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Volume 6, Chapter 14

Culverts / Drains Maintenance Plan

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1.0 PURPOSE

Successful maintenance planning of culvert and drains relies on conducting maintenance at the right time to the right level such that the performance may be optimized and equipment life may be maximized.

The purpose of this document is to provide the Entity with principles and guideline for developing and improving maintenance management plans for culvert and drains. These are minimum requirements for the maintenance, inspection, repair, and rehabilitation of common and typical culverts and drains. The Entity shall modify the requirements specific to its maintenance needs.

The maintenance, inspection, repair, and rehabilitation shall conform to requirements detailed in Section 5.0 - Codes, Standards, and References and any specific Entity maintenance requirements.

2.0 SCOPE

The scope of this document is to provide guidelines to improve and enhance current practices and develop new maintenance plans for managing effective maintenance regimes and improving the Entity maintenance team's quality assurance and quality control.

The maintenance requirements provided herein, or cited by reference, are based on the American Association of State Highway and Transportation Officials (AASHTO), industry standards, and best practice that should be embraced by the relevant Entity.

Furthermore, this document covers:

- An understanding of following roadway elements:
  - Culverts
  - Drains
- Civil and structural engineering aspects of the asset
- Civil and structural engineering requirements for existing culverts and drains through the following life cycle stages:
  - Maintenance
  - Inspection
  - Repair
  - Rehabilitation
- Minimum technical requirements to be adopted by the Entity and/or Contractors to enable safety, quality, and cost effectiveness in the maintenance, repair, and rehabilitation of culverts and drains assets that meet the needs and expectations of the relevant Entity
- Set procedures for the continuous maintenance, care, and performance efficiency of the structural components of the existing culverts/drains

3.0 DEFINITIONS

Term	Definition
Confined Space	The space with limited access and egress
Culvert	A structure that provides passage of water or utilities through an embankment/roadway. (Usually with a clear opening of less than 6.1m)
Culvert Management System (CMS)	A computerized tool that keeps all data for the culvert assets and allows informed decisions to be made regarding the management of these culverts
Design Life	The period for which the element has been designed to withstand the combined effects of all the deteriorating forces to which it may reasonably be expected to be exposed before it becomes more economical to replace the element than to repair it assuming that regular maintenance is undertaken
Detailed Inspection	An in-depth inspection is a close-up inspection by one or more members above or below the water level to identify any deficiencies not readily detectable using routine inspection procedures
Emergency Maintenance	Maintenance activity on a culvert to rectify the danger to the public and restore culvert/culvert components serviceability after an emergency event

Term	Definition
Inspection	The evaluation of the condition of an asset(s) through a formally defined and controlled process. The process shall include all relevant information, site inspection surveys, and analytical assessments where required by this document or any other standard
Load Rating/ Culvert Assessment	The culvert or its components dead and live load carrying capacity
Maintenance	The undertaking of planned or unplanned action, or both, including repairs, to ensure that the condition of the asset continues to meet the required duty over the service life of the asset
Performance Deficiency	State of the culvert that makes it perform ineffectively due to which it requires repairs and monitoring of culvert/components of culvert
Planned Maintenance	A planned strategy of cost-effective treatments to an existing culvert and culvert systems/components that preserves the culvert asset, retards future deterioration, and maintains or improves the functional condition of the culvert (without substantially increasing structural capacity)
Rehabilitation	Rehabilitation restores culvert/culvert component integrity and ceases the reason of the damage to the culvert component. Because rehabilitation includes addressing the cause of the problem itself, it lasts significantly longer
Repair	Repair techniques are used to restore the structural integrity and shape of culvert elements such as carrying out works on damaged concrete or unsafe depressions
Service Life	The service life of an asset, element, or component is the total period during which the asset remains in use. Maintenance can extend the service life of an asset
Strengthening and Renewal	Strengthening and renewal work shall be corrective action to address life-expired assets or elements in accordance with the supplier's program for lifecycle management or a change in use, function, or duty of the asset or element
Visual Inspection	Close inspection of all parts of the structure carried out within touching distance
Acronyms	
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACR	Asset Condition Report
ADT	Average Daily Traffic
CAPEX	Capital Expenditures
CCTV	Closed Circuit Television
HSSE	Health, Safety, Security, and Environment
LFRD	Load and Resistance Factor Design
MOMRA	Ministry of Municipal and Rural Affairs
NCHRP	National Cooperative Highway Research Program
OPEX	Operational Expenditures
PVC	Polyvinyl Chloride
SAR	Saudi Arabian Railway

Table 2: Definitions

4.0 REFERENCES

The maintenance requirements provided herein, or cited by reference, are based on the following industry standards and best practices:

- American Concrete Institution (ACI 3rd Edition) – Concrete Repair Manual
- American Concrete Institution (ACI 562-19) – Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary
- Kingdom of Saudi Arabia Ministry of Municipal and Rural Affairs (MOMRA), General Directorate of Operation and Maintenance – Bridges and Tunnels Maintenance Manual – Chapter 8

- Minnesota Department of Transportation, January 2014 – Culvert Repair Best Practices, Specifications, and Special Provisions – Best Practices Guidelines
- National Manual of Assets and Facilities Management - Volume 2: Asset Management
- National Manual of Assets and Facilities Management - Volume 3: Condition Assessment
- National Manual of Assets and Facilities Management - Volume 4: Financial Planning
- National Manual of Assets and Facilities Management - Volume 6, Chapter 4: Maintenance Management
- National Manual of Assets and Facilities Management - Volume 7: Work Control
- National Manual of Assets and Facilities Management - Volume 10: Health, Safety, Security, and Environment (HSSE)
- National Cooperative Highway Research Program (NCHRP 14-26) – Culvert & Storm Drain System Inspection Manual
- National Cooperative Highway Research Program (NCHRP 15-54) – AASHTO Culvert Load Rating Specifications
- New York State Department of Transportation, May 2006 – Culvert Inventory and Inspection Manual
- Nevada Department of Transportation, August 2017 – Storm Water Operations & Maintenance Plan
- Texas Department of Transport, August 2009 – Culvert Rating Guide
- The American Association of State Highway and Transportation Officials (AASHTO) – Culvert and Storm Drain System Inspection Guide
- The American Association of State Highway and Transportation Officials (AASHTO 2007) – Maintenance Manual for Roadways and Bridges
- U.S. Department of Transportation, Federal Highway Administration (FHWA), May 1995 – Culvert Repair Practices Manual – Volume 1
- U.S. Department of Transportation, Federal Highway Administration (FHWA), May 1995 – Culvert Repair Practices Manual – Volume 2

5.0 RESPONSIBILITIES

All staff and suppliers carrying out operation, inspection and maintenance activities shall be suitably experienced, qualified and competent to undertake these tasks. The Entity and the specialized Contractors/Operators shall have:

- An organizational structure having adequate staff with clear roles, responsibility, and competency to effectively oversee and monitor the operation and maintenance activities and works
- A competence management system in accordance with the published guidance and standards for operations and maintenance of the assets
- Continuous training programs on developing and maintaining staff competence

6.0 PROCESS

The Entity shall establish and develop set process and procedures for continuous maintenance and performance efficiency of the culverts. The comprehensive culvert maintenance plan shall employ actions and strategies (Refer Figure 1) to preserve the service life of culverts.

Following key components shall be considered in the plan for effective maintenance of the culverts:

- Development of a Culvert Maintenance System (CMS) tool in order to assist asset managers in managing culvert assets
- Effective routine and planned maintenance program
- Inspection schedule and reporting
- Effective emergency maintenance
- Timely and good practice with regards to repair, rehabilitation, and replacement of culverts

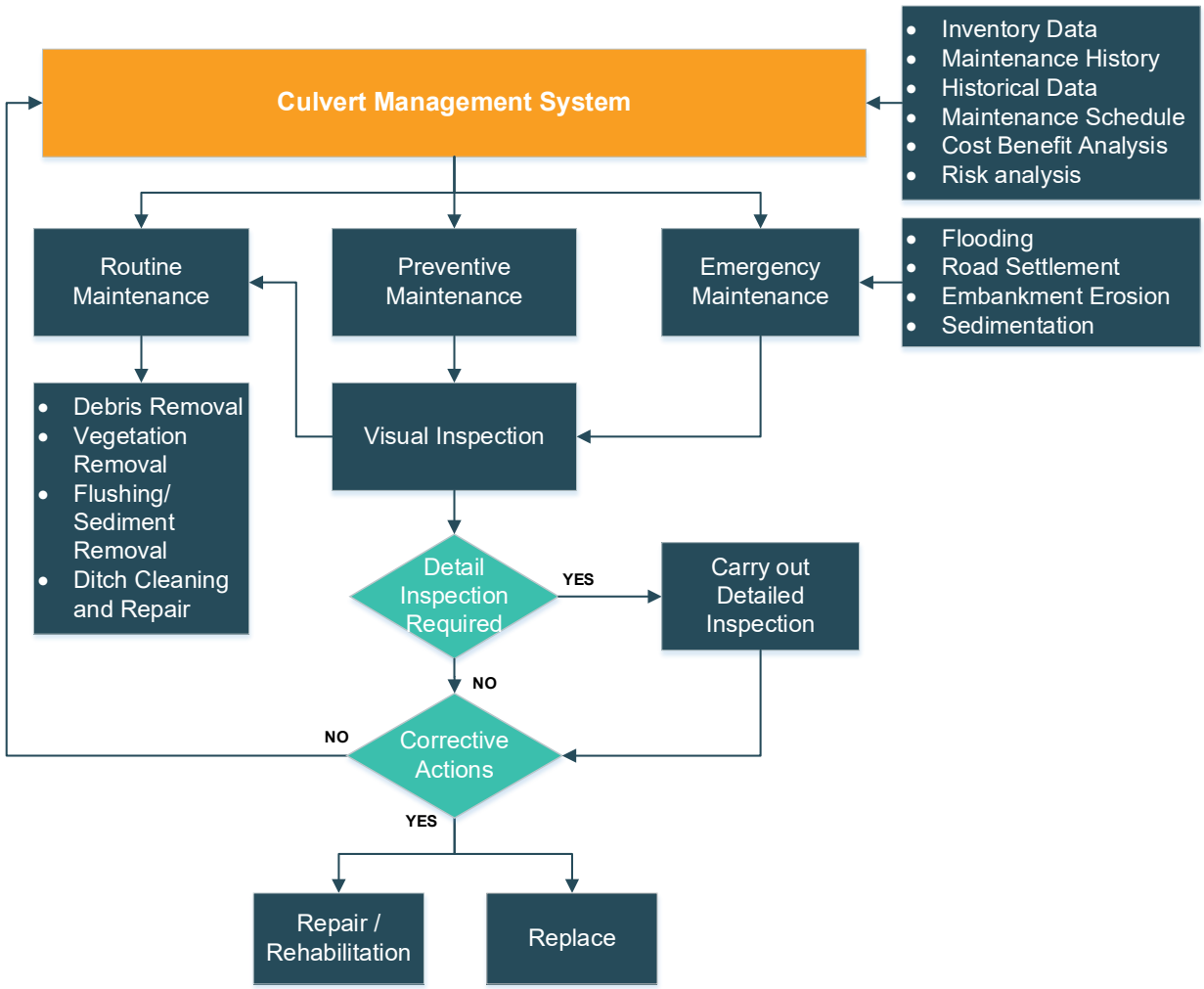

Figure 1 Culvert Operation and Maintenance Process

6.1 General Requirements

- All staff and suppliers carrying out works in culverts and drain areas shall be qualified and competent to undertake these tasks
- Health and safety aspects shall be considered throughout the maintenance, inspection, repairs, rehabilitation, and replacement of existing culvert and drains; and due account taken of the applicable health and safety regulations. While carrying out maintenance and inspection activities, the following health and safety aspects shall be considered:
    - Working on highways
    - Confined space inspection
    - Encountering toxic mold
    - Diving operations for underwater inspections
- All activities including the maintenance, inspection, and repairs/rehabilitation/replacement of existing culverts and drains must comply with current environmental and wildlife legislation, approved codes of practice and authoritative guidance literature issued by relevant statutory bodies and entities
- During all activities including the maintenance, inspection and repairs/rehabilitation of existing culverts and drains, the Contractor/Entity shall consider customers and users during these operations e.g., Health &Safety, safe access and egress, traffic management
- Maintain inherent structural integrity (support itself so as not to suffer complete or partial collapse) during the maintenance, inspection and repairs/rehabilitation of existing culverts
- Provide appropriate access and egress for all planned uses (including maintenance), and for reasonably anticipated emergency uses. Ensure safe access/egress by passengers, general public, employees, and emergency services in planned and reasonably anticipated emergency scenarios

- Safeguard the health and safety of users, employees, inspectors and members of the general public

6.2 Environmental Considerations

- Where maintenance works are proposed, the environmental impacts of the works shall also be assessed and managed
- Where remedial maintenance works are proposed, the potential for improvements to the structure with respect to the environment shall be considered
- Improvements to the structure can include the provision of aids to fish migration and mammal ledges
- Sacrificial linings should be provided where the integrity of structural concrete could be adversely affected by deleterious environmental liquids. These include, but not limited to:
    - Urea
    - Animal slurry
    - Petrol
    - Diesel fuels

6.3 Culvert Groups

The principles, guidelines, and requirements specified under this document shall apply to the culvert groups shown below:

- The most common shapes used are:
    - Circular (most common shape)
    - Pipe arch and elliptical (used where there is limited cover)
    - Box (singular or multiple boxes)
    - Three-sided arch (used for spanning water with natural bed as the bottom)
- The most common materials used are:
    - Cast-in-place concrete
    - Precast concrete
    - Corrugated steel
    - Plastic - Polyvinyl chloride (PVC)
    - Vitrified clay pipe (VCP)
- The most common uses are:
    - Culverts
    - Storm drain
    - Flood drain
    - Sewer
    - Wide water channels
    - Pedestrian, livestock, vehicle access
    - Lowering/ reducing underground water table

6.4 Culvert Management System

The CMS should provide a detailed guide for appropriate asset management practices, processes, and activities specific to the culvert assets. When implemented, these will aid in efficiently managing the physical and operational attributes of the structure to prolong its life while maintaining defined levels of service. The Entity should consider the requirements detailed in Volume 2 (Asset Management) to develop its CMS or a similar tool to manage its culvert assets.

The CMS should be developed by the Entity and should contain the following key aspects:

- Program Management such as developing a long-term plan for repairs/rehabilitation/replacement typically over the next 5 years
- Culvert inventory (e.g., location of culvert, type, material, size & length)
- Inspections (tracking the condition of the culverts)
- Assets risk analysis/matrix

- Decision making, evaluation & strategic review of asset maintenance needs (do nothing, repair, rehabilitation, replace)
- Provides a system to develop optimum works programs and capture the cost of works against the culvert assets
- Cost-benefit analysis
- Schedule and deliver works

6.5 Culvert Maintenance

Culverts convey surface water through a roadway or other structure into a channel and in some instances pedestrian access. This document provides concept maintenance for the types of structures (refer to **Section 6.3**) that would be required to carry highways over existing culverts.

6.5.1 Maintenance Work (General)

- Maintenance work shall be undertaken to ensure assets meet their required duty for the Design Life of the asset
- Maintenance shall be undertaken to maintain and prolong the working life of culverts
- The condition and cause of deterioration identified through an inspection of culverts shall be used to plan, cost, and undertake effective maintenance work
- Maintenance work shall be justified on the principles of whole lifecycle asset management
- Regular maintenance can be more cost-effective than early replacement of a culvert as the costs of regular maintenance are usually significantly lower than the capital cost for replacement
- Strengthening or replacement of culverts where critical defects have been identified shall be undertaken when the adequacy cannot be demonstrated through a structural/hydraulic assessment
- Critical defects are those which raise concerns over the stability and safety of the structure
- In the case of concrete box culverts, carrying out a more detailed method of analysis of the culvert can sometimes prevent unnecessary expenditure on the strengthening or replacement of serviceable culverts when the initial assessment by calculation has shown the concrete box culvert to have a critical defect
- Site constraints shall be evaluated to determine whether replacement is more cost effective than undertaking extensive remedial works including:
    - The cost of temporarily diverting the watercourse
    - The potential traffic management requirements and resultant traffic delays
- Extensive remedial works can involve the renewal of the soffit or waterproofing system, or strengthening using a reinforced concrete saddle
- Extensive remedial works can be necessary, particularly for older culvert structures designed and constructed to less onerous standards
- Traffic management and traffic delays can be substantial for culverts on the main roads and highway network. Relining the structure with, for example, a glass reinforced plastic liner can avoid significant traffic management and statutory undertaker's costs
- Where critical defects are observed which result in the concrete culvert being classed as an immediate risk, the culvert shall be managed in accordance with Entity requirements
- Tilting/settlement of a culvert supporting a highway/road can be an indication of an immediate risk
- Rehabilitation, upgrade to similar type of culvert, or complete culvert replacement shall be based on the principles and methodology highlighted in Figure 2

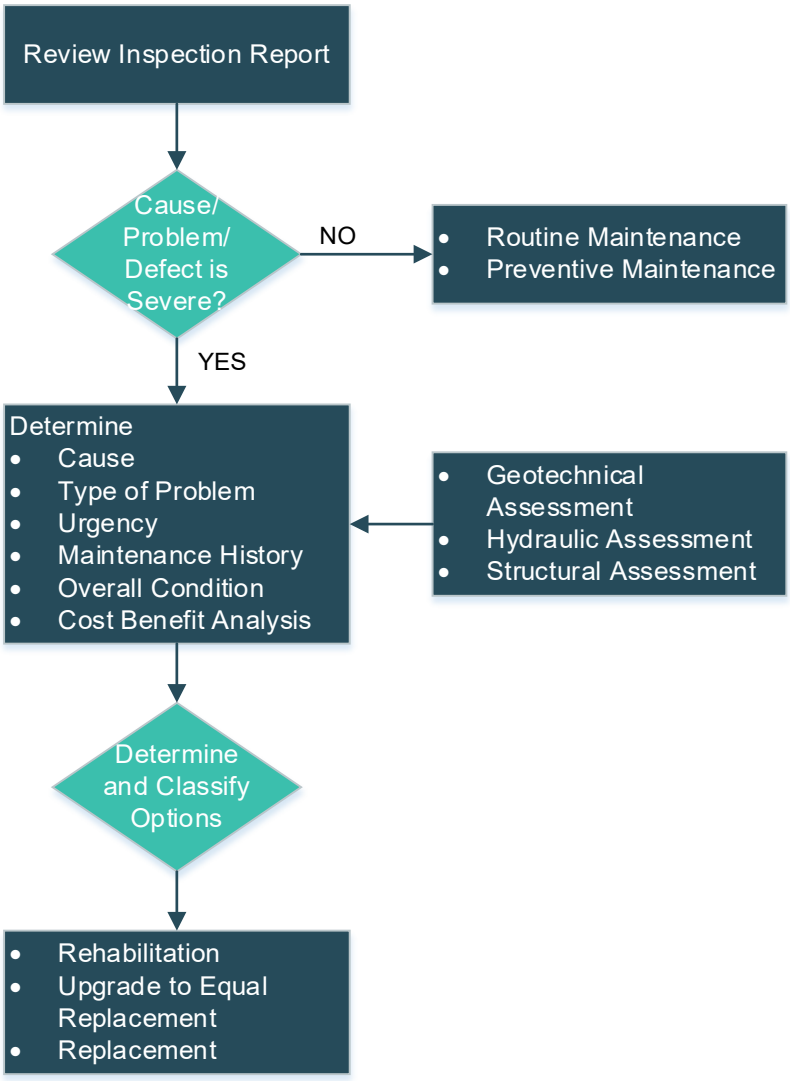

Figure 2: Rehabilitation and Culvert Replacement Maintenance Option Process

6.5.2 Maintenance Types

The Entity/Contractor shall develop a culvert preservation strategy based on the following maintenance types to prevent deficiency of the culverts. These maintenance activities are considered necessary to maintain and increase the life of the culverts.

- Planned Maintenance: Preventive and Predictive (PM, PdM)
- Unplanned Maintenance: Corrective and Emergency (CM, EM)

This document focuses primarily on Planned Maintenance, other maintenance types are described within NMA & FM, Volume 6 Chapter 3 – Descriptions and Definitions (EOM-ZM0-PR-000002).

6.5.2.1 Routine Maintenance

Routine maintenance shall be undertaken to maintain and prolong the working life of culverts. The aim of routine maintenance is to keep a culvert in a uniform and safe condition by repairing specific defects as they occur. The Entity/Contractor shall develop a routine maintenance program in order to optimize the service life of its culvert assets.

The following works shall be addressed during routine maintenance including, but not limited to:

- Debris removal
- Sediment removal
- Thawing frozen culverts in some specific areas in the Kingdom
- Invert silting
- Blocked drainage including pipes, weep holes, and internal gullies
- Vandalism
- Repair of mortar joints
- Reinstate perished joint seals
- Clearance of silt, debris, or vegetation without damaging the structure
- Graffiti should be removed from concrete surfaces where:
    - It is detrimental to the structure
    - It is deemed to be an aesthetic issue

Clearance of silt, debris, and other vegetation can be necessary in order to inspect the invert of the culvert. Vandalism is usually a local hazard confined to structures with pedestrian access. Superficial damage to lights, fittings, and drainage; and damage by fire are in most cases not structurally significant but their early repair can prevent further deterioration. The effect of graffiti on unprotected concrete is commonly limited to be an aesthetic issue. The method of removal of graffiti shall not cause damage to the concrete.

6.5.2.2 Preventive Maintenance

Preventive maintenance is a more extensive strategy than routine maintenance intended to arrest light deterioration and prevent progressive deterioration.

The following works shall be addressed during preventive maintenance including, but not limited to:

- Joint sealing
- Concrete patching
- Mortar repair
- Invert paving
- Scour prevention
- Ditch cleaning & repair
- Cracked or perished mortar joints and joint seals repair or replacement

Deteriorated and damaged mortar joints and joints seals can lead to the ingress and egress of water or effluents.

6.5.2.3 Rehabilitation

Rehabilitation is the strategy that takes maximum advantage of the remaining unstable structure in a culvert to build a reconditioned culvert. The following works shall be addressed during rehabilitation including, but not limited to:

- Repair of sound end walls & wing walls
- Invert paving
- Repair of scour
- Slope stabilization
- Streambed paving
- Addition of apron of cut-off wall
- Improving inlet configuration
- Installing debris collector

6.5.2.4 Upgrade to Equal Replacement

This maintenance strategy is carried out in order to upgrade a component to provide service that is equal to that by a new component/structure. The following works shall be addressed during upgrade to equal replacement including, but not limited to:

- Addition, repair, or replacement of appurtenant structures
- Lining of the barrel
- Provision of safety grates or safety barriers

6.5.2.5 Replacement

This maintenance strategy is carried out in order to provide a completely new culvert with a new service life. The following works may be associated during replacement of new culvert including, but not limited to:

- Realignment
- Hydraulic structural and safety improvements
- Change in culvert shape or material

6.5.2.6 Reactive/Emergency Maintenance

The Entity/Contractor shall develop an emergency maintenance plan to cater for and to mitigate the unscheduled, unplanned maintenance, unforeseen or extreme events that may arise during the asset's life e.g., flooding, road collapse. This is usually reported through a service call when a component or a system has been perceived to be not working appropriately or is not fit for purpose. Where possible, this should be recorded against the asset number to allow historical data to be collated and made essential for demonstrating where CAPEX/OPEX funds may need to be assigned. The consequent inspection after the service call can result in the following actions:

- If the problem is affecting the service life of the structure and posing a threat to the users, then emergency response and corrective action is required immediately
- If the problem is not critical, then a routine planned maintenance response may be adequate
- Undertaking a review of the current maintenance regime in place and, if necessary, adjusting to meet the present conditions
- Responses that include major repair/rehabilitation of the asset or asset component to protect life and property to moderate/major repair requiring qualified and skilled labor

The Entity should also refer to the requirements detailed in **Section 5.2.4** of Expro Projects Operations & Maintenance Manual for emergency response actions during hazard events.

6.6 Culverts Inspection

6.6.1 General Requirements

- Inspections shall be carried out by experienced, competent, and qualified staff
- Inspections shall be reported on the forms approved by the Entity
- The asset register for each culvert shall be reviewed and the records updated as part of the reporting process
- Inspection reports and forms shall be retained for the life of the asset
- No inspection shall commence unless the inspector has reviewed previous inspection reports, asset register, and asset files to establish as far as possible information about the asset, its previous condition, and likely hazards. This should include attributes, residual risks, hidden critical elements, falling elements, and any partial inspection information
- The inspector as part of his planning must be fully aware of access arrangements, so there are no delays to the inspections
- The inspector as part of his planning must be fully aware of environmental considerations for the culvert
- The Entity shall establish the following minimum requirements in its inspection program:
    - Entity inventory shall contain all culverts
    - All systems should be inventoried upon installation, when creating an asset management system, during maintenance, or during minor roadway work

    - The Entity shall inspect all culverts including characteristics of culverts to be inventoried and inspected
- The tools and equipment for the inspection shall be adequate to carry out inspection. The tools and equipment required for culvert inspection include but are not limited to the following:
    - Access tools and equipment
    - Cleaning tools and equipment
    - Inspection and measurement equipment
    - Visual aid equipment
- The remote inspection tools may be required for the inspection of culverts/pipes/storm drains where human entry is not possible. Typical remote inspection equipment are listed below, but not limited to:
    - Remote-controlled vehicles equipped with CCTV
    - High resolution video/CCTV cameras
    - Lasers
    - Sonar inspection
    - Optical sensing equipment

6.6.2 Inspection Purpose

Inspections of culverts shall be carried out for the following purposes:

- To establish the condition of the culverts with respect to:
    - Hydraulic performance
    - Structural performance
    - Serviceability
- To provide the necessary inputs for the Entity to collect the data to be used for
    - Maintenance needs
    - Decision making (Do nothing, repair, rehabilitation, replacement)
    - Budget needs for effective culvert asset management
- To establish the overall rating of the culvert assets keeping in mind the culverts are safe for desired operations
- To provide the information necessary to assess the condition of the culverts in a consistent and accurate manner
- To provide information enabling the asset register to be maintained as an accurate record of the physical features of the culverts
- To provide all the necessary physical information on culverts to meet the requirements for the Asset Condition Reporting (ACR) process
- To collect data that assess roadway safety for the traveling public

6.6.3 Inspection Frequency

- The Entity/Contractor inspection frequencies should be risk based, the risk being that of a culvert developing a fault sufficient to interrupt the user service either by partial or complete road closure
- Inspections of assets shall be undertaken at a frequency that shall be at least as frequent as the normal frequencies defined in Table 1
- The Entity may request assistance in creating/conducting an inspection regime for their culvert assets. Inspection frequencies should be agreed with the Entity
- Table 2 below provides example inspection frequency by barrel size in accordance with the best practices and AASHTO Culvert and Storm Drain System Inspection Guide

Barrel Size (S)/Type	Inspection Frequency
S < 1.22 m	Inspect during roadway maintenance
1.22 ≤ S ≤ 3.1m	Every 10 years or prior to routine roadway maintenance activities, whichever is less
S > 3.1m	Every 5 years or prior to routine roadway maintenance activities, whichever is less

Table 2: Inspection Frequencies

- Culverts structurally similar to bridges including multi barrel, with total span less than or equal to 6.1 m should be inspected every 2 years similar to bridge structure but note that Entity-specific requirements may vary with some treating 3.1m span and above as bridges.
- The Entity shall develop its inspection frequency considering the following factors:
  - Size
  - Condition rating
  - Structure age
  - ADT (average daily traffic)
  - Environmental conditions
  - Special function that needs to be considered by the Entity

6.6.4 Condition Rating System

- The Entity shall establish a condition rating system similar to the one shown in Table 3 to assess common types of culvert or storm drain system distress and recognize the severity and significance of distress
- The inspector(s) has some degree of freedom when classifying defects in accordance with the below system. However, it is important that inspectors classify defects with all reasonable care and that more specialized opinions are sought when there is doubt. Defects noted during inspection shall be matched to the standard severity/condition rating and priority rating mentioned in Table 3 of this document or similar categorization approved by the Entity in order to deduce the severity score that is to be entered in the Inspection Report
- The inspectors shall do the following:
  - Review all the information collected during the inspection
  - Summarize the extent and severity of the defects recorded on the specific report forms approved by the Entity
  - Give a condition rating, recommend appropriate action and suggest the level of priority for that action

	RATING SCALE ASSOCIATED ACTION				
	1	2	3	4	5
	GOOD	FAIR	POOR	CRITICAL	FAILED
CONDITION	Like new. With little or no deterioration, structurally sound and functionally adequate	Some deterioration, but structurally sound and functionally adequate	Significant deterioration and/or functional inadequacy, requiring maintenance or repair	Very poor conditions that indicate possible imminent failure which could threaten public safety	Failed or non-functional condition
ACTION NEEDED	No action is recommended. Note in inspection report only.	No immediate action is recommended, but more frequent inspection maybe warranted. Maintenance person should be informed	Team leader (Inspector) evaluates need for corrective action and makes recommendation in inspection report	Corrective action is required and urgent. Engineering evaluation is required to specify appropriate repair	Emergency action is required to address public safety hazard. Roadway closure is typical

Table 3: Condition Rating Table and Associated Action

6.6.5 Types of Inspection

Generally, following are the types of inspections for culverts:

- Initial (Inventory) inspection
- Routine inspection
- Special inspection
- Damage inspection

6.6.5.1 Initial (Inventory) Inspection

The Entity/Contractor shall carry out the initial inspection on its culvert assets after its commissioning and usually at the time of road construction for the following purposes:

- For inventory details and records
- To help Entity in the asset management decisions
- For future inspections and maintenance tracking

The Entity shall develop an inventory form/report similar to **Attachment 1** to develop their culvert inventory.

6.6.5.2 Routine Inspection

The Entity shall carry out routine inspection for each culvert at least as described in this document. The Entity shall develop a comprehensive culvert inspection program according to the needs of its culvert assets.

Routine Inspection Purpose

- The Entity/Contractor shall carry out routine inspection with the following considerations and purposes:
  - Verifying the general serviceability of the structure
  - Identifying any emerging problems
  - Assuring the safety of the public traveling on culverts
  - Identifying deficiencies to incorporate into the Asset Management Program/BMS that would initiate maintenance activities and/or rehabilitation/replacement of structures
- The routine inspections shall be carried out to obtain and record a visual check. This type of inspection may require remote inspection tools as highlighted in **Section 6.6.1**
- Visual Inspections shall bring to notice deterioration in condition or visible development of overall asset as highlighted in Table 3 and rating system highlighted in various tables in **Section 4** of NCHRP 14-26 Culvert and Storm Drain System Inspection Manual for specific type of culvert systems and defects. These tables cover following distress conditions and defects including, but not limited to:
  - Approach roadway
  - Embankment
  - Channel alignment and protection
  - End treatments and appurtenant structures
  - Concrete footings and invert slab
  - Barrel alignment
  - Plastic barrel
  - Concrete barrel
  - Corrugated metal barrel
  - Masonry barrel
  - Timber barrel
  - Joints
  - Seams (corrugated metal plate)
  - Manholes, catch basins, and buried junctions
- General inspections shall be of sufficient quality to detect and report any visual changes since the last inspection or evidence of circumstances which may impact on the condition of the asset before the next scheduled inspection

Planning for Routine Inspection

- Prior to commencing site inspections, the Entity/Contractor shall ensure that the inspector is suitably competent to carry out the inspection. The inspector shall ensure that he has all the relevant documentation, inspection equipment, safety equipment to carry out the inspection
- All staff involved in culvert inspections must be familiar with their responsibilities under the Workplace Health and Safety Act and applicable environmental regulations. The safety plans should be reviewed by the inspection crew and major hazards clearly identified prior to commencement of the inspection
- The traffic control procedures shall be covered under generic road/rail maintenance safety plans. The hazard of operating within the lateral confines imposed by culvert barriers is significantly different from the hazard posed while operating in the "open" road. Safety equipment shall include signage for traffic management purposes and, where applicable, other safety equipment relevant to routine maintenance activities

Preparing for Routine Inspection

Prior to commencing inspection, the inspectors shall ensure that they have all relevant documentation, locations, inspection equipment and safety equipment and the appropriate arrangements with the relevant road, governmental or other authorities for temporary access. Arrangements should be made with relevant authorities as required to carry out the inspection. Safety plans must be prepared and approved by the relevant Entity as well. Permit to Work (PTW) should also be approved by the relevant authority or Entity before commencing the inspection. The type of entry is dependent on the access and egress of the asset and typically includes:

- Human/person entry which may give access to both internal and external components of the asset
- Human/person entry which may give access to only external components of the asset
- Remote internal inspection (person entry not possible) when it’s necessary by use of equipment such as CCTV in the following cases:
    - Deep sedimentation
    - Deep water
    - Closed end conduits
    - Small diameters

Performing Routine Inspection

The inspector’s duties associated include:

- Maintaining the proper structure orientation
- Element numbering system
- Developing an inspection sequence
- Following proper inspection procedures

The inspector shall collect the following minimum information, but this may vary on the culvert barrel size and access arrangements:

- The general terminology used to label culvert components
- Measurements of the dimensions of all elements
- Photographs
- All elemental defects shall be defined in terms of:
    - Location
    - Orientation
    - Area
    - Depth
    - Residual section
    - Rate of deterioration
    - Severity (condition state)

  The defects shall be sufficiently described (in the inspection forms), dimensioned, photographed, and shown by hand drawings/sketches to show their nature, extent, and severity.
- The drawings shall be annotated with photos of severe defects and all severe defects shall be highlighted so they stand out

- The criticality, maintenance needs, and performance deficiencies of each element shall be noted in the inspection forms and the rating system highlighted in various tables in **Section 4** of NCHRP 14-26 Culvert and Storm Drain System Inspection Manual or similar categorization developed by the Entity.
- The inspector shall identify items that need maintenance and/or repairs
- The inspector shall identify each item to ensure public safety and help maximize the longevity of the asset

Reporting of Routine Inspection

The Entity/Contractor shall complete the comprehensive technical routine inspection reports/forms as shown in **Attachment 2** or similar standard forms developed and approved by the Entity. The forms shall be prepared and reviewed by qualified and competent engineers. The routine inspection reports shall include the following, but not limited to:

- Structure inventory and appraisal data
- An extract from map coordinates clearly showing the location of the structure
- As-built drawings (if available) or sketches
- Record of the location, extent, and severity of all defects
- Overall condition rating and comments
- Element condition tables, charts, sketches, diagrams, others, as necessary
- Relevant recorded observations, measurements, and readings of monitoring points
- Where necessary, the time for further investigation or additional examination required, and recommendation for the scope of such work. Buried or hidden parts that have been revealed should be reported
- Photographs (general and defect)
- Recommendation for maintenance actions/needs and remedial work necessary, including the extent and priority for such work
- Details of any emergency action required for the culvert
- Confirmation that the inspection has been completed
- List of any significant defects which have occurred or worsened, or changes which have occurred since the last inspection
- Identification of a need for further investigations or other action

Routine inspections shall be reported on a form approved by the Entity.

6.6.5.3 Special Inspection

Special Inspection Purpose

The Entity/Contractor should carry out the special inspection of the culvert when triggered by critical or failed rating in a routine inspection.

Special Inspection Scope

The Entity/Contractor shall perform an extensive inspection carried out by qualified and competent personnel, which may include physical testing and/or structural analysis. These are a close inspection of all inspection items and/or critical elements of the asset, carried out to give detailed visual confirmation on conditions necessary for the management of the assets. These special inspections shall bring to notice deterioration in condition or visible development of defects and appraise their effect on the asset. The inspections shall assess:

- Current structural condition, behavior, and capacity
- Rate of deterioration and residual life expectancy
- Asset management strategies

The inspections shall also include, but not limited to:

- Non-destructive field tests

- Special inspection of all relevant culvert components including measurements, testing, and analyses as necessary to supplement the visual inspection
- Determination of material properties and structural, hydraulic, and geotechnical behavior
- Identification of components which are limiting the performance of the structure due to their current condition and capacity or are likely to deteriorate to such a level within the next few years
- Identification of the probable causes and projected rate of deterioration and the effects of continued deterioration on the performance, durability, and residual life of the structure
- Identification of factors which will influence the dynamic load allowance to be used in load rating
- Examination of the hydraulic performance of the structure including any signs of siltation, scour, debris impact or build-up, bank or embankment erosion, tree and vegetation encroachment

6.6.5.4 Damage Inspection

- Defect advice inspections shall be carried out following notification or a report of an incident that causes damage to an asset or has the potential to adversely affect the ability of the asset to perform its required duty
- Sufficient information shall be collected to enable safety of the asset to be assessed and for the full reporting of an incident being investigated to identify immediate and root causes

6.7 Culvert Repairs

Repair of culverts is usually required due to inadequate maintenance, excessive loading, change in use or code of practice, and/or exposure to adverse environmental conditions. Regular repair of existing culverts is an efficient and cost-effective procedure to maintain the serviceability of the existing culvert inventory.

- The Entity shall carry out repair of all culvert structure components, elements and assets according to the procedures and requirements listed in the applicable codes and standards in **Section 5** and manufacturer's specifications
- The manufacturer's recommendations or original specifications should be consulted in each instance
- The Entity should develop a comprehensive culvert maintenance manual to detail the specifications, procedures, and requirements for culvert repairs and rehabilitation
- Maintenance repair specifications included in this document are for informational purposes only. They are not intended to be used for actual repairs. Any other use of this document shall be the responsibility of the design engineer. Repair details and specifications are distinct for each culvert and vary with the defect type, culvert type, material and location.
- The Entity reviews and approves all drawings and specifications related to repairs of existing culvert structures and structural systems. This is shared with the culvert owner, if other than the Entity.
- The culvert repairs should be carried out through a process as detailed in Figure 3

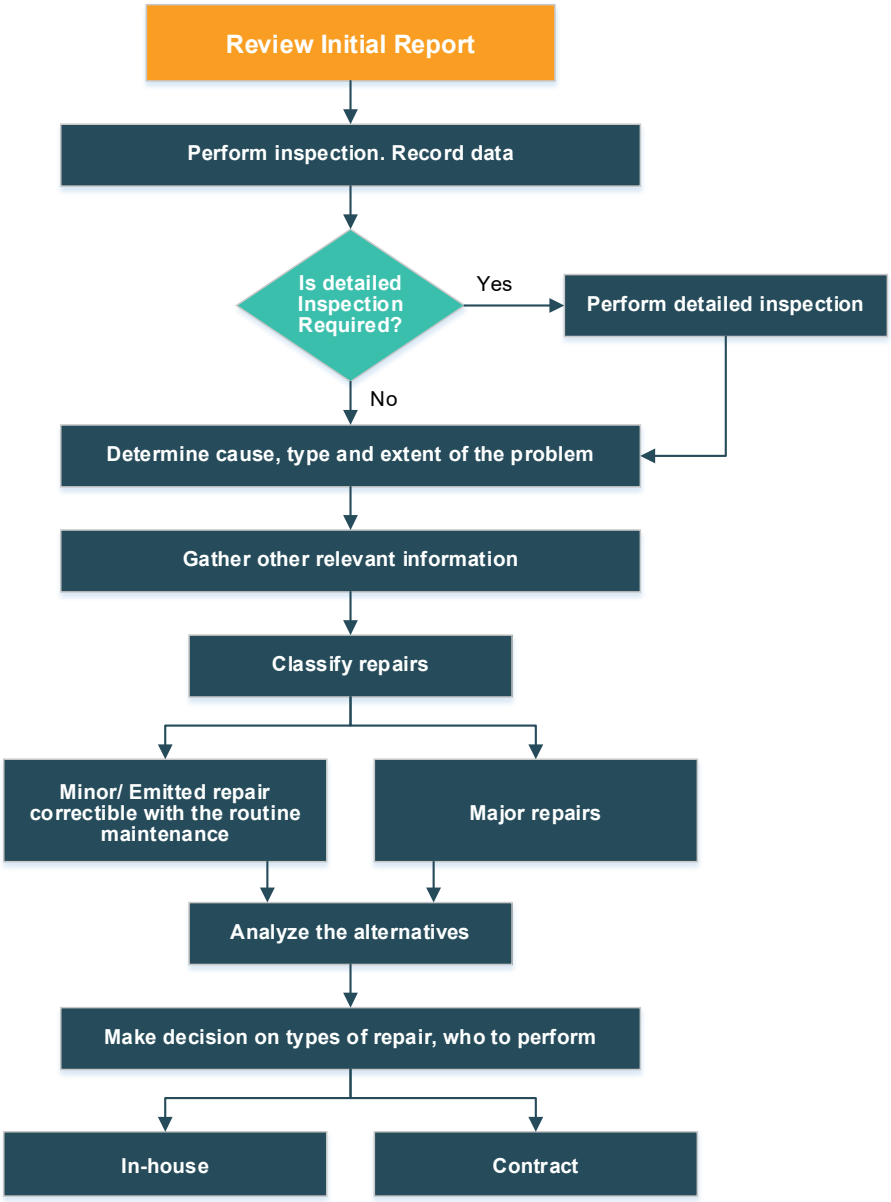

Figure 3: Culvert Repair Process

6.8 Concrete Repairs

Effective repair of concrete structures requires understanding the causes of deterioration and assessment of the effect of the selected repair technique on future survival. This must be based on a good test of the existing structure. Corrosion of the reinforcement steel is the most common reason for repairing concrete structures. In this case, the following should be focused on:

- Reinforcement steel covering
- Carbonization depth – the depth of carbon penetration into the concrete
- The area contaminated with chlorides
- Details of the concrete mixture
- Concrete age
- The environmental factors that have caused the contamination and contamination condition

The test program and its outcomes will lead to understanding the extent of the existing defect and the cause of deterioration.

Concrete repair may be required for many reasons other than reinforcement steel corrosion. Among these are damages resulting from fire, in which case the same general strategy will be adopted in the repair.

Concrete repairs to the existing culverts shall be carried out in accordance with the detailed requirements highlighted in codes and references of **Section 5.0** of this document and the following ACI documents:

- 546R-14: Guide to Concrete Repair
- 562-19: Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary

The requirements detailed in the codes and references in Section 5.0 and above documents encompass following key aspects in the repair and rehabilitation of the existing concrete culvert structures:

- General requirements for concrete repair
- Evaluation/condition assessment requirements for concrete repair
- Structural analysis for concrete repair
- Design, implementation, execution, durability and quality assurance requirements for concrete repair

6.9 Culvert Rehabilitation/Strengthening

Strengthening and rehabilitation work shall be:

- Controlled to ensure assets meet the required duty
- Corrective action to address life-expired assets or elements in accordance with the supplier's program for lifecycle management or a change in use, function, or duty of the asset or element
- Justified on the principles of whole lifecycle asset management
- Based on inspection reports (**Section 6.7**), load rating/culvert assessment (**Section 6.10**) and analytical assessment

The work carried by the Entity Contractors for the purpose of strengthening and rehabilitation to the existing culvert assets shall comply with the provisions mentioned in the relevant sections and relevant provisions detailed in AASTHO design and maintenance documents, white book guidelines (Document No. EPM-KES-GL-000001) and any other relevant Entity specific regulations.

- The strengthening and rehabilitation work shall be carried out in a manner that the minimum design loads shall be similar to the loads when the culvert was constructed. If any of the structural component is exposed during the strengthening/rehabilitation and if the condition assessment of the components establishes that these structural elements are unsound or dangerous, then these shall be made to comply with applicable clauses of AASTHO LFRD codes, white book guidelines (Document No. EPM-KES-GL-000001) and any other relevant Entity specific regulations
- The Contractors shall provide and gain approval from Entity for the designated work area and access. The work area shall be clearly highlighted and identified within the construction documents
- The Entity reviews and approves all drawings and specifications related to strengthening and rehabilitation of existing culvert structures and structural systems. This is shared with the culvert owner, if other than the Entity

6.10 Culvert Assessment/Load Rating

6.10.1 Culvert Assessment Purpose:

The assessment or load rating is carried out for a culvert in the following circumstances:

- When the culvert has developed deterioration to the level that it has reduced its strength
- The loading standards have changed

The outcome of assessment is very important with respect to the decision on when and what type of maintenance is to be carried out on the culvert assets. The entity shall develop a culvert assessment/culvert load-rating program in order to:

- Establish their load carrying capacity
- Assure their safety where routine inspection/examination alone is insufficient to confirm their load carrying capacity
- Establish actions, following an assessment, including programs of physical works and/or consultation with customers and stakeholders on asset capability requirements

6.10.2 Culvert Assessment Scope:

- The culvert assessment shall include the use of two- and three-dimensional computer grillage or frame analysis (as appropriate for the structural configuration)
- The elements of the structure to be assessed shall include all elements where insufficient load carrying capacity would pose a risk to people on or about the structure, the operation of the network

6.10.3 Culvert Assessment/Load Rating activities

The Entity shall undertake the following culvert assessment and load rating activities; and develop the following culvert assessment/load rating requirements:

- Desktop studies including surveys and record searches
- Reconnaissance
- Planning the inspection for assessment as well as the assessment itself
- Identification and provision of data for the management of hidden parts and fatigue susceptible details
- Inspection for assessment including specific targeted aspects to address issues identified in earlier routine inspections
- Determination of load carrying capacity of the structure
- Assessment report with calculations, photographs, and drawings
- Addition of results and report in asset management systems (such as CMS)
- Defect and culvert risk matrix
- Recommendations on future actions following the load rating/culvert assessment such as:
    - Culvert strengthening or replacement
    - Impose traffic restrictions for safe load carrying capacity of the culvert
    - Culvert monitoring only in case the failure will not be fatal and signs of failure are readily visible

6.11 Drains

The purpose of the sub-section of this document is to provide principles, guidelines, and minimum requirements for the maintenance of the drains. Drains serve a functional requirement to safely and effectively collect, convey, and direct roadway runoff away from the road surface, which is provided by following typical components:

- Grate
- Cover
- Drop inlets
- Sediment traps

6.11.1 Inspection

The inspection of drains shall be carried out annually to check and assess the amount of sediment or debris accumulated to ensure more frequent maintenance is not needed. The seasonal inspection shall also be carried out post-storm rain season to ensure that the drains are in good condition and the sediment capacity has not been exceeded. The Entity/Contractor shall complete the

comprehensive routine inspection checklist as shown in **Attachment 3** to report the observations and maintenance need of the drains.

6.11.2 Maintenance

The maintenance of drains shall be carried out on a regular basis and as per the requirement and outcome of the inspection to avoid frequent maintenance. The Entity should develop maintenance index condition rating system as shown in **Attachment 3** to highlight the maintenance needs as an outcome of the inspection. The following maintenance activities are generally carried out on drains:

- Trash removal
- Debris removal
- Sedimentation removal
- Erosion removal

7.0 ATTACHMENTS

Attachment 1: EOM-ZM0-TP-000039 – Culvert & Storm Drain Initial (Inventory) Inspection Template
Attachment 2: EOM-ZM0-TP-000040 – Culvert Inspection Template
Attachment 3: EOM-ZM0-TP-000042 – Drain Inspection/Maintenance Checklist

Attachment 1 – EOM-ZM0-TP-000039 – Culvert & Storm Drain Initial (Inventory) Inspection Template

CULVERT & STORM DRAIN INVENTORY FORM							
Structure ID: Route & Milepost:				Date of Last Inspection: Inspection Frequency: Date of Last Maintenance:			
LOCATION, FEATURES & ROADWAY				**CULVERT/DRAIN TYPE & GEOMETRY**			
Region				Year Built			
Maintenance Unit				Year Reconstructed			
City/Town				Barrel Material			
Roadway surface				Shape			
Number of lanes				Span (m.)			
ADT (yearly)				Rise (m.)			
Truck ADT (Yearly)				Length (m.)			
Features Crossed				Skew (deg.)			
Features Carried				Wall Gage/ Thickness			
Inlet Latitude				Pipe Slope (deg.)			
Inlet Longitude				#Barrels/cells			
Outlet Latitude				Max Cover (m.)			
Outlet Longitude				Min. Cover (Road, m.)			
Location Remarks				Access Remarks			
CHANNEL, HYDROLOGY & HYDRAULICS				**END TREATMENT TYPE & GEOMETRY**			
Drainage Area (acres)				Inlet type/Size			
Abrasive Conditions				Inlet Extension Year			
Design Discharge (cms)				Inlet Ext. Length (m.)			
Inlet Skew (Deg.)				Inlet Remarks			
Inlet Protection				Outlet Type/Size			
Outlet Skew (Deg.)				Outlet Extension Year			
Outlet protection				Outlet Ext. Length (m.)			
AOP Remarks				Outlet Remarks			

CONDITION RATINGS (LAST INSPECTION)	Good (1)	Fair (2)	Poor (3)	Severe (4)	Comments:
Approach roadway					
Embankment					
Channel Alignment and Protection					
End Treatment and Appurtenant structures					
Concrete Footings and Invert Slab					
Barrel Alignment					
Plastic Barrel					

CULVERT & STORM DRAIN INVENTORY FORM					
Structure ID: Route & Milepost:					Date of Last Inspection: Inspection Frequency: Date of Last Maintenance:
Concrete Barrel					
Corrugated Metal Barrel					
Masonry Barrel					
Timber Barrel					
Joints					
Seams (Corrugated Metal Plate)					
Manholes, Catch Basins, Buried Junctions					
Comments:					

Attachment 2 – EOM-ZM0-TP-000040 – Culvert Inspection Template

CULVERT INSPECTION FORM								
Structure ID: Route & Milepost: Shape/Span:						Date of Inspection: Entry Type: Inspector:		
APPROACH ROADWAY	**Good (1)**	**Fair (2)**	**Poor (3)**	**Severe (4)**	**NR**	**Comments:**	**RATING:**	
Pavement								
Guardrail								
Shoulders								
EMBANKMENT	**Good (1)**	**Fair (2)**	**Poor (3)**	**Severe (4)**	**NR**	**Comments:**	**RATING:**	
Slope Stability and Embankment Erosion								
CHANNEL ALIGNMENT AND PROTECTION	**Good (1)**	**Fair (2)**	**Poor (3)**	**Severe (4)**	**NR**	**Comments:**	**RATING:**	
Channel Alignment								
Bank Erosion and Scour								
Protection								
Waterway Adequacy								
END TREATMENT AND APPURTNANT STRUCTURES	**Good (1)**	**Fair (2)**	**Poor (3)**	**Severe (4)**	**NR**	**Comments:**	**RATING:**	
Cracking (Concrete)								
Surface Damage Spalling or Delamination (Concrete)								
Deformation and Damage (Metal)								
Corrosion (Metal)								
Scour and Stability								
Settlement/Rotation								

Attachment 3 – EOM-ZM0-TP-000042 – Drain Inspection/Maintenance Checklist

Inspection Date: Location: Route: Mile Post:	Inspection Name: Inspection Type: Routine ☐ Follow up ☐

Rare Condition as:	
Good	*Good condition, no corrective action required*
Fair	*Fair condition but still functional. Follow-up based upon prioritization ranking*
Poor	*Poor condition, needing maintenance, repair and/or replacement*
	Blank Photo was taken

No.	INSPECTION ITEM	Task	Good	Fair	Poor	
1	Grate, Cover	Inspect for sediment, debris or trash collected around the inlet structure	☐	☐	☐	☐
2	Collection Sump	Sediment accumulation should not exceed 60% of the sump	☐	☐	☐	☐
3	Inlet and Outlet Pipes	Inlet and outlet pipes within the sump should be free of obstructions	☐	☐	☐	☐
4	LIST ANY OBSERVATIONS					
5	LIST COMMENTS/RECOMMENDATIONS/ CORRECTIVE/FOLLOW UP ACTIONS					
6	SPECIFIC PM NOTES					
6.1	Maintenance crews should be prepared to identify erosion, remove accumulated sediment, remove any accumulated trash or debris and repair damaged covers or inlets					
6.2	The area surrounding the manhole should be observed for signs of weakness in the pavement or surrounding area					
6.3	Material within inlet or outlet pipes may indicate blockage within the pipe that may require additional maintenance					
6.4	If emergency maintenance needs are identified, the inspector should either correct the problem or contact the maintenance manager					

Inspection Date: Location: Route: Mile Post:	Inspection Name: Inspection Type: Routine ☐ Follow up ☐

Rare Condition as:	
Good	*Good condition, no corrective action required*
Fair	*Fair condition but still functional. Follow-up based upon prioritization ranking*
Poor	*Poor condition, needing maintenance, repair and/or replacement*
	Blank Photo was taken

6.5	A follow-up inspection should be conducted to verify that actions have been taken and needs have been addressed. Document on Checklist.				

No.	Reviewer's Comments	Resolution

Originator's Name/Signature and Date:	Checker's Name/Signature and Date: