MANUAL

for

INSPECTION

Of

EARTHEN EMBANKMENTS

For

DAMS, CANALS & FLOOD PROTECTION

NARMADA WATER RESOURCES WATER SUPPLY & KALPSAR DEPARTMENT

GOVERNMENT OF GUJARAT

APRIL 2009

Mission Statement

Harnessing the untapped water resources for the survival of millions of people and environmentally sound sustainable development of Gujarat State by providing the essence of life – water and energy.

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Preface

Like any engineering work, earthen embankments require continual care and maintenance, first to ensure that they remain operational and capable of performing all intended purposes and then to preclude endangering people and property.

The safety of all embankments is of considerable concern. Given that, the principle purpose of this Manual is to enhance the safety of embankments. The purpose is to ensure adherence to approved procedures over long periods of time and during changes in operating personnel.

The Manual is prepared primarily for the use of section officers in charge of various embankments of dams, canals & Flood protective schemes, who are assigned the responsibility for the operation and maintenance of the embankments.

THIS MANUAL CONTAINS, AS A MINIMUM, ALL INFORMATION AND INSTRUCTIONS NECESSARY FOR SECTION OFFICERS TO PERFORM THEIR DUTIES.

The instructions provided in this manual are applicable to embankments of all sizes and types and are useful to all. The guidance provided is generally applicable to all situations. However, it is recognised that the degree to which the methods and principles are adopted will rest with the officer in charge of the embankments.

Manual for inspection of structures is also required to be read and operated simultaneously.

C O N T E N T S

PART I

INSPECTING THE EMBANKMENT

Chapter 1

INSPECTING THE EMBANKMENT

Purpose:

1. To identify deficiencies, which potentially affect the safety of the embankment. A deficiency is an anomaly or condition that affects or interferes with the proper safe operation of the reservoir / canal/ river banks.

Reviewing data

2. Review any available data about the embankment before you begin your inspection. An important aspect of inspection is tracking conditions and potential problems to determine how and to what extent they are changing over time. Historical and design information can alert you to conditions and features that are of special concern and that should be checked and documented.

Types of information that may be useful to review include:

- Design criteria
- Material data
- Construction records
- Records of operation
- Records of maintenance
- Previous inspection reports
- Manual of operation **&** maintenance.

General Guidelines:

3. When an inspection is conducted several things are required to be kept in mind:

- The purpose of an inspection is to gather facts. Person inspecting should probe for causes till he is satisfied.

- One should look for continuities or relationships among deficiencies.

- All features of embankment should be inspected. No shortcuts need to be taken. Enough time should be spent for inspection. Particular attention should be paid to areas where data indicate that change is occurring or where past deficiencies have been noted.

- Person inspecting should know his limits and should consult higher officers in case of doubt.

- **SMPL** rule should be observed for documenting conditions:

  S **Sketch** the deficiency and note its important characteristics

  M **Measure** the deficiency

  P **Photograph** the deficiency/ describe its characteristics in writing

  L **Locate** the deficiency relative to some standard reference point

- Good notes should be taken; thorough records should be made.

- Findings of inspection should be reported in form of precise report immediately after the inspection is over. This would be very much useful at the time of subsequent inspections and also would help evolve plan of action.

Inspection tools and equipments:

4. Following outlines the tools and equipments that will be needed for conducting inspection of canals:

Binocular	For sighting along top of bank, crest
Camera	For recording conditions
Rock hammer	For sounding rock
Measuring tape	For measurement
Probe	For measuring width of crack at a depth
Pocketknife	For scraping rock, scraping crevices/cracks
Shovel	For clearing drains, manholes, pipes
Bucket and timer	For measuring seepage & flow rates
Jar	For taking water samples, measuring turbidity

Inspecting the slopes:

5. The general practice for slope inspection is to walk over the slope as many times as is necessary in order to see the entire surface area clearly. From a given point on slope, you can visually see small details for a distance of 3 to 10 meter in each direction, depending upon the roughness of the surface, vegetation etc. Therefore to ensure that you have covered the entire broad surfaces of the embankment, you must repeatedly walk back and forth across the slope until

you have clearly seen the entire area. Following patterns can be used for walking:

Zigzag

Parallel

Walk along the upstream face of the embankment and observe erosion, puddles or wet areas, slumps, wood vegetation or animal burrows etc as listed out in the enclosed checklist. (Look below the waterline for any additional irregularities or animal burrows).

6. Viewing the downstream toe and slope of the embankment at a time of the day when sun is low can reveal wet areas. Wet areas become more visible due to the reflection created by the sun. Walk along the downstream face of the embankment in a zigzag, top to bottom fashion to observe any erosion, puddles or wet areas, slumps, woody vegetation or animal burrows etc as listed out in the enclosed checklist.

Subsurface drains:

7. Locate each of the subsurface drains located along the toe of the downstream embankment. Using a flashlight, inspect each of the pipes and manholes for flow conditions, obstructions or cracking.

The downstream area:

8. Walk along the downstream of the Bank from one end to the other and look for any signs of seepage, wet area, sand boiling, undue vegetative growth, Burroughs, wash outs, sink holes.

Inspecting the groins

9. Inspect carefully the groins i.e. areas where abutments contact embankment for seepage, cracks, slides, vegetation and erosion.

Inspecting the crest(top of bund) and berms

10. This is similar to slope inspection. View from a close up as well as from a distance for catching the deficiency. Sight from different angles. Walk along the top of the Bank from one end to the other and look for erosion, puddles, or settlements, cracks in the surface or animal burrows, etc as listed out in the enclosed checklist.

11. The inspection checklist included in this Manual should be copied and completed every time a maintenance inspection is performed.

PART II

SEEPAGE PROBLEMS

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SEEPAGE PROBLEMS

Seepage occurs to some extent at almost all embankments. The monitoring and control of any seepage are essential to proper maintenance. The amount of seepage may vary from wet spots to large quality flows.

Let's look at some specific seepage problems. Uncontrolled seepage is a major case of embankment failure. Seepage problems can be divided into the following two categories :

: **Stability Problems**
: **Piping Problems**

Seepage Problem : Stability.

Seepage causes stability problems when high water pressure and saturation in the embankments and foundations cause the earth materials to lose strength. If uncontrolled seepage emerges on the lower downstream slope, as illustrated previously in **Figure – 1**, very often the seepage will cause sloughing or massive slides.

Seepage Problem : Piping.

If seepage is concentrated through materials such as sands or cohesion-less slits, the force of the flowing water can start to remove materials at the exit point, and cause progressive erosion known as piping. A common example of piping is shown in **Figure 2**.

In the above illustration, the seepage is exiting near the downstream too and has caused a sand boil.

If you observe a sand boil, you should

-Photograph and record the size of the deposition cone.

-Monitor the flow rate, if possible. The flow rate may be difficult to ascertain since sand boils are often under water.

-Make sure that all sand boils are evaluated so that appropriate remedial action can be taken.

Sometimes placing sandbags around the boil to increase the depth of water (head) over the boil will prevent continued growth of the boil.

Not all piping causes sand boils. Sand boils may not occur when concentrated seepage occurs through an embankment, along the groins, or in contact with concrete structures. In fact, severe piping problems can occur when seepage moves embankment material into voids in rock foundations. **Figure 3** illustrates embankment piping into voids in a rock foundation.

The type of seepage illustrated above is difficult to detect since nothing is visible until the embankment starts to collapse, or until a vortex appears in the pool of water in the reservoir / canal. A vortex is the rotational movement that will appear as the water rapidly enters the foundation. This same type of rotational movement can be seen when you pull the plug in a sink full of water.

APPEARANCE OF SEEPAGE

Seepage varies in appearance. Seepage may appear as a wet area or as a flowing “spring”. Vegetation is another indicator of seepage. Areas with a lot of water-loving vegetation, such as reeds, and mosses, should be checked for seepage. Also, areas where the normal vegetation appears to be greener or mote lush should be checked for seepage.

- ✓ ***INSPECTION TIP:***

  Viewing the downstream slope from a distance is sometimes helpful in detecting subtle change in vegetation. A distinct line of vegetation probably indicates the intersection of the seepage line with the slope.

AREAS PRONE TO SEEPAGE.

The contacts between the downstream slope and the abutments (or groins) are especially prone to seepage because the embankment, and therefore less watertight. The embankment fill near the abutments is less dense because compaction is difficult along the embankment/abutment interface. Also, improperly sealed porous abutment rock can introduce abutment seepage into and along the embankment.

Difficulties with compaction also make areas around conveyance structures like outlet works, conduits, or siphon barrels more susceptible to uncontrolled seepage problems.

Seepage existing from around conveyance structures is particularly alarming because it may also indicate that there is a crack or opening in the structure that is allowing reservoir water under pressure into the embankment. Rapid erosion and an eventual breach of the embankment can result.

MONITORING SEEPAGE

If seepage is observed, then it should be monitored. To monitor seepage, you should record

- The location and quantity or flow rate of all seepage at exit points.

- The occurrence of recent precipitation that may affect the appearance and quantity of seepage.

- The water level in the reservoir/ canal at the time of the observation

✓ ***INSPECTION TIP :***

Notes, sketches, and photographs are useful in documenting and evaluating seepage problems.

The amount of seepage usually correlates with the water level in the pool of reservoir/ canal. Generally, as the water level of the reservoir/ canal rises, the seepage flow rate increases.

✓ ***INSPECTION TIP :***

Any changes in seepage flow rate which deviate from past seepage history are cause for concern.

In some cases, a dye test can be used to test whether or not the reservoir/ canal is the source of seepage. A dye test is not a routine procedure. The length of time it takes to conduct a test may vary since the dye may take different amounts of time to penetrate the embankment or foundation. In most cases, records of seepage volumes that correlate with pool elevations are needed to show that seepage comes from the reservoir/ canal.

Seepage Measurement: Weirs and Flumes

Weirs and flumes can be installed to measure seepage, especially seepage exiting from the embankment or foundation at random locations. When properly calibrated and kept free of silt and vegetation, weirs and flumes can measure seepage accurately. Quantity of seepage so measured should be recorded in the operating log (logbook). Guidance pertaining to water measurement may be found in the U.S.Bureau of Reclamation Water Measurement Manual.

Weirs and flumes that are silted-in may indicate that

- Embankment or foundation material is being piped out of the dam, or
- Sediment from surrounding surface runoff – erosion is collecting in the structure.

If weirs and flumes become silted-in, you should evaluate the situation carefully to determine the cause of the siltation.

Toe Drains

Many toe drains have collector pipes that discharge embankment seepage and, in some cases, foundation seepage. Before conducting an inspection of an embankment that has toe drains, you should

- -Review the site plan to determine the location of the toe drains and outfalls.
- -Review previous data on both the water level in canal and flow rate from the drain(s). Data on drain flow must be looked at in conjunction with data of water-level in the reservoir/ canal. Knowing how the water level affects the drain flow can help you to determine if there is a problem. If you observe a drain flow that is atypical for the given water level in reservoir/ canal, more investigation may be warranted.

During the inspection, you should

- -Locate each toe drain outfall.
- -Measure the flow. A simple method of measuring the flow from a toe drain outfall is to catch the flow from the pipe in a container of know volume and to time how long if takes to fill the container. The flow rate is usually recorded in liters per minute.
- -Compare the amount of flow with the amount of flow you anticipated for the current water level in the reservoir/ canal based on previous readings.

Blocked Drains.

A drain that has no flow at all could simply mean that there is no seepage in the area of the canal serviced by the drain. However, an absence of flow could also indicate a problem.

If the drain

- Has never functioned, it could mean that the drain was designed or installed incorrectly.
- Flowed at one time but has not stopped flowing, it may have become plugged.

A plugged drain can be a serious problem because seepage may begin to exit down slope, or may contribute to internal pressure and instability. If possible, blocked drains should be cleaned so that the controlled release of seepage may be restored.

Decreasing amounts of flow from a drain for the same water level in canal may indicate that the drain is becoming blocked; conversely, a sudden increase in drain flow may indicate that the core is becoming less water tight, possibly as the result of transverse cracking.

✓ ***INSPECTION TIP :***

Recording drain flow rates and reservoir/ canal water levels will help you to assess a drain's seepage problems.

Relief Wells.

Before conducting an inspection of an embankment that has relief wells, you should ….

-: Review the site plan to determine the location of the wells.

-: Review previous data on both the water level in the reservoir/ canal and well flow. Data on well flow must be looked at in conjunction with data of water-level in reservoir/ canal. Knowing how the reservoir/ canal water level affects the wall flow can help you to determine if there is a problem. If you observe a well flow that is atypical for the given reservoir/ canals water level, more investigation may be warranted.

During the inspection, you should

-: Locate each relief well.

-: Visually check whether or not water flow is occurring.

IF NO WATER IS FLOWING… Determine if a flow should be present based on your assessment of the previous readings and the current reservoir/ canal water level.

IF WATER IS FLOWING… Measure the rate of flow. The rate of flow can be measured either at the well or at the collector pipe discharge. You can use weirs,

flumes, or a bucket and stop watch to measure the flow rate.

-:Compare the amount of well flow measured with the amount of flow you anticipated for the current reservoir/ canal water level based on previous readings.

If the well flow is less than the amount you anticipated, the well screens or filters may have become clogged. If you suspect that the well is not functioning properly because it is clotted, cleaning should be recommended.

If the well flow is greater than the amount you anticipated, there may be excessive seepage. Make sure that you accurately record the flow amount and reservoir/ canal water level. You should also note that there has been a change from the well-flow trends previously observed.

TURBIDITY.

In addition to measuring the flow rate of seepage, you should evaluate the clarity of the seepage. Turbidity is cloudy seepage, which indicates that soil particles are suspended in the water. Turbidity means that the water passing through the embankment or foundation is carrying soil with it.

- ✓ ***INSPECTION TIP:***

  Turbidity is cause for extreme concern. Each time seepage is measured, the clarity of the seepage should also be evaluated for change.

Checking Turbidity:

A good way of detecting a change in turbidity is to collect a number of water samples as follows:

STEP	DESCRIPTION.
1.	Collect a sample of the water in a quart jar. Date the jar and note the level of clarity. Store the jar in a safe location.
2.	Repeat step 1 each time seepage flow is measured until several samples have been collected.
3.	Each time you collect a sample, shake up each jar and visually compare the new sample with the samples collected previously. Look for changes in the cloudiness of the samples. Also note amount of sediment that accumulates in the bottom of the jars as suspended material settles out.

If seepage is clear, but you suspect that if contains dissolved material from the foundation (because, for instance, seepage has increased), it may be necessary to perform water quality testing.

- ✓ ***INSPECTION TIP:***

  As mentioned previously, the rate and turbidity of seepage flow should be recorded at each inspection.

  If seepage problems are suspected, then the frequency of inspections should be decided by Deputy Executive Engineer.

  If seepage problems do occur, further testing should be conducted.

  Remember, uncontrolled seepage is a major cause of embankment failure.

PART III

CRACKS

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CRACKS

A. DESICCATION CRACKING.

Desiccation cracking is caused by the drying out and shrinking of certain types of embankment soils. Desiccation cracks usually develop in a random, honeycomb pattern. Typically, desiccation cracking occurs in the crest and the downstream slope.

The worst desiccation cracking develops when a combination of the following factors is present

- A hot, dry climate accompanied by long periods in which the dam/ canal remains empty.
- An embankment that is composed of highly plastic soil, such as clay.

Usually, desiccation cracking is not harmful unless it becomes severe. The major threat of severe desiccation cracking is that this type of cracking can contribute to the formation of gullies. Surface runoff erosion concentrating in the desiccation cracks or gullies can result in eventual damage to the embankment of dams/ canals.

Also, heavy rains can fill up these cracks and cause portions of the embankment to become unstable and to along crack surface where the water has lowered the strength of the

embankment material. Deep cracks that extend through the core conceivably can cause a breach of the embankment of dams/ canals when the water level inreservoir/ canal rises and the cracks fall to swell rapidly enough to reseal the area.

Desiccation Cracking : Inspection Actions

If you observe desiccation cracking, you should

-:Probe the more severe cracks to determine their depth.

-:Photograph and record the location, depth, length, and width of any severe cracks observed.

-:Compare your measurements with past measurements to determine if the condition is worsening.

✓ ***INSPECTION TIP:***

If the depth of the cracking extends below the water level in reservoir/ canal or potential water level, consult Design organization to help identify appropriate remedial measures.

B. TRANSVERSE CRACKING.

Transverse cracking appears in a direction roughly perpendicular to the length of the embankment. If these cracks extend into the core below the reservoir/ canal water level they are especially dangerous because they could create a path of concentrated seepage through the core. Transverse cracks usually appear on the embankment crest, near abutments, and in U-shaped or trapezoidal-shaped valleys.

The presence of transverse cracking indicates differential settlement within the embankment or underlying foundation. This type of cracking frequently develops when

- Compressible material overlies abutments consisting of steep or irregular rock.
- Areas of compressible material are in the foundation.

Figure II-6, on the following page, shows how transverse cracks from in an embankment.

Transverse cracks may provide a path for seepage through the embankment. When the depth of the crack extends below the water level of the reservoir/ canal, very rapid erosion of the embankment may occur, eventually breaching the embankment.

Transverse Cracking : Inspection Actions.

If you observe transverse cracking you should

-:Photograph and record the location, depth, length, width, and offset of each crack observed.

-:Closely monitor the crack for changes.

- ✓ ***INSPECTION TIP :***

Executive engineer should be consulted in order to determine the cause of the cracking.

C. LONGITUDINAL CRACKING.

Longitudinal cracking occurs in a direction roughly parallel to the length of the embankment. Longitudinal cracking is an indication of

- Uneven settlement between adjacent embankment zones of differing compressibility.
- The beginnings scrap of an unstable slope. In this case, the crack may appear arc shaped

Figures 5 and 6, on the following page, illustrate longitudinal cracking.

Longitudinal cracks allow water to enter the embankment. When water enters the embankment the strength of the embankment material adjacent to the crack may be lowered. The lower strength of the embankment material can lead to or accelerate slope stability failure.

Longitudinal Cracking : Inspection Actions.

As with transverse cracking, if you observe longitudinal cracking you should

-:Photograph and record the location, depth, length, width, and offset of each crack observed.

-:Closely monitor the crack for changes.

✓ ***INSPECTION TIP :***
Executive engineer should be consulted in order to determine the cause of the cracking.

PART IV

SLIDES.

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SLIDES.

Slide phenomena have various names including displacements, slumps, slips, and sloughs. Slides can be grouped into two major categories…

- Shallow Slides
- Deep-Seated Slides

Next you will learn more about each category of slides.

Shallow Slides : Upstream Slope

Shallow slides in the upstream slope are often the result of an overly steep slope aggravated by a rapid lowering of the water level in canal. Shallow slides in the upstream slope pose no immediate threat to the integrity of the embankment. However, shallow slides may lead to …

- The obstruction of water conveyance structure inlets.
- Larger, deep-seated slides.

Shallow Slides : Downstream Slope

Shallow slides in the downstream slope also indicate an overly steep slope. In addition, these slides may also indicate

a loss of strength in the embankment material. A loss of strength in the embankment material can be the result of saturation of the slope from either seepage or surface runoff. Additional loads from structures can aggravate the condition.

Figure 7, shows a diagram of a shallow slide on the downstream slope.

Shallow Slides : Inspection Actions.

If you observe a shallow slide you should

-:Photograph and record the location of the slide.

-:Measure and record the extent and displacement of the slide.

-:Look for any surrounding cracks, especially uphill from the slide.

-:Probe the entire area to determine the condition of the surface material.

-:Monitor the area to determine if the condition is becoming worse.

✓ ***INSPECTION TIP :***

Consult Design Organisation if you are unsure whether the slide presents a serious threat to the integrity of the embankment.

Deep-Seated Slides.

Deep-seated slides are serious threats to the safety of the embankment. To recognize deep-seated slides look for

- **Well-Defined Scraping.**

  A scrap is a relatively flat area with a steep back slope.

- **Toe Bulge**

  A toe bulge is produced by the rotational or horizontal movement of embankment material. (Bulges are discussed in the next part of this Section.)

- **Arc-Shaped Cracks**

  Arc-shaped cracks in the slope are indications that a slide is beginning. This type of crack may develop into a large scrap in the slope at the top of the slide.

Figure 8 presents a diagram of a deep-seated slide.

Deep-Seated Slides : Inspection Actions

A deep-seated slide or scraping in either the upstream or downstream slope may be an indication of serious structural problem.

- ✓ ***INSPECTION TIP :***

  IMMEDIATE ACTION IS NECESSARY: In most instances, deep-seated slides will require the lowering of the water level inreservoir/ canal to prevent the possible breaching of the embankment.

BULGING.

Bulging is a phenomenon that usually is associated with the lateral spreading of the embankment or with slides. Bulging as a result of lateral deformation is accompanied by settlement. The bulging is most evident at the toe of the embankment. **Figure 9** illustrates how bulges from due to lateral spreading of the embankment.

Figure 10 illustrates how bulges from in association with slides.

Bulging Due to Lateral Spreading: Inspection Actions

A toe bulge due to lateral spreading may mean that there has been some loss of freeboard.

- ✓ ***INSPECTION TIP :***

  If you suspect loss of free-board, a survey of the crest should be performed. A survey will verify if there has been a loss of freeboard.

In addition to checking for freeboard loss

-:Closely inspect the area above the bulge for cracking or scraps which indicate that a slide is the cause.

-:Probe the bulge to determine if material is excessively moist or soft. Excessive moisture or softness also indicates that a slide is the cause.

Bulging Associated with Slides.

Bulging associated with slides is a much more serious problem. The area above a bulge should be examined carefully in order to identify other indicators of instability such as cracks and scraps.

- ✓ ***INSPECTION TIP :***

  If you observe bulging associated with cracks or scraps, determine the cause of the bulging and work out a course of action.

PART V

DEPRESSIONS

PART V

DEPRESSIONS

WHAT ARE DEPRESSIONS?

Depressions are caused by ….

- Localized settlement in the embankment or foundation.
- Embankment spreading in the upstream and/or downstream direction. This type of spreading may result in a loss of freeboard and over topping of the embankment.
- Erosion, Wave action against the upstream slope that removes embankment fines or bedding from beneath riprap may form a depression as the riprap settles into the vacated space.

Some areas that appear to be depressions may be the result of improper final grading following construction.

Depression can be minor or they can be very serious. Sinkholes are a serious type of depression. A good way of distinguishing between minor depressions and sinkholes is to look at their profiles.

Minor Depressions : Minor depressions have gently slopping bowl-like sides.

Sinkholes: Sinkholes usually have steep, bucket like sides.

Figure 11 illustrates the difference between minor depressions and sinkholes.

Detecting Depressions.

Depressions and other misalignment in the crest and embankment slopes often can be detected by sighting along fixed points. You should sight and take photographs along guardrails, parapet.

Walls or pavement striping. Some apparent misalignment may be due to irregular placement of the fixed points. For this reason, irregularities should be evaluated over time to verify suspected movement.

Sighting irregularities is facilitated by surveying permanent monuments across the crest to determine the exact location and the extent of misalignment. A record of survey measurements also can establish the rate at which movement is occurring.

Minor Depressions : Inspection Actions

Although minor depressions, in most cases, do not represent an immediate danger to the embankment, they may be early indicators of more serious problems.

If you observe a depression

-:Photograph and record the location, size, and depth of the depression.

-:Probe the floor of the depression to determine whether or not there is an underlying void. An underlying void is indicative of a sinkhole.

-:Frequently observe the depression to ensure it has stopped developing.

WHAT ARE SINKHOLES?

Sinkholes are a more serious type of depression. Sinkholes are formed when the removal of subsurface embankment or foundation material has caused overlying material to collapse into the resulting void. The decomposition of embedded wood or other vegetative matter also can cause sinkholes. In addition, animal burrows can contribute to the formation of sinkholes.

The presence of a sinkhole indicates that material is or has been transported out of the dam or foundation through the process of piping. (See the section on seepage for more information on piping.)

Figure 12, on the following page, illustrates how a sinkhole is formed.

Sinkholes : Inspection Actions.

If you observe a sinkhole

-: Probe the sinkhole to determine if the void is larger than it appears.

-: Photograph and record the location, size, and depth of the sinkhole.

✓ ***INSPECTION TIP :***

Sinkholes can be very serious. Evaluate the situation immediately.

PART VI

MAINTENANCE CONCERNS

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MAINTENANCE CONCERNS

WHAT ARE MAINTENANCE CONCERNS?

Maintenance includes the routine measures taken to protect and maintain the embankment. Deficiencies associated with inadequate maintenance include…

- Inadequate Slope Protection.
- Surface Runoff Erosion.
- Inappropriate Vegetative Growth.
- Debris.
- Animal Burrows.

In this section you will lean how to detect common maintenance concerns and what corrective actions should be taken.

1. Erosion And Slope Protection.

The constant action of flowing water on the upstream slope may result in scarping, and degrading of the slope protection. Unless measures are taken to maintain adequate slope protection, this will begin to erode the embankment material. Let's look at the different effects of erosion on the upstream slope.

- **Scarping :** In the upstream slope local settlement due to removal of earth behind lining can cause soil to erode and slide to the lower part of the slope. This type of erosion causes scarps to form which could lessen the width and possibly height of the embankment, possibly leading to increased seepage, instability, or overtopping of the embankment.

- **Degrading :** Degradation of the lining may occur when it cracks, becomes weathered, or breaks down. The degrading of the lining is accelerated by flowing water. Degraded portion of lining should be monitored. If evidence shows that serious damage to the embankment is occurring, degraded lining must be repaired or replaced. Care should be taken to see that

entire panel of lining is redone instead of going for patches.

Figure 13, illustrates the effect of erosion on lining.

Inadequate Slope Protection: Inspection Actions.

During the inspection you should ….

-: Make sure that the slope protection is adequate enough to prevent erosion.
-: Look for scarping, and degrading of the slope protection.

If inadequate slope protection is observed

-: Record your findings and photograph the area.
-: Determine the extent to which the embankment has been damaged (i.e., embankment material has been removed).
-: Recommend that corrective action be taken to repair or to replace the inadequate slope protection.

2. SURFACE RUNOFF EROSION.

Surface runoff erosion is one of the most common maintenance problems of embankment structures. If not corrected, surface runoff erosion can become a more serious problem.

Gullies.

The worst damage from surface runoff is manifested by the development of deep erosion gullies on the slopes, both at the groins and in the central portion of the embankment.

Severe gullies can

- Cause breaching of the crest.
- Shorten the seepage path through the embankment, possibly leading to piping.

Gullies can develop from poor grading or sloping of the crest that leads to improper drainage, causing surface water to collect and to run off at the low points along the upstream and downstream shoulders. Gullies caused by this type of runoff eventually can reduce the cross-sectional area of the embankment.

3. Slope and Crest Protection.

Bald areas or areas where the protective cover is sparse are more susceptible to surface runoff erosion problems.

In the upstream slope, erosion may undermine the lining and cause it to settle. Settlement of the lining may lead to the eventual degradation of the slope itself.

The crest also can experience weathering and erosion if it is not protected. Crest erosion protection may consist of a road surfacing such as metalled, asphalt, or concrete pavement. The type of crest protection used depends on the amount of traffic anticipated. If little or no traffic is expected on the crest, a grass cover should be adequate. Remember to check to see that the crest surfacing is providing adequate protection from erosion. Too much traffic on WBM -or grass-covered crests, especially during rainy periods, can lead to ruts in the crest surface. Ruts are undesirable because they will pond water, potentially causing stability problems.

There are a number of special circumstances that can contribute to or initiate surface erosion of the crest and downstream slope. In some areas, livestock may establish trails on the embankment. Livestock traffic can damage the slope's vegetative cover. Vehicles can cause ruts in the crest and can damage the slope protection. You need to be aware of any unique problems that may be common in a particular location or past problems that were noted on previous

inspections. Make sure to look for these types of problems in your inspection.

Surface Runoff Erosion : Inspection Actions.

During the inspection you should

-:Make sure that the slope and crest protection is adequate to prevent erosion. Remember, bald areas or areas where the surface protection is spares are more susceptible to surface runoff problems.

-:Look for gullies, ruts, or other signs of surface runoff erosion. Make sure you check the low points along the upstream and downstream shoulders and groins since surface runoff can concentrate in these areas.

-:Check for any unique problems, such as livestock or vehicles, which may be contributing to erosion.

If surface runoff erosion is observed

-:Record your findings and photograph the area.

-:Determine the extent or severity of the damage.

-:Recommend that corrective action be taken to repair the areas damaged by surface runoff and that measures are taken to prevent more serious problems.

4. INAPPROPRIATE VEGETATIVE GROWTH.

Inappropriate vegetative growth is another common maintenance problem. Inappropriate vegetative growth generally falls into two categories…..

- Excessive Vegetative Growth.
- Deep-Rooted Vegetation.

Excessive Vegetative Growth.

Excessive vegetation is a problem wherever it occurs on an embankment dam. Excessive vegetation can. . . .

- Obscure large portions of the embankment preventing adequate visual inspection. Problems that threaten the integrity of the embankment can develop and remain undetected if they are obscured by vegetation.
- Prevent access to the embankment and surrounding areas. Limited access is an obvious problem both for inspection and maintenance, and especially during emergency situations, where access is crucial
- Provide a habitat for rodents and burrowing animals. Burrowing animals can pose a threat to embankment by causing piping.

Also, there should be no vegetation in the lining on the upstream slope. Vegetation in the lining promotes degradation of the slope protection.

Vegetative growth should be controlled by periodic mowing or other means.

- ✓ ***INSPECTION TIP :***

  To ensure that you will have the greatest visibility of the slopes and crest, schedule your inspection shortly after mowing has been completed.

Deep-Rooted Vegetation.

Although a healthy cover of grass is desirable as slope protection, the growth of deep-rooted vegetation, such as large shrubs and trees, is undesirable.

Large trees could be blown over and uprooted during a storm. The resulting large hole left by the root system could breach the embankment or shorten the seepage path and initiate piping.

Root systems associated with deep-rooted vegetation develop and penetrate into the embankment's cross section. When the vegetation dies, the decaying root system can provide paths for seepage and cause piping to occur.

Even healthy root systems of large vegetation can pose a threat by providing seepage paths. These seepage paths eventually can lead to internal erosion and threaten the integrity of the embankment.

- ✓ ***INSPECTION TIP :***

  It is generally agreed that trees and shrubs more than 2 feet in height are undesirable growing on or adjacent to embankments.

  However, there is some debate over when and how to remove well-developed trees and root systems that are already in place in the embankment.

  The location, size, type of tree and prevailing policy will determine the course of action at a given site.

The best approach to trees in the crest, slopes, and adjacent to the embankment is to cut them down **before** they reach significant size. If large trees have been cut down, but the root system not removed, carefully monitor the area around the remaining stumps for signs of seepage.

Inappropriate Vegetation Growth: Inspection Actions.

During the inspection you should

-:Look for excessive and deep-rooted vegetation on all areas of the embankment.

-:Make sure that there is no vegetation growing in the riprap on the upstream slope.

-:Check for signs of seepage around any remaining stumps or decaying root systems on the downstream slope or toe area.

If inappropriate vegetation is observe

-:Photograph the area and record your findings.

-:Note the size and extent of the inappropriate vegetation.

-:Recommend that appropriate corrective action be taken to eliminate inappropriate vegetation and that measures be taken to prevent the future growth of undesirable vegetation.

5. DEBRIS.

The collection of debris on and around the embankment is not an immediate danger to the integrity of the embankment. However, unattended debris can lead to serious problems. Listed below are common problems associated with debris.

- The build up of brush on the embankment can obscure the upstream slope and can prevent adequate inspection.
- Debris can accelerate the process of degradation of the lining or other slope protection by impact from wave action.
- Woody debris can become waterlogged and sink, possibly blocking an outlet works inlet or siphon entrances. The blocking of these structures can cause overtopping of the embankment.

Certain animals, such as beavers, can contribute to the accumulation of debris in and around the embankment. As you will see in the next section, beavers are not the only animals to cause potential harm to an embankment.

Debris : Inspection Actions.

If you see debris in and around the embankment

-: Photograph and record your observations.

-:Recommend that appropriate corrective action be taken to remove the debris and that, if possible, measures are taken, such as the installation of a log boom, to prevent the future accumulation of debris.

6. ANIMAL BURROWS.

Animal burrows can be dangerous to the structural integrity of the embankment since they weaken the embankment and can create pathways for seepage. The following animals can cause destruction to embankments…..

- Groundhogs (Woodchucks)
- Muskrats
- Prairie Dogs
- Badgers
- Pocket Gophers
- Richardson Ground Squirrels

Burrowing animals make nests and passageways. These passageways may cause piping failures when they

- Connect the water pool to the downstream slope.
- Penetrate the embankment's core.

Shallow burrows or burrows that are confined to one side of the embankment may be less dangerous than these deep or connective passageways.

✓ **INSPECTION TIP :**

If shallow burrows are so prevalent that they honeycomb an embankment, the integrity of the embankment is suspect. You should consult Executive Engineer to determine how the deficiency might be corrected.

Burrowing Animals : Inspection Actions.

If burrowing animals are evident

-: Photograph the area and record your findings.

-: Recommend that measures be taken before serious damage occurs to the embankment. Eradication or removal is usually the recommended course of action.

Remove animals immediately upon detection. Woodchucks, squirrels, rabbits, moles and muskrats can be exterminated or flushed out with smoke. Beavers must be relocated.

Excavate burrows to the maximum extent possible and fill excavation with earth or a mixture of 9 parts of soil and 1 part cement. The filling material should be placed as deep as possible and should be tamped into place with a pole.

7. Embankment Drains

Embankments have drainage systems comprising of Longitudinal and Catch-water drains installed for collection and safe exit of seepage. Such systems have drain pipes / chutes terminating at or near the downstream toe of the embankment. Visible ends of such drain pipes/ chutes provide easy exit of any seepage and allow observation and possible measurement of seepage flows. Such drains and exist points may become clogged with chemical deposition, sediment, or debris such that the drains cannot function effectively.

Inspection Action

- **Annually inspect the ends of drainage pipes/ chutes at or near the downstream toe of the embankment** and clean out any debris and material that may clog the drains and exit channels.
- Material covering unexposed ends of drainage pipes / chutes should be removed.
- If animals occupy the drains, as may be the case when drains are dry, it is appropriate to clean the pipe/ chutes and install large-mesh corrosion-resistant screens in the ends of the drains to preclude entry.

PART V

SCHEDULE OF ROUTINE INSPECTION

PART V

SCHEDULE OF ROUTINE INSPECTION

Operation of the dam/ canal during normal conditions shall be the responsibility of the section officer in charge of the dam/canal. It shall be ensured that unauthorized encroachments do not occur, that existing or potential conditions do not lead to public criticism or injury to the public and that nothing is done which conflicts with the primary purpose of the project. Following gives schedule of duties to be performed by the **Section officer:**

Daily

1. Record water surface elevation
2. Record seepage measurements at the toe of embankment.
3. Record pertinent information in Operating Log.

Monthly

1. Check condition of :

- Top of embankment
- Upstream and downstream faces
- Abutment contacts
- Rodent problems
- Measuring devices
- Toe drains, L-drains

2. Inspect and repair animal burrows, eliminate animals
3. Inspect, remove and repair encroachments.

Quarterly

1. Inspect and repair settlement, sloughs, slumps, bulges, cracks and depression.

Semiannually

1. Inspect embankment for trees, vegetation, shrubs, bush growth and remove deep rooted vegetation and shrubs.
2. Inspect embankment for erosion.
3. Inspect and record quality and clarity of seepage and corresponding water level in canal.

Annually

1. Inspect ends of drainage pipes at or near upstream toe of embankment and clean out debris / material that might choke that drain.

After Heavy Rains

1.Inpect and repair embankments

Following officers shall carry out inspection as per the frequency shown against their designation:

Designation Of inspecting officer	*Inspection to be carried out during month of*	*Note*
Deputy Executive Engineer	March, October	
Executive Engineer	April October	
Superintending Engineer	Mid-May Mid-November	Vulnerable area
Chief Engineer	May November	At Random

PART VI

CHECKLIST FOR EXAMINATION OF EMBANKMENT

PART VI

CHECKLIST FOR EXAMINATION OF EMBANKMENT

_____ dam/ **canal**

Chainage _____

Date of Examination **Signature Completed**

_____ _____

Operational Status at Time of Examination

Canal Water Surface-Elevation _____ M

Releases:

Escape _____ m^3/s

Outlet Works for irrigation _____ m^3/s

Water supply _____ m^3/s

Examination Participants

Name Affiliation

_____

_____

_____

_____

_____

Top of Bund

Surface cracking (*whether Transverse / Longitudinal*) _____

Durability (*See top material / Vegetation / burrows / Level of maintenance*) _____

Settlement _____

Lateral movement (alignment) (*Misalignment)* _____

Camber (*Possibility of channelization / Surface drainage*) _____

UPSTREAM FACE

Erosion-breaching(*Observe Erosion of filter / Removal of*

rock by wave / scarps / slides) ----------

Vegetative growth (*Should be none*) _____

Settlement (*of filter erosion / Depression (minor) / Sink holes*) _____

Debris (*Accumulation – remove*) _____

Burrows or borrowing animals (*See presence – Eradicate*) _____

Unusual conditions _____

DOWNSTREAM FACE

Sign of movement (*Observe Depression / Sink holes / Toe Bulging / slides*) _____

Seepage or wet areas (*SMPL / Boils at groins or Outlet*) _____

Vegetative growth (*watch for Sparse / greener line as seepage line / Not excessive and deep-rooted)* _____

Channelisation (*Check for its presence & low spots at shoulders, groins / Position of d/s drains)* _____

Condition of slope protection (*Adequacy / Sparse / Indicate bald areas*) _____

Burrows or borrowing animals (*See presence – eradicate*)_____

Unusual condition _____

ABUTMENTS

Seepage(*watch for Greeneries / Sandboils / Wetness*) _____

Cracks, joints, and bedding planes (*see Transverse Cracks*)_____

Channelisation (*observe Low spots / drainage arrangements*) _____

Slides (*whether Deep / Shallow)* _____

Vegetation (*whether Excessive / Deep Rooted*) _____

Sign of movement _____

SEEPAGE AND DRAINAGE SUMMATION

Location(s)(*Groins / Junctions / HR*) _____

Estimated flow(s) _____

Color (staining) (*For silt / Washing out of earth particles*

causing piping) _____

Erosion of outfall _____

Toe drain and manholes (*look for Cleanliness / Silt collection / Review of their locations / out falls*)_____

MEASUREMENT

Method _____

Amount _____

Change in flow

(*Rate, For same water level compare with past data / Increase is alarming decrease means shrinking/ also watch for transverse cracks*) _____

Clearness of flow _____

Color _____

Fines(*Allow water to stand. Compare daily heights*)_____

Condition of measurement device _____

Records (*Plot flow rates*) _____

OTHER POINTS

_____ _____

PART VII

INSPECTION DURING EMERGENCY

PART VII

INSPECTION DURING EMERGENCY

Detailed guidelines are prepared for inspection and operation during emergency situations. These form part of Manual for Operation of each of the dams and canals.