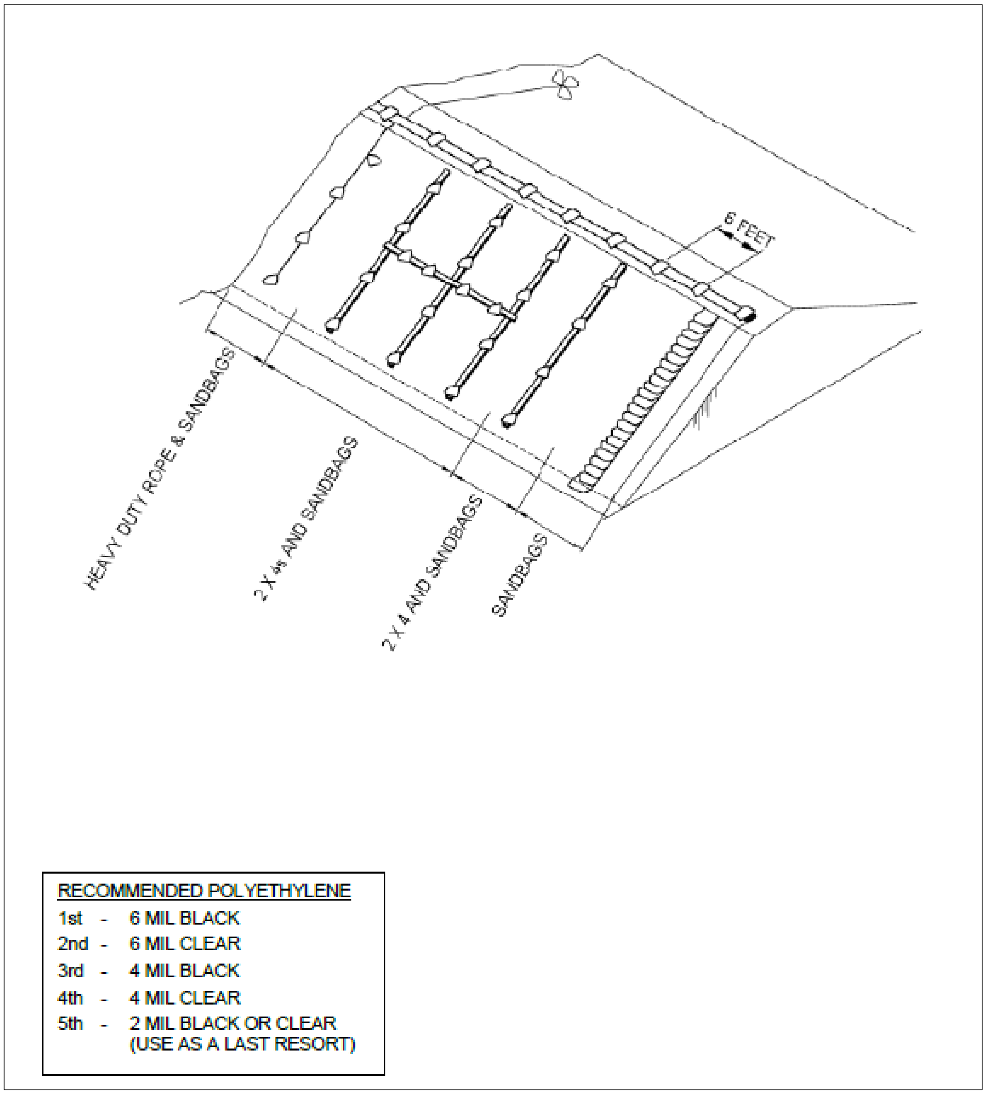


Figure 20. Recommended Method for placement of polyethylene sheeting on riverside of levee.

A grid system of counterweights is more suitable for placement under wet conditions. Counterweights consisting of two or more sandbags connected by a length of quarter-inch rope are 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. This counterweight method is shown below (Figure 21).

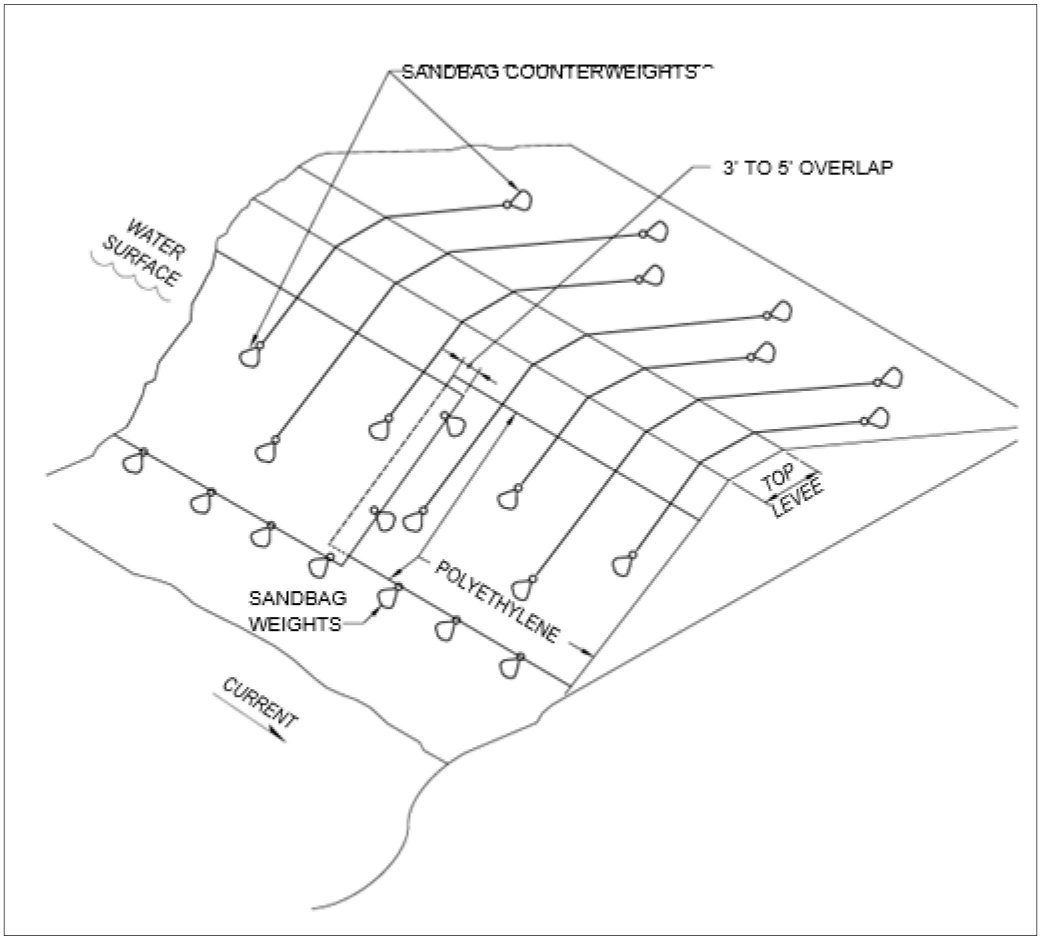


Figure 21. Recommended Method for placement of polyethylene sheeting on levee in flowing water.

If the counterweight method is used, 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.

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.

Poly and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. While the implementation of poly with sandbags is an effective remedy, it can be overused or misused. For example:

a. 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.

b. 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.
c. 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.

See photos below (Figure 22 through Figure 24) which show poly being placed in the field during a high flow events. Note Figure 23 that shows work crews standing on poly while placing sandbags. This is a risky behavior and is unsafe since standing on poly can endanger an individual by potentially sliding into floodwaters and also standing on the poly leads to puncturing it. Figure 24 shows the proper method for placing poly and sandbags on riverside of levee while minimizing exposure of standing on poly.

Figure 22. Placing poly from the levee crest during high flow on the Rio Grande at Presidio, TX.

Figure 23. Scour protection on the Rio Grande at Presidio, TX using poly and sandbags.

Figure 24. Scour protection using polyethylene (poly) and sandbags.

5.9 RIPRAP

The use 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. Rock riprap can be used for slope protection. Such rocks should be angular rather than round to resist rolling. Refer to Section 5.7 for bank riprap revetment applications.

LIMITATIONS: Currents on mountain streams frequently exceed 10 feet per second, and rock used for bank protection must be heavy enough to resist displacement from the force of the flowing water. Rocks weighing about 250 pounds are needed to provide a margin of safety for current velocity of 10 feet per second. Heavier rocks are needed for higher velocity flows. See Table 2 below for recommended rock riprap size for associated stream flow velocity.

Table 2. Recommended rock riprap size for associated stream flow velocity.

Suggested Maximum Permissible Mean Channel Velocities For Various Emergency Streambank Protection Measures

Channel Material	Maximum Allowable Mean Channel Velocity (feet per second)	Maximum Allowable Mean Channel Velocity in Turbulent Areas (feet per second)
Fine Gravel	6	3
Stone (D_{100} = 9"; D_{50} = 6")**	8	6
Stone (D_{100} = 15"; D_{50} = 9")**	10	7
Stone (D_{100} = 24"; D_{50} = 15")**	12	9
Stone (D_{100} = 30"; D_{50} = 21")**	15	10
Stone (D_{100} = 45"; D_{50} = 30")**	18	12
Fine Sand	2	
Course Sand	4	
Soil Cement	8	
Jetty Jacks	9	
Gabion Mattress 9" thick	10	
Gabion Mattress 12" thick	15	
Gabion Mattress 18" or thicker	18	

* This table was developed as general guidance for use during floodfights and is not intended as a design guide.

** **Assumes:** D_{100} is the diameter of the largest stone and D_{50} is the diameter that is larger than 50 percent of the stones; Layer thickness is the diameter of the largest stone except that the layer thickness will be 1.5 time the diameter of the maximum stone size if the stone is placed underwater; Maximum Slope of the surface of the placed stone will be 1Vertical on 1.5 Horizontal; and The unit weight of stone must equal or exceed 145 pounds per cubic foot.

5.10 ANCHORED TREES

Another method of erosion control is by use of trees tied to an anchored cable. In this method, trees are cut in the vicinity of the trouble and the butt ends of several trees are tied to a cable which in turn is securely anchored to a standing tree or dead man, such as a buried railroad tie. The trees are then pushed over the bank. They act as a deflector to divert the water away from the danger area and the tree branches tend to trap sediment to repair the eroded condition. Tree should be oriented butt upstream as shown below (Figure 25).

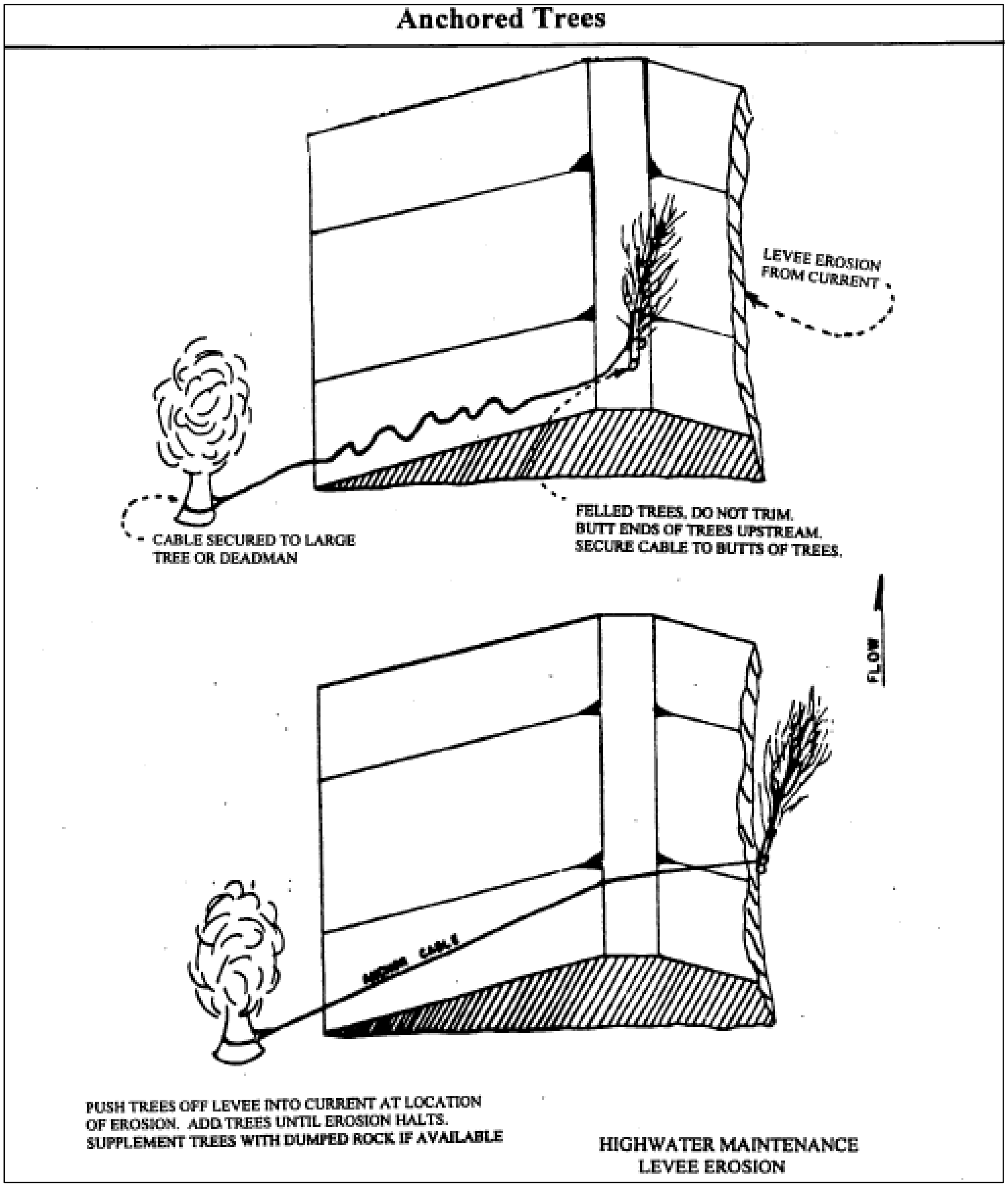


Figure 25. Anchored Trees.

5.11 GABIONS

Gabions may be used to construct deflection dikes, if available. Gabions are patented wire baskets which can be filled with rock on the bank and then can be pushed into the water. USACE Albuquerque District maintains a small stock of gabions for flood fight use.

5.12 DEBRIS REMOVAL

Large trees and other debris often lodge at culvert or bridge openings, creating serious and immediate threats during a flood. Such problems should be dealt with promptly by removing or dislodging the debris. Large trees may run aground near a levee or natural bank and deflect flood flows unexpectedly into the bank or levee. Such an obstruction should be pulled to the bank or completely out of the channel, if possible

5.13 TOPPING

Immediate consideration should be given to the grade line of each levee section. When available, a study of high-water profiles and levee grades will show where low places in the levee exist. If it is considered desirable to increase the grade of the levee to expected high-water elevations, emergency topping may be done (1) with sandbags, (2) with lumber and sandbags, and (3) by raising crown of levee with borrow material. When evaluating the method and degree of levee raise actions, it is important to consider the need to maintain a useable vehicle passage along the levee top, and the need for a minimum clearance beneath power lines or bridges which span the levee.

5.14 SANDBAG TOPPING

If lumber is not available, a sandbag topping may be used to raise the crown of the levees about three feet. All bags should be laid lengthwise along the crown of the levee with the folded end facing upstream. The seams in each row of sandbags should be offset to prevent water from penetrating from one side of the levee to the other. The bags in the second layer should overlap the seams in the first layer, and so on. The bags should be lapped at least 1/3 on all sides and be well mauled into place. When properly stacked and tamped, one bag will give about a three-to-four inch topping. If gravel is available, it should be used for the front facing to avoid washing out.

5.16 RAISING CROWN

When time and other conditions permit, the crown height of the levee may be raised by reconstruction in a manner similar to the original construction by borrowing material from the adjacent riverside borrow pits or from other available sources. This may be accomplished, where the width of the crown permits, by small dragline machines. Tractors and wheeled scrapers may be used if seepage has not developed on the back slopes of the levee. The latter expedient should not be undertaken without specific authorization from the District Engineer, and great care should be used in traveling up and down the landside slopes. In an extreme emergency, when filled sandbags or lumber cannot be obtained and other sources of borrow cannot be reached, cut crown topping, consisting of borrowing the landside of the crown for raising the riverside, may be constructed. Where possible, all newly constructed fill should be reinforced on the front slope with filled sandbags, lumber, or polyethylene sheeting.

5.17 EMERGENCY LEVEE BREACH REPAIR

Once a levee has breached, repairing the levee with flood waters flowing through the breach is very difficult. In some cases the water velocity through the breach will be faster than velocity in the river. The breach should be filled to 1 foot above the water surface elevation with 36 inch stone or the largest stone available. Then smaller riprap should be placed to cover the riverside and landside faces of this stone plug. This riprap should be extended as high as the water surface and extend the breach plug to the full levee width. Next the upper levee should be rebuilt using suitable soils placed and compacted in lifts. After the floodwater recedes, a clay fill layer should be placed on the riverside of the levee as shown below (Figure 26). This should only be considered as a temporary emergency flood fight repair. Following the emergency, the temporary repair work should be removed and the levee rebuilt to current engineering standards.

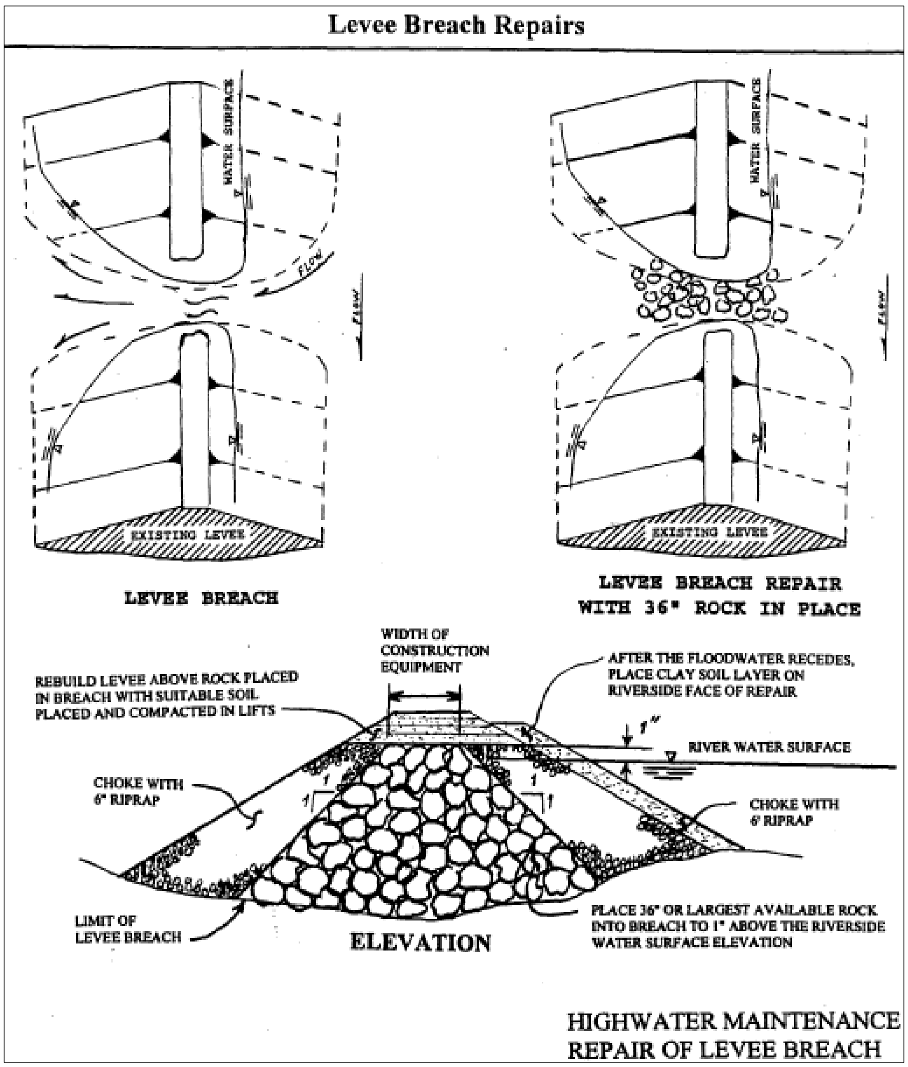


Figure 26. Emergency Levee Breech Repairs.

5.18 DAMS

Flood fight activities by USACE are authorized to prevent the failure of flood control dams and other dams where the failure would create a serious flood threat. Draining of the reservoir or controlled breaching of the dam may be the only practical protective measure. Draining or breaching the dam may be suggested to local and state officials, if warranted, but should be directly accomplished by USACE only when requested in writing with suitable assurances by the owner of the dam. The State Engineer's Office has responsibility for the safety of dams and has the authority to order the draining or breaching of an unsafe reservoir.

5.19 LOG BOOMS

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.

5.20 MISCELLANEOUS MEASURES

Other available methods of slope protection include placement of straw bales pegged into the slope and spreading straw on the slope, overlaying with snow fencing, and other bio engineering methods.

5.21 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.

5.22 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. Culverts passing flow under roadways and other structures are susceptible to plugging due to sediment and debris flow. Regular maintenance is necessary both prior to and in some cases during flood events to assure flow capacity is maintained. Flooding can be greatly exacerbated when culvert capacity is reduced or lost. Figure 27 shows a concrete box culvert full of sediment with almost no capacity for passing flow.

Figure 27. 8 ft x 10 ft Concrete Box Culvert (CBC) under roadway filled with sediment.

5.23 CHANNELS

Channels passing flow through communities and along roadways are susceptible to reduced carrying capacity due to sediment and debris flow. Regular maintenance is necessary both prior to and in some cases during flood events to assure flow capacity is maintained. Flooding can be greatly exacerbated when channel capacity is reduced or lost.

a. **Natural Channels without Significant Improvement.** Natural channels should be cleared by local interests prior to a flood emergency. Emergency flood control work by USACE is authorized only to remove debris or other channel obstructions, during a flood fight, which is damaging or endangering flood control works, improved property, or human life. Also USACE authority for post flood repair of damaged flood control works does not include removal of sediment from natural channels.

b. **Improved Channels Constructed for flood Control Purposes.** An improved channel constructed for flood control is considered a flood control works under the intent of PL 84-99 and USACE is authorized to conduct major protective and flood fight efforts when the situation exceeds local and state capability.

5.24 IRRIGATION FACILITIES

Irrigation facilities are not normally considered flood protection works under PL 84-99. Flooding which results from irrigation water flowing from breaks in ditch banks may necessitate USACE flood fight assistance including furnishing technical assistance, sandbags and other supplies.

5.25 ICE JAMS

Ice jams rarely occur on rivers in the Albuquerque and the surrounding area but must be considered a possibility. In 1962, an ice jam on the Rio Grande caused some flooding at San Felipe Pueblo in New Mexico. A bridge across the Rio Grande at this location was endangered at the same time as uplifting pressure from the ice threatened to raise the bridge from its abutments. Removal of ice jams is difficult. Blasting is not very successful since the ice often extends over a reach several miles in length. Also, if blasting suddenly releases the trapped water, severe downstream flooding can result. USACE policy is that ice jam removal is a local flood measure responsibility. USACE support is limited to technical advice.

5.26 FLOOD FLIGHT PROBLEMS

Many issues can arise during a flood fight. The most valuable asset in problem solving under emergency conditions is capable field personnel and following safety procedures. Many problems can be solved quickly and efficiently through the application of common sense and sensitivity to human relations. Physical problems with the levees and related infrastructure can be identified early if a well-organized levee patrol team with a good communication system exists.

5.27 BREACHES

A breach is a rupture, break, or gap in a levee system whose cause has not been determined. An overtopping breach is a breach whose cause is known to be a result of overtopping (system exceeded). 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. Levee breaches may occur as a result of overtopping; however there are other causes as well. A failure breach is a breach in a levee system for which a cause is known and which occurred without overtopping. A failure breach occurs due to a failure of the embankment at a level below the top of the levee. Unlike overtopping, the solutions for breaches vary depending on the cause. The following subsections describe the different causes and how to prevent them.

5.28 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 landside 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 a following subsection and if not addressed could lead to a levee breach.

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 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.

5.29 OVERTOPPING

Overtopping occurs when water levels exceed the crest elevation of a levee and flow into protected areas. A breach may occur as a result of overtopping. 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 28 illustrates overtopping results. Figure 29 illustrates levee failure without overtopping. 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 emergency levee, or (3) unexpected settlement or failure of the emergency levee. Generally, emergency levees are built two feet above the predicted crest level. If the crest prediction is raised during construction, additional height must be added to the emergency levee. On an existing levee or completed emergency levee, predictions of increases to water levels or settlement of the levee will call for some form of capping to raise the levee. Capping should be done with earth fill or sandbags using normal construction procedures.

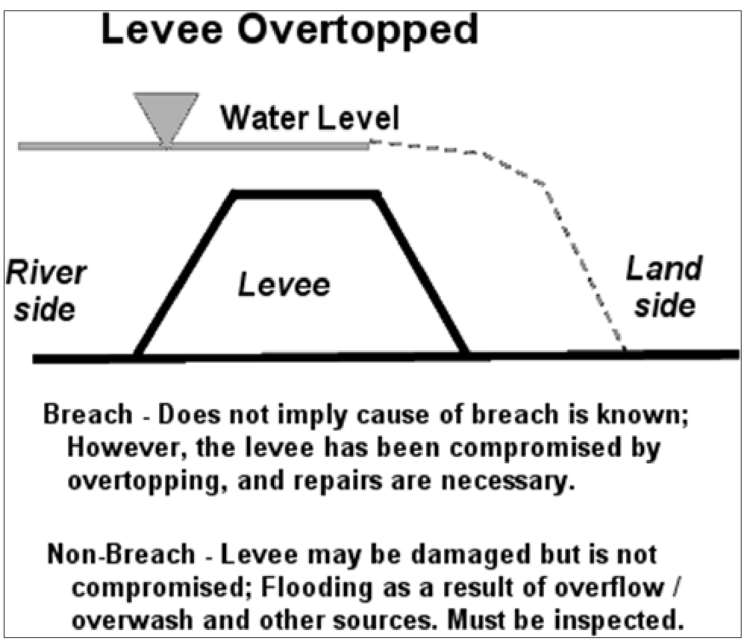


Figure 28. Possible results when levee is overtopped.

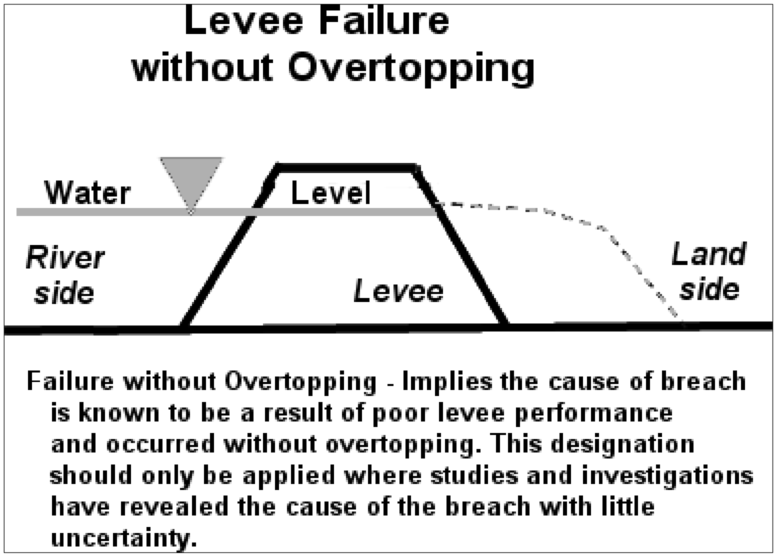


Figure 29. Breach failure.

The chart below (Figure 30) further defines the appropriate flooding descriptions that correspond to the levee responses to rising water.

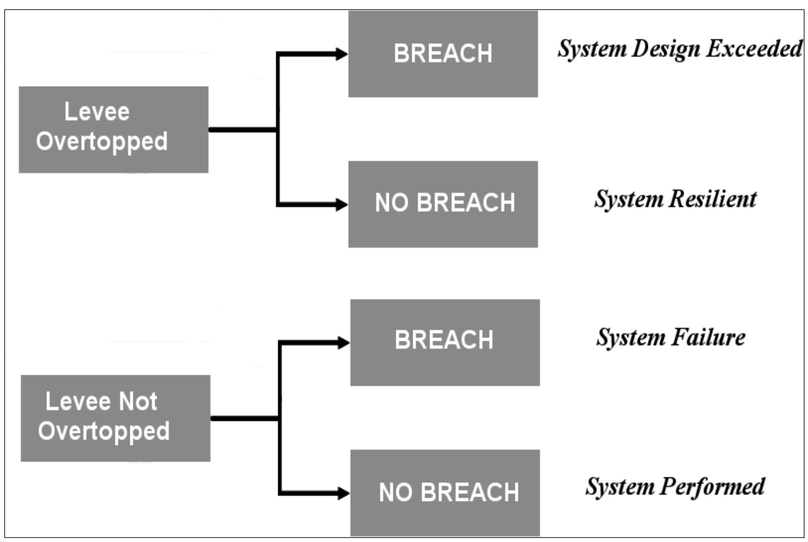


Figure 30. Appropriate flooding descriptions corresponding to the levee responses to rising.

5.30 OTHER CAUSES OF LEVEE FAILURE

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

a. Joining of an earth 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 crossing through the levee fill.
d. The elevation of the tops of “stoplogs” on roads or railroad tracks are at a lower elevation than the top of the levee.
e. 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.
f. Allowing pump discharge lines to discharge directly on the riverside 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.

5.31 WILDFIRE BURN SCAR FLOODING

Depending on the severity of the burn, there can be a dramatic reduction in the infiltration rates in burned areas. This can result in a four-to eight-fold increase of runoff and sediment/debris flow can pose a severe threat to infrastructure and downstream communities. Conditions may develop that increase the potential for widespread property damage and can create a life/safety hazard. Existing drainage facilities within and downstream from severely burned areas of affected watersheds will likely be overwhelmed by a series of average rainfall events following the fire for several years. In addition, even major channels through affected communities will no longer have the conveyance capacity necessary to safely pass large post-fire flows. Hundreds of residential and public structures are likely to be at risk from flood and debris flows if no action is taken. This extreme hazard can continue for as long as 10 years until the burned watershed can recover to some degree as vegetation grows back. Even then, it is unlikely the watershed will have the same infiltration rates as in the pre-fire condition. Flood fighting can last for several years since the threat is long lasting following a severe wide spread burn. Therefore, the approach will have several phases illustrated as follows:

Immediately after the fire is contained and it is safe, any remaining infrastructure should be prepared and maintained to operate at maximum efficiency. For example, channels should be cleared of all sediment and debris including vegetation and other obstructions to flow. Bridges should be cleared of any obstructions to flow, including trees, fences and other obstructions. In some cases bridges may need to be removed entirely to pass post fire flood flow.

Traffic plans should be considered that close roadways that are subject to flooding prior to rainfall events. An emergency action plan should be put in place and the public should be made aware of the danger through public meetings and other means. Advanced warning systems should be considered which include measures such as rainfall gages and stream flow gages well upstream of communities at risk to warn of impending flooding. This will allow time to close roadways subject to flooding and allow for evacuations in areas if necessary.

In some instances, emergency measures should be considered that include sandbagging, flexible debris flow barrier structures, gabion check dams, rapidly deployable Hesco Baskets and any structures that might aid in diverting or trapping sediment & debris in the upper watershed.

In extreme cases, such as a levee or dam breech, “Super Sand Bags” may be deployed and can be effectively placed by air using appropriately sized helicopters such as Chinook or Blackhawk that may only be available through the military such as the Army or National Guard. Super Sand Bag dimensions are 3 ft X 3 ft X 3 ft and can weigh nearly 3000 pounds. A cable is attached to the bag for lifting and placing which should be recovered and reused. A flight plan is important to prevent injury to persons or damage to structures below in case a cable or connection fails.

These are specialized structures that require consultation with Engineers whom have this type of expertise prior to making structural commitments of this magnitude.

Examples of these emergency measures are shown in Figure 31 to Figure 33 below:

Figure 31. Preparing Hesco Baskets.

Figure 32. Filling and Deploying Hesco Baskets.

Figure 33. Hesco Baskets filled and installed.

Figure 34. Flexible Debris Flow Barrier - before and after debris capture.

Figure 35. Gabion Check Dam placed in channel to trap sediment and debris from post-fire flooding.

Figure 36. Chinook helicopter placing super sandbags near the Rio Grande at Presidio, TX.

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USACE – St. Paul District (2016). *Flood Fight Handbook*. United States Army Corps of Engineers (USACE) – St. Paul District. St. Paul, MN.

USACE – Vicksburg District (2018). *Flood Emergency Handbook*. United States Army Corps of Engineers (USACE) – Vicksburg District. Vicksburg, MS.

LIST OF RESOURCES AND WEBSITES

USACE Albuquerque District:
http://www.spa.usace.army.mil

New Mexico Department of Homeland Security and Emergency Management
https://www.nmdhsem.org/

After wildfire: A Guide for New Mexico Communities.
https://afterwildfirenm.org/

New Mexico Department of Transportation (NMDOT) Road Closures
www.nmroads.com/

Disaster Preparedness
www.ready.gov/

Federal Emergency Management Agency (FEMA)
www.fema.gov

FEMA Flood Response Training for Community Emergency Response Teams (CERTs): Training Information
www.fema.gov/media-library/assets/documents/28668

National Flood Risk Management Program:
www.nfrmp.us/

National Oceanic and Atmospheric Administration
www.noaa.gov/

National Weather Service:
www.nws.noaa.gov/

American Red Cross Flood Information
www.redcross.org/prepare/disaster/flood

United Sates Geological survey (USGS) Water Data for New Mexico
www.waterdata.usgs.gov/nm/nwis/rt

APPENDIX A – FREQUENTLY ASKED QUESTIONS ABOUT SANDBAGS

The following information was obtained and adapted from Lewis County, WA, Emergency Management: [https://lewiscountywa.gov/departments/emergency-management/flood-information/sandbags-frequently-asked-questions/]

Q: WHAT IS A SANDBAG AND WHAT IS ITS PURPOSE?

A: A sandbag is a sack made of burlap or woven polypropylene that is filled with sand or soil and used for such purposes as flood control and military fortification. Sandbags are an excellent choice for the construction of levees, berms, dikes and barricades for erosion control, flood walls, and traffic control. Sandbags may be used during emergencies when rivers threaten to over-flood, or a levee or dike is damaged. Quick action and bags on-hand could save countless dollars in personal and property damage.

Q: WHEN CAN SANDBAGS BE USED?

A: The use of sandbags is a simple, but effective way to prevent or reduce flood water damage. Properly filled and placed sandbags can act as a barrier to divert moving water around, instead of through, buildings. Sandbag construction does not guarantee a water-tight seal, but is satisfactory for use in most situations. Sandbags are also used successfully to prevent overtopping of streams with levees, and for training current flows to specific areas.

Sandbags alone should not be relied on to keep water outside a building. Use baffle boards (plywood sheeting) or sheets of plastic tarp with sandbags. To form a sandbag wall, place bags tightly against one another to form the first layer of defense. Stagger the second and subsequent layers of bags, much like the pattern of bricks in a wall.

Sandbags, when properly filled and placed, will redirect storm and debris flows away from homes, property and other improvements.

Q: WHAT ARE THE DIFFERENT TYPES OF SANDBAGS?

A: The most commonly used sandbags are described below:

- **Burlap** The most commonly used bags for temporary protective barriers are untreated burlap sacks available at feed or hardware stores. Burlap Sandbags have been used by the military and government for many years. They resist all kinds of severe weather and are very useful for flood and traffic control. Burlap bags will eventually rot if not covered or protected from the elements. Empty bags can be stockpiled for emergency use, and will be serviceable for several years, if properly stored.
- **Woven Polypropylene** When treated for UV exposure, commercial plastic (polypropylene) sandbags are available. They provide the strongest material for flood control, levee, trench and berm construction and all temporary or permanent protective barriers. When covered from ultra violet exposure, Polypropylene Sandbags last almost indefinitely with a minimum of care, but are not biodegradable. Thus they have to be disposed of, or will remain around a long time.

Q: WHAT SIZE BAGS WORK BEST FOR PRIVATE RESIDENCES AND BUSINESSES?

A: Use bags about 14-18" wide, and 30-36" deep. Sandbags should be filled half full for easy stacking and will weigh approximately 30 pounds. Thirty sandbags are equal to approximately ½ ton (one ton is 2000 pounds) and is the maximum legal load limit for a ½ ton truck.

Q: HOW CAN I FIGURE OUT HOW MANY SANDBAGS I NEED?

A: It takes an average of 600 sandbags to cover a 100 foot section, 1-foot high.

Q: HOW FULL SHOULD THE BAG BE FILLED?

A: Bags should be filled between one-half (1/2) to two-thirds (2/3) of their capacity. This keeps the bag from getting too heavy, and permits the bags to be stacked with a good seal.

Q: WHAT MATERIAL SHOULD BE USED TO FILL THE SANDBAGS?

A: A heavy bodied or sandy soil is most desirable for filling sandbags, but any usable material at or near the site has definite advantages. Coarse sand could leak out through the weave in the bag. To prevent this, double bag the material. Gravelly or rocky soils are generally poor choices because of their permeability. Filled bags of earth material will deteriorate quickly.

Q: HOW MANY PEOPLE DOES IT TAKE TO FILL SANDBAGS?

A: Sandbag barriers can easily be constructed by two or three people, as most individuals have the physical capability to carry or drag a sandbag weighing approximately 30 pounds.

Q: WHAT IS THE BEST METHOD TO USE TO FILL SANDBAGS?

A: It is recommended to use a two or three-person operation to fill sandbags. Both people should be wearing gloves to protect their hands. One member of the team should place the empty bag between or slightly in front of widespread feet with arms extended. The throat of the bag is folded to form a collar, and held with the hands in a position that will enable the other team member to empty a rounded shovel full of material into the open end.

The person holding the sack should be standing with knees slightly flexed, and head and face as far away from the shovel as possible. The person shoveling should carefully release the rounded shovel full of soil into the throat of the bag. Haste in this operation can result in undue spillage and added work. The use of safety goggles and gloves is desirable, and sometimes necessary.

Q: WHY DO YOU SOMETIMES TIE THE SANDBAGS AND OTHER TIMES DON'T?

A: Untied sandbags are recommended for most situations. Tied sandbags should be used only for special situations when pre-filling and stockpiling may be required, or for specific purposes such as filling holes, holding objects in position, or to form barriers backed by supportive planks. Tied sandbags are generally easier to handle and stockpile.

Q: WHAT IS THE HEIGHT LIMIT TO STACK SANDBAGS SAFELY?

A: Limit placement to three layers, unless a building is used as a backing or sandbags are placed in a pyramid.

Q: HOW DO YOU STACK SANDBAGS?

A: A helpful guideline is provided by the following steps:

- Fold top of sandbag down and rest bag on its folded top (preferably untied so it will lay flat).
- Take care in stacking sandbags. It is important to place the bags with the folded top of the bag in the upstream or uphill direction to prevent the bags from opening when water runs by them.
- Tamp each sandbag into place, completing each layer prior to starting the next layer.
  Clear a path between buildings for debris flow.
- Lay a plastic sheet in between the building and the bags to control the flow and prevent water from seeping into sliding glass doors.
- Limit placement to three layers, unless a building is used as a backing or sandbags are placed in a pyramid.

Q: HOW DO YOU DISPOSE OF SANDBAGS AFTER THEIR USE?

A: Homeowners should empty the material in the bags in their gardens or yards, then throw the bags in the trash. Before disposing used sandbags, check for contamination. Sandbags exposed to contaminated floodwaters may pose an environmental hazard and require special handling.

SANDBAG LIMITATIONS

- Sandbags will not seal out water.
- Sandbags deteriorate when exposed for several months to continued wetting and drying. If bags are placed too early, they may not be effective when needed.
- Sandbags are basically for low-flow protection (up to three feet). Protection from high flow requires a permanent type of structure.
- Sandbags are not always an effective measure in the event of flooding because water will eventually seep through the bags and finer materials like clay may leak out through the seams.

SANDBAG DON'Ts

- Sandbags should never be used to build a fortress around the perimeter of one's property. Doing so can actually trap flood-waters between sandbag walls and structures, leading to further damage.
- Do not use garbage bags, as they are too slick to stack. Do not use feed sacks, as they are too large to handle.