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Volume 6, Chapter 25

Hydraulic Structures (Dams) Plan

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1.0 PURPOSE

Successful maintenance planning of dams 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 guidelines for developing and improving operations and maintenance management plans for dams. These are minimum requirements for the operations, maintenance, inspection, repair, and rehabilitation of common and typical dams. The Entity shall modify the requirements specific to its maintenance needs.

The operations, maintenance, inspection, repair, and rehabilitation shall conform to requirements detailed in Section 5.0 – Codes, Standards, References and any other specific Entity Operations and Maintenance (O&M) requirements.

2.0 SCOPE

The scope of this document is to guide those responsible for ensuring that operations are carried out in a consistent and reliable manner, focusing on planned activities and the reduction of costly and disruptive reactive maintenance. The Entity and/or specialized contractors/operators shall take steps to enhance the current practice of developing an O&M plan to attain maximum efficiency of dams.

The document is designed to provide guidance for O&M of dam and spillway aspects of the asset. However, it doesn't cover the functional requirements of the asset related to water treatment and power generation plants.

Dam assets include the following components:

- Water retaining structure (Dam)
- Water releasing structure (Spillway)
- Water treatment plants
- Power generation plants
- Hydraulic and motorized plant/equipment

3.0 DEFINITIONS

Term	Definition
Condition Based Maintenance (CBM)	The maintenance needs/strategy for an asset based on the actual condition and evaluation
Emergency Maintenance	Maintenance activity of an asset to rectify the danger and restore asset serviceability after an emergency event
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
Maintenance	The undertaking of preventative or corrective action or both, including repairs to ensure that the condition of asset continues to meet the required duty over the service life
Preventive Maintenance	A planned strategy of cost effective treatments to an existing asset that preserves, retards future deterioration, and maintains or improves the functional condition of the asset
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 service life of the asset
Abbreviations	
CAS	Condition Assessment Survey
CCTV	Closed Circuit Television
CMS	Competence Management System

Term	Definition
D/S	Downstream
DSRP	Dam Safety Review Panel
EAP	Emergency Action Plan
EDA	Energy Dissipation Arrangement
FEMA	Federal Emergency Management Agency
ICODS	Interagency Committee on Dam Safety
O&M	Operations and Maintenance
PPM	Preventive Planned Maintenance

4.0 REFERENCES

- Indiana Dam Safety Inspection Manual (Parts 1, 2, 3 ,4, 5), Department Of Natural Resources Division Of Water Indianapolis, Indiana, 2007
- An Owners Guidance Manual for the Inspection and Maintenance of Dams in New York State
- Dam Operation, Maintenance, And Inspection Manual – North Carolina Department of Environment and Natural Resources Division of Land Resources Land Quality Section 1985 (revised 2007)
- Dam Removal Analysis Guidelines for Sediment – Advisory Committee on Water Information
- Federal Emergency Management Agency (FEMA P-911) – Pocket Safety Guide for Dams and Impoundments, October 2016
- Federal Emergency Management Agency (FEMA P-1032) – Evaluation and Monitoring of Seepage and Internal Erosion, Interagency Committee on Dam Safety (ICODS), May 2015
- Guidelines for Inspection and Maintenance of Dams – Connecticut Department of Environmental Protection, September 2001
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- Ministry of Environment, Water & Agriculture statistical book 2018-2019, Kingdom of Saudi Arabia
- National Manual of Assets and Facilities Management, Volume 2 – Asset Management
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- National Manual of Assets and Facilities Management, Volume 6 Chapter 14 – Roads Maintenance Plans
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- National Manual of Assets and Facilities Management, Volume 14 – Emergency Management
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- Sustainable sediment management in reservoirs and regulated rivers – Experiences from five continents, G. Mathias Kondolf, Yongxuan Gao

5.0 RESPONSIBILITIES

The responsibilities of Entity/operator/staff include, but not limited to:

- All staff and suppliers carrying out O&M activities shall be qualified and competent to undertake these tasks
- Entity and the specialized contractors/operators shall have an organizational structure having adequate staff with clearly identified roles, responsibilities, and competencies to effectively oversee and monitor the O&M activities and works
- Entity and the specialized contractors/operators shall have a Competence Management System (CMS) in accordance with the published guidance and standards for O&M of the assets
- Entity and the specialized contractors/operators shall have continuous training programs on developing and maintaining staff competence
- Inspections of assets shall be carried out by suitably experienced, competent, and qualified staff

6.0 PROCESS

The Entity shall establish and develop the set processes and procedures for continuous O&M, and performance efficiency of the dams. A detailed O&M strategy such as detailed in Figure 1 will ensure that systemic procedures are in place for safe functioning and optimum use of the dam and reservoir.

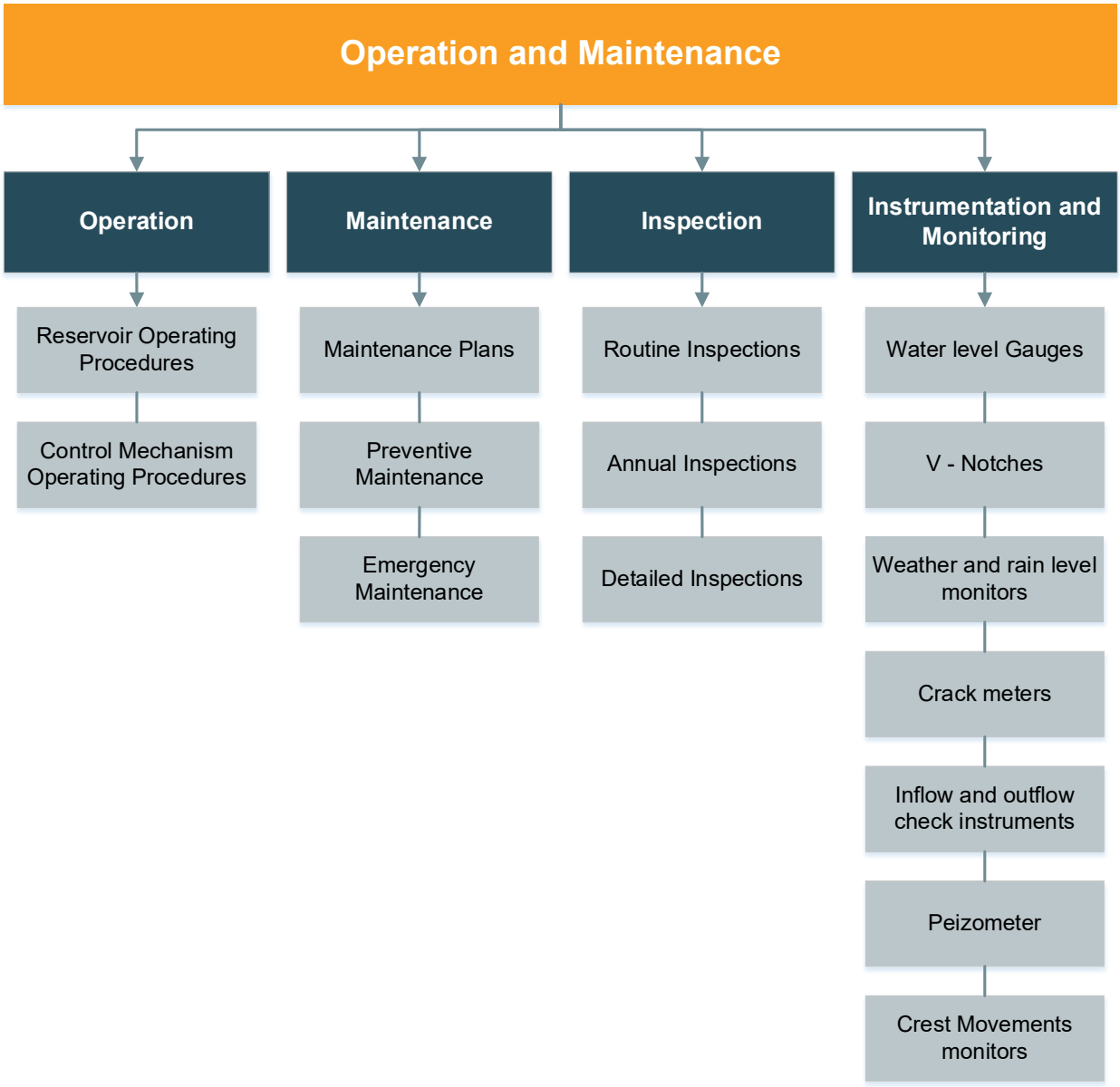

Figure 1: Dam Operation and Maintenance Strategy

The effective O&M strategy shall contain following minimum components:

- **Operation** providing the details and procedures for operating the reservoir and dam equipment
- **Maintenance** outlining procedures, and instructions on how to carry out the periodic and preventive maintenance and upkeep of the dam
- **Inspection** detailing the requirements, frequencies, information, and instruction on how to perform regular inspections by the Entity or Operator of the dam
- **Instrumentation and Monitoring** providing the information, instructions, and procedure for reporting, monitoring, recording and updating data

6.1 Dam Groups

The principles, guidelines, and requirements contained herein, shall apply to the dam types defined below:

6.1.1 Material Based

- Masonry Dams
- Concrete Dams
- Earthen Dams
- Rock Fill Dams

6.1.2 Structure and Design Based

- Gravity Dams
- Arch Dams
- Buttress Dams
- Embankment Dams

6.1.3 Function Based

- Storage Dams
- Diversion Dams
- Detention Dams
- Debris Dams
- Coffer Dams
- Hydroelectric Dams

Note: Most of the dams in Saudi Arabia are embankment dams, rock fill dams, or concrete dams. Around 509 dams are built in different locations in Saudi Arabia with a total capacity of more than 2.24 trillion cubic meters, in order to protect lives from floods, provide a sustainable source for agricultural water and daily uses.

6.2 General Requirements

- Health and safety aspects shall be considered throughout the O&M activities and due account be taken of the applicable Health and Safety regulations
- All O&M activities shall comply with the current environmental legislation, approved codes of practice, and authoritative guidance literature issued by the relevant statutory bodies and Entities
- The operator/specialized contractor shall consider users during these O&M activities:
    - Provide appropriate access and egress for all planned uses (including O&M), and for reasonably anticipated emergency uses. Ensure safe ingress/egress by users, public, employees, and emergency services in planned and reasonably anticipated emergency scenarios
    - Safeguard the health and safety of employees and general public
    - Operation management plans such as startup, shutdown, monitoring, and emergency procedures shall be in place for plant and equipment operation
    - Staff are to be suitably trained and competent in the operation of plant and equipment at site
    - Training shall be in place for new staff, and continuation/refresher training for existing staff
    - Maintenance work shall be preventative or remedial action, including repairs to damages and defects
    - Maintenance work shall be justified on the principles of whole lifecycle asset management
    - Preventive and predictive maintenance programs and procedures shall be in place to effectively carryout maintenance of the assets
    - Emergency maintenance plans, procedures, escalation matrix, and call out procedures shall be in place to manage emergencies effectively

6.3 Asset Management System

The Entity should develop asset management procedures and plans in order to assist asset managers to manage the dam assets. The asset management procedures and plans should provide a detailed guide for appropriate asset management practices, processes, and activities specific to the dam assets. When implemented, these will aid in efficiently managing the physical and operational attributes of the dams to prolong its life whilst maintaining the defined levels of service.

For effective asset management throughout the lifecycle of each asset, the following shall occur:

- Define and approve asset solutions based on whole of life costs
- Select, create, and commission assets that are fit for purpose
- Modify or upgrade assets to increase capability and/or reduce lifecycle costs
- Operate assets to sustainable levels of performance, cost, and risk
- Maintain assets cost effectively to the defined performance levels
- Dispose of assets in a sustainable and compliant manner
- Comply with any statutory and regulatory as per O&M requirements
- Focus on the continuous improvement of asset and asset management system performance
- Identify, assess, and manage asset related risk
- Ensure that materials for maintenance and emergency repairs are available

Accurate asset data, information and inventory of dams is a key requirement for all the asset management activities. An asset management system shall contain list of all assets that carries pertinent details about each asset to track the value, physical location, operating cost, condition, utilization, and all other details necessary to better manage the asset typically in a computerized system. Dam asset management system shall contain systems and components as highlighted in Figure 2.

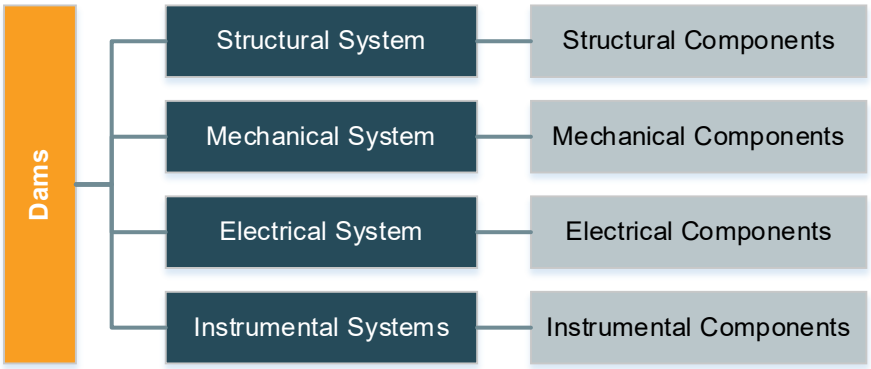

Figure 2: Dam Typical Systems and Components

The Entity should consider the specific requirements detailed in NMA & FM, Volume 2 – Asset Management to develop its Dam Asset Management System or a similar tool to manage its dam assets.

6.4 Operation

The Entity/operator shall develop details and information on the operation of various elements of the dams. Operating procedures are to be developed for both normal and emergency operations. The details shall include the following:

- Instructions for operating the reservoir
- Instructions for operating control mechanisms
- Guidelines for the safe operation of the dam appurtenances
- Staff competencies and assessment requirements
- Inflow forecasting
- Flood release procedure

6.4.1 Reservoir Operating Procedures

The Entity/operator shall develop general dam operations procedure, and include the below details:

- Regulation of inflow and outflow ditches (if applicable)
- Reservoir capacity and maximum allowable water levels at different times of the year including rain/ flooding seasons
- Maximum or minimum permissible outlet releases
- Operation of the outlet to limit or prevent excessive spillway flow
- Method for lowering the reservoir to permit outlet or upstream slope inspection
- Instructions and procedure on which gates and/or valves must be operated to regulate the reservoir

6.4.2 Control Mechanisms Operating Procedures

The Entity/operator shall develop step by step, complete, and clear procedure on how to operate all control mechanisms specific to dam, including:

- Outlet control valve(s)
- Spillway gates
- Hydraulic and Electric gates

The operation procedure shall also include:

- Instructions on general description of the mechanism, location, and purpose
- Proper sequences, sketches, drawings, and photographs to aid in identifying specific tools e.g., handles, cranks, buttons
- Correct method of opening and closing guard gates
- Gate usage during low and high flows
- Gate openings at which excessive vibrations are experienced
- Operating problems peculiar to a specific gate
- For hydraulic and electric gates, a schematic diagram should be provided showing each component (including back-up equipment) and its place in the operating sequence
- The gate manufacturers' O&M Manual for gates & hoists shall be implemented for overall gate operations
- Operational testing checks such as flow test, static test, and dry test on equipment including spillway and outlet gates shall be carried out, in accordance with the manufactures' testing frequency
- Provisions and uses of backup equipment such as petrol/diesel operated generators should be outlined
- Location of emergency or standby plant
- Call out procedures and reporting methods

The Entity shall also develop Emergency Action Plan (EAP) for operating procedures during specific emergencies. In such situation, special operating procedures should be followed as detailed in **Section 6.11.1**.

6.5 Maintenance

6.5.1 General

Maintenance work shall be undertaken to ensure that assets meet their stipulated design life. Assets that fail to meet the design life shall have restricted operations or be withdrawn from service.

6.5.2 Maintenance Work

Maintenance work can be preventive or remedial in action and may include repairs and damage control. This activity constitutes a key aspect of whole lifecycle asset management.

Maintenance action shall be based on Inspection procedure detailed in **Section 6.6**.

6.5.3 Maintenance Plan

The Entity/operator shall develop comprehensive maintenance plan for a dam in order to prolong its serviceability, prevent deterioration, and maintain its safety. The Entity/operator shall develop plan considering types of maintenance highlighted in Figure 3.

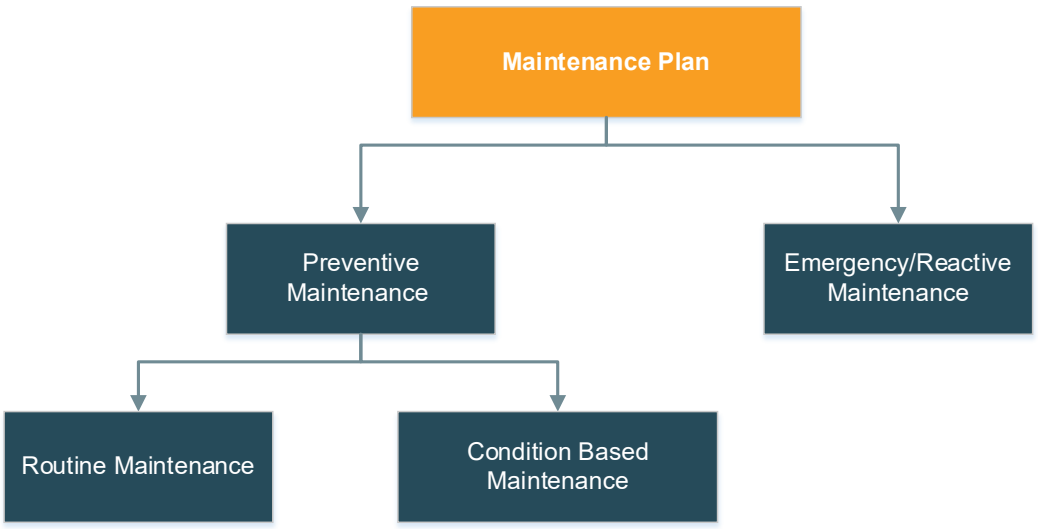

Figure 3: Dam Maintenance Types

6.5.4 Planned Preventive Maintenance (PPM) Schedule

The Entity/operator shall develop scheduled preventive maintenance tasks in accordance with references highlighted in **Section 4.0**, manufactures specifications and if any, specific Entity maintenance requirements. **Attachment 1** represents a sample checklist for the scheduled preventive maintenance tasks. **Attachment 2** provides identification of works/issues which may require periodic maintenance for typical types of dams.

6.5.5 Emergency/Reactive Maintenance

The Entity/operator should have an emergency maintenance plan to carry out the deficiencies that may occur at any time which need to be addressed with repairs or replacement. At times, this may result from the preventive maintenance activities, actions from periodic inspections, as safety event or a flood. Typical activities and instances can include, but not limited to:

- Repairs due to erosion and slope failures
- Repair of emergency spillways being blocked or with some inoperable gates
- Repair of overtopped dam during high flood
- Repair gates, valves and other equipment
- Repair evidence of excessive seepage at the dam site
- Repair hydraulic equipment (e.g., leaks, accumulator faults, limit switches, pumps)

6.6 Inspection

The Entity/operator shall develop an effective inspection program in order to identify problems and to operate and maintain dams safely. The best practice is to carry out following three types of inspections at periodic intervals:

- Routine inspections

- Scheduled inspections
- Comprehensive evaluation inspections (typically 5 yearly)

6.6.1 Routine Inspections

These types of inspections are performed on a daily, weekly, and monthly basis. The Entity/operator may develop a more stringent frequency of these types of inspections, based on the need of O&M requirement of a particular asset. Typically, these types of inspections should record details of the following activities by checklist or similar method approved by the Entity:

- Reservoir level
- Seepage flow
- Piezometer levels
- Asset specific information
- Observations which may affect safety of the asset such as:
    - Seepage
    - Debris
    - Settlement
    - Sinkholes

6.6.2 Scheduled Inspection

The Entity/operator shall carryout scheduled inspections typically on annual basis that shall provide detailed information on all the equipment and features of the asset. The annual inspection information shall be recorded on checklists through a proper rating/criticality system as detailed in **Attachment 4** or similar system approved by the Entity.

Scheduled inspections shall include the following four components as a minimum:

- Historical data review including inspection reports, photographs, maintenance history/records
- Dam, its components, and appurtenances visual inspection
- Preparation of a report or inspection brief, with relevant documentation and photographs
- Education and training, if someone other than the owner is performing the inspection

Typically, the annual inspection shall provide following asset information:

- Condition of crest
- Upstream and downstream slope condition
- Condition of the spillway
- Outlet condition
- Seepage measurement and observation
- Condition and test operation of all equipment including valves, control works, monitoring equipment, and other mechanisms
- It is recommended that an oil sample program is implemented to assess plant (e.g., hydraulic and combustion plant) condition
- Any asset specific information

The inspection information shall be recorded on the approved forms by the Entity.

6.6.3 Comprehensive Evaluation Inspections

Entity/operator shall carry out the detailed and comprehensive inspection of dams to assess structural safety of the dams. This type of inspection shall be carried out by independent panel of experts usually referred as Dam Safety Review Panel (DSRP). Typically, this inspection shall entail information on the following elements of the asset, but not be limited to:

- General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures

- Review and analysis of available data of dam design including seismic safety, construction, O&M, and performance of dam structure and appurtenant works
- Evaluation of procedures for operation, maintenance, and inspection of dam and to suggest improvements/modifications
- Evaluation of any possible hazardous threat to the dam structure such as dam abutment slope stability failure or slope failures along the reservoir periphery
- A detailed visual inspection of all assets, components, and elements of the dam
- Analysis of all asset components relative to extreme events such as flooding and earthquake
- Review of O&M procedures of the asset
- Report highlighting the findings and recommendations

The table in **Attachment 3** provides a typical inspection plan for dam assets. This is an indicative inspection plan, which shall be modified by the Entity/Operator for the asset type and individual asset requirements.

6.7 Instrumentation and Monitoring

The instruments installed on dam assets provide the data and information on their continued functionality, surveillance, and safety. The extent and complexity of instrumentation at the dam depends on size of the structure, its intended purpose, and the potential for loss of life and property damage downstream from the facility. Typical instruments to monitor the dams include, but are not limited to:

- Seepage flow measurements instruments e.g., flumes, pipes, weirs
- Water level monitors e.g., staff gauges
- Piezometers
- Crack meters
- Stress and strains meters
- Movements (horizontal, vertical, rotational, and lateral) measurement instruments
- V – notches
- Survey monuments to measure the vertical and horizontal movements at crest
- Flumes, weirs, and/or gauges to measure reservoir inflow and/or outflow
- Rain gauge to measure precipitation
- Weather and temperature gauges
- Water quality check instruments
- Seismic activity monitors

The Entity/operator shall follow manufacturer's instructions on the use and interpretation of the instruments data. All the data should be recorded on the forms that shall be approved by the Entity and as per manufacturers' instructions and manuals. It is important to calibrate the devices at periodic intervals as per manufacturers' instructions and manuals. The personnel using, recording, and reporting the data from instruments shall be trained, competent, and qualified to use the monitoring equipment highlighted above.

6.8 Records

The Entity/operator shall keep accurate records related to operation, maintenance, and monitoring of dam assets. The records provide historical data which help in safe functioning and optimum use of the dam and reservoir. The historical data and records shall include the following as a minimum:

- Water Audit register:
  - Rainfall and reservoir levels
  - Water inflow and outflow records
  - Water quality
  - Flood levels
- Complete record of all operating procedures
- Weather records
- Security and emergency protocols
- Maintenance types
- Maintenance works, times, and dates
- Equipment and materials used for maintenance

6.9 Access Roads and Bridges

The Entity/operator shall also carry out inspection and maintenance of road and bridge assets under its jurisdictions, in accordance with the requirements detailed in NMA & FM, Volume 6 Chapter 14 – Maintenance Management: Roads Maintenance Plans.

6.10 Sedimentation

Sedimentation is a natural and inevitable process during the design life of the dam assets. Sedimentation process occurs when earth particles are isolated during water flow and rain and this occurs in both natural lakes and dams. Although, sedimentation is inevitable, but this can be delayed, and rate of occurrence can be reduced by effective maintenance and PPM strategy – refer to **Section 6.5.4**. The Entity should develop following typical PPM measures to prevent reservoir sedimentation:

- In the catchment area:
  - Soil conservation and reduce soil erosion
  - Settling basins
  - Slope and bank protection
  - Bypassing structure
  - Off-stream storage reservoir
- In the reservoir:
  - Dredging
  - Dead storage
  - Sediment Flushing
  - Hydrosuction sediment-removal systems
  - Avoiding settling of fine sediments
- At the dam:
  - Sluicing
  - Dam heightening
  - Heightening of intake and bottom outlet structures
  - Turbidity current venting
  - Turbining suspended sediments

The Entity should develop a process illustrated in Figure 4, for sediment analysis and sediment management of existing dams. The Entity should also develop a mitigation plan for sedimentation management and remedial, similar to the actions highlighted in Figure 5.

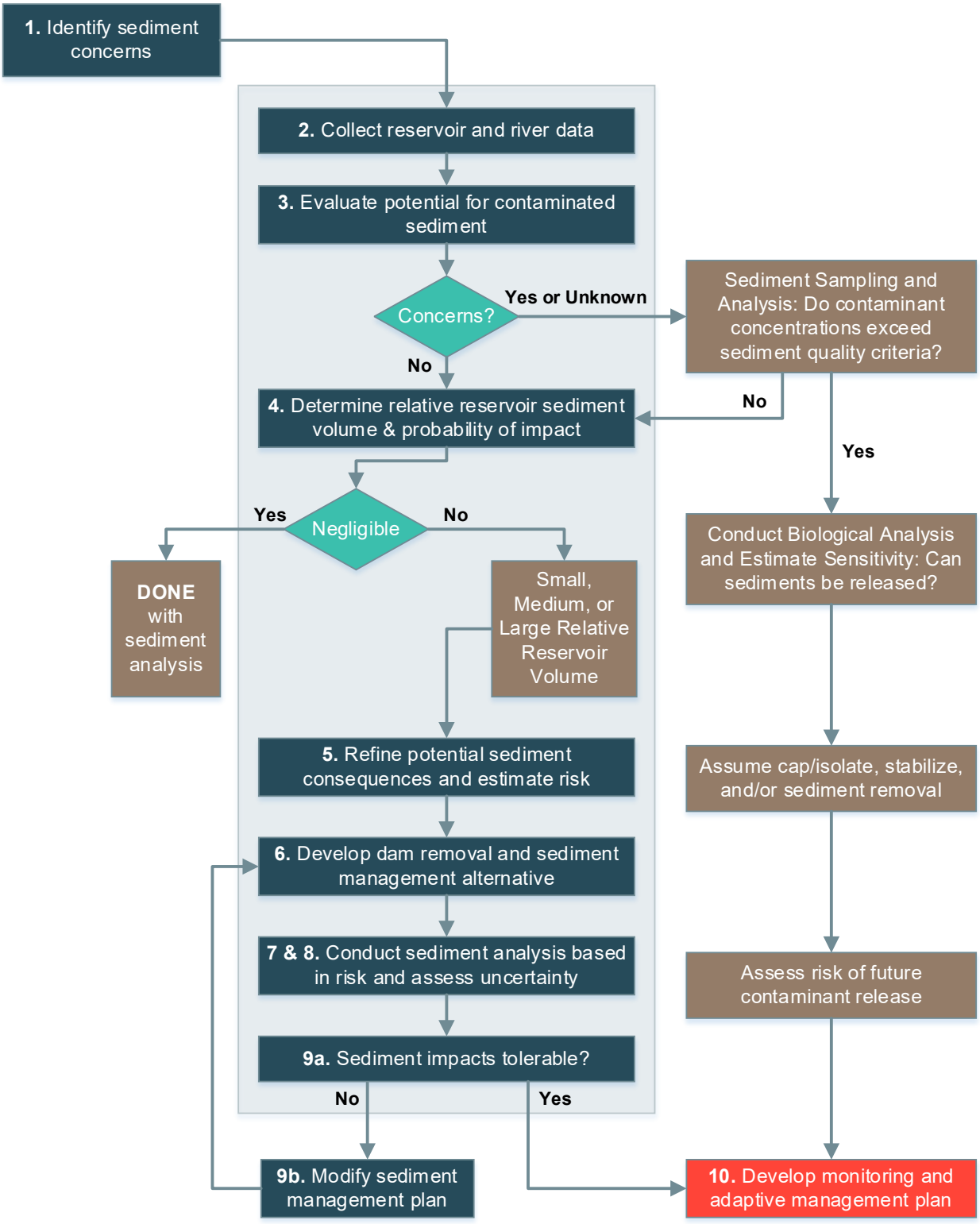

Figure 4: Sediment Analysis and Management Process

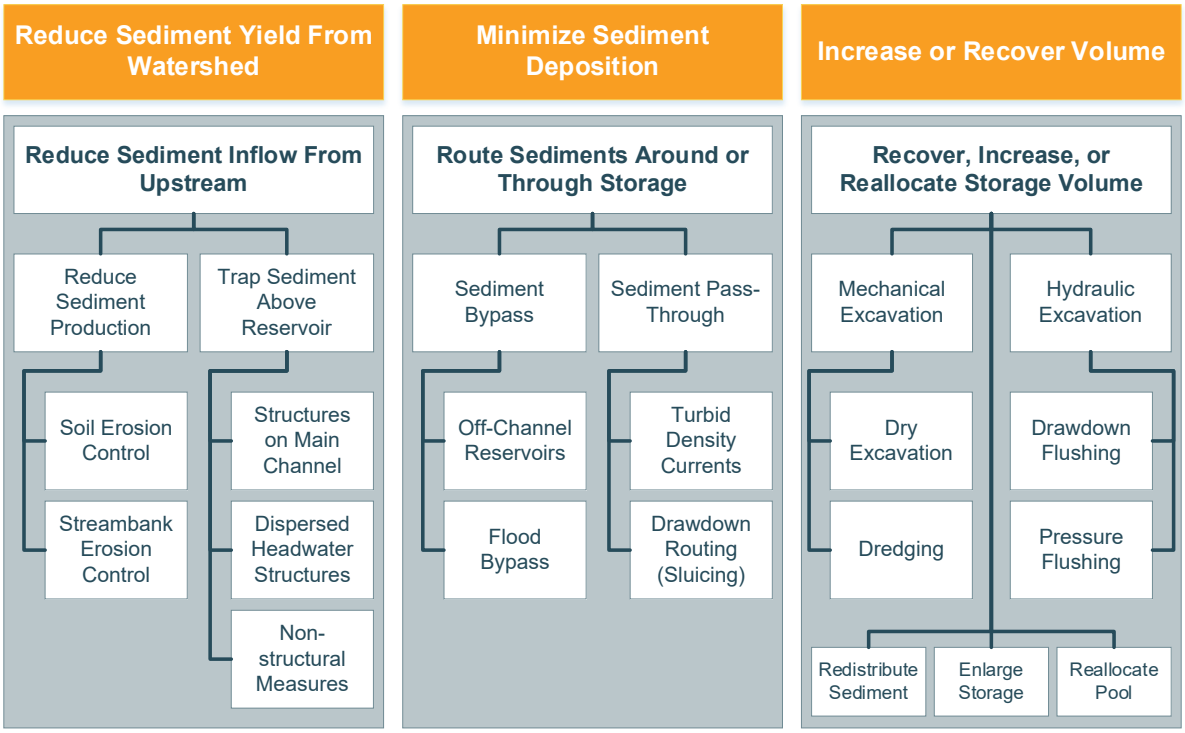

Figure 5: Classification of Strategies for Sediment Management from the Perspective of Sustaining Reservoir Capacity

6.11 Dam Safety

Dams are subjected to several active forces such as hydrostatic pressures, causing damage and failures over their service life. Whilst dams can withstand these forces for a long time, there is a possibility that they can cause failures such as seepage through the foundations or dam embankment itself. Seepage in turn can cause overturning and erosion. Similarly overtopping can happen due to insufficient emergency spillway capacity or a clogging of spillways causing a safety risk. Structural failures such as cracking, settlement, and major slide will require emergency measures to ensure safety, especially if these problems occur suddenly.

The Entity shall establish a legislation or a mandatory requirement for the operator or in case of self-delivery that all dams under its jurisdiction be periodically inspected under a dam safety program to ensure that their continued operation and use does not constitute a hazard to life and property downstream.

6.11.1 Emergency Action Plan (EAP)

Sudden dam failures can happen in few minutes to hours due to the following:

- Seepage
- Erosion
- Overturning
- Structural defects
- During extreme events such as flooding and earthquake

It is, therefore, imperative that the Entity/operator shall have an EAP in place to warn and evacuate residents and affected parties by including procedures for notification including:

- Emergency warning signals
- Coordination with local law enforcement and other governmental agencies
- Information on potential areas of inundation
- plans for warning and evacuation

- Information on resources and procedures for making emergency repairs

The Entity shall also refer to the requirements detailed in NMA & FM, Volume 14 – Emergency Management for further details regarding emergency response procedures during hazardous events.

6.12 Dam Security

Physical structures such as dams can be a target for terrorist threat due to the large impact that can be caused by destruction or effects upon normal operation. The Entity shall develop a dam site security plan to ensure that security of the dams is maintained at all times. The security of dams is essential to avoid the threats outlined and including vandalism to the dam equipment and components, unauthorized use of outlet and spill way. The security of dams is ensured by restricting access to the general public and providing the following means of security, but not limited to:

- Closed Circuit Television (CCTV)
- Fences and barriers
- Manned security
- Access control to vulnerable areas

The Entity should also refer to the requirements detailed in the following:

- NMA & FM, Volume 5 Chapter 2 – Facility Surveillances
- NMA & FM, Volume 5 Chapter 9 – Manned Security Procedures
- NMA & FM, Volume 5 Chapter 9 – Security Systems – Operations

6.13 Environmental Assessment

The Entity should conduct periodic environmental assessment and establish environment monitoring plan for the dam assets. Typical activities include, but not limited to:

- Assessing the surface water quality and keeping the reports during any O&M activities
- A pollution quality check of the water body prior to and during any O&M activity is necessary
- Clearing and trimming woods and vegetation from the embankments and areas near the dam
- Cleaning the disposal of litter gathered from visitors
- Reporting any environmental hazards and threats to the responsible personnel
- The impact of dam's O&M activities on the aquatic livings, particularly focusing on the effects on fishes
- Materials used in maintenance activities that do not cause environmental impact
- Disposal of materials to recognized facilities and recorded

The Entity should also refer to the requirements detailed in the following:

NMA & FM, Volume 10 Chapter 5 – Environmental Requirements
NMA & FM, Volume 5 Chapter 17 – Waste Management Procedures

7.0 ATTACHMENTS

1. EOM-ZM0-TP-000154 – Dam Preventive Maintenance Schedule Checklist
2. EOM-ZM0-TP-000155 – Maintenance Guidelines for Dams Template
3. EOM-ZM0-TP-000156 – Dam Inspection Plan Checklist
4. EOM-ZM0-TP-000157 – Dam Condition Assessment Survey (CAS) Checklist

Attachment 1 – EOM-ZM0-TP-000154 – Dam Preventive Maintenance Schedule Checklist

No.	INSPECTION ITEM	Task	Frequency	CHECKED SATISFACTORY		
				N/A	YES	NO
1.0	**DAM EMBANKMENT**					
1.1	Vegetation Control	Cut grass at least twice annually or more frequently to allow for visual surveillance of the embankment surfaces	Biannually*	☐	☐	☐
1.2	Maintain Crest and Roadway	• Seal road cracks resulting from normal wear and aging • Maintenance of expansion joints at Crest	Annually*	☐	☐	☐
1.3	Maintain Crest Design Elevation	• Maintain the design elevation of unimproved crest surfaces by leveling and grading the crest to design specifications • Fill any ruts or minor depressions	Annually*	☐	☐	☐
1.4	Maintain Upstream and downstream Slope Protection	• Repair of riprap by regarding the slope to original lines and replacing the bedding material and riprap • Repair voids in the riprap by adding or moving riprap	Annually*	☐	☐	☐
1.5	Erosion Control on Downstream Face	Repair erosion gullies by removing loose materials and replacing them with compacted fill	Annually*	☐	☐	☐
2.0	**CONCRETE ELEMENTS/ ONCRETE SPILLWAYS**					
2.1	Maintain Concrete Features**	Make repairs to concrete surfaces and joints, including: • Patching spalled areas with a bonding agent • Strengthening areas by applying coatings or by adding reinforcements • Repairing corroded areas by Cathodic protection, where applicable • Repairing minor cracks with an adhesive or epoxy injection • Keeping concrete joints and surfaces free of vegetation	Annually*	☐	☐	☐
2.2	Spillway Channel	Remove any obstructions/vegetation or debris from the spillway channel	Weekly*	☐	☐	☐
		Keep drains free and clear. Periodically rod and ream internal drains to keep them functioning	Monthly*	☐	☐	☐
2.3	Return Channel	Remove obstructions within the return channel	Monthly*	☐	☐	☐
3.0	**EARTHEN SPILLWAY CHANNEL**					
3.1	Erosion Control	• Repair erosion gullies by removing loose materials and replacing them with compacted fill • Gravel and cobbles or planted grass should be added, as appropriate to the damaged area to prevent future erosion	Annually* And After Floods	☐	☐	☐
3.2	Maintain Spillway Channel	• Remove any obstructions, vegetation or debris from the • Spillway channel	Weekly*	☐	☐	☐

No.	INSPECTION ITEM	Task	Frequency	CHECKED SATISFACTORY		
				N/A	YES	NO
		• Cut grass • Remove small trees and bushes that would affect flows now or in the future if let to grow	Annually*	☐	☐	☐
4.0	**DROP INLET SPILLWAY**					
4.1	Clean Trash rack	Remove all floating logs and debris from trash rack and spillway opening	Weekly*	☐	☐	☐
4.2	Clear Air Vent(s)	Clear debris from air vent entrance	Monthly*	☐	☐	☐
4.3	Inspect and Maintain Log boom	• Replace waterlogged or submerged log boom members • Repair or replace loose or missing anchors	Biannually*	☐	☐	☐
4.4	Inspect and Repair Concrete elements, joints and Riser	• Concrete Elements: Make repairs to concrete surfaces and joints • (Refer to Section 2.1 in the **Attachment 1** on maintaining concrete features)	Annually*	☐	☐	☐
4.5	Maintain Metal Features	• Remove mineral deposits and paint metal features • Inspect the Cathodic protection. • Restore corroded metal to original condition by welding on new metal • Paint the metal surface and apply protection system	Annually*	☐	☐	☐
5.0	**OUTLET WORKS**					
5.1	Gates and Valves	Test gates and valves for proper operation and leakage	Annually*	☐	☐	☐
		• Gates and valves are to be maintained according to the manufacturers' instructions • Follow the guidelines specified by the manufacturer	As Specified*	☐	☐	☐
5.2	Gate and Valve Controls	• Follow guidelines specified by manufacturer	As Specified*	☐	☐	☐
5.3	Intake Structure	• Lower reservoir level or hire divers to inspect intake for low-level outlet works • Clear debris from trash rack • Apply protective coating to Metalwork • Repair concrete, as needed	5 Years*	☐	☐	☐
5.4	Conduit	Visually inspect conduit from downstream end for corrosion, leakage, or other significant problems	Annually*	☐	☐	☐
		• Inspect entire conduit interior either manually or via remote control camera • Repair or reline as needed	5 Years*	☐	☐	☐
12.0	**SPECIFIC PPM NOTES**					
	* Task nature and frequency to be determined by site-specific risk assessment - depends inter alia upon materials, exposure, and location.					

No.	INSPECTION ITEM	Task	Frequency	CHECKED SATISFACTORY		
				N/A	YES	NO
	**Get appropriate advice and assistance from qualified and competent personnel before making repairs to concrete surfaces and joints. Concrete problems may be an indication of a serious dam safety problem. Also, report any new or changing (increasing or decreasing) cracks.					

No.	Reviewer's Comments	Resolution
Originator's Name/Signature and Date:		Checker's Name/Signature and Date:

Attachment 2 – EOM-ZM0-TP-000155 – Maintenance Guidelines for Dams Template

Required Maintenance Item	Earthwork	Riprap	Vegetation Removal	Chute/long./toe drains	D/S Rock Toe	Piping Issues	Monitoring Grass Turfing	Seepage Issues	Livestock damage	Rodent damage	Vehicular traffic damage	Mechanical equipment	Electrical equipment	Cleaning	Concrete/ Masonry	Metal components
Earth fill / Rock fill Embankment																
Upstream slope	●	●	●			●			●	●				●		
Downstream slope	●		●	●	●	●	●	●	●	●	●			●		
Left/right abutments	●	●	●	●	●	●	●	●	●	●	●					
Crest (Dam Top)	●		●			●			●	●	●			●	●	
Area D/s of Dam	●					●		●						●		
Concrete / Masonry Dams																
Upstream face														●	●	
Downstream face								●						●	●	
Left/right abutments	●	●	●					●	●	●	●					
Crest (Dam top)													●	●	●	
Internal Body Drains								●				●	●	●		●
Foundation drainage holes								●				●	●	●		●
Galleries								●					●	●	●	
Sluice / Controls								●				●	●	●	●	●
Spillways																
Approach channel	●	●	●											●	●	
Control Structure								●						●	●	●
Stilling basin / EDA			●											●	●	
Discharge conduit/ channel	●	●	●									●	●	●	●	●
Control Features (Gates, Hoists)								●				●	●	●	●	●
Erosion Protection d/s of EDA	●	●	●											●	●	
Side Slopes	●	●	●					●						●	●	
Outlet																
Outlets	●		●					●				●	●	●	●	●
Stilling basin														●	●	
Trash racks/debris removal												●	●	●		●
General Areas																
Reservoir Surface														●		
Reservoir Periphery	●	●	●											●		

Attachment 3 – EOM-ZM0-TP-000156 – Dam Inspection Plan Checklist

No.	INSPECTION ITEM / TASK	CHECKED SATISFACTORY		
		N/A	YES	NO
1.0	**DAILY/WEEKLY/MONTHLY**			
	Record Reservoir Level	☐	☐	☐
	Determine Reservoir Inflow	☐	☐	☐
	Check and Record Outlet Flow	☐	☐	☐
	Dam Crest Visual Examination	☐	☐	☐
	Upstream and Downstream Faces Visual Examination	☐	☐	☐
	Spillways Visual Examination	☐	☐	☐
	All Drainage Visual Examination	☐	☐	☐
	Security Devices Visual Examination	☐	☐	☐
	Safety Devices Visual Examination	☐	☐	☐
	Check and Record Piezometer Readings	☐	☐	☐
	Check and Record Crack meter Readings	☐	☐	☐
	Check and Record Inclinometer Readings	☐	☐	☐
	Check and Record V-Notch Readings	☐	☐	☐
	Check and Record Pendulum Readings	☐	☐	☐
	Check Spillway Channel For Debris	☐	☐	☐
	Check Hydraulic Systems	☐	☐	☐
	Check All Equipment	☐	☐	☐
2.0	**ANNUAL**			
	Perform Detailed Annual Inspection of all Project Elements Using Checklist	☐	☐	☐
	Test Operate All Gates and Valves Through a Complete Cycle	☐	☐	☐
	Inspect Spillway	☐	☐	☐
	Test Operate all Backup Operating Equipment	☐	☐	☐
	Survey Settlement Monuments on Dam Crest	☐	☐	☐
	Check Corrosion Protection on all Exposed Metalwork	☐	☐	☐
	Review and Update Emergency Action Plan	☐	☐	☐
3.0	**SEASONAL**			
	When reservoir is full, increase frequency of Monthly inspection duties to once weekly	☐	☐	☐
	When reservoir is full increase frequency of Monthly inspection duties to once every two weeks	☐	☐	☐
4.0	**ANY SPECIFIC INSPECTION ITEMS**			

Attachment 4 – EOM-ZM0-TP-000157 – Dam Condition Assessment (CAS) Survey Checklist

Rating Scale			PRIORITY		Hazard Classification		Asset Name	
A	Satisfactory	Dam condition is in good condition with no deficiencies	1	URGENT	☐	VERY LOW	Asset Number	
B	Fair	Dam condition is in fair condition but has some minor maintenance deficiencies	2	ESSENTIAL	☐	LOW	Location	
C	Poor	Dam condition is in Poor condition, and has multiple maintenance deficiencies	3	DESIRABLE	☐	SIGNIFICANT	Inspection Date	
D	Unsatisfactory	Dam condition is in an unsatisfactory condition and safety deficiency exists that requires prompt remedial action	4	LONG-TERM work	☐	HIGH	Inspector	
E	Not Rated	Inadequate information exists to make a condition assessment determination					General Asset Condition	ADEQUATE ☐ SUBSTANDARD ☐ INADEQUATE ☐

Inspection Activity		CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT		A	B	C	D	E		1	2	3	4
A10	CREST										
	Any visual settlements										
	Cracking										
	Lateral movement										
	Visible sinkhole										
	Erosion										
	Trees & brush										
	Rodent holes										
A20	UPSTREAM SLOPE										

Inspection Activity		CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT		A	B	C	D	E		1	2	3	4
	Erosion										
	Visual settlements										
	Longitudinal cracks										
	Transverse cracks										
	Visible sinkhole										
	Debris										
	Visual depression or bulges										
B10	**DOWNSTREAM SLOPE**										
	Erosion										
	Trees & brush										
	Longitudinal cracks										
	Transverse cracks										
	Visual depressions or bulges										
	Visible sinkhole										
	Visual settlements										
	Seepage present										
	Is the drain dry and are Boils present at toe?										
B20	**ABUTMENT CONTACTS**										
	Erosion										
	Visual differential movement										
	Cracks										
	Seepage present										
	Trees & brush										
B30	**GROIN**										
	Erosion										
	Visual differential movement										
	Cracks										
	Seepage present										
	Trees & brush										
C10	**RESERVOIR CONTROL**										
	Recent downstream development										
	Slides in reservoir area										
	Change in reservoir operation										

Inspection Activity		CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT		A	B	C	D	E		1	2	3	4
	Other large impoundments u/s										
	Evidence or recreational use										
C20	**INSTRUMENTATION**										
	List any instrumentation present										
	Is instrumentation functional?										
	Record measurements										
EMBANKMENT SAFETY RATING:											
EMBANKMENT											
C30	**INTAKE STRUCTURE**										
	a. Debris present										
	b. Concrete surface condition										
	Spalling										
	Cracking										
	Erosion										
	Scaling										
	Exposed reinforcement										
	Other										
	c. Joint condition										
	Displacement or offset										
	Loss of joint material										
	Leakage										
	d. Metal appurtenances										
	Corrosion present										
	Breakage present										
	Anchor system secure										
D10	**CONDUIT**										
	a. Debris present										
	b. Concrete surface condition										
	Spalling										
	Cracking										
	Erosion										
	Scaling										

Inspection Activity		CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT		A	B	C	D	E		1	2	3	4
	Leakage										
	Exposed reinforcement										
	Displacement or offset										
	c. Metal conduit condition										
	Corrosion present										
	Loss of joint material										
	Leakage										
	d. Metal appurtenances										
	Corrosion present										
	Protection coating adequacy										
	Leakage										
	e. Plastic conduit condition										
	Displacement or offset										
	Leakage										
	Broken										
D20	**GATES**										
	a. Flood gate condition										
	Broken or bent										
	Corroded or rusted										
	Regularly maintained										
	Gates operational										
	b. Is there a low-level gate?										
EMERGENCY SPILLWAY or OUTLET WORKS											
D30	**STILLING BASIN**										
	a. Concrete surface condition										
	Spalling										
	Cracking										
	Erosion										
	Scaling										
	Exposed reinforcement										
	Other										
	b. Joint condition										

Inspection Activity		CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT		A	B	C	D	E		1	2	3	4
	Displacement or offset										
	Loss of joint material										
	Leakage										
	c. Energy dissipater condition										
	Deterioration										
	d. Channel condition										
	Eroding or back-cutting										
	Sloughing										
	Obstructed										
	Undercut by released water										
	Embankment erosion by water										
	e. Gabion Condition										
	Corroded										
	Deterioration										
	Basket misaligned										
	Basket settlement										
	Brush growing in gabions										
	f. Riprap condition										
	Erosion undercut or settlement										
	Vegetation										
	Extent of riprap adequacy										
D40	**SPILLWAY or OUTLET WORKS**										
	a. Spillway concrete condition										
	Spalling										
	Cracking										
	Erosion										
	Scaling										
	Exposed reinforcement										
	Other										
	b. Joint condition										

Inspection Activity	CONDITION					Identified Defects/Recommended Action	Recommended Priority			
EMBANKMENT	A	B	C	D	E		1	2	3	4
Displacement or offset										
Loss of joint material										
Leakage										
c. Energy dissipater condition										
Deterioration										
Signs of deterioration										
Covered with debris										
Riprap dissipater										
Missing										
d. Excavated earth spillway condition										
Slopes eroding										
Slopes sloughing										
Head-cutting										
Trees and brush — obstructed										
e. Natural earth spillway condition										
Slopes eroding										
Slopes sloughing										
f. Damage from released water										
Eroded embankment										
Undercutting of outlet										
Recent discharge										
Other damage, list										
g. Is weir in good condition?										