STANDARD OPERATING PROCEDURE
FOR
Inspection of Pipes
23 February 2021

Note: The following guidance is from Chapter 6 of EM 1110-2-2902, "Conduits, Pipes, and Culverts Associated with Dams and Levee Systems", publication date on 31 December 2020. The complete manual can be found at https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/EM%201110-2-%202902.pdf?ver=dWvkKGoSFozppG1qRnya4Q%3d%3d. Refer to the full document for descriptions of all terminology and concepts.

Chapter 6
Inspections, Condition Assessments, and Prioritized Mitigation Plans

6.3. Special Considerations for Levee Toe Drain Inspections. There are occurrences within the USACE levee portfolio in which toe drains were installed without the effort of a design analysis to prove their necessity to the project. As such, USACE may require inspection of features that do not serve an essential function. Since toe drain inspections are usually expensive and can be difficult or impossible to access in some cases, the relevant District may suggest that the project owner review the design documentation to see if the toe drain was designed for site-specific usage. If it was not, the relevant District may request that the owner perform a seepage analysis, at its own expense, which will be reviewed by the District to determine if the feature may be decommissioned in place. In cases where USACE is the project owner, the relevant District will determine the need for a seepage analysis and perform and review the analysis, as appropriate.

6.4. Inspection Limits.

6.4.1. Real Estate Rights. Although all or portions of a pipe requiring inspection may be located outside of the levee/floodwall right-of-way, inspection of the pipe may be conducted according to the real estate rights associated with the pipe. Access to these pipes should be permitted either under their own specific easement or allowed as part of the levee or floodwall right-of-way. The owner of the pipe must be familiar with the real estate instruments associated with the pipe to ensure that inspections are conducted consistent with the terms of the easement. Utility/pipeline easements generally allow the owner of the pipe to construct, operate, maintain, alter, replace, and inspect the pipe(s) within the pipe's easement limits. In cases where a records search has been conducted by a real estate professional or an attorney and an easement for a particular pipe does not appear to exist, the pipe owner should obtain legal services to acquire an easement from the landowner. In some cases, the pipe may be subject to an easement by prescription, which is an easement acquired by continued use without legal permission of the landowner for a legally defined period of time. Laws regarding prescriptive easements vary by state and the pipe owner should consult an attorney to assess whether they may be applicable. The "required" inspection limits shown in Figure 6-2 through Figure 6-10 assume no right-of-way issues were encountered. All opportunities to resolve right-of-way disputes should be investigated so that any pipe or portion of a pipe within the influence zone is inspected; however, until resolved, the inspection limits must legally terminate vertically at disputed rights-of-way.

6.4.2. Inspection Limits Overview. There are two reasons for establishing pipe inspection limits: the first is to maintain the structural integrity of the levee system, and the other is to prevent inundation of the leveed area by maintaining its operational adequacy; these limits are not necessarily the same. The following limits are considered minimums and it is recommended that the respective USACE District determine if there is a need to increase these limits on a case-by-case basis based on site-specific knowledge. In addition to pipes associated with existing levees, existing pipes along the proposed alignment of new levees must be inspected within these limits and meet USACE assessment requirements prior to allowing the pipe to remain in place.

6.4.3. Inspection Limits Related to Structural Integrity. The area within which pipe-related defects could impact the structural integrity of the levee or hinder access along it is considered the "influence zone." The limits of the influence zone were established assuming the loss of soil into a pipe produces a stope (Figure 6-1) that advances more or less vertically to the surface before the interior sides start to successively slough over time toward its angle of repose. The 1H:1V (45°) slope angle of the zone limits may be more steep than the angle of repose for a specific soil in question, especially with loose fine-grained soils or dry sands; however, it is anticipated the sloughing process will be gradual, allowing the issue to be detected and addressed before crossing over into the influence zone limits. As shown in the following figure, a minimum horizontal distance from the structure is included before the downward slope begins. This not only provides a buffer, but also provides sufficient O&M and emergency access adjacent to the embankment or floodwall should a sinkhole develop.

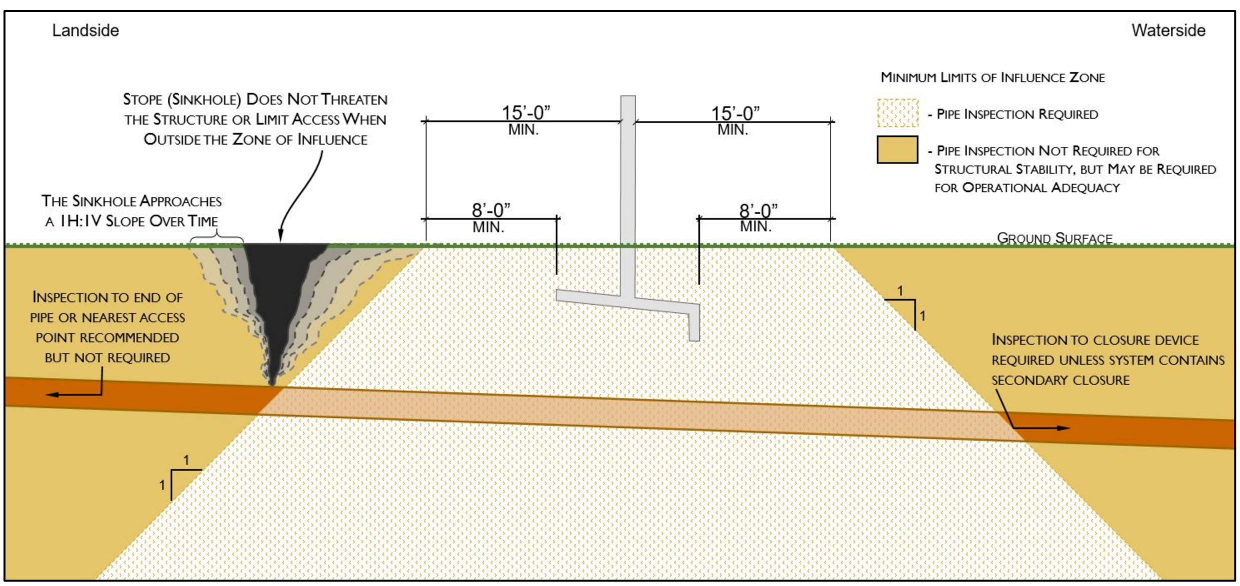


Figure 6-2. Example for purpose of influence zone limits.

6.4.4. Inspection Limits Related to Operational Adequacy. Operational adequacy here refers to a system's mechanical ability to keep the leveed area from becoming inundated. The inspection limits used to ensure structural stability will not necessarily ensure operational adequacy because it is possible for water to bypass the embankment or floodwall without affecting the integrity of the structure. Figure 6-2 shows a vulnerable area outside the influence zone, between the waterside inspection limits and the outlet headwall, where a defect in the pipe can allow water to bypass the closure device and enter the leveed area. In cases where there is no secondary (backup) closure device, USACE requires that the waterside inspection limits be extended beyond the influence zone limits, defined in Section 6.4.2 to the closure device.

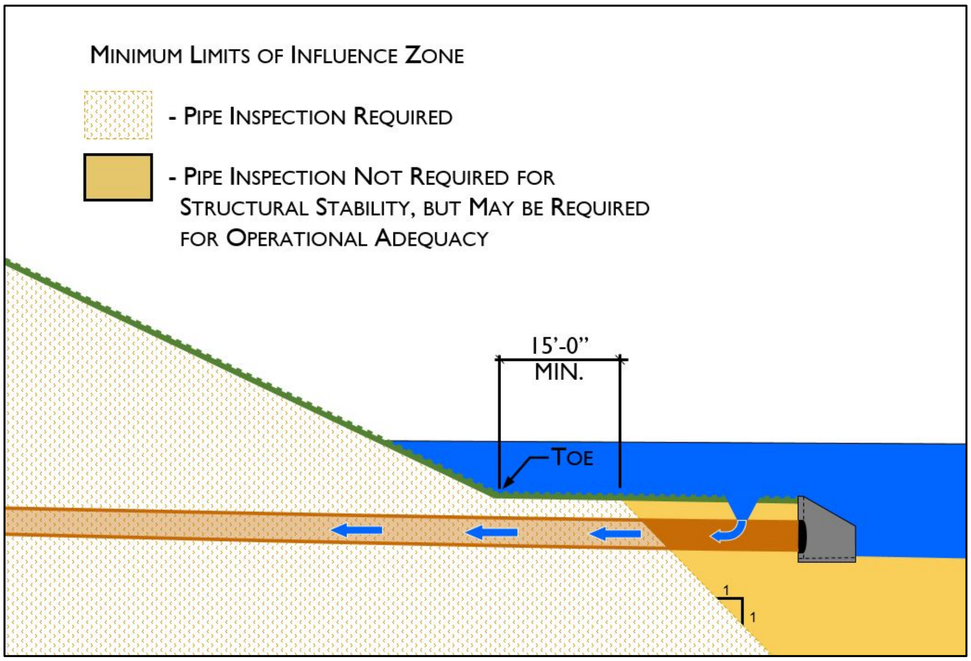


Figure 6-3. Structural integrity inspection limits can fail to inform operational adequacy.

6.4.5. Gravity Pipes Through and Beneath Levee Embankments. Gravity pipes penetrating the levee embankment cross section are inspected from headwall to headwall (Figure 6-3, upper pipe). Gravity pipes beneath levee embankments or floodwalls which do not daylight at the landside levee toe are inspected to 15 feet at a minimum, with a projected 1H:1V slope below the ground surface (Figure 6-3, lower pipe). Access to gain entry into pipes may be required beyond the project rights-of-way. Figure 6-4 and Figure 6-5 show the minimum limits of inspection for pipes passing beneath floodwalls.

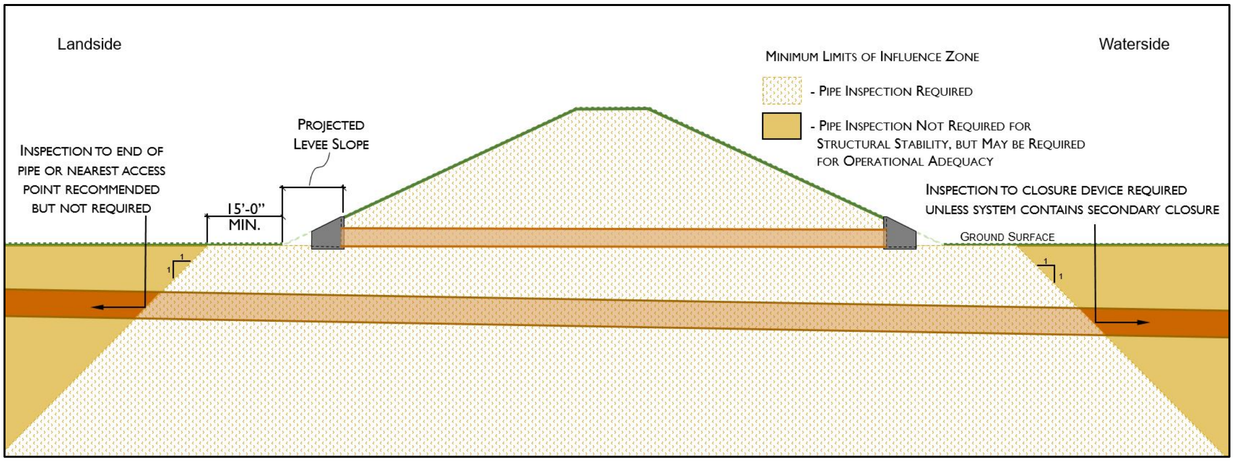


Figure 6-4. Gravity pipes through and beneath a levee embankment.

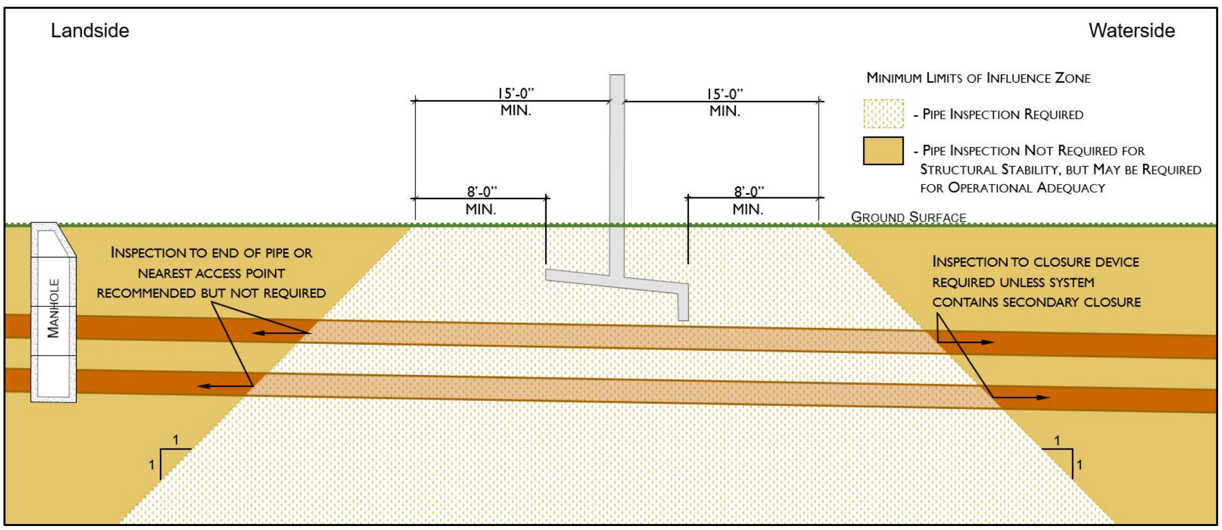


Figure 6-5. Gravity pipes beneath a floodwall (T-wall).

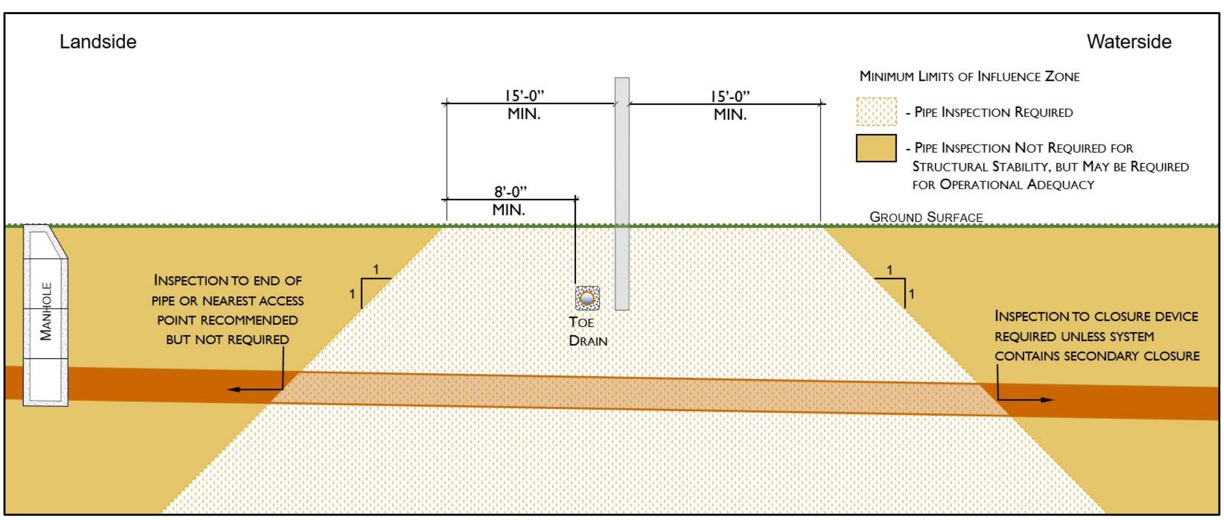


Figure 6-6. Gravity pipes beneath a floodwall (I-wall).

6.4.6. Gravity Pipes that Do Not Cross a Levee Alignment. Pipes running adjacent to a levee embankment or floodwall that are within 15 feet horizontally of the levee toe or floodwall (I-wall) face, within eight feet of the floodwall (T-wall) foundation or toe drain, or below a 1H:1V slope from that point, require inspection. Examples of these types of pipes include toe drains, collector systems, and third-party pipes Figure 6-7 and Figure 6-8).

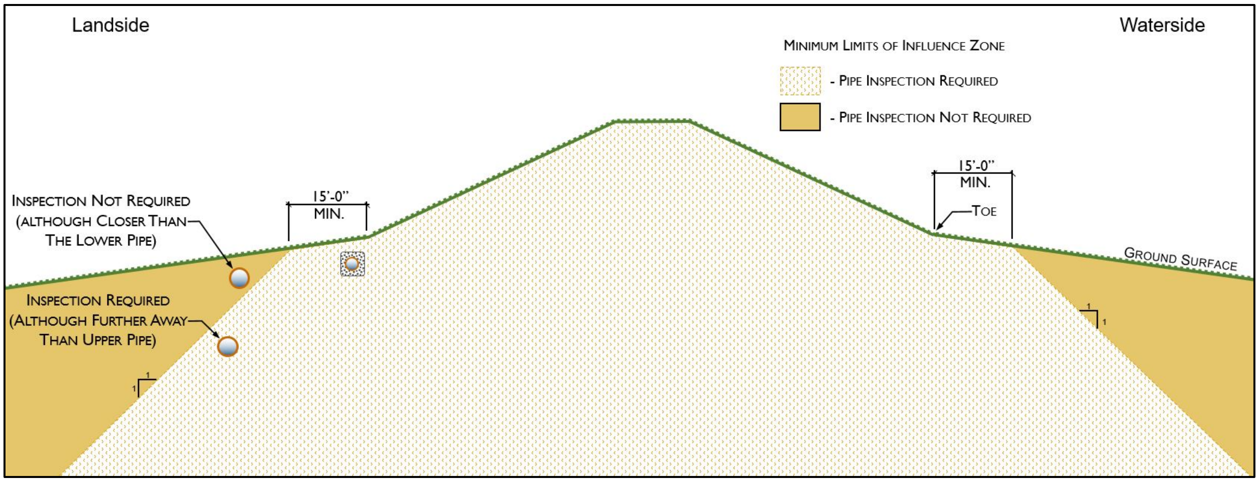


Figure 6-7. Gravity pipes adjacent to a levee.

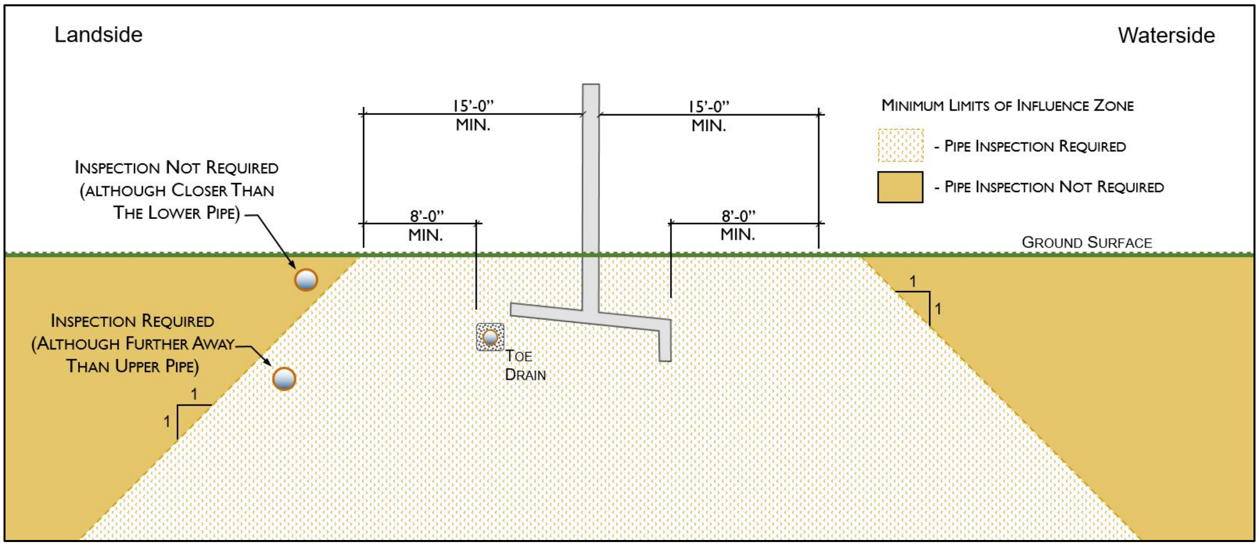


Figure 6-8. Gravity pipes adjacent to a floodwall (T-wall).

6.4.7. Discharge Pipes from Pump Stations (Through or Profile). Discharge pipes from pump stations are inspected from inside the pump station starting at the flange connection and ending at the end of the discharge line at the headwall/gatewell (Figure 6-9 and Figure 6-10). Pipe access is possible through outlet headwalls, gatewell discharge locations, and sometimes air vents/siphon breakers (Figure 6-11, reference Section 9.4.4.1.). The discharge pipes must be inspected from the pump station all the way to the outlet structure, regardless of whether they are interrupted by a gatewell. This applies to the entire waterside pipe length, even for the portion beyond the 15-foot limit/distance from the levee toe.

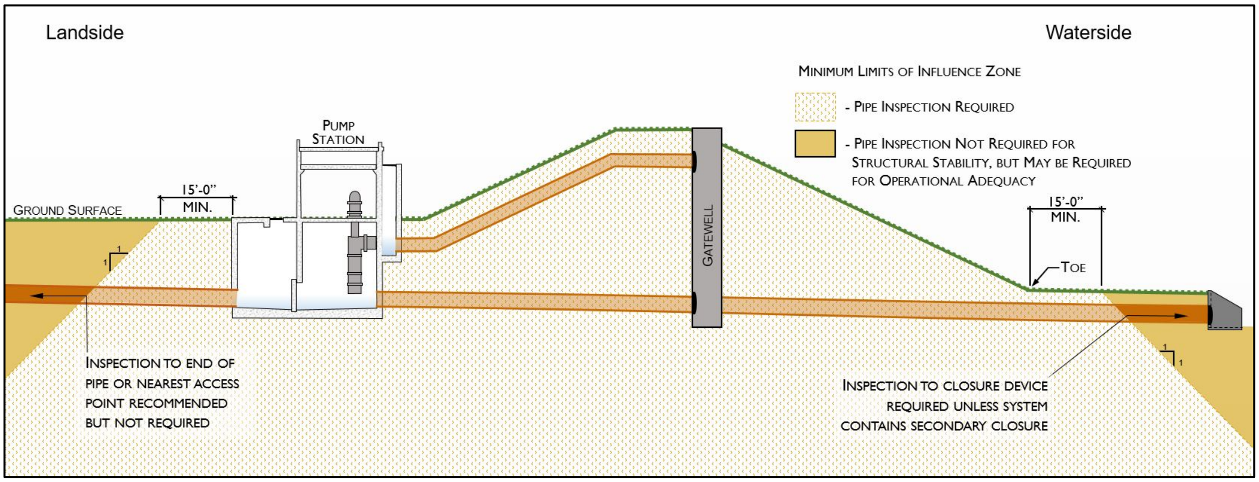


Figure 6-9. Pump station discharge pipes into gatewell.

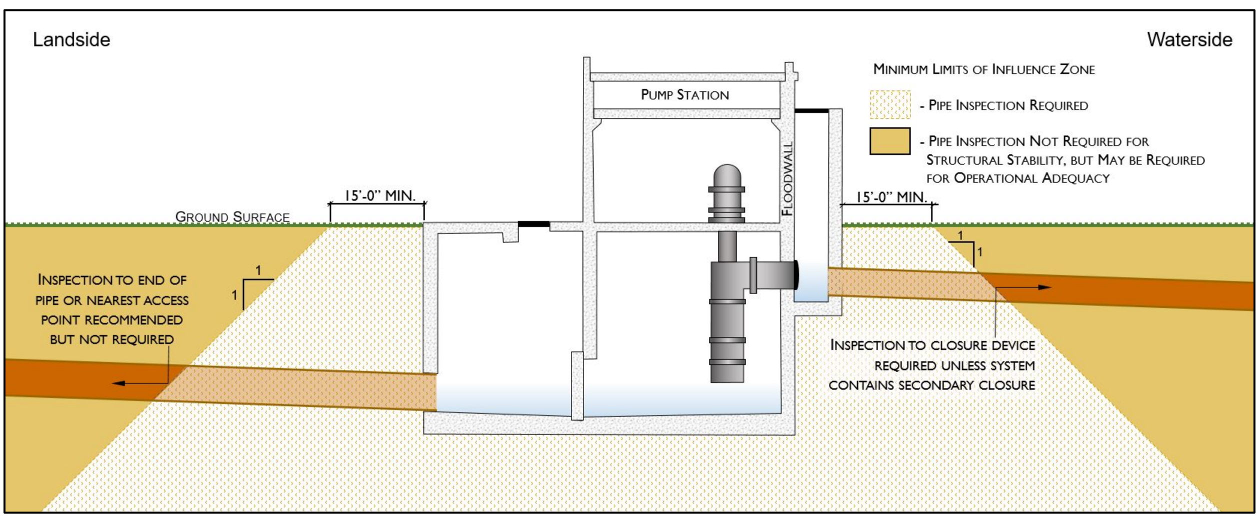


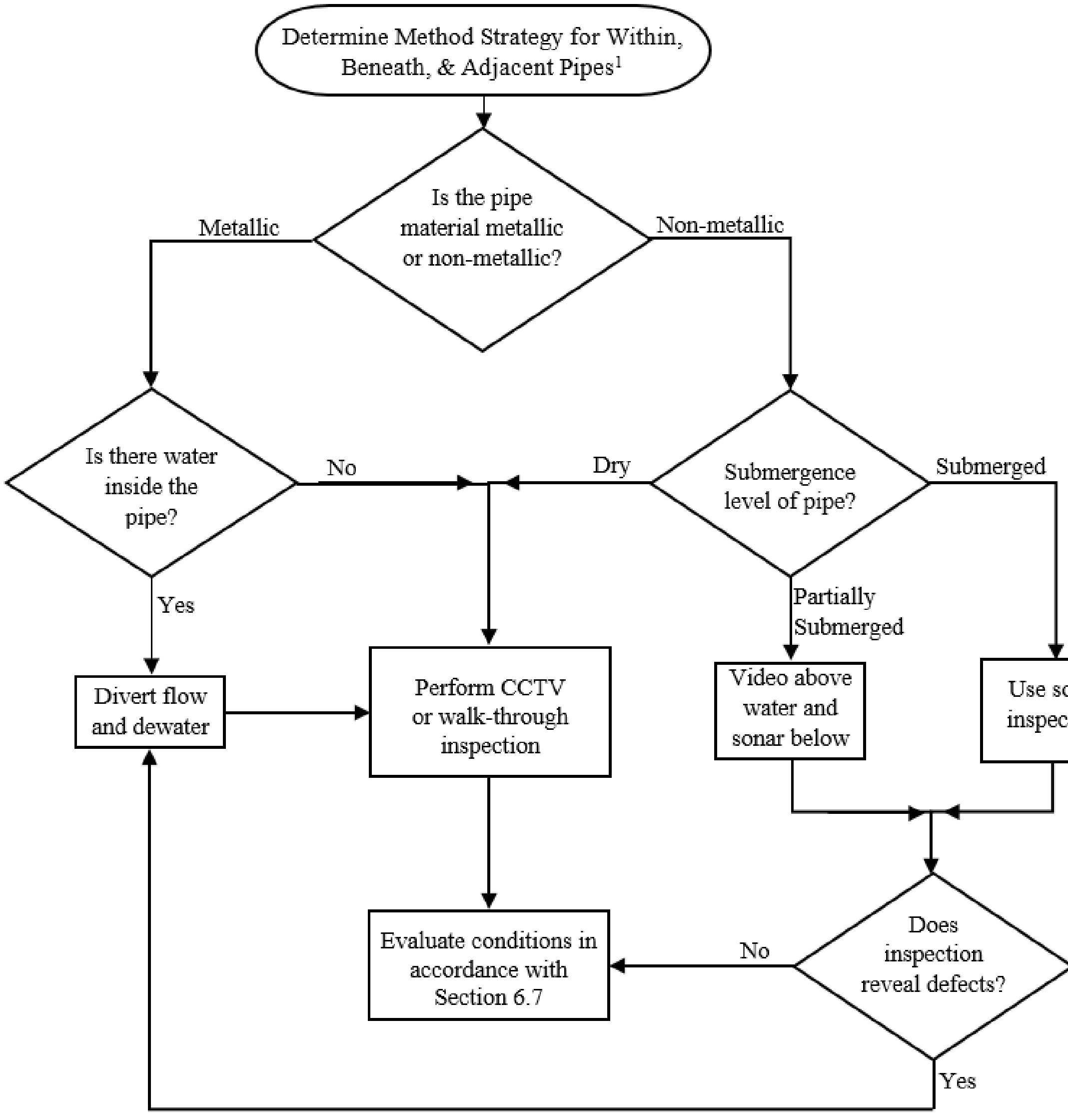
Figure 6-10. Pump station integral with floodwall and associated pipes.

(Courtesy of USACE Louisville District)
Figure 6-11. Potential inspection access points for pump station discharge pipes.

6.5. Inspection Methods.

6.5.1. General Planning. An inspector should consider the following before starting or scheduling a pipe inspection: high water may prevent access due to pumping operations or pipe submergence; freezing temperatures may produce ice within the pipe that hinders visibility or access; seasonal nesting or spawning of certain species inhabiting culverts could affect access; height of vegetation that could obscure visibility and hide ground surface defects; and sediment and debris can obscure the invert of the pipe, which is typically in the worst condition.

6.5.2. Pipe Size and Submergence Factors. Pipes less than 48 inches in diameter are typically considered too confined for a "walk-though" inspection and are therefore most often inspected using remote cameras or another comparable methods approved by the respective USACE District. Pipes larger than 48 inches in diameter are easier for man-entry but other factors, such as air quality, may necessitate or provide a preference for remote cameras. The appropriate inspection method is determined by the presence or absence of water in the pipe and the pipe material. Figure 6-12 is used to determine proper inspection methods based on the pipe material and setting.



Note 1: Excluding third-party pipes

Figure 6-12. Inspection method strategy for essential pipes.

6.5.3. Walk-through Method. When safe, a walk-through inspection is preferred for pipes associated with both dams and levees, since it provides the inspector the ability to touch and test areas of interest as well as make very accurate measurements. Flows up to six inches deep in the pipe invert can be tolerated when the water is clear enough that the condition of the bottom of the pipe can be seen. The direction of inspection should be conducted opposite of the flow, from downstream to upstream, to prevent creating turbid conditions that may obscure the invert. Walk through inspections for pipes both associated with dams and levees should be performed to the standards of National Association of Sewer Service Companies' (NASSCO) Pipeline Assessment Certification Program (PACP), or an organization with equivalent standards. Closed-circuit television (CCTV), video recording, or digital still photos should be used to document defects, as described in Section 6.4.

6.5.4. Remote Methods.

6.5.4.1. CCTV. Pipes with dry or nearly dry interiors can be remotely inspected using CCTV cameras mounted on tracked or wheeled vehicles. Push-type CCTV cameras can also be used to remotely inspect sloped or vertical pipes when access will not allow tracked or wheeled CCTV equipment. Metallic pipes (i.e., steel, aluminum, ductile iron, and cast iron) are subject to corrosion which can only be adequately observed when completely dewatered.

6.5.4.2. Sonar. Sonar is the preferred method for inspecting fully submerged non-metallic pipe (i.e., reinforced and non-reinforced concrete, vitrified clay, fiberglass reinforced, and plastic pipes) when it is not practical to dewater the pipe. However, the quality of the visual record obtained by sonar is less detailed than CCTV. A sonar inspection portrays offsets and distortions in the interior pipe profile as well as sediment build up in the pipe invert. As such, sonar will not clearly reveal the presence of fractures without offsets or open cracks with soil visible. Sonar inspections are rarely used on pipes subject to corrosion (i.e., steel, aluminum, ductile iron, and cast iron) due to the inability of sonar to determine surface corrosion without measurable section loss. Debris or sediment in the pipe will limit the sonar's capability to produce useful images. Pipes should be cleaned before a sonar inspection, if possible.

6.5.4.3. CCTV and Sonar Hybrid. Partially-submerged pipes that cannot be dewatered are inspected using CCTV inspection above water and sonar inspection below water. When sonar inspection of a submerged pipe indicates that the pipe cross-sectional profile deviates from the as-built condition, the pipe must be dewatered and CCTV inspected.

6.5.5. Advances in Technology. As new pipe inspection technologies become available, they will be considered as alternative methods for determining the internal condition of levee pipes. Proposed new methods of inspection must be approved by the respective USACE District prior to use to ensure adequate and accurate documentation can be captured and still provide protection of the pipes.

6.6. Inspection Requirements.

6.6.1. Walk-through Requirements.

6.6.1.1. Inspector Qualification. Inspectors must be trained and certified by the NASSCO PACP, or an organization with equivalent standards. Inspectors should also be knowledgeable about pipe design and installation, how pipe defects can lead to PFMs, and pipe joint and structure connection details. Inspectors should be familiar with site-specific details about the type of pipe, limitations of pipe joint movement, and plan and vertical alignment. The inspector should review construction and inspection history prior to the inspection.

6.6.1.2. Cleaning. Any pipe with debris, sediment, or other obstruction that inhibits the inspection of the pipe must be cleaned prior to inspection (reference Chapter 7).

6.6.1.3. Equipment and Tools. The following are required for walk-through pipe inspection:

6.6.1.3.1. Inspection Form. Inspection form for documenting inspection and pipe defects (reference Section 6.7).

6.6.1.3.2. Permits. All appropriate permits (if applicable) in addition to air monitoring, communication, and rescue equipment required for safe entry. This includes confined space training and equipment when necessary.

6.6.1.3.3. Light Source. Bright, high intensity light source, preferably intensity-adjustable to provide visual clarity of defects. Lighting during the inspection should be adequate to fully illuminate, but not overly illuminate, the entire pipe. Excessive lighting or an overly-adjusted camera iris can result in a flaring of the image and exaggeration of pipe joint displacement or other pipe conditions.

6.6.1.3.4. Camera. Camera to document all defects with digital video and/or still photos.

6.6.1.3.5. Measurements. Method for determining the distance from the entry point (i.e., headwall, manhole, or sluice gate) to the nearest 0.1 foot for accurate location of defects within the pipe.

6.6.1.3.6. Global Positioning System. Global Positioning System equipment capable of determining coordinates of the inlet and outlet locations to six-decimal accuracy, preferred in decimal format (e.g., 38.845972 instead of 38˚ 50' 45.5"). Ensure sufficient satellite connection before recording readings.

6.6.2. Remote Requirements.

6.6.2.1. Inspection Operator Qualifications. The individual performing the inspection is required to demonstrate their qualifications by providing training and experience records. Individuals operating the remote inspection equipment must be trained and certified by the NASSCO PACP, or an organization with equivalent standards. A minimum of one year of experience with pipe inspections using the NASSCO's PACP or an equivalent industry standard is required. It is recommended that personnel demonstrate experience with levee or dam pipes. All inspections using remote equipment are required to meet the minimum visibility and operation requirements of NASSCO's PACP or an equivalent industry standard.

6.6.2.2. Cleaning. Debris, obstructions, and sediment must be cleaned to provide an unobstructed view of the pipe's interior before video or other remote inspections are conducted. CCTV inspection is adequately accomplished through shallow depths (up to four to six inches) of clear water. If the water is turbid or too deep to permit a clear view of all pipe and joint surfaces, dewatering or diversion is required. Reference Chapter 7 for more information on cleaning pipes.

6.6.2.3. CCTV. CCTV is required to have the following capabilities or features to execute and record the inspection. Additional pipe inspections using specialized equipment may be required to document specific measurements (e.g., detected offset joints or metal loss due to corrosion).

6.6.2.3.1. Light Source. Bright, high-intensity light source that travels with the camera. Ability to control the light intensity to control glare is an important feature that can improve the quality of the video images. Lighting during the inspection must be adequate to fully illuminate, but not overly illuminate, pipe joints and individual points of interest (at a right angle to the direction of travel) for an accurate assessment. Excessive lighting or an overly-adjusted camera iris can result in a flaring of the image and exaggeration of pipe joint displacement or other pipe conditions.

6.6.2.3.2. Camera. Color, high definition (720p or better) resolution camera with remote focus, zoom, pan, and tilt capability.

6.6.2.3.3. Video. Video image digitally recorded using a current digital multimedia video format.

6.6.2.3.4. Measurements. Footage meter with capability to record footage reading on the video at all times. Ability to record and display distance from starting point within 0.1-foot accuracy.

6.6.2.3.5. Travel speed. Maximum travel speed through the pipe not exceeding 25 feet per minute.

6.6.2.3.6. Still Images. Ability to take still images in .jpg or .png format of all significant defects observed during the inspection.

6.6.2.3.7. 360-degree Joint Views. Ability to stop traversing and record a 360-degree view of each joint.

6.6.2.3.8. Defect Recording. Ability to stop traversing if any defects are suspected and record a detailed video inspection.

6.6.2.4. Sonar. Sonar equipment must be specifically adapted using multi-frequency sound waves to locate and map irregularities by creating continuous sonar images recorded in "real time" mode. Sonar equipment must utilize digital, multi-frequency profiling in order to model the submerged portion of the pipe. Using a rotating transducer, the sonar unit must transmit an acoustic signal toward the pipe walls in a radial fashion. The time delay between transmission and reception of reflected pulse echo is used to determine the distance from the transducer to the surface that reflected the pulse.

6.6.2.5. CCTV and Sonar Hybrid. Inspection equipment must be positioned in the pipe according to the manufacturer's recommendations and able to complete a 360-degree inspection of the pipe circumference at one-inch intervals along the length of the pipe. During the inspection, the following information must be clearly and continuously displayed on the periphery of the screen, monitor, and CCTV recording: starting location ID, ending location ID, and distance from access point.

6.7. Inspection Documentation.

6.7.1. General. Pipe inspections must be documented either using an inspection form during a walk-through inspection similar to the one shown in Figure 6-13 or a digital program that records the pipe condition during a remote inspection. For both walkthrough and remote inspections, PACP (or equivalent) ratings must be used to rate the defects of the pipe. Below is a list of the information that is required to be obtained as part of a pipe inspection and provided in a report for each pipe:

- Narrative report (Section 6.7.2)
- Date of inspection
- Inspector(s) name(s)
- Nearest dam or levee as-built station number to pipe that is being inspected
- Coordinates of the inlet and outlet locations to six-decimal accuracy, preferred in decimal format (e.g., 38.845972 instead of 38˚ 50' 45.5")
- Segment length (from inside wall of adjacent manholes to nearest 0.1 foot)
- Description of pipe purpose
- Type of pipe (material, diameter, shape, segment length)
- Inspection method (walk-through or remote inspection)
- Inside diameter of pipe
- Defect, PACP (or equivalent) rating
- Clock position of defect relative to the position of the hour hand of a clock
- Distance from reference (starting) end of pipe
- Defect measurements to establish height, width, and depth, if possible
- Picture of each defect

6.7.2. Narrative Report. The CCTV and/or sonar operator/inspector must provide a brief narrative report that summarizes the following for each pipe inspected: the pipe location; start and end points; conditions of the inspection; equipment used; general condition of the pipe; and specific defects with location.

6.7.3. Submittals. Regardless of whether an inspection is performed by an inspection company or a USACE District, a digital report must be developed (and submitted, in the case of an inspection company) including the documentation in Section 6.4., paper inspection log (similar to Figure 6-13) or digital inspection log (similar to Figure 6-14 and meeting requirements of NASSCO's PACP or organization with equivalent standards), narrative report (Section 6.7.2.), and inspection video. The inspection video must be configured in a current digital multimedia video format. Digital files must be configured to have the ability to use all features of the CCTV player, including fast forward capability. Submission should include all raw and native data formats. The following items must be submitted after completion of all required inspection activities:

- Clearly labeled and organized electronic inspection videos.
- Electronic still-capture pictures and/or sonar images of significant defects.
- Printed and/or electronic inspection form or logs with information noted in Section 6.4. (Figure 6-13 and Figure 6-14).
- Aerial map locating deficiencies with the as-built pipe stationing or local name of culvert (Figure 6-15). The location of the embankment waterside and landside toe, or location of the floodwall centerline, must be clear and/or labeled on the aerial map. The map must also show the direction of CCTV camera travel. Sonar inspection defects are also mapped in a similar manner.
- A summary table showing the stationing and results of each pipe inspection rating based on NASSCO's PACP or equivalent industry standard.

SEGMENT/SYSTEM NAME:	

Inspection Details

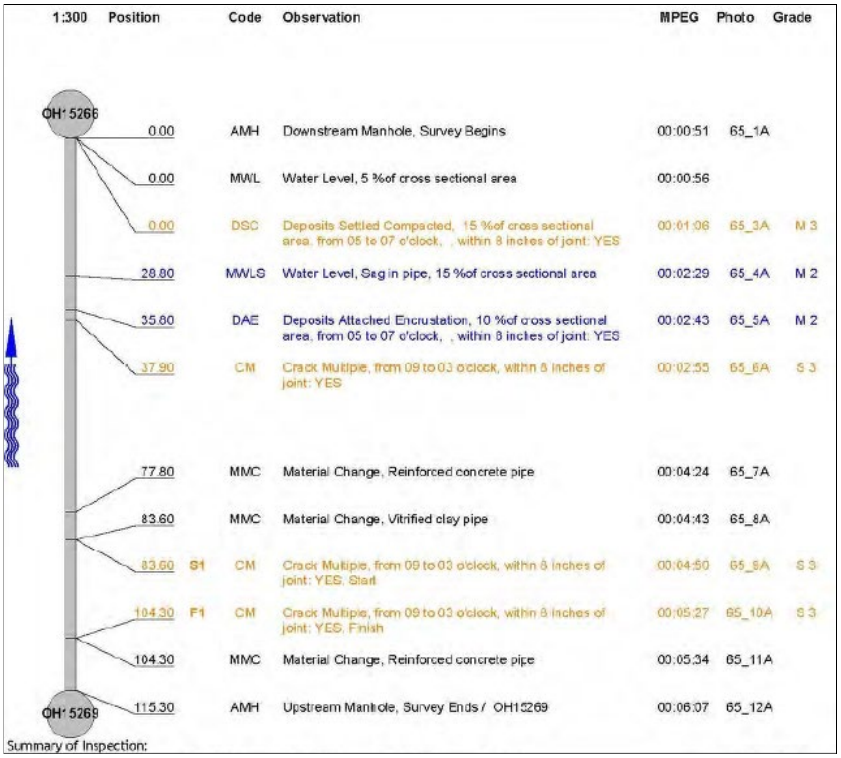
Inspected by (Name, Certification):		
Description:		
Station:		Date of Inspection:
Type of Pipe:	Segment length (e.g. from inside wall of adj. manholes):	Pipe Diameter:
Inlet Coordinates:	Outlet Coordinates:	Accuracy:
Inspected via:		
Sketch (Path of Inspection, approx. Location of defect, location of pipe in relation to river portion of pipe under levee, etc.)		

Deficiency Details

PACP Defect Code	Location (ft.):	Time Stamp	Comments	Photo	Clock Position
Results Summary:					

Rating:	

Figure 6-13. Example inspection form for use during a walk-through inspection.



1:300	Position		Code	Observation	MPEG	Photo	Grade
OH15268	0.00		AMH	Downstream Manhole, Survey Begins	00:00:51	65_1A	
	0.00		MWL	Water Level, 5 %of cross sectional area	00:00:56		
	0.00		DSC	Deposits Settled Compacted, 15 %of cross sectional area, from 05 to 07 o'clock, , within 8 inches of joint: YES	00:01:06	65_3A	M 3
	28.80		MWLS	Water Level, Sag in pipe, 15 %of cross sectional area	00:02:29	65_4A	M 2
	35.80		DAE	Deposits Attached Encrustation, 10 %of cross sectional area, from 05 to 07 o'clock, , within 8 inches of joint: YES	00:02:43	65_5A	M 2
	37.90		CM	Crack Multiple, from 09 to 03 o'clock, within 8 inches of joint: YES	00:02:55	65_6A	S 3
	77.80		MMC	Material Change, Reinforced concrete pipe	00:04:24	65_7A	
	83.60		MMC	Material Change, Vitrified clay pipe	00:04:43	65_8A	
	83.60	S1	CM	Crack Multiple, from 09 to 03 o'clock, within 8 inches of joint: YES, Start	00:04:50	65_9A	S 3
	104.30	F1	CM	Crack Multiple, from 09 to 03 o'clock, within 8 inches of joint: YES, Finish	00:05:27	65_10A	S 3
	104.30		MMC	Material Change, Reinforced concrete pipe	00:05:34	65_11A	
OH15269	115.30		AMH	Upstream Manhole, Survey Ends / OH15269	00:06:07	65_12A	

Summary of Inspection:

Figure 6-14. Example digital log from remote inspection.

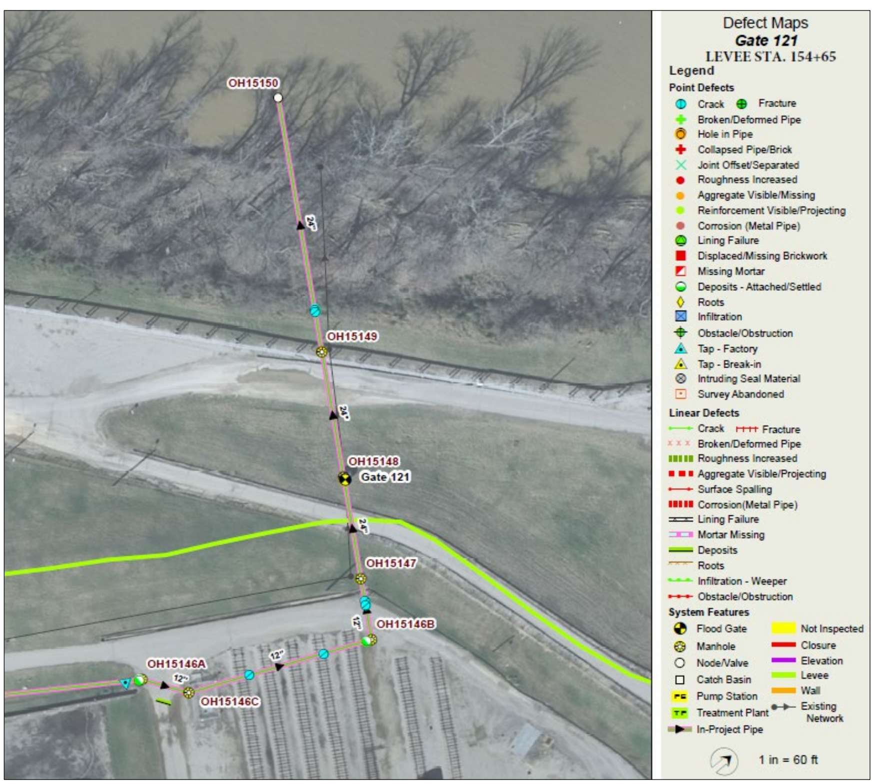


Figure 6-15. Example aerial map.

6.8. Condition Assessment.

6.8.1. General. Once the respective USACE District office has completed or received the submittals listed in Section 6.7.3, a USACE condition assessor will perform an assessment of each pipe based on the pipe inspection documentation (Section 6.8). There is no specific format needed for this assessment, but the individual pipe condition ratings should be shared with the project owner to facilitate the development of a cooperative prioritized mitigation plan (Section 6.9). For pipes associated with levees, each pipe's condition assessment, along with external conditions observed during an inspection, will be used to rate the overall condition of the pipes (based on the worst graded pipe in the system) according to the current levee inspection guidelines.

6.8.2. Condition Assessor Qualifications. The condition assessor assigned to determine the pipe inspection rating is typically a USACE engineer or other qualified person adequately trained and experienced to ensure appropriate and consistent ratings are assigned for each pipe inspection. Assessors must be certified by NASSCO's PACP or an equivalent industry standard; NASSCO maintains a category of structural defects specifically related to levees and dams. Because of the potential consequences, the acceptance standards for pipes associated with dams and levees are more stringent than those for storm or sanitary sewers not in dams or levees. Assessors should have the ability to review the dam or levee system as-built drawings and specifications before reviewing the inspection reports and inspection video or assigning a rating for each pipe.

6.8.3. Pipe Condition Assessment Grade. The condition assessor will use the inspection report along with the defects to determine the overall condition for each pipe. The condition assessor must determine the portion of the pipe that is likely to impact the structural integrity and operational adequacy of the dam or levee (reference Section 6.4); pipe defects within the portion of the pipe determined to be relevant by the condition assessor can generally be graded in correlation with the highest PACP (or equivalent rating system) structural defect grade. Whenever necessary, the condition assessor will use his or her training and experience to assign the most appropriate structural or O&M rating, which may differentiate from the recommended ratings in Table 6-1 and Table 6-2. For pipes associated with levees, each pipe's latest recorded condition assessment, along with external conditions observed during an inspection, will be used to assign the overall inspection item rating for pipes in the USACE levee inspection checklist.

Table 6-1
PACP structural defect grade correlation to required action

Defect Codes per NASSCO PACP [1] or other Organization with Equivalent Standards (reference Section 6.3 for inspection limits)		NASSCO PACP Defect Grade for Dams and Levees	Required Action
- Any crack hinge code - Any fracture, broken, or hole code - Collapse - Any flexible deformation > 10% - Any brick deformation ≥ 10% - Any rigid deformation Code - Any joint offset, separated, or angular code - Dropped invert	- Any weld failure code - Any point repair defective code - Missing brick - Any surface damage reinforcement code - Missing mortar medium and large - Surface damage missing wall - Surface damage corrosion (without further inspection or section loss ≥ 25%)[2]	4 or 5	Mitigate
- Crack longitudinal, multiple, or spiral - Any flexible deformation ≤ 10% - Any brick deformation < 10% - Displaced brick - Surface damage corrosion (with inspection and section loss < 25%)[2]	- Surface damage surface spalling - Any point repair code (non-defective) - Any surface damage aggregate code - Missing mortar small - Any lining feature code	3	Monitor
All other codes		1 or 2	Continue Inspection Frequency

[1]Defect codes are explicitly defined by the latest version of NASSCO's PACP manual. Some codes only pertain to specific pipe materials, while others indicate a location within a pipe segment.
[2]Additional inspection is recommended for observed corrosion to determine the extent of section loss using devices to measure remaining pipe wall thickness (e.g. ultrasonic thickness measuring instrument).

Table 6-2
PACP O&M defect grade correlation to required action

Defect Codes per NASSCO PACP [1] or other Organization with Equivalent Standards (reference Section 6.3 for inspection limits)	NASSCO PACP Defect Grade for Dams and Levees	Required Action
- Any deposits code ≥ 25% blockage - Any roots medium or ball code - Any infiltration runner or gusher code - Any obstruction code ≥ 25% blockage - Any intruding seal code ≥ 25% - Any tap defective code	4 or 5	Maintenance & Repair
- Any roots tap code - Any obstruction code 15% - 20% blockage - Any intruding seal code 15% - 20% blockage - Any tap intruding code - Any deposits code 15% - 20% blockage - Any infiltration dripper code	3	Monitor
All other codes	1 or 2	Continue Inspection Frequency

[1]Defect codes are explicitly defined by the latest version of NASSCO's PACP manual. Some codes only pertain to specific pipe materials, while others indicate a location within a pipe segment.

6.8.4. Required Mitigation and Maintenance of Pipes Graded 4 or 5. Pipe mitigation measures to correct structural defects include repair, rehabilitation, removal (with or without replacement), or decommissioning. Other pipe defects may be able to be corrected through routine maintenance (e.g., jetting, root and ice removal per Section 7.4). A pipe condition assessment will aid in choosing the most appropriate measure; however the following criteria must be considered:

6.8.4.1. Collapsed Pipes. Pipes that have collapsed per the latest version of the NASSCO's PACP manual cannot be rehabilitated or decommissioned and must be removed (and replaced, as necessary).

6.8.4.2. Pipes Exceeding Maximum Deflection. Pipes that have exceeded their maximum percent deflection per Table 4-1 but have not yet collapsed should be rehabilitated (reference the slip lining methodologies describe in Section 7.5.2).

6.8.4.3. Internal Soil Erosion or Voids. If internal soil erosion or voids adjacent to an existing pipe are identified during an inspection or are strongly suspected through the observation of surface depressions or sinkholes, the probability of PFM-1 and PFM-3 occurring eliminates repair, rehabilitation, and decommissioning as reasonable alternatives and the pipe must be removed (and replaced, as necessary). In some cases, pressure grouting of voids adjacent to the pipe may be authorized as an interim risk reduction measure (or for emergency repair) while other alternatives are evaluated; however it must follow the regulations outlined in ER 1110-1-1807. When alternate mitigation options are not practical from a cost or technical perspective, pressure grouting may be the only feasible long-term option.

6.8.4.4. Mitigation Methods. Refer to Chapter 7 for further information on pipe repair and rehabilitation, and Chapter 8 for removal and decommissioning.

6.9. Prioritized Mitigation Plan.

6.9.1. General. Levee sponsors often face the challenge of maintaining or extending the life of project-related pipes using limited resources, and therefore need to prioritize their efforts to address pipes that pose the most risk. USACE and levee sponsors should work together to develop and continuously update a planned approach to manage all levee-related risk, including pipes. Typically, the risk management strategy for pipe mitigation is initially limited to a pipe-focused prioritization plan that would not consider risk from any other sources, a point that must be clearly communicated to the sponsor. This prioritized pipe list can then be used to help determine the order of overall management activities for the levee.

6.9.2. Evaluating Risk.

6.9.2.1. Overview. A pipe-focused risk management strategy prioritizes mitigation efforts by considering several aspects of each pipe and targeting actions that efficiently lower risk rather than relying solely on condition assessment results. As covered in Chapter 2, risk is a function of the probability of a certain hydraulic loading, response of the project to that loading, and the consequences of failure while loaded.

$$\text{Risk} = \overbrace{\text{Likelihood of Loading} \times \text{Likelihood of Poor Performance}}^{\text{Likelihood of Failure}} \times \text{Consequence of Failure}$$

The term "likelihood of failure" is often used to consolidate the loading and performance terms and is necessary for plotting risk. Based on this equation, the chance of flood loading and the associated consequences are both given equal weight to the condition of the pipe, which means that mitigating a pipe with a better rating over one with a worse rating may provide more risk reduction because that pipe is more frequently loaded and has higher associated consequences.

6.9.2.2. Considerations for Evaluation. To create a preliminary prioritized mitigation plan for the pipes in a levee system, the time and money required to produce a detailed and comprehensive mitigation plan must be replaced by prompt and sound engineering judgment based on available information. The following aspects of the pipe and system must be considered during prioritization to help the levee sponsor manage mitigation funds in the most efficient manner:

6.9.2.2.1. Condition. A pipe with a greater number of higher graded structural defects will have a higher likelihood of causing a levee failure; this includes associated structures and appurtenances (reference Chapter 9). This consideration informs the performance variable and will require the most engineering judgment to evaluate.

6.9.2.2.2. Return Frequency. The flood return frequency for the landside invert elevation will determine when it is possible that water may begin uncontrolled flow into the leveed area through or around a specific pipe. A pipe that is loaded more frequently is usually more likely to fail than one that is loaded less frequently, and is more likely to cause consequences than pipes founded higher in elevation. Once determined, these values should not require reevaluation for future prioritization plans unless significant watershed changes occur.

6.9.2.2.3. Topography. Where detailed inundation mapping is unavailable, it may be necessary to roughly estimate from existing topographic information. Questions to consider include the following: if water does flow through the pipe into the leveed area, will it immediately begin to spread and inundate a wide area? Will it remain within a drainage channel and at what return frequency will the water exceed the channel and begin to inundate a larger area? Are there return frequency break points where inundation significantly changes? And, will flow through pipes located near the upstream end of the system cause overland flow towards the downstream end of the leveed area? These are hydraulic loading considerations that may also impact consequence considerations.

6.9.2.2.4. Location. What is the pipe's proximity to critical infrastructure (i.e., hospitals, schools, airports, military facilities), and could uncontrolled flow cut off evacuation routes or endanger lives? What is the population at risk for different water levels? Is the pipe located on the upstream end where a breach could produce higher flow velocities through populated areas as it follows the downstream grade, or is it near the downstream end of the system where a breach would typically cause backwater flooding to a lower level? These considerations relate to consequences.

6.9.2.2.5. Diameter. Pipes with larger diameters are generally considered harder to flood fight unless an accessible gatewell exists where sandbags or other suitable material can be introduced to stop or greatly reduce the flow. This informs both the performance and loading variables since the percentage of the pipe's cross-sectional area passing water must be considered.

6.9.2.2.6. Filtering. Was an internal seepage filter (reference Section 5.5.9.3) installed around the pipe to address PFM-1? A filter will not stop flow that enters the pipe, but it can address seepage along the pipe.

6.9.2.2.7. Cost. Once developed, the preliminary prioritized pipe mitigation plan must then be balanced with the cost of addressing each pipe and the levee sponsor's budget constraints. Depending on the cost disparities associated with properly addressing each pipe, it is possible that the pipe presenting the most risk will not be addressed first. A simplified pipe-focused prioritized mitigation plan is shown in Figure 6-16.

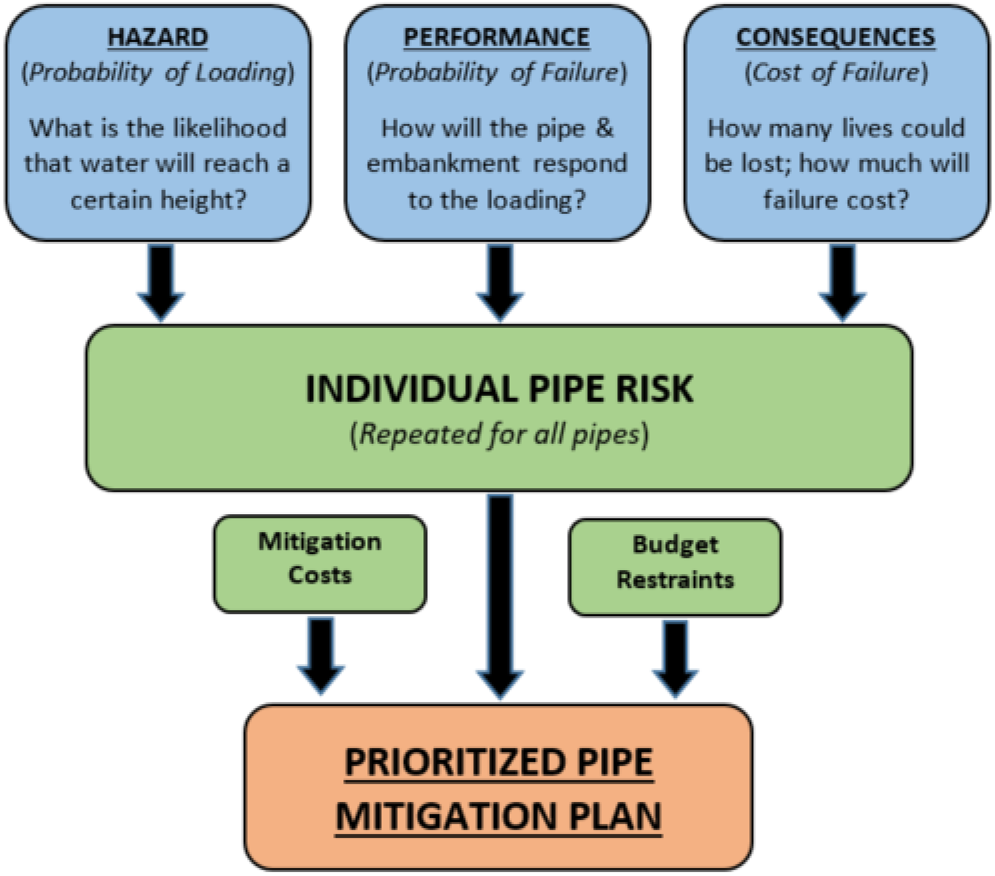
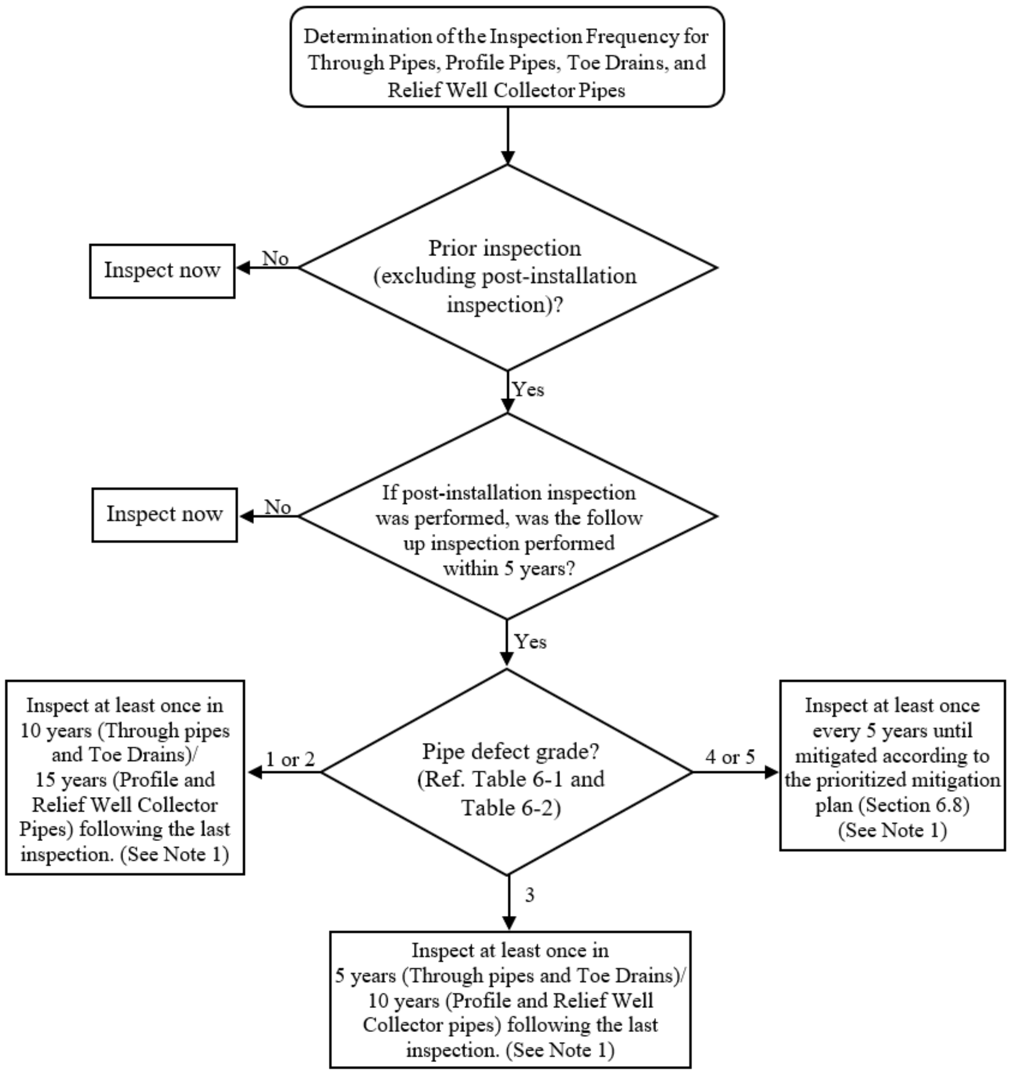


Figure 6-16. Example risk management approach to a prioritized mitigation plan.

6.10. Inspection Frequency.

6.10.1. Essential Pipes. Essential pipes must be inspected at recurring intervals; the limits of those inspections for levees are covered in Section 6.4, dam essential pipes must be inspected in their entirety. The intervals between inspections indicated in Figure 6-17 may be more frequent based on consideration of the factors listed in Section 6.9.2.2, but may not be extended. In addition to these factors, the respective USACE District or levee sponsor may determine an unscheduled inspection is required during a flood event, after a flood or seismic event, or because of sabotage or other unusual events. A post-installation inspection is required immediately after installing a new pipe system, and a follow-up inspection is required within the first 5 years since the continued consolidation of the surrounding soil may shift the pipe alignment and compromise pipe connections. After the follow-up inspection, the frequency for future inspections will be determined by the pipe's condition assessment rating (Figure 6-17). Updates or changes to pipe inspection frequencies must be included in the project's operations and maintenance manual when revised.



Note 1: Reference Section 6.8.2.2. 6.8.2.2. for factors that may be considered to adjust inspection frequencies. The intervals shown in the boxes related to the PACP grades are maximums and must not be exceeded.

Figure 6-17. Inspection frequency determination for essential pipes within levees.

6.10.2. Nonessential Pipes. Typically, nonessential pipes are third-party pipes, such as utility pipes or crossings, that are neither owned nor operated by the levee sponsor or USACE. The most common third-party pipes are for water distribution, force-main sewers, gravity sewers, natural gas distribution, and hazardous liquid transmission. Some third-party pipes serve as casings for utilities (electric, fiber optics, etc.) and cross levees within a larger casing pipe. Neither the utility carrier pipe nor its larger casing pipe requires regular inspections as long as the ends of the larger casing pipe are sealed and the utility carrier pipe is continuous. The inspection requirements and frequency for nonessential pipes are either governed by a specific Code of Federal Regulations (CFR) or a mutually agreed upon arrangement between the pipe owner, the levee sponsor, and USACE. Gas pipelines and hazardous liquids transmission pipelines are regulated under 49 CFR Parts 192 and 195, respectively, and their inspections are determined by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. Inspection intervals for new third-party pipes crossing a levee that are not regulated under a CFR will be established as part of the approval documents through the 33 USC 408 process. USACE Districts should work with existing third-party pipe owners and the levee sponsor to establish pipe inspection schedules. USACE Districts should use the third-party inspection information to assess and assign the pipe condition ratings and ensure any recommended actions are communicated to the appropriate pipe owner through the levee sponsor.