ISBN 0 7309 7805 2

October 1998

GUIDELINES

ON THE

DEVELOPMENT

OF AN

OPERATING MANUAL

FOR

TAILINGS STORAGE

GOVERNMENT OF
WESTERN AUSTRALIA

DEPARTMENT OF
MINERALS AND ENERGY
WESTERN AUSTRALIA

FOREWORD

The Department's first set of guidelines on tailings management looked at design and construction following reports that many tailings storage facilities were inadequately designed and not built according to sound engineering practice. Since the release of those guidelines in March 1996 both the general quality of design input and the standards of construction have improved considerably.

It is now clear that while the required degree of professionalism is evident in the design and construction of tailings structures, many of them are not operated in line with all design parameters, resulting in particular problems at several mine sites. The majority of the tailings incidents reported to the Department could have been avoided if the tailings storage facility had been operated within the design parameters or had been more diligently managed.

This document is intended to help companies improve the overall operational management of tailings storage facilities through the preparation of their own site specific operating manuals.

It is hoped that with the Department's two complementary tailings design and management guidelines, industry enterprises will be well equipped to design, build and operate tailings storage facilities in a manner acceptable to the Department and consequently to the community of Western Australia.

J M Torlach
STATE MINING ENGINEER

October 1998

TABLE OF CONTENTS

Page

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF APPENDICES

FIGURES

1. INTRODUCTION

Tailings management plans are an essential prerequisite for sound storage practice as most failures of tailings storages around the world result from inadequate management of the storages. The effective implementation of a management plan will not only result in a safer tailings storage facility (TSF), but will frequently reduce the overall costs associated with operation and closure of the facility.

These Guidelines have been prepared by the Department of Minerals and Energy, Western Australia (DME) to provide a consistent basis for the preparation of Operating Manuals for TSFs in Western Australia. They provide both the technical basis for site-specific Operating Manuals and an administrative framework which meets the requirements of regulations currently covering the mining industry in Western Australia.

These Guidelines assume that a design has been carried out for the TSF in accordance with the *Guidelines on the Safe Design and Operating Standards for Tailings Storages*. For pre-existing facilities where a formal design has not been carried out, it may be necessary to conduct additional investigation work to provide the necessary information for inclusion in the Operating Manual.

The preparation of an Operating Manual should take into account the provisions that relate to TSFs in the following Acts of Parliament:

- Mines Safety and Inspection Act, 1994
- Mining Act, 1978 (tenement conditions)
- Environmental Protection Act, 1986, Parts IV and V
- The Rights in Water and Irrigation Act, 1914, Part III.

The Operating Manual should identify all areas of TSF management requiring consideration during the operating phase of the facility and outline a course of action if performance is inadequate. One of the aims of these Guidelines is to encourage the mining industry to take a longer term view of the storage of tailings, so each Operating Manual should also address the rehabilitation, closure and post-closure monitoring requirements of the TSF. A carefully prepared Operating Manual will form part of an overall management plan that encompasses all of these aspects while ensuring that TSFs are rehabilitated and closed cost effectively so meeting public expectations relating to environmental performance.

2. COMPONENTS OF AN OPERATING MANUAL

2.1 Introduction and General

An Operating Manual for a TSF has two primary purposes:

1 To provide a documented procedure for the safe and efficient storage of tailings in line with the assumptions and principles adopted by the designer;

2 To provide a documented process that complies with all legislation and with public expectations, and can be used as a reference during any auditing of the facility.

Every TSF is unique, and consequently every Operating Manual will differ from the next. It is not practicable to provide an exhaustive list of Operating Manual contents that will cover all potential cases, so these Guidelines contain a suggested list of *minimum requirements* for inclusion in each Operating Manual. These minimum requirements vary depending on the Category for the TSF, which is determined in accordance with the Matrix below.

Hazard Rating/Height Matrix to Derive TSF Categories

Factors Affecting Categories		**TSF Categories**		
Hazard Rating[1]		**High**	**Significant**	**Low**
Maximum	> 15 m	1	1	1
Embankment	5 - 15 m	1	2	2
Height[2]	< 5 m	1	2	3

Notes:

1. Hazard Ratings are assigned on the basis of potential impact on human life, economic loss and environmental impact as per the Table in Appendix I.
2. All cross valley TSFs which block or significantly impede the flow in natural drainage lines are to be considered as Category 1 TSFs regardless of embankment height.

An Operating Manual for a TSF should cover all pertinent information with respect to operation, rehabilitation and closure. In some cases the operational requirements will be complex, while in other cases the procedure will be relatively straightforward. In all cases the Operating Manual should include sufficient details to enable mine management and operational personnel to readily understand and implement the operational requirements as determined by the *Guidelines on the Safe Design and Operating Standards for Tailings Storages*.

Where appropriate, an indication is given where relaxation of some of the minimum requirements is acceptable. Information for pre-existing facilities that can be considered for omission from the Operating Manual is indicated in these Guidelines. A scope of the technical information to be included in the Operating Manual and how that information could be structured is given in Appendix II.

2.2 Description of Contents of Operating Manual

The following sections of these Guidelines present a description of the minimum requirements for inclusion in an Operating Manual.

2.2.1 Introductory Section

The introductory section of the Operating Manual should contain a general description of the relevant TSF(s) together with appropriate figures and drawings. A summary of the minimum requirements for the introductory section is given in Table 1.

Table 1 Recommended minimum requirements for introductory section

Description Storage	Categories
Objectives of the Operating Manual and storage management plan	All
Project background	All
Life of mine & life of TSF(s)	All
Figure indicating general location of TSF(s)	All
Hazard rating	All
Key dates (commencement of TSF(s), expected closure date)	All
General description of mineral processing and tailings storage	All
Drawing showing general arrangement of TSF(s)	1 & 2

2.2.2 The Tailings Storage Operating Plan

The TSF operating plan is the most important part of the document and careful attention to the structure and content of this section is essential. The minimum requirements for inclusion in the Operating Manual for the three categories of TSFs are given in Table 2.

Table 2 Recommended minimum requirements for TSF operating plan

Description	Storage Categories
Deposition methodology	All
Pond control and water management	All
Seepage control (*drain details** & requirements)	All
Pipeline management	All
Geometry of the TSF (levels and coordinates, side slope geometry and figure showing development) {past* & future}	1,2

Note: * may be omitted for TSFs pre-existing these guidelines

2.2.3 Monitoring and Auditing Requirements

Each Operating Manual should contain a complete description of the monitoring and auditing requirements for the TSF. The requirements will differ from facility to facility according to details outlined in Appendix D of the *Guidelines on the Safe Design and Operating Standards for Tailings Storages*. The Operating Manual should contain a description of all the monitoring and auditing procedures. As a minimum, documented procedures are required for the list of activities given in Table 3.

Table 3 Monitoring and auditing requirements

ACTIVITY	RECOMMENDED FREQUENCY		
	Category 1	**Category 2**	**Category 3**
Routine inspection of TSF	Daily	daily	weekly
Operational audit of TSF	every year	every two years	every three years
Groundwater monitoring	As specified in terms of DEP licence conditions		
Monitoring instrumentation	Dictated by conditions to be specified in Operating Manual		
Environmental aspects	Refer EPA Best Practice and DME Guidelines		

Appendix III contains pro forma inspection checklists for routine inspections and operational audits.

Details pertaining to monitoring instrumentation (e.g. piezometers) should describe the method and frequency of measurement. The Operating Manual should describe the short and long term range of readings that are anticipated for all monitoring instruments, underdrain flows, open channel flows etc, throughout the life of the TSF. Actions to be followed in the event that readings are recorded outside an anticipated envelope of measurements should be stipulated in the Operating Manual.

A tailings management system should be introduced that includes regular meetings and promotes the culture and discipline required to uphold the content of the Operating Manual. Minutes of inspections and meetings should be maintained for record purposes.

2.2.4 Rehabilitation Measures

All TSFs will reach the end of an operational phase and require decommissioning, post closure monitoring and maintenance. The Operating Manual should clearly set out all measures that should be followed during the operating phase to reduce the amount of work required at decommissioning. Appropriately planned measures also limit environmental impacts during the operational phase of the facility (through, for example, reducing wind-borne dust by vegetating the outer

slopes). The rehabilitation measures will generally reflect those set out in the Notice of Intent, and progress in this regard will be recorded in the annual environmental report.

2.2.5 Emergency Action Plan

Adherence to the *Guidelines on the Safe Design and Operating Standards for Tailings Storages* should ensure that all TSFs are designed with an acceptably low level of risk associated with failure. Nevertheless, an emergency action plan should be included in the Operating Manual in the event of a failure of the TSF. There is also a legal requirement for emergency preparedness in terms of the Mines Safety and Inspection Act (Regulation 3.13). The action plan should contain, as a minimum, the following:

- Details of any evacuation procedure that may be required in the event of failure, or impending failure.
- A diagram indicating the whereabouts of an assembly point for all nominated personnel in the event of a failure event.
- A list of names and residential addresses of all nominated safety personnel and their home/emergency contact telephone numbers.
- A list of the telephone numbers of the local/regional emergency services (fire, ambulance, police).
- A list of all personnel that are associated with operation of the TSF and evidence that they have attended and understood all induction/safety procedures.

2.2.6 Incident Reporting

In addition to those occurrences required under section 78 and 79 of the Mine Safety and Inspection Act of 1994, the DME is to be informed of all incidents associated with the TSF. The Operating Manual should contain the definition of an incident as follows:

- Any fauna death on, or in the vicinity of the TSF
- Any uncontrolled release of tailings and/or liquor (including pipe breaks, overtopping events, or similar)
- Any major seepage occurrence (e.g. a discernible impact on vegetation, soil contamination)
- Any defects in the structure of the TSF (e.g. cracking, slumping of walls, significant wall erosion, daylighting phreatic surfaces, decant collapse).

In the event that an incident occurs, the applicable reporting form should be completed and submitted to the DME within seven days of occurrence of the incident. A copy of the form, as contained in Appendix IV to these Guidelines, is to be included in an appendix to the Operating Manual.

2.2.7 Appendices to the Operating Manual

APPENDIX A - Summary of Design Assumptions

Operating Manuals for all new TSFs should contain a summary of design assumptions in an appendix to the manual as shown in Table 4. Wherever possible, this information should be provided for pre-existing TSFs. However, this may frequently prove to be impossible and therefore some of the design assumptions (indicated with an asterisk) in Table 4 need not be included in Operating Manuals for pre-existing facilities.

Table 4 Summary of design assumptions

DESIGN ASSUMPTION	INCLUDED IN MANUALS FOR		
	Category 1	Category 2	Category 3
Foundation characteristics & strengths	*Yes**	*Yes**	Optional
Tailings strength parameters & density	Yes	Yes	Optional
Hydrological data & water management	Yes	Yes	Yes
Hydrogeological data	Yes	*Yes**	Optional
Tailings chemistry	Yes	Yes	Yes
Stage/capacity relationship	Yes	Yes	*Yes**
Embankment stability	*Yes**	*Yes**	Optional
Side slope geometry	Yes	*Yes**	Optional
Erosion control measures	*Yes**	*Yes**	*Yes**
Placement method and anticipated density/consolidation behaviour	*Yes**	Optional	Optional

Note: * may be omitted for pre-existing TSFs

The Operating Manual should provide cross-references to where the details pertaining to the above can be found, e.g. the design documents submitted in support of the Notice of Intent and the location within the company where they are filed or stored.

APPENDIX B - Details of Pre-deposition Works

Where possible, it is advisable to include selected and pertinent details of the predeposition works in the Operating Manual for reference. The inclusion of the details clarifies the intentions of the designer and facilitates communication between the designer and the operator of the facility. As a general guideline, the following "as-built" drawings should be included in an appendix to the Operating Manual:

- General arrangement & layout plan
- Starter embankment details
- Drainage details
- Decant facility details
- Access road and ramp details.

Note that the appendix to the manual containing “as-built” drawings can be added at some time after the TSF has been commissioned.

3. ADMINISTRATIVE PROCEDURES

An Operating Manual is to be prepared by a competent person for every operational TSF, or any TSF that may become operational in the future. (Where at least one flank of a facility abuts a neighbouring facility it is permissible to prepare one manual for the combined facilities.) As noted in the preceding section, the content of the manual can be trimmed to suit the design hazard category, as well as tailored to omit certain information if the deposit pre-exists the publication of these Guidelines. A summary manual may be required for use on a day-to-day basis by operational personnel.

Evidence of completion of an Operating Manual may be requested by the DME within 12 months of publication of these Guidelines. The form contained in Appendix V may be completed to this effect and forwarded to the DME. A copy of the Operating Manual is to be made available for inspection by a DME inspector during any subsequent visit to the mine. For new TSFs the Operating Manual should be completed and the relevant form submitted to the DME before tailings are deposited in the facilities.

Amendments are to be made to the Operating Manual as and when circumstances dictate. As a minimum, all manuals are to be reviewed by a competent person as part of the periodic audit of the TSF for the need to carry out amendments. The applicable form (refer Appendix V) may be used to advise the DME of the result of the review.

In addition to the above reporting procedure, any incident (for definition see Section 2.2.6) is to be reported to the DME by completing the applicable form contained in Appendix IV within seven days of occurrence of the incident.

4. REFERENCES

ICOLD (1989). *A Guide to Tailings Dam Safety.* International Commission on Large Dams (ICOLD), Bulletin No. 74.

ICOLD (1995). *A Guide to Tailings Dams - Transport and Placement.* International Commission on Large Dams (ICOLD), Bulletin No. 101.

ICOLD (1996). *Tailings Dams and Environment - Review and Recommendations.* International Commission on Large Dams (ICOLD), Bulletin No. 103.

ICOLD (1996). *Monitoring of Tailings Dams - Review and Recommendations.* International Commission on Large Dams (ICOLD), Bulletin No. 104.

ICOLD (1996). *A Guide to Tailings Dams and Impoundments.* International Commission on Large Dams (ICOLD), Bulletin No. 106.

ANZMEC (1995). *Security Deposit Systems for Minesite Rehabilitation.* Australian and New Zealand Minerals and Energy Council (ANZMEC), Report No 95.01, 7p.

EPA (1996). *Best Practice Environmental Management in Mining - Environmental Auditing.* Environment Protection Agency (EPA), 64p.

MERIWA (1998). *Research into Saline Tailings Disposal and Decommissioning.* Minerals and Energy Research Institute of Western Australia, Report No 189, 595p, Vols 1 & 2

DME *Guidelines for Preparation of Annual Environmental Reports on Mining and General Purposes Leases.*

DME *Guidelines on the Safe Design and Operating Standards for Tailings Storages.*

ICOLD publications are available from:

Australian National Committee on Large Dams
124 Fortesque Street
Spring Hill Qld 4000

Phone (07) 383 95 862

APPENDIX I

Hazard Ratings for Mine TSFs

TYPE OF EFFECT	HAZARD RATING		
	High	**Significant**	**Low**
Uncontrolled releases or seepage			
Loss of human life	Location such that contamination of a water supply likely to be used for human consumption and consumption of the contaminated water is expected.	Location less critical but contamination of a water supply likely to be used for human consumption and consumption of the contaminated water is possible but not expected.	No contamination of a water supply likely to be used for human consumption expected.
Loss of stock	Location such that contamination of a water supply likely to be used for stock consumption and consumption of the contaminated water is expected.	Location less critical but contamination of a water supply likely to be used for stock consumption and consumption of the contaminated water is possible but not expected.	No contamination of a water supply likely to be used for stock consumption expected.
Environmental damage	Location such that damage to an environmental feature of significant value is expected.	The significance of the environmental feature is less or damage is possible but not expected.	No environmental features of significance or no damage expected.
Embankment failure			
Loss of human life	Loss of life expected because of community or other significant developments.	No loss of life expected, but the possibility recognised. No urban development and no more than a small number of habitable structures down stream.	No loss of life expected.
Direct economic loss	Excessive economic loss such as serious damage to communities, industrial, commercial or agricultural facilities, important utilities, mine infrastructure, the storage itself or other storages downstream.	Appreciable economic loss, such as damage to secondary roads, minor railways, relatively important public utilities, mine infrastructure, the storage itself or other storages downstream.	No significant economic loss, such as limited damage to agricultural land, minor roads, mine infrastructure, etc.
Indirect Economic Loss	Storage essential for services and Repairs not practicable.	Repairs to storage practicable.	Repairs to storage practicable. Indirect losses not significant.

Hazard ratings for mine TSFs (after DME (Qld), 1995).

APPENDIX II

Details Associated with Tailings Storage Management Plan

APPENDIX II

Details Associated with Tailings Storage Management Plan

Deposition Methodology

The methodology of deposition into the tailings storage facility (TSF) is of critical importance with respect to:

- pond control and water management (see next section);
- short and long term stability of the structure;
- volume stored (and hence overall life of the TSF);
- demands on the slurry pumping system; and
- ease of operation.

The methodology is stipulated by the designer after due consideration of the factors that control these aspects of the TSF.

Commonly employed methods of deposition in Western Australia include:

- spigot discharge behind a compacted embankment;
- open-end discharge into the upstream end of a valley impoundment;
- in-pit disposal;
- single point discharge {not preferred for ring-dyke (paddock) structures}.

Other, less commonly employed techniques that may be adopted from time to time include:

- central thickened discharge;
- cyclone separation, using the underflow as wall-building material;
- placement as a paste;
- dry placement.

The Operating Manual should contain a detailed description of the methodology(ies) of placement that are envisaged by the designer for all stages of construction. The description should contain the following:

1. A figure showing the height/volume/rate of rise relationship for the life of the facility.
2. A figure, or figures, showing the method of placement into the TSF and a written description of the technique.
3. An envelope of acceptable material properties for the envisaged deposition methodology(ies), including, but not limited to:

- particle size distribution plotted from 1mm upwards;
- slurry water:solids ratio or slurry density;
- slurry flow rate;
- production rate of tailings dry solids by mass;
- specific gravity of solids.

Actions required in the event that measured parameters fall outside the expected range should also be included in the Operating Manual:

1. A description (with drawings, if appropriate) of the delivery and distribution pipeline system and its method of operation, showing the pipe positions, discharge conditions, method of movement (if applicable), materials of construction, pipe pressure rating, flange type and pressure rating, pipe diameters and number/type of outlets. An emergency response plan is also to be included.
2. A description of any special precautions/measures required at any stage of TSF development, eg the use of flexible hosing to limit the risk of damage to underdrainage systems, or the progressive movement of pipelines to maximise the available storage volume of the basin immediately prior to decommissioning.

Pond Control and Water Management

A. Freeboard

The maintenance of an adequate freeboard on a TSF is of paramount importance, particularly when the deposited tailings and/or fluid level reaches the embankment crest level. The purpose of freeboard is to provide a safety margin over and above all the estimated inflows of fluids from extreme natural events and operational situations, so that the risk of overtopping leading to embankment erosion and ultimate failure of an above ground TSF is minimised. The freeboard should be sufficient to contain unforeseen increases in the level and movement of fluid within the storage caused by the following:

1. Tailings spills or overflow from spigot malfunctioning.
2. Back flow and overtopping as a result of mounding of tailings at discharge points.
3. Outlet and/or recovery system failures.
4. Uncertainties in the design rainfall estimates.
5. Uncertainties in the design catchment and runoff estimates.
6. Extreme wind effects such as wave runup and wind setup.
7. Any other effects, such as seismicity, land slips etc that may generate waves.

The Operating Manual should contain the definitions of freeboard applicable for the facility and highlight the minimum freeboard required to satisfy the above mentioned conditions. It is recommended that the freeboard should be specified according to the following, and as shown on Figure 1.

1. For a TSF with a water pond normally located away from any perimeter embankment:

   Total Freeboard = Operational Freeboard + Beach Freeboard = 500mm with a sub-minimum of 300mm Operational Freeboard.

2. For a TSF with a water pond normally located against a perimeter embankment but with no upstream catchment apart from the storage itself:

   Total Freeboard = Operational Freeboard = 500mm.

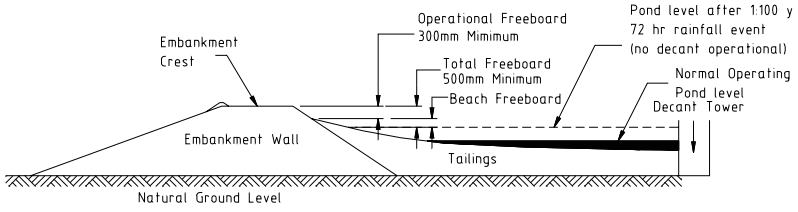
3. For a TSF with a water pond normally located against a perimeter embankment but with an upstream catchment in addition to the storage itself:

   Total Freeboard = Operational Freeboard = 1,000mm.

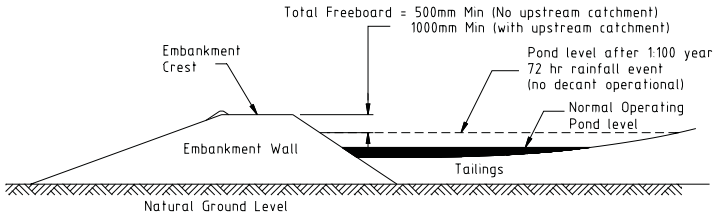
Total Freeboard is defined as the vertical height between the lowest point on the crest of the perimeter embankment of the TSF and the normal operating pond level plus an allowance for an inflow corresponding to the 1:100 year 72 hour duration rainfall event falling in the catchment of the pond, assuming that no uncontrolled discharge takes place for the duration of the rainfall event. (Note: the Total Freeboard also corresponds to the sum of the *"Operational Freeboard"* and the *"Beach Freeboard"* as defined below.)

Operational Freeboard is defined as the vertical height between the lowest elevation of the perimeter embankment and the tailings beach immediately inside the embankment. The operational freeboard varies over the course of a deposition cycle as the storage is raised and fills with tailings. The operational freeboard becomes critically important at the end of a deposition cycle, particularly to minimise the potential for back flow and overtopping as a result of mounding of tailings at discharge points.

Figure 1 Definition of Freeboard



FOR CASE WHERE POND IS NORMALLY LOCATED AWAY FROM ANY PERIMETER EMBANKMENTS



FOR CASE WHERE POND IS NORMALLY LOCATED AGAINST PERIMETER EMBANKMENTS

Beach Freeboard is defined as the vertical height between the normal operating pond level plus an allowance for an inflow corresponding to the 1:100 year 72 hour duration rainfall event falling in the catchment of the pond, assuming that no uncontrolled discharge takes place for the duration of the rainfall event, and the point on the beach where the wall freeboard is measured. The Beach Freeboard can vary significantly during the life of the storage and depends upon beach length, slurry/tailings characteristics, deposition methodology etc. Beach Freeboard is not applicable where the pond is normally located against a perimeter embankment.

B. Pond Control

In a TSF with a centrally located decant, operational factors can give rise to a pond which is pushed away from the decant, or elongated towards the perimeter of the storage. In the case of an elongated or displaced pond the effective beach freeboard may be decreased. This may concomitantly increase the risks associated with overtopping of the perimeter wall and therefore good pond control is a prerequisite requirement for all TSFs. The Operating Manual should provide details on the envisaged methods to control the pond and suggest methods to correct any adverse pond location or geometry. For example, in the case of a long, narrow facility, it may be advisable to raise the beach across the shorter perimeter walls by, say, 1m ahead of the beach across the longer walls. This will assist in creating a more centralised and circular pond. There are several alternative techniques which could also be considered, such as:

- forming a steeper beach across the longer flanks of the facility by adjustment of the deposition methodology;
- controlled and managed spigotting from selected positions around the perimeter;
- constructing pond control walls around the decant position;
- subdividing the facility into more geometrically symmetrical configurations.

The Operating Manual should describe the lateral limits that the pond is expected to vary between and specify actions that are to be taken in the event that the pond position or normal operating level exceeds those expected.

C. Water Management

Operational difficulties and faults such as decant blockages, pump breakdown, return water sump problems and poor water clarity during/after storms may necessitate large volumes of water being retained on the surface of the TSF for a period of time. This practice is not advisable for the following reasons:

- a large pond on the upper surface of the TSF will raise the level of the phreatic zone and have a detrimental influence on the outer slope stability;
- a large pond will encourage more material to settle subaqueously and have a negative impact on the available storage volume due to a lower settled dry density, as well as a negative impact on the long term consolidation (and hence ease of rehabilitation);

- a larger pond will increase the amount of seepage which may or may not be controlled through underdrains - either way there may be an adverse effect on the surface and ground water quality, and the management of the water will be more difficult.
- during this time the plant needs to obtain water from an alternative source, which may be costly or have a detrimental effect on the general surface and ground water quality in the area.

The Operating Manual should therefore address the management of water to and from the facility and include a conceptual water balance that illustrates all the inflows and outflows associated with the TSF.

Inflows to a TSF include:

- water in the slurry;
- rainfall (direct, runoff from catchment);
- waste water/flushing water.

Outflows from a TSF include:

- decanted supernatant water;
- evaporation;
- drainage water;
- interstitial losses (water retained in the pores of the tailings);
- seepage water.

Geometry of the Tailings Storage Facility

The geometry of the TSF will be determined as a fundamental part of the design. To ensure compliance with the design, the Operating Manual for category 1 and category 2 storages should contain a setting out plan that shows sufficient coordinates and levels to demonstrate the envisaged geometry of the facility. In some cases the external walls will be constructed for the full height of the facility prior to commencement of deposition. In these cases the inclusion of as-built drawings of the predeposition works is likely to be sufficient. However, in most cases there will be a process of progressive wall raising (and possibly additional wall construction) that is envisaged as part of the TSF construction. In these cases the Operating Manual should include a plan showing the designed geometry up to final height of the facility. The as-built geometry should comply with the design geometry as closely as possible and any discrepancies are to be recorded in the Operating Manual, together with a certification by the designer that the safety of the TSF has not been compromised.

Wherever possible, a figure showing the historical development of category 1 and category 2 facilities should also be included in the Operating Manual. This will facilitate determination of the overall stability and future life of the facility.

Side Slope Geometry and Factor of Safety

The adherence to an acceptable outer slope geometry may be crucial with respect to:

- stability of the slope;
- erosion control;
- rehabilitation of the slope.

The side slope geometry for category 1 and category 2 facilities is to be measured and plotted to a suitable scale for inclusion in the Operating Manual. This information will assist in the determination of a slope factor of safety from time to time. The slope factor of safety is a ratio of all of the forces that are acting to mobilise the slope along a particular failure surface, to all of the forces acting to resist the mobilisation along the same surface. Other information, apart from the abovementioned geometry, that is necessary to calculate a slope factor of safety includes:

- strength parameters of the foundation and wall material, and the deposited tailings;
- location of the phreatic surface.

Material strength parameters will be ascertained as part of the design, but the phreatic surface needs to be measured during the life of the facility to ensure that the design assumptions are reasonable and that any deviations therefrom do not pose a threat to the stability of the wall.

The Operating Manual should state the limits that the piezometric levels are expected to vary between and specify actions that are to be taken in the event that actual values or measurements exceed those expected.

The slope factor of safety should be checked annually for category 1 storages, every two years for category 2 and every three years for category 3, or as required (through evidence of cracking, for example). To facilitate interpretation of the results, the instruments should be read on a monthly basis as a minimum requirement, and more frequently if the piezometric levels are approaching the anticipated maximum levels.

Seepage Control

Seepage flow through tailings contained in a storage facility is inevitable. The control of seepage water during the operational and post-operational phases of a TSF is important to ensure that the stability of the structure is not compromised and to ensure compliance with environmental standards relating to ground and surface water qualities. Seepage flow is best controlled through the installation of adequate underdrains and the Operating Manual should contain details of any underdrainage that is installed in the TSF, including:

- drawings showing details of filter drains;
- a plan showing the location and reference numbers of underdrain outfall pipes;
- a plan showing the location and reference numbers of any dewatering bores.

The Operating Manual should also contain the expected flows or rest water levels associated with the drainage systems. A procedure for action in the event of flows or levels falling outside the expected values is to be included. Such action may include:

- installation of piezometers to monitor the phreatic surface (and/or increasing the monitoring frequency of pre-existing piezometers);
- installation of other monitoring devices eg: inclinometers to monitor slope movements;
- installation of dewatering bores or near-horizontal drainage holes;
- installation of external surface drains and/or slope buttresses;
- reduction in deposition tonnage or water deposited on the TSF.

In many of the older storage facilities (and some of the more recent facilities) deposition has progressed without the installation of underdrains. In these cases it is common for seepage to emerge from the toe of the perimeter embankment. The Operating Manual should identify where this is likely to occur and note the expected volumes of seepage water, as well as the maximum height that water can safely emerge above the toe without affecting the embankment stability. The Manual should stipulate actions that are required in the event that expected seepage volumes are exceeded, or the saturated zone rises above the expected level on the outer face of the perimeter wall.

In all cases, unless a sophisticated lining system is installed, seepage to the groundwater will occur from the TSF. The expected influence on groundwater levels and groundwater quality is to be noted in the Operating Manual, together with the method(s) of ascertaining these measurements. Actions to be taken in the event that actual conditions exceed those expected are to stipulated in the Manual.

Pipeline Management

Appropriate management of delivery, distribution and return water pipelines will reduce the risks of down time and/or environmental damage associated with pipe blockages, leaks and bursts. The management strategy that is included in the Operating Manual will be dependent upon the type of delivery/distribution system that is installed, i.e. the materials of construction, the type of discharge technique, the pipe supports (if any), the pressure rating of the pipes etc. Management measures that may be considered include:

- periodic rotation of steel pipelines (flanges to be date stamped for reference);
- pipe wall thickness checking (steel pipes);
- preventative maintenance through a periodic replacement policy;
- daily visual checks;
- automatic shut-off valves linked to pressure transducers located on the pipelines;
- periodic clearing of vegatation under and around the pipelines to prevent damage from bush fires.

The Operating Manual should describe the limits that the above parameters are expected to vary between and specify actions that are to be taken in the event that they exceed them.

APPENDIX III

Pro Forma Inspection Checklists

Routine inspection and operational audits

APPENDIX III

Pro Forma Inspection Checklists

A. Routine Inspections

Routine inspections are to be carried out by TSF operators in accordance with the Operating Manual. The minimum frequency of routine inspections is as follows:

- **category 1** - daily
- **category 2** - daily
- **category 3** - weekly

A checklist to facilitate the routine inspections is to be included in the Operating Manual. A pro forma inspection list follows. The pro forma checklist is to be adapted/modified as necessary to suit the TSF under consideration.

Pro Forma TSF Checklist For Routine Inspections

Name/Number of TSF: .....

Inspected by: .....

Designation: .....

Date/Time: .....

General Item	Specific Criteria	Defective? Yes/No	Comments
Roadways	Condition of roads & ramps		
Open	Damage and erosion of sides		
Trenches	Flow efficiency		
Drain outlets	Flow efficiency		
Outer	Evidence of spillage		
Perimeter	Evidence of seepage		
	Presence of wet areas		
Slurry	Slurry flow rate		
Behaviour	Slurry density		
	Pond position		
Freeboard	Pond depth		
	Wall freeboard		
Decant	Clarity of discharge fluid		
Facility	Structural integrity of decant		
Return Water	Available capacity		
Storage	Return water pumps		
Tailings	Deposition position		
Delivery	Condition of pipes & valves		
Monitoring	Damage to instruments		
	Read according to programme		
Gates &	General condition		
Fencing	Signage in place & legible		

Operational Audits

The *Guidelines on the Safe Design and Operating Standards for Tailings Storages* recommend that periodic operational audits be carried out on all facilities. The Operating Manual should contain a checklist of items that are relevant to the TSF in question. The use of the checklist will facilitate the auditing process and ensure that all relevant aspects are addressed during the audit.

A pro forma checklist to facilitate the periodic operational audit is given below. The pro forma checklist is to be adapted/modified as necessary to suit the TSF under consideration.

Pro Forma TSF Checklist for Operational Audit

Name/Number of TSF ..... Date/Time: .....

Audit by:..... Designation: .....

Company: ..... Signature: .....

General Item	Specific Criteria	Defective? Yes/No	Comments
Roadways & Access	Perimeter roads		
	Access ramps		
Effluent & Storm water Trenches	Vegetation growth		
	Erosion of sides		
	Flow efficiency		
	Animal damage		
	External wet spots		
Drain outlets	Flow efficiency		
	Breakages		
	Animal life		
Outer Perimeter	Evidence of spillage		
	Evidence of seepage		
	Presence of wet areas		
	Vegetation growth		
Outer wall & Basin	Quality of wall construction		
	Evidence of cracking		
	Slope geometry		
	Deposition tonnage		
	Slurry density		
	Rate of rise		
	Available capacity		
	Pond depth & position		
	Freeboard		

General Item	Specific Criteria	Defective? Yes/No	Comments
Decant facility & Access	Adequacy of catwalk/access		
	Structural integrity of decant		
	Pond wall position/integrity		
	Pond control		
Tailings Delivery System	Operation & control		
	Condition of pipes & valves		
	System effectiveness		
Monitoring Instruments	Obvious damage		
	Abnormal trends		
	Read according to program		
	Interpretation of results (eg stability analyses)		
Return Water Storage Facility	Storage level		
	Degree of siltation		
	Condition of wall		
	Spillway condition		
	Decant facility		
	Pumps, valves and pipes		
Rehab. Work	Monitor against program		
	Fertiliser applications		
	Performance of vegetation		
Water quality	Clarity of decant water		
	Water chemistry testing		
	General condition		
Gates & Fencing	Security requirements		
	Signage in place & legible		
	Gates		
General	Routine logs completed		
	Monitoring carried out		
	Emergency preparedness		

APPENDIX IV

Incident Reporting Form

Department of Minerals and Energy

Tailings Storage Facility or Evaporation Pond Incident Report Form

INSPECTORATE	**COLLIE** **KARRATHA** **KALGOORLIE** **PERTH**
STORAGE DATA	Name of Mine: ..... Phone No: ..... Name of person completing report: ..... Name of Facility: ..... Storage area: ..... (m^2) Date and time of incident: ..... Incident location (draw sketch on next page): ..... Facility type: ☐ Tailings storage ☐ Evaporation Pond ☐ Other Status; ☐ Operational ☐ Decommissioned Date decommissioned: Layout: ☐ *Ring-dyke (Paddock)* ☐ *Sidehill* ☐ *Cross-valley* ☐ *Other* Discharge method: ☐ *End of pipe* ☐ *Single spigot* ☐ *Multi-spigot* ☐ *Other* Water recovery: ☐ *Gravity decant* ☐ *Pumped decant* ☐ *Pump on pontoon* ☐ *Other* Type of tailings stored: ☐ *Gold* ☐ *Nickel* ☐ *Lead/Zinc/Copper* ☐ *Iron ore* ☐ *Alumina* ☐ *Mineral sand* ☐ *Other (Name)* ..... Annual production rate: Mtpa Water quality: pH ..... TDS ..... mg/l Known hazardous chemicals: .....
WALL FAILURE INCIDENTS (tick more if required)	Embankment failure dimensions: [LxWxH (m)] (L measured along crest) Failure mode: ☐ *Wall sliding* ☐ *Sliding through foundation* ☐ *Wall erosion by rain/pipe failure* ☐ *Piping* ☐ *Overtopping* ☐ *Other* Describe failure event (eg initiation point, sequence of events, etc): ....
Water issues in the vicinity before wall failure occurring	Seepage/leakage through: ☐ Embankment ☐ Foundation ☐ Buried pipes ☐ Other (describe): ..... Estimated quantity: ..... (litres/sec) ☐ *Moist/damp or* ☐ *Wet only* Control methods: (describe) ..... Rainfall in the previous 72 hours: .....(mm) Downstream ponding adjacent to failure? Yes / No Upstream pond located: ☐ *Against failure wall* ☐ *Away from failure wall & Distance: .... (m)* ☐ *Other (describe)* ..... Freeboard behind crest: To top of tailings: ..... (m) To top of water: ..... (m)
Foundation soil/ rock types, weathering, etc	Describe foundation geology in immediate failure area: ....
Construction details of wall that failed	Construction completion date: ..... Overall embankment height: .....(m) and slope angle in failure area: ..... (deg.) Wall designed by: ☐ *Experience* ☐ *Geotechnical methods* ☐ *None* Embankment construction materials and methods: .... Date of most recent geotechnical review: ..... By: .....
OTHER INCIDENTS	☐ Pipe failure ☐ Return water pond overflow ☐ Overtopping with no wall failure ☐ Other (describe)
RESULTS OF THE INCIDENT	Type material released: ☐ Tailings ☐ Saline water ☐ Other (describe)..... Duration of release: ☐ <1 hour; ☐ 1 to 2 hours; ☐ 2 to 6 hours; ☐ 6 to 24 hours; ☐ > 24 hours Amount or volume of material released: ..... t, m^3, bcm Released material contained? Yes/No Area affected: ..... m^2/Ha. Maximum distances travelled by (a) tailings material: ..... (km); (b) water: ..... (km)
ENVIRONMENTAL DAMAGE (list adverse effects; flora/fauna deaths, water pollution etc)	Describe environmental impact and downstream facilities that are affected ....
MONITORING DETAILS (eg visual, EDM, piezometers, frequency of monitoring, etc)	Signs of failure observed or monitored prior to failure? Yes / No..... Monitoring methods used: .... Summarise observations or monitoring results: ....

Department of Minerals and Energy

Tailings Storage Facility or Evaporation Pond Incident Report Form

Sketch plan of facility showing extent of failure area

Show the following on the above sketch plan:

- Extent of embankment and tailings material failure as appropriate
- All access ways into underground mines (eg shafts, declines, sink holes, intake and exhaust rises, etc)
- All tailings storage facilities
- Evaporation ponds, water storage facilities (including thickeners)
- Open pits, waste dumps
- Offices, accommodation, etc
- Roads, airfields
- Buildings (e.g. mill, concentrator, workshops, etc) and fuel storage areas
- Direction of surface drainage flow
- Indicate True North direction and approximate scale

Additional comments:

.....

.....

.....

.....

.....

APPENDIX V

Forms Confirming the Preparation of or Amendments to the Operating Manual

EVIDENCE OF COMPLETION

Tailings Storage Operating Manual

For and on behalf of .....

I, ... (Registered Manager), do hereby confirm that an Operating Manual for the ..... Tailings Storage Facility has been prepared in accordance with the current edition of the *Guidelines on the Development of an Operating Manual for Tailings Storages* issued by the Department of Minerals and Energy, Western Australia. A copy of the Manual is stored at ..... and is available for inspection by any authorised representative of the DME.

Signature:..... (Registered Manager)

Signature of witness: .....

Name of witness: .....

.....

.....

Date: .....

EVIDENCE OF AMENDMENT OR UPDATE

Tailings Storage Operating Manual

For and on behalf of .....

I, ... (Registered Manager,

do hereby confirm that the Operating Manual for the ..... Tailings

Storage Facility has *

- been amended/updated in accordance with the current edition of the *Guidelines on the Development of an Operating Manual for Tailings Storages* issued by the Department of Minerals and Energy, Western Australia. An amended/updated copy of the Manual is available for inspection by any authorised representative of the DME.
- been subjected to a review in accordance with the current edition of the *Guidelines on the Development of an Operating Manual for Tailings Storages* issued by the Department of Minerals and Energy, Western Australia and no amendments were considered to be necessary. A copy of the Manual is available for inspection by any authorised representative of the DME.

* delete inapplicable paragraph

Signature: ..... (Registered Manager)

Signature of witness: .....

Name of witness: .....

Date: .....