Rehabilitation Management Guidelines (RMGs) for Water Resources
Project Steering Committee Meeting 04

Technical Presentation for Lakes/Dams & Groundwater Reports

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WATER IS LIFE - SANITATION IS DIGNITY

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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Purpose of Lakes/Dams Report

- The aim of the **Lakes and Dams Report** is to develop Rehabilitation Management Guidelines (RMGs) that address the following characteristics of watercourses:
  - ✓ *Hydrology;*
  - ✓ *Geomorphology;*
  - ✓ *Water quality;*
  - ✓ *Habitat; and*
  - ✓ *Biota*

Water Resources Themes

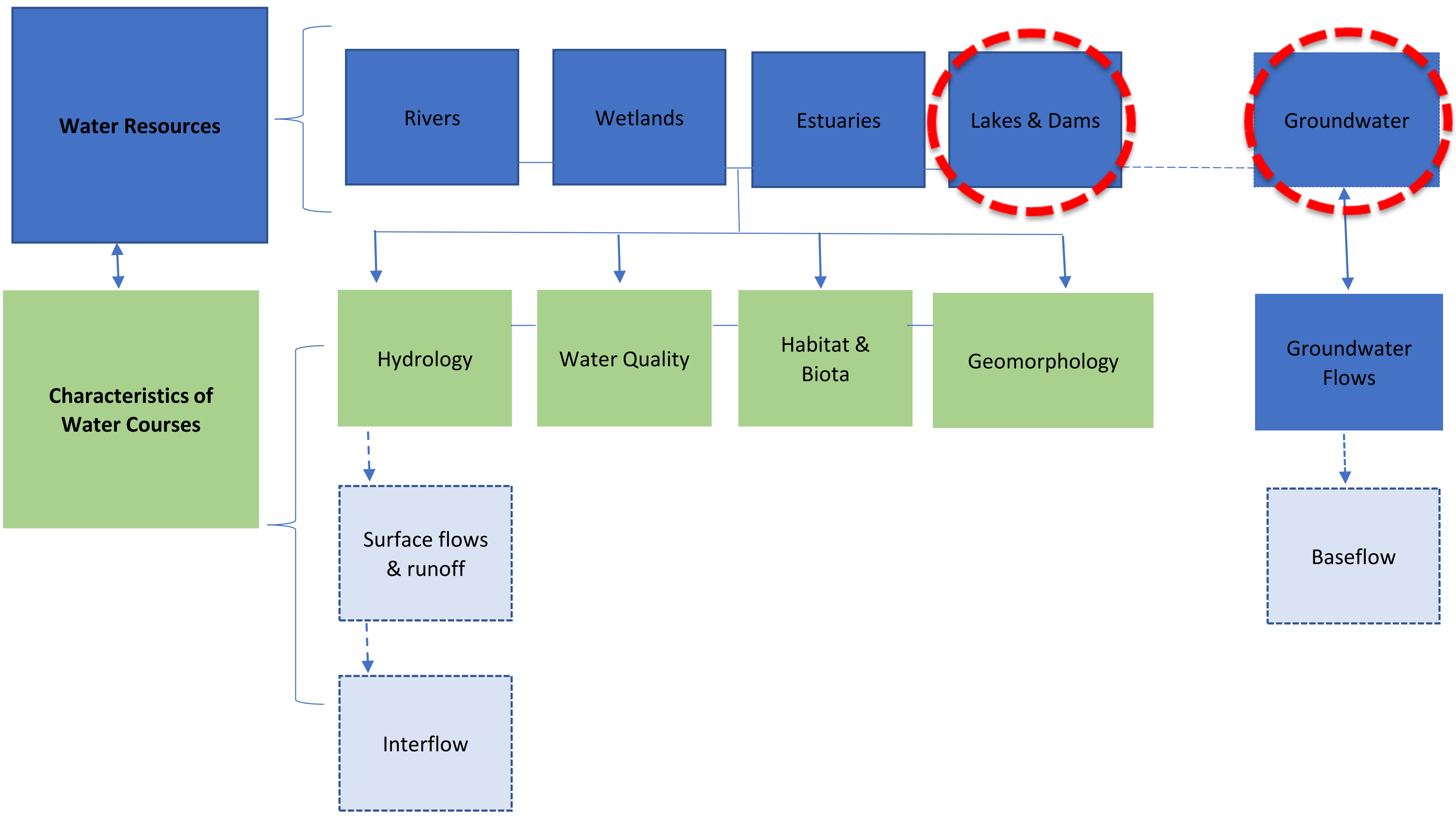
- Themes identified & categorized into **Rivers, Wetlands, Estuaries, Lakes and Dams** and **Groundwater** as per the definition of water resource (National Water Act)

THEME 1	THEME 2	THEME 3	THEME 4	THEME 5
Rivers	Wetlands	Estuaries	Lakes & Dams	Groundwater

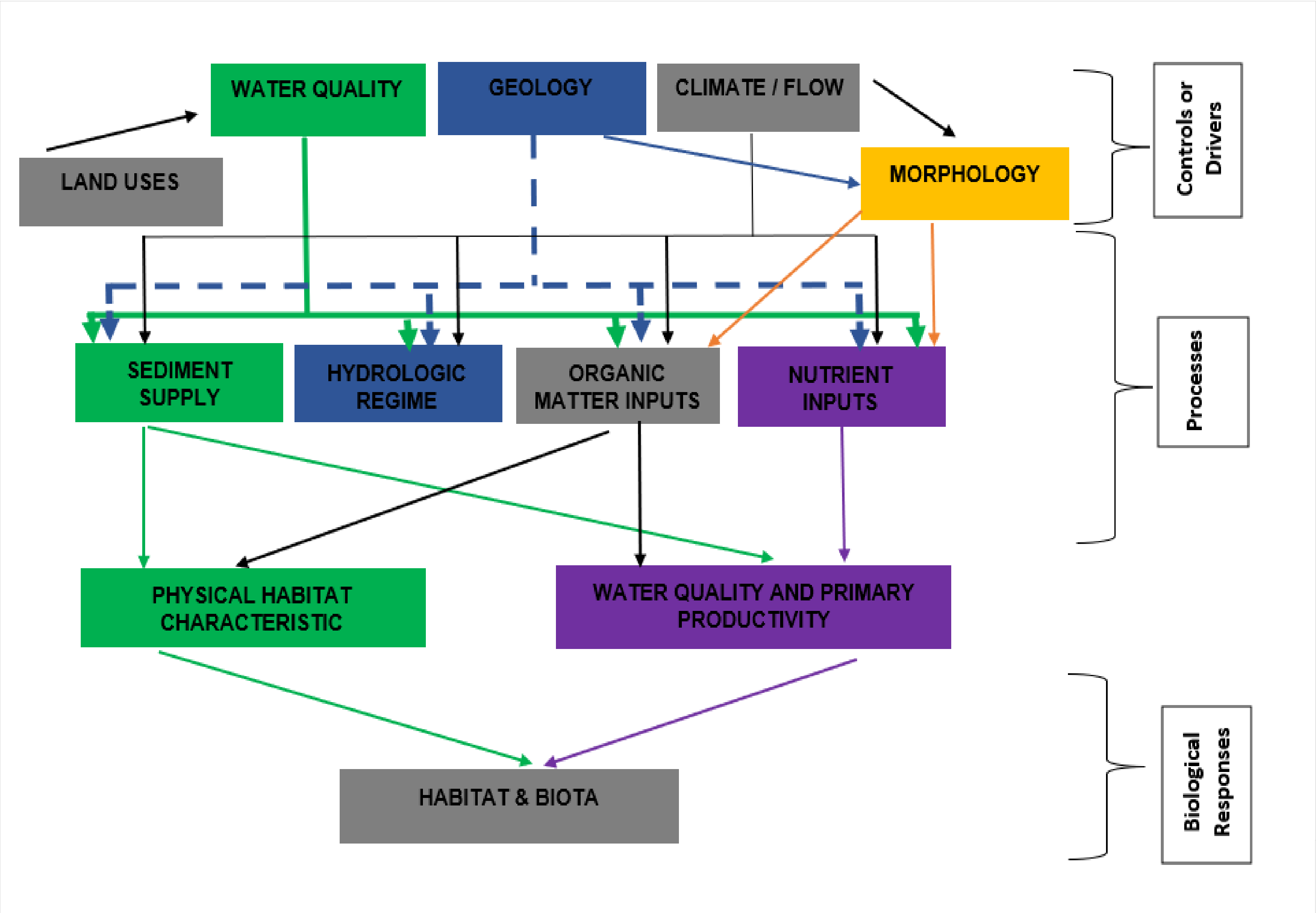
Definition of Watercourses

- In terms of the definition contained within the NWA, Act 36 of 1998, a watercourse means:
  - ✓ *A **river** or **spring**;*
  - ✓ *A **natural channel** from which water flows regularly or intermittently;*
  - ✓ *A **wetland, dam**, or **lake** into which, or from which, water flows;*
  - ✓ ***Any collection of water** which the **Minister** may, by notice in the **Gazette**, **declare** to be a watercourse; and*
    - *- A **reference** to a watercourse includes, where relevant, its **bed** and **banks***

Link between Water Resources & Watercourses



Interlinkages between drivers and responses



Adapted from Beechie and Bolton (1999)

Rehabilitation Approach

PHASE 1:

Diagnostic Phase

Determine the conditions and the type, size, extent of impacts on characteristics of watercourses

PHASE 2:

Planning & Assessment Phase

- Assess and collate available information from maps & datasets on the affected watercourses
- Review and assess legal considerations

PHASE 3:

Identify & Define the Rehabilitation Objectives

Detail the objectives of rehabilitation to ensure the impacts on the characteristics of watercourses are addressed

PHASE 4:

Execution Phase

Recommend techniques and methods to address impacts identified. Consider protection of water resources ecosystem services, people & livelihoods.

PHASE 5:

Monitoring & Evaluation

- Monitor the results of the techniques and methods employed for rehabilitation
- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Stakeholder Engagement

List of applicable legislation for Lakes and Dams

Characteristics of Watercourses	Applicable Legislation
Hydrology	• **NWA**, Act 36 of 1998 - Section 36(2) • **NEMA**, Act 107 of 1998
Geomorphology	• **NWA,** Act 36 of 1998 - Section 21 • **NEMA,** Act 107 of 1998 • **NEM: BA,** Act 10 of 2004 • **NEM: WA,** Act 59 of 2008
Water Quality	• **NWA**, Act 36 of 1998 - Section 21 of NWA • **NEMA**, activity 19
Habitat	• **NWA**, Act 36 of 1998 - Section 21 (a), (c) & (i) • **CARA**, Section 6(i)
Biota	• **NWA**, Act 36 of 1998 - Section 21(c) & (i), (e)-(h) • **NEMA**, Act 107 of 1998 • **NEM:BA**, Act of 2004 • **Environmental Conversation Act**, Act 76 of 1989

Rehabilitation Management Guidelines for Lakes & Dams Scenarios

REHABILITATION MANAGEMENT GUIDELINES SCENARIOS

- **HYDROLOGY**
  - **Scenario 1**
    Re-design and maintenance of improperly designed weirs to restore free –flowing conditions of associated instream dam/lakes
- **GEOMORPHOLOGY**
  - **Scenario 1**
    Rehabilitation of modified vegetation (upstream and downstream of dam) to promote flood attenuation and soil stabilization
- **WATER QUALITY**
  - **Scenario 1**
    Improvement of degraded water quality in the instream dam due to eutrophication caused by effluent discharged from WWTW
- **HABITAT**
  - **Scenario 1**
    Rehabilitation and management of sedimentation for ecological function of dams and improvement of storage capacity
- **BIOTA**
  - **Scenario 1**
    Re-establishment of biota migratory routes (i.e. fishways)

LAKES & DAMS
Hydrology

Identified Impacts

- **Constructed weirs affecting hydrology, physico-chemistry, and connectivity**
- Dam/Lakes induced impacts on connectivity and flow affecting physical habitats such as bars, riffles and floodplains
- Over-abstraction causing decline in water levels

Scenario 1: Re-design and Maintenance of improperly designed weirs to restore free-flowing conditions of associated instream dam/lakes

Phase 1: Diagnostic

STEP 1:

- Identify the weir in question within the river/stream that is affected
- Initiate communications with the responsible authorities (i.e., local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located

STEP 2:

- At a desktop level, use various tools such as Google Earth/Engine, satellite images, GIS, QGIS ArcMap, and Remote Sensing to obtain information on the type of weir that is affected
- Some examples of the different types of weirs are V-notch, sharp and broad crested weirs

Phase 2: Planning & Assessment

STEP 1:

Conduct a site visit survey to collect the following information regarding the weir in question:

- Site location and description of the locality of the weir
- Biodiversity features associated with the weir
- Designs and dimensions
- Weir hydraulics
- Construction material used for the weir

STEP 2:

Based on information collated in **Step 1**, determine the main factors affecting the functioning of the weir. Examples of impacts are as follows:

- Flood events*
- Erosion and siltation clogging the weir
- Degradation and ageing of the weir
- Structural impacts

Note: *for purpose of this scenario, the assumption is that the functioning of the weir has been compromised due to a flood event)*

Phase 3: Defining Rehabilitation Objectives

STEP 1:

Define clear rehabilitation objectives based on information and data gathered in **Phase 1** and **2**.

Examples:

The objectives of rehabilitation will entail addressing the affected weir. Some of the most common aims and objectives of rehabilitation of weirs are to:

- Mitigate the increased runoff and prevent flooding events
- Provide a passage-way for biota i.e. fishway for migratory fish
- Operate dam to natural flow and temperature regimes
- Ensure Ecological Water Releases
- Correct structural problems i.e. deterioration of concrete, failure of spillways, cavitation of outlet pipes

Phase 4: Execution

REHABILITATION METHODS/TECHNIQUES

- Rehabilitation with a steel enforced concrete weir and piped outlet works
- The weir should be re-designed with new dimensions (i.e. height, length, and width) to ensure the ability to withstand future flooding events
- New pipeline would be constructed such that it will feed water from the weir

OTHER AVAILABLE METHODS/TECHNIQUES

- Modification of weir to increase the spillway capacity to allow passage of flood conditions of suitable dam safety
- Installation of deflectors at appropriate angles in the channel to regulate velocity of the water during flood events
- Installing a safety and debris boom upstream as part of the weir
- Energy Dissipation Basin - to dissipate flow energy, support fish passage, and reduce operations and maintenance

Phase 5: Monitoring & Evaluation

Monitoring

Evaluation

STEP 1:

Monitoring:

- The weir must be monitored quarterly, before rainy season and directly after a heavy rainfall event to ensure the crest of the weir is in good condition and free of obstructions
- Ensure that the weir remains in a safe working condition through continuous monitoring during the implementation phase i.e. avoid slumping, cracking or obvious changes to the crest of wall
- Determine maintenance objectives

STEP 2:

Maintenance:

- Clearing debris from the crest, removing silt from upstream of the weir, providing safety booms, and carrying out repairs to the structure
- Maintenance at the river reaches upstream and downstream of the weir during implementation phase
- Clearing vegetation, cutting back overhanging trees, removal of silt and repairs for erosion protection may form part of the channel maintenance regime in the vicinity of the weir

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes

Geomorphology

Identified Impacts

- **Intensive agricultural practices causing soil erosion, modification of vegetation**
- Poor land use and management practices such as sand mining and road construction
- Alien Invasive Vegetation Species

Scenario 1: Rehabilitation of modified vegetation (upstream and downstream of dam) to promote flood attenuation and soil stabilization

Phase 1: Diagnostic

STEP 1:

- Undertake a desktop study using tools such as Google Earth/Engine, satellite images, GIS, QGIS ArcMap, and Remote Sensing to identify the areas in the vicinity of the lake/dam in question that has experienced modification of vegetation cover
- Initiate communications with the responsible authorities (i.e., local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located

STEP 2:

Using the desktop study results from **Step 1,** undertake an assessment to identify the potential impacts, causes and effects of modified vegetation. Impacts may include:

- Excessive grazing and trampling activities by cattle, goats, sheep and wild animals
- Alien Vegetation Infestation
- Dumping activities
- Development in close proximity to lake/dam
- Erosion

STEP 3:

Describe the biome and vegetation types within which the lake/dam in question is located

Phase 2: Planning & Assessment

STEP 1:

On a desktop level, undertake the below activities in conjunction with the site visit to supplement and ensure reliable information pertaining to affected site is obtained:

- Collection and collation of data with regards to the site from existing literature by using available tools such as Google Earth/Engine, satellite images, GIS, QGIS ArcMap, and Remote Sensing
- Review of historical status (reference conditions)
- Review of vegetation maps
- Review of threatened ecosystems
- Review of Conservation Management Plan
- Review of historical Google Earth aerial imagery trends to provide clues on the vegetation patterns around the dam and disturbances over time

STEP 2:

Conduct a field/site visit to accurately ascertain area(s) within the lake/dam affected by vegetation modification. The results must include the following:

- Description of all areas affected by vegetation modification including photographs and GPS co-ordinates
- The causes and effects of vegetation modification
- The type(s) of vegetation prevalent on site
- The extent of the affected areas with the details relating to estimated hectares

Phase 2: Planning & Assessment (2)

STEP 3:

Map and delineate the areas clearly indicating the extent in hectares of the area(s) affected. This step must also consider upstream and downstream conditions of the area(s) affected

STEP 4:

Mapping must be undertaken by comparing geo-referenced field survey data to the visual inspection of available Google-Earth Imagery

STEP 5:

Undertake a vegetation sensitivity assessment to identify the following features of ecological importance:

- Ecosystem or threatened vegetation unit
- Habitat or potential habitat to plant species of conservation concern
- Ecologically sensitive areas such as riparian areas

Phase 3: Defining Rehabilitation Objectives

STEP 1:

Define clear rehabilitation objectives based on information and data gathered in **Phase 1** and **2**.

Examples:

The objectives of rehabilitation will entail addressing modified vegetation. Below is a list of common aims and objectives:

- Revegetate all disturbed areas with suitable local plant species
- Shape to original or better topography
- Achieve stabilization of the disturbed area and minimize erosion
- Improve the aesthetics of disturbed areas
- Ensure that disturbed areas are rehabilitated to a functional condition similar to that found prior to disturbance

Phase 4: Execution

REHABILITATION METHODS/TECHNIQUES

- Brush mattresses are recommended to restore riparian vegetation habitat, biota and enhance conditions for colonization of indigenous plants
- This method reduces soil erosion and intercepts sediment flowing down the stream
- Once vegetation reaches a certain height, it can improve biota by shading the stream, lowering water temperatures, and offering protection from predators

OTHER AVAILABLE INTERVENTIONS

Revegetation plan/strategy option that should be implemented with some of the below considerations:

- Soil preparation prior to revegetation
- Use of indigenous seeds and plants
- Revegetation must be based on the specific conditions of the site
- Seeds must be thoroughly mixed before applying
- The seeds must be applied according to the required rates
- Application rates can be increased in areas that are unfavourable or steep, but no more than double the recommendations

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

Monitoring of rehabilitated and revegetated areas must be undertaken on an annual basis to ensure that interventions methods employed are adequate and effective

STEP 2:

Additional measures must be implemented in the event the monitoring results show no substantial changes i.e. double the application rates of seeds in areas where there is no signs of vegetation growth

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes;
- Determine maintenance objectives

Water Quality

Identified Impacts

- **Eutrophication driven by effluent discharge from WWTWs**
- Discharges from industries and mines
- Poor water quality attributed to ageing infrastructure
- Salinization
- Acidification

Scenario 1: Improvement of degraded water quality in the instream dam due to eutrophication caused by effluent discharged from WWTW

Phase 1: Diagnostic Phase

STEP 1:

- Carry-out a feasibility study first to diagnose problems (i.e. eutrophication in the Lake or Dam) and causes (effluent discharge from WWTWs) per specific resource
- Understanding of the characteristics of Lakes and Dams (resource) is a critical step to take prior to choosing and applying an appropriate rehabilitation approach

STEP 2:

- Undertake a desktop assessment to identify the WWTWs (source) negatively impacting water quality of the Lake or Dam
- Focus on facilities situated in 1: 100-year floodline of a Lake or Dam, and check if there are any other point sources in the vicinity

STEP 3:

Initiate communications with the responsible authorities (i.e. WWTW facility personnel, local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located)

Phase 1: Diagnostic Phase (2)

STEP 4:

- Utilize tools i.e Google Earth/Engine, satellite images, GIS, QGIS ArcMap, and Remote Sensing to identify changes in land use (land-based) catchment pollution that could be associated with changes in the resource water quality

STEP 5:

Conduct ground survey to identify visible signs of water quality changes in the resource such as:

- Extremely foul odour
- Dead fish
- Leached plants (loss of biodiversity)
- Visible clumps of sewage in the Lake or Dam and feeding river streams

STEP 6:

Conduct diagnostic assessment of the facility in terms of:

- The overall integrity and functioning of the WWTWs
- Challenges associated with power cuts and failures
- Land based activities and the overall management of the catchment

Phase 2.1: Planning Phase

STEP 1:

Request local government officials (i.e. including DWS regional office responsible catchment manager) and community forums responsible to assist with identifying point source of inflow and providing guidance on available regulatory processes

STEP 2:

Investigate other sources of pollution and water quality e.g. non-point sources of pollution

Phase 2.2: Assessment Phase

STEP 1:

- Collect the actual final effluent water samples from the source i.e. WWTW
  - 1 upstream of the WWTW discharge point,
  - 1 downstream of the WWTW discharge point
- Collect representative water quality samples from the resource i.e. Lake or Dam, ideally from inside the dam close to the wall
- Have samples analysed at an accredited laboratory to determine the water quality at the source and resource, respectively

STEP 2:

- Compare laboratory-generated water quality data to the expected state for identification of areas of concern
- Data analysis should be compared against the RQOs/RWQOs, or water quality standards if RQOs/RWQOs have not yet been established for that catchment

STEP 3:

Analysis of available data to determine the trophic status of the Lake or Dam, the WWTW as well as an overall water quality status (upstream and downstream) in terms of the below:

- Salinity
- Temperature
- Dissolved oxygen
- Suspended solids
- Turbidity
- Inorganic nutrients

Phase 3: Defining Rehabilitation Objectives

STEP 1:

- The objective(s) of rehabilitation must be informed by the catchment vision and goal, and data collected during the assessment phase
- This process must include conditions and prioritized actions informed by problems (i.e. eutrophication in the Lake or Dam) and causes (effluent discharge from WWTWs) identified in the feasibility study
- Each prioritized action may have its own distinct objective which is set based on any of these categories i.e ecological, infrastructure, social, or recreational

STEP 2:

The identified objectives must be checked for feasibility and affordability, and there must be a reasonable timeframe

- Short-term (0-3 years)] or
- Long-term (>5 years)) set to allow a Lake or Dam to respond to the rehabilitation actions

Phase 4: Execution

Techniques/Methods for rehabilitation of instream dam or lake

REHABILITATION METHODS/TECHNIQUES

Short-term solutions to minimize impacts on the Lake or Dam include:

- Dilution and/or diversion of final effluent from the problematic WWTW
- Nature-based solutions (i.e. cconstruction of artificial wetlands) which can effectively remove pollutants associated with municipal and industrial wastewater; and stormwater

OTHER AVAILABLE METHODS/TECHNIQUES

- Bio-manipulation is the deliberate alteration of an ecosystem by adding or removing species, especially predators
- Bio-manipulation is well known as a management tool for eutrophic systems
- An example is hyacinth harvesting

Phase 4: Execution

Techniques/Methods for rehabilitation of WWTW

- **Contain and temporarily store** the effluent discharged at the source for possible **treatment prior** to discharge;
- **Implement surface water management measures** around the problematic WWTW i.e. **installation of cut off trenches** around the WWTW to divert surface runoff to drain back into the natural drainage lines and the natural environment;
- **Construct temporary berms** along the dam/lake/river to prevent further offsite migration/discharge of effluent ending up into the dam/lake/river.

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

- Continuous monitoring of WWTW effluent and water quality upstream and downstream of Lake or Dam to capture changes in the Lake or Dam (i.e. habitat, odour, and colour) to help determine the water quality and the extent to which treatment is necessary
- Continuous monitoring inside the dam close to the wall as well as upstream and downstream of the dam as part of catchment monitoring activities

STEP 2:

- Remote sensing can be used to monitor changes on the surface of the Lake or Dam, which might also be used as an early warning tool and to check if there are other possible polluters in the vicinity other than a WWTW

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes;
- Determine maintenance objectives

Habitat

Identified Impacts

- **Sediment trapping by dams - accumulation of sediment in dams affects the ecosystem structure and function**
- It also alters ecology, affecting species composition and ultimately both recreational and subsistence fishing

Scenario 1: Rehabilitation and Management of sedimentation for ecological function of dams and improvement of storage capacity

Phase 1: Diagnostic Phase

STEP 1:

- Identify the dam in question within the river channel that is affected by sedimentation
- Initiate communications with the responsible authorities (i.e., local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located

STEP 2:

At a desktop level, use various tools i.e. Google Earth/Engine, satellite images, GIS, QGIS ArcMap, and Remote Sensing to gain insight and evaluation on the sediment deposition patterns in a reservoir

STEP 3:

Using the tools mentioned in **Step 2**, identify the possible source(s) of sedimentation by examining the following three main aspects:

- Characteristics of the source (i.e. the catchment)
- Characteristics of the sediment transfer into dam (i.e. the transportation mode)
- Characteristics of the dam

STEP 4:

Describe the specific details of the dam affected in terms of the below given characteristics:

- Land use
- Sediment loads
- Economic, ecological, cultural importance;
- Current storage volume vs. sediment load
- Flood peaks and volumes

Phase 2: Planning & Assessment

STEP 1:

Undertake a site inspection to collate the below pertinent information and data regarding the dam in question:

- Catchment hydrology inclusive of - mean annual runoff (MAR), mean annual precipitation (MAP) and catchment yield
- Land use to determine the type of management practices
- Sediment characteristics (such as particle size grading, hazardous nature)
- Sediment management design features (sediment flush gates, bypass channels, sediment traps) and the functionality of these, if there are any in place
- Erosion risk

STEP 2:

- Determine the type of dam in question (i.e. small or big). The dam type will dictate the techniques to be employed for rehabilitation
- Less significant dams on small catchments could be assessed using simpler tools, however large dams with high economic importance should be examined in much greater detail with more exact estimates of sediment impacts

Phase 2: Planning & Assessment (2)

STEP 3:

Determine the main source(s) of sedimentation i.e. erosion, land use impacts, climate change, alien vegetation and environmental degradation

STEP 4:

Based on comprehensive information and data acquired in **Step 1-3**, determine the main source(s) of sedimentation (i.e. erosion) and recommend the most feasible intervention

Phase 3: Defining Rehabilitation Objectives

STEP 1:

The objectives of rehabilitation of dams must be clearly defined and set. The objectives for rehabilitation must be informed by the data collated in **Phase 1** and **2**.

Examples:

Some of the most common aims and objectives of rehabilitation of sedimentation of dams are to:

- Reduce sediment yield to dams by erosion control in the upstream river basin
- Provide a passageway i.e. fishway for migratory fish
- Restore sediment continuity, move sediment around or through the dam via sediment bypass, sluicing and flushing
- Operate dam to natural flow and temperature regimes

Phase 4: Execution Phase

REDUCE SEDIMENT YIELD

Sediment delivery to a reservoir can be reduced by techniques such as:

- Soil conservation measures (erosion control, reforestation, or revegetation), and
- Upstream sediment trapping

ROUTE SEDIMENTS

- **Seasonal drawdown** - increase flow velocity with corresponding decrease in retention time and sediment trapping
- **Sluicing** - releasing most of the sediment load with the flow through the dam before the sediment particles settle
- **Sediment by-pass** - a large capacity channel or tunnel can be constructed to bypass sediment-laden flow around an instream storage reservoir

SEDIMENT REMOVAL

- **Hydraulic dredging and dry excavation** - uses a mechanical pump to supply the energy to remove deposited sediment
- **Hydraulic flushing** - flushing uses drawdown and emptying to scour and release sediment after it has been deposited
- **Hydrosuction sediment removal systems (HSRS)** - remove sediments from reservoirs using the energy represented by the difference between water levels upstream and downstream from the dam

Note:

- Plant Species plans must be drawn up by the relevant specialist i.e., landscape architect or botanist for approval and implementation; and
- Constructed wetlands and nature-based solutions should be included as part of rehabilitation measures

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

- Monitoring of rehabilitated dams must be undertaken on an annual basis to ensure that interventions methods employed are adequate and effective
- Water quality monitoring downstream of the dams/lakes due to disturbed sediments

STEP 2:

- Additional measures must be implemented in the event the monitoring results show no substantial changes i.e. if erosion persists after revegetation, other erosion control measures be considered

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Biota

Identified Impacts

- **Dams induce connectivity impacts which affects biota and have a negative impact on ecology due to prevention of the migration of biota**
- Alien invasive species (animal and plant species)

Scenario 1: Re-establish biota migratory routes (i.e. fishways)

Phase 1: Diagnostic

STEP 1:

- Determine which instream dam is affected
- Initiate communications with the responsible authorities (i.e., local and district municipality as well as DWS Regional Office) responsible for the catchment in which the resource affected is located
- At a desktop level, identify the instream dam in which the biota migratory routes are affected

STEP 2:

- Describe the specific details of the river affected within which the instream dam is located – Primary or Secondary River
- Describe the specific reach of the river affected within which the instream dam is located – Upper, Middle and Lower reaches

Phase 2: Planning & Assessment

STEP 1:

Assess the ecological need for a fishway at an instream barrier

STEP 2:

If the assessment result prove that there is no need for a fishway consider the following alternatives and mitigation measures:

- Artificial spawning beds;
- Captive breeding; and
- Capture and transport.

STEP 3:

If there is a need for a fishway, quantify the ecological impact of the instream barrier on migratory species present – i.e., importance of providing a fishway at the barrier

Phase 2: Planning & Assessment (2)

STEP 4:

Once the need and importance are identified and determined, conduct a cost benefit analysis of an effective fishway to be designed and constructed at the instream barrier

STEP 5:

Prepare a motivation and secure appropriate funding

Phase 3: Defining Rehabilitation Objectives

STEP 1:

- The objectives of rehabilitation of the impacts of instream barriers on biota migratory routes must be clearly defined and set; and informed by the data collated in **Phase 1** and **2**

Examples:

Some of the most common aims and objectives are to:

- Provide migration routes to some species for spawning, feeding, dispersion after spawning, colonisation after droughts
- Provide migration routes between fresh water and the sea or saline waters

Phase 4: Execution

STEP 1:

Based on the information gathered, a relevant specialist i.e., Engineer and/or Aquatic Specialist must design a fishway

STEP 2:

The fishway to be designed will depend on the site conditions. Based on the conditions, the relevant specialist i.e., Engineer and/or Aquatic Specialist must design the fishway based on the general hydraulics

STEP 3:

The fishway designs must be informed by the following key factors:

- Species composition
- Types of migration
- Season/time period when species are active
- Swimming ability of species
- Swimming speed of species
- Endurance of species
- Physiological factors of species i.e. aerobic vs anaerobic muscles
- Current velocities and turbulence factors

Phase 4: Execution (2)

STEP 4:

The fishway design process must be supported by and include the following:

- Ecological, Hydrological and Engineering studies
- Analysis of the barrier hydraulics
- Selection of a suitable location for the proposed fishway
- Hydraulic analysis of the selected fishway type(s)
- Provision for maintenance of the fishway

STEP 5:

Identify the appropriate fishway design suitable for the site-specific conditions

STEP 6:

The fishway must be constructed according to the approved engineering standards and must be informed by the selected designs, dimensions and all the results of analysis conducted in **Step 3**.

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

Conduct site visits to ensure the rehabilitation methods employed are adequate and require no further additional measures

STEP 2:

Monitor the following categories of parameters:

- Biological / Ecological Parameters i.e. size and numbers of species that successfully pass through the biota barrier
- Physical Parameters i.e. temperature, conductivity, pH, turbidity

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

DISCUSSION

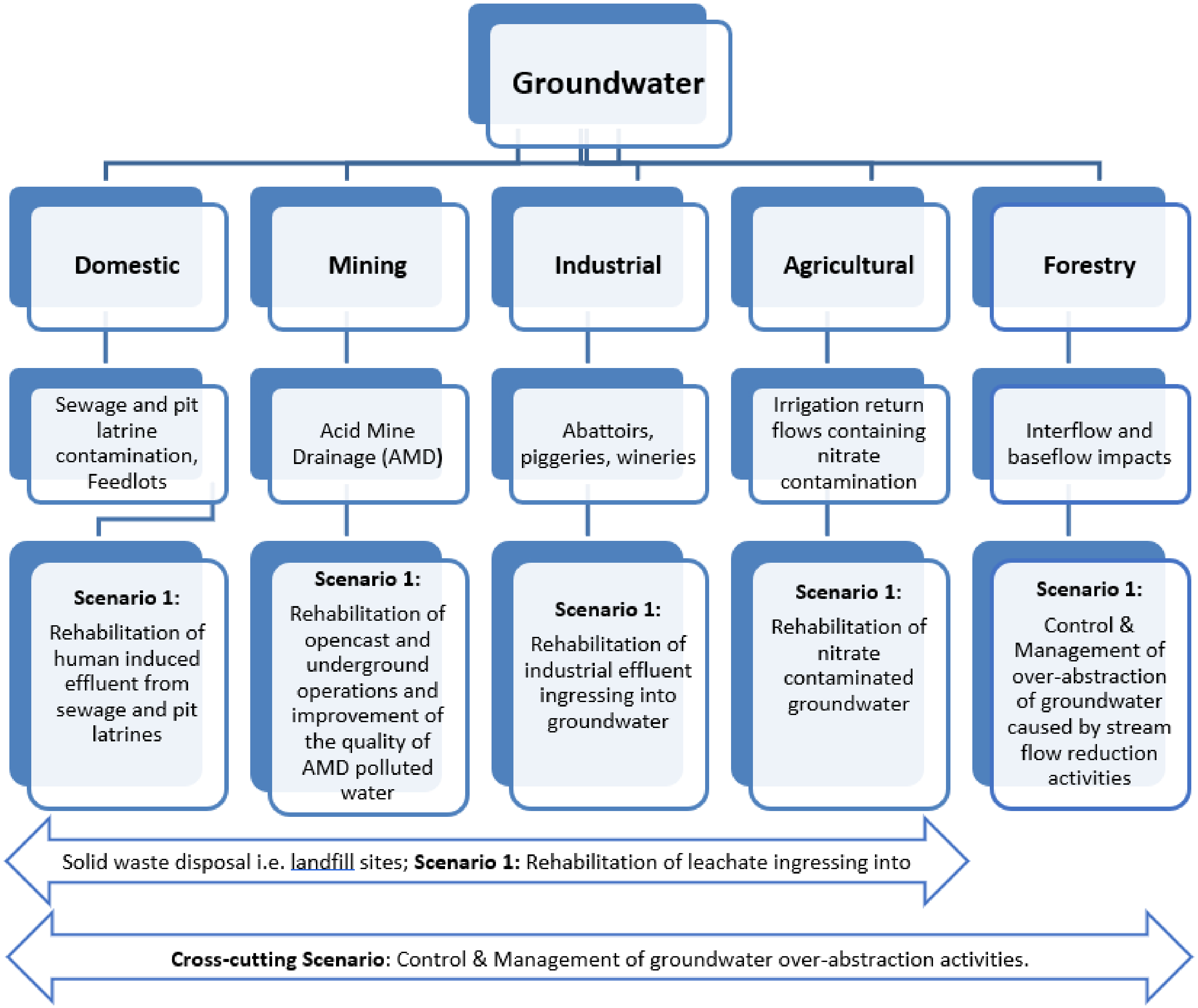
Purpose of Groundwater Report

- The aim of the **Groundwater Report** is to develop RMGs for the following sectors:
  - ✓ *Domestic,*
  - ✓ *Mining,*
  - ✓ *Industries,*
  - ✓ *Agriculture;*
  - ✓ *Forestry; and*
  - ✓ *Solid Waste*

List of applicable legislation for Groundwater

Sectors		Applicable Legislation
Solid Waste	**Domestic**	• **White Paper on water policy of 1997** • **NWA**, Act 36 of 1998 • **NEMA**, Act 107 of 1998 • **MPRDA**, Act 28 of 2002
	Mining	
	Industrial	
	Agriculture	
	Forestry	

Rehabilitation Management Guidelines for Groundwater Scenarios



GROUNDWATER
Domestic

Identified Impacts

- **Sewage and pit latrine contamination**
- Over-abstraction
- Feedlots

Scenario 1: Rehabilitation of human induced effluent from sewage and pit latrines

Phase 1: Diagnostic Phase

STEP 1:

Conduct environmental audit periodically (at least biannual)

STEP 2:

- Undertake review of historical groundwater quality data
- Review incident reports supplied by various organizations involved in potentially polluting activities and annual reports on the monitoring of waste-water treatment works (e.g., Green Drop annual reports)

STEP 3:

- Ascertain and summarize the types of groundwater contaminants based on reviewed data and literature

Phase 2: Planning and Assessment

STEP 1:

Undertake a site visit and assessment for ground truthing

STEP 2:

Establish location of boreholes and their proximity to pit latrines or WWTW

STEP 3:

- Identify potential sources of groundwater pollution such as WWTW in urban areas and septic tanks or pit latrines in the case of informal settlements and rural areas
- Establish and summarize the extent of groundwater pollution in the area

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

- The objectives must be informed by the data collated in **Phase 1** and **2**

Examples:

The objective of undertaking groundwater rehabilitation for domestic is to reduce microbiological pollution down to the acceptable levels as stipulated in the water quality guidelines for domestic water use

Phase 4: Execution

STEP 1:

Apply Ex-situ treatment technology such as the Pump and Treat technique

STEP 2:

- Apply a filtration system to remove particulate matter from the pumped groundwater
- Apply ultraviolet (UV) light radiation for effective removal of bacteria, viruses, and protozoa
- Apply chlorine for effective disinfection against harmful bacteria and viruses

STEP 3:

- Establish protection zone to protect a borehole from pathogenic micro-organisms (e.g., bacteria and viruses) which can emanate from a source (e.g., septic system) located close to the borehole

Ex-situ

Extraction of groundwater through pumping from aquifer, treatment on surface, and returning of the treated water back into the aquifer. Ex-situ techniques are mainly characterised by Pump and Treat approach.

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

Monitor the following:

- Changes in the concentrations of microbiological contaminates over time
- Water quality in terms of chemical reactions, before injecting it back to the aquifer*
- Pollution migration in relation to groundwater flow direction

STEP 2:

Routine monitoring to determine if the groundwater quality is improving or deteriorating further, for improved management of the resource

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Note:
After pumping water from underground to the surface, chemical reactions when exposed to oxygen and other gases may change the chemical content or pollute water.

Mining

Identified Impacts

- **Acid Mine Drainage**
- Degradation of aquatic ecosystems
- Corrosion of metal equipment and appliances

Scenario 1: Rehabilitation of operations and improvement of the quality of AMD polluted water

Phase 1: Diagnostic Phase

STEP 1:

Identify the sources of AMD i.e AMD decanting from a opencast pit or underground operations

STEP 2:

- Conduct a desktop assessment to determine the conditions of the opencast pit or underground operations
- From the existing information, deduce the dewatering rates, seepage rates, recharge rates, groundwater levels & lowest topographical level

STEP 3:

- Collect groundwater samples from the operations and submit to an accredited laboratory for analysis
- Interpret the groundwater results to inform suitable treatment options for the water to be pumped from the source

STEP 4:

- Collect waste rock material samples from the operations and conduct a geochemical assessment
- The results of the assessment must be used to inform whether the waste rock material is non-acid generating & suitable for backfilling

Phase 2: Planning and Assessment

STEP 1:

Rehabilitation of AMD water emanating from the operations trigger Section 21 water uses

STEP 2:

The person undertaking rehabilitation must determine the water uses likely to be triggered by the rehabilitation activities. Examples are:

Sec 21 (j) – dewatering of groundwater

Sec 21 (g) – temporary storage of water pumped

Sec 21 (f) – discharging of treated water

GN.704, Reg 4(c) – backfilling of pit

STEP 3:

The person undertaking rehabilitation activities must determine the following:

- Geohydrological conditions of the operations
- Rates of inflow & outflow in the operations
- Groundwater levels
- Geochemical assessment detailing the type of waste material to be used for backfilling

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

Define clear rehabilitation objectives using information obtained in **Phase 1** & **2**

Examples:

Below is a list of common aims and objectives:

- Reduce and maintain groundwater levels below decanting levels
- Treat AMD polluted water to acceptable standards
- Backfill the operations and use the rehabilitated land for other purposes

Phase 4.1: Execution (Passive Methods)

PUMP & TREAT

- Pump/dewater AMD water from the operations to ensure the hydraulic head is reduced below decanting levels
- The pumped water must be captured, retained, and managed within the mine water systems *i.e.,* lined evaporation dams

SEEPAGE INTERCEPTION

- Intercept polluted seepage from the operations through concrete trenches
- The design of the trench gradient must be such that the water is free-flowing without eroding the channel and polluting water resources

BACKFILLING

- Backfill the operations using material such as waste rock material that has been subjected to geochemical testing
- The material should be non-acid generating
- Backfilling or deposition of material back into the operations must follow a scientifically sound backfilling methodology

Note:
Consideration must be given to the passive treatment methods to include constructed wetlands and nature-based solutions

Phase 4.2: Execution (Active Methods)

TREATMENT STRATEGY

In the event there are high volumes of AMD water encountered (> 5 ℓ/s), treatment strategies must be investigated and implemented in order to render the water suitable for reuse

DISCHARGE INTO WATER RESOURCE

If there is still a residual treated water, one must evaluate and negotiate alternatives options with DWS *i.e.,* discharge of such water back into the water resource

Phase 5: Monitoring & Evaluation

Monitoring

STEP 1:

Monitor the following:

- **Pump and Treat -** monitor groundwater levels within the operations and report to the DWS on a monthly basis
- **Seepage Interception** - monitor the quality of water at the trenches and downstream of the constructed wetland to assess the changes in quality of water over time
- **Backfilled areas** - develop and implement a dedicated monitoring programme to monitor the groundwater level recovery and pit water quality of the rehabilitated/backfilled area

STEP 2:

Routine monitoring to determine if the quality groundwater is improving or deteriorating further, for improved management of the resource

Evaluation

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Industrial

Identified Impacts

- **Industrial effluents discharges**
- Organic pollutants

Scenario 1: Rehabilitation of industrial effluent ingressing into groundwater

Phase 1: Diagnostic Phase

STEP 1:

Identify the source of industry and the type of effluent

STEP 2:

- On a desktop level, assess the conditions of the site within which the industry is located

STEP 3:

- Collect groundwater samples from the source effluent in question and submit them to an accredited laboratory for groundwater quality analysis
- The results from the analysis will inform the treatment methods/options to be employed

STEP 4:

- Identify current potential groundwater use around the area and the likelihood of migration of pollution from the source

Phase 2: Planning and Assessment

STEP 1:

- Undertake a site visit to determine and obtain general site information
- The data to be collected is critical and will assist in identifying potentially affected sensitive receptors (i.e. schools, homes, water bodies)

STEP 2:

Based on information collected, determine whether pollution pathways exist and the possibility of humans or ecological receptors to be affected

STEP 3:

Determine aquifer status in terms of vulnerability to pollution

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

- Establish clear goals or objectives of the rehabilitation (using data collected in **Phase 1** and **2**) in relation to the types of contaminants emanating from industries
- Examples of contaminants are dissolved organics, suspended solids, priority pollutants (e.g., phenols), heavy metals, nutrients (nitrogen and phosphorus), oil & grease, refractory compounds, volatiles, and aquatic toxicity

Examples:

Common aims and objectives of undertaking groundwater rehabilitation for industrial effluent would be:

- To prevent all contaminants from ingressing into polluting groundwater; and
- To prevent contaminants from migrating offsite into the nearby sensitive receptors

Phase 4: Execution

STEP 1:

Waste Minimisation

- Examining the sources of waste within a facility and then trying to minimise their discharge
- This can be achieved through improved management of materials and operations

STEP 2:

Primary Treatment

- Removal of solids & oils, excessive acidity or alkalinity and preparation of the effluent for either further downstream treatment (biological or chemical) or for final discharge
- Unit operations include flow equalisation, acid, or alkali dosing, hydrocyclones, static or rotary screens, flotation & flocculation/sedimentation.

STEP 3:

Biological (Secondary) Treatment

- Involves reaction of the effluent (after primary treatment) with oxygen and microorganisms (bacteria and fungi) to remove oxygen consuming materials
- Examples are the moving bed biofilm reactor (MBBR) and the HYBACS process

STEP 4:

Tertiary Treatment

- Involves filtration to remove remaining suspended matter from upstream biological processes or following coagulation in a physical chemical treatment
- Another form of tertiary treatment is the removal of colour and residual refractory pollutants by use of ozone or other suitable oxidizing agents
- Treatment with granular activated carbon (GAC) may also be necessary
- In certain cases, electrodialysis is useful to remove various ionic species

Phase 5: Monitoring & Evaluation

Monitoring

Evaluation

STEP 1:

Monitor the following:

- Changes in the concentrations of contaminates over time – trend analysis
- Migration of pollutants in relation to groundwater flow direction

STEP 2:

Establish if treatment technology applied is effective or whether there are any additional interventions required

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Agriculture

Identified Impacts

- **Elevated concentration of Nitrate in groundwater**
- Wash off of pesticides into surface & groundwater

Scenario 1: Rehabilitation of nitrate contaminated groundwater

Phase 1: Diagnostic Phase

STEP 1:

- Identify available boreholes and springs within the area
- Review historical groundwater quality data

STEP 2:

Identify potential sources of contamination – natural (i.e. geogenic) or anthropogenic

STEP 3:

Identify the extent of groundwater use in the area

Phase 2: Planning and Assessment

STEP 1:

- Conduct site visit with the relevant specialist
- Conduct hydrocensus and determine groundwater flow direction

STEP 2:

- Collect groundwater samples from the boreholes within the area, including samples from upstream and downstream of the area
- Submit samples to an accredited laboratory for analysis
- Data from the analysis should be used to determine the concentration of contaminants

STEP 3:

- Map the extent and spatial distribution of contamination
- Determine the hydro-geochemical processes influencing groundwater quality to identify the source of contamination

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

- These objectives must be determined by the information and data gathered in **Phase 1** and **2** above.

Examples:

Below is a list of common aims and objectives:

- Rehabilitate groundwater for water supply
- Rehabilitate groundwater for the improvement of groundwater quality in the aquifer

Phase 4: Execution

STEP 1:

Apply the Ex-situ treatment technology such as the Pump and Treat technique for groundwater supply

STEP 2:

- Apply In-situ rehabilitation such as such as Managed Aquifer Recharge (MAR) and Permeable Reaction Barriers (PRB) for improvement of groundwater quality in the aquifer

In-situ
Involves on-site rehabilitation without removal of contaminated groundwater. This technique combines injection of degrading microorganisms and nutrients into the aquifer to stimulate biodegradation

Phase 5: Monitoring & Evaluation

Monitoring

Evaluation

STEP 1:

Monitor the following:

- Monitor changes in the concentrations of contaminates over time – trend analysis
- Migration of pollutants in relation to groundwater flow direction

STEP 2:

Establish if treatment technology applied is effective or whether there are any additional interventions required

STEP 3:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Forestry

Identified Impacts

- **Afforestation** & **Alien Vegetation** have impacts on interflow and baseflow which leads to stream flow reduction

Scenario 1: Rehabilitation of over-abstraction of groundwater caused by stream flow reduction activities

Phase 1: Diagnostic Phase

STEP 1:

- Identify available commercial forestry e.g., pine trees, and gum trees (eucalyptus trees) within the area
- Review historical data on stream flow within the area

STEP 2:

Identify potential sources of stream flow changes: abstraction for water supply or forestry and vegetation impacts

STEP 3:

Identify the extent of groundwater use in the area

Phase 2: Planning and Assessment

STEP 1:

- Conduct site visit with the relevant specialist
- Conduct hydrocensus and determine groundwater flow direction

STEP 2:

- Conduct field assessment on the extent of the receding groundwater and river water levels

STEP 3:

- Map the extent and spatial distribution of plantations within the area
- Establish the extent of forestry impacts on stream flow reduction in the area

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

- These objectives must be determined by the information and data gathered in **Phase 1** and **2** above

Examples:

Below is a list of common aims and objectives:

- To improve groundwater contribution to river baseflow (groundwater discharges into rivers)
- To improve groundwater contribution to wetlands (groundwater discharges into wetlands)
- To improve groundwater contribution to springs (quantification of spring flows) and other groundwater-dependent ecosystems (GDEs)

Phase 4: Execution

STEP 1:

Select appropriate and successful plantation removal approaches for implementation i.e, namely, physical (or mechanical) control, chemical control, and biocontrol

STEP 2:

Remove the plantations (using the methods and/or combination of methods in **Step 1** that interfere with the passage of precipitation to the water table in recharge areas

STEP 3:

Prioritize the remove of plantations with deep root system (tap root) that intercept with groundwater table using appropriate techniques mentioned in **Step 1**.

STEP 4:

Establish a protection zone along a river/stream/wetland to protect stream flows

Phase 5: Monitoring & Evaluation

Monitoring

Evaluation

STEP 1:

Monitor the changes in groundwater and surface water levels

STEP 2:

Establish if treatment methods applied are effective or whether there are any additional interventions required

STEP 3:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

Solid Waste

Identified Impacts

- **Leachate percolating through soil into groundwater**

Scenario 1: Rehabilitation of leachate ingressing into groundwater

Phase 1: Diagnostic Phase

STEP 1:

- Review historical groundwater quality and levels data
- Identify available boreholes and springs in the vicinity of the area

STEP 2:

- Collect groundwater samples from the source effluent in question and submit them to an accredited lab for groundwater quality analysis
- The results from the analysis will inform the treatment methods/options to be employed

STEP 3:

Identify current or potential groundwater use around the and the likelihood of migration of pollution from the source

Phase 2: Planning and Assessment

STEP 1:

Conduct a desktop assessment to determine the conditions of the landfill site

STEP 2:

Establish if pollution pathways exist and the possibility of humans or ecological receptors to be affected

STEP 3:

Determine aquifer status in terms of vulnerability to pollution

Phase 3: Defining the Rehabilitation Objectives

STEP 1:

- Establish clear goals or objectives of the rehabilitation (using data collected in **Phase 1** and **2**) linked to the protection of human health and the environment
- Examples of toxic metals are Lead (Pb), Cadmium (Cd), Chromium (Cr), and Nickel (Ni), to acceptable levels

Examples:

The objective of undertaking groundwater rehabilitation for landfill sites is to reduce or prevent all identifiable contaminants from polluting groundwater in the vicinity of the site

Phase 4: Execution

STEP 1:

- Apply the In-situ treatment technology such as the Barrier and Cap Systems, and/or Phytoremediation techniques

STEP 2:

- Construct groundwater containment or barrier systems through the injection of reagents within the treatment zone to prevent off-site migration of contaminants

Phase 5: Monitoring & Evaluation

Monitoring

Evaluation

STEP 1:

Monitor the following:

- Monitor changes in the concentrations of metal contaminates over time – trend analysis
- Migration of pollutants in relation to groundwater flow direction

STEP 2:

Establish if treatment technology applied is effective or whether there are any additional interventions required

STEP 1:

- Evaluate the effectiveness of interventions against achievement of rehabilitation objectives and outcomes
- Determine maintenance objectives

THANK YOU

Project website:
https://www.dws.gov.za/RDM/SDCCO.aspx