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REPORT

Waimakariri Irrigation Ltd Storage Ponds – Dam Safety Management System (Pre-Construction Issue)

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Prepared for Waimakariri Irrigation Ltd

Issue 4.1

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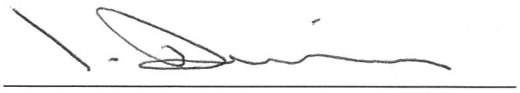
Approved For Issue Ian Davison Signature: 

Executive Summary

Waimakariri Irrigation Ltd (WIL) are constructing Waimakariri Storage Ponds to provide off-stream irrigation water storage in time of excess and to supplement irrigation supply when supply is restricted due to low flow in the Waimakariri River.

This storage consists of two adjoining lined ponds with combined capacity of 8.2 million m^3. The ponds are large dams as defined by The Building Act (2004) and HIGH PIC in accordance with the methodology of the 2015 NZ Dam Safety Guidelines.

This document sets out the operation, maintenance, surveillance and emergency procedures for the ponds and associated inlet and outlet structures.

This Dam Safety Management Plan conforms to the recommendations of the 2015 NZ Dam Safety Guidelines.

Detailed procedures set out in this Dam Safety Management Plan are provided for the safe management of storage and release of water from the ponds and to maintain all associated appurtenant structures and equipment in a serviceable condition.

This plan is a “live” document and must be reviewed on a regular basis to ensure it reflects the actual procedures carried out on site.

Summary of Procedures

The following bullet points identify the key stages in the dam safety management system and the implementation of the Emergency Action Plan.

- Normal operation of the ponds – Sections 5.0, 6.0, 7.0, Appendix A
- Normal surveillance of the ponds – Section 8.0, Appendix D, Appendix G
- Dam Safety incident or event identified and WIL Dam Manager notified – Section 8.11
- Failure mode identification – Table 6
- Incident confirmed by site visit and Alert Level set – Table 7
- Police and Civil Defence teams notified if required – Table 7, Figure 5
- Implement Emergency Action Plan – Appendix E
    - Notify WIL management and external parties – contact details – Appendix E
    - Identification of people at risk – Inundation maps in Appendix E
    - Identify safe access routes to site – Appendix E7.1
    - Emergency resources – Appendix E7.5, E7.6, E7.7
    - Dewater guidelines – Appendix E7.11
    - Emergency contact details – Appendix E11

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1.0 Introduction

Waimakariri Irrigation Ltd. (WIL) owns and operates the Waimakariri irrigation scheme. This scheme was built in 1997 and uses water taken from the Waimakariri River. Presently, the scheme extends to about 18,000ha in North Canterbury. This water is distributed through races between the Waimakariri River and the Ashley River.

WIL are constructing the Waimakariri Storage Ponds to store excess water diverted from the Waimakariri River. Stored water will be used to supplement irrigation supply when water from the Waimakariri River is restricted during periods of low river flow.

This storage consists of two adjoining lined ponds with combined capacity of 8.2 million m^3.

On account of their height, the volume of water stored and potential downstream breach effects the ponds are large dams as defined by the Building Act (2004) with a “HIGH” Potential Impact Classification (PIC). Although the embankments surrounding the Tub have been defined as Medium PIC whilst the rest of the embankment are defined as High PIC, for the purposes of dam safety management all of the ponds and their embankments shall be treated as High PIC.

1.1 Purpose of the Dam Safety Management Plan

This Dam Safety Management Plan sets out the Operations, Maintenance, Surveillance and Emergency Procedures for the Waimakariri Storage Ponds in conformance with the NZ Dam Safety Guidelines (2015). It includes routine maintenance requirements and procedures relating to surveillance and dam safety.

This plan includes the embankments that form the two ponds along with their appurtenant structures (refer to Figure 3), which are:

- Six inlet and outlet culvert pipes G1 through G6;
- One service spillway which delivers flows from the Buffer Pond to Pond 2;
- Three emergency spillways protect the Buffer Pond, Pond 1 and the Tub;
- Fuse Plug spillway in the Buffer Pond;
- The Tub, which conveys flow from Ponds 1 and 2 into the main race MR4 through G6;
- Buffer Pond pump station to fill Pond 1;
- Pond 2 pump station to lift bottom water from Pond 2 into main race MR4 via the Tub and G6;
- Two flow measuring crump weirs on distribution races R2 and R3 downstream of G2 and G3 outlets.

This plan does not cover the WIL irrigation distribution network.

1.2 Maintenance of this Plan

Detailed procedures are required to safely manage the storage and release of water from the ponds and maintain all associated appurtenant structures and equipment in a serviceable condition.

This plan is a “live” document and must be reviewed on a regular basis to ensure it reflects the actual procedures carried out on site. The plan shall be reviewed and approved by WIL management:

- Prior to operation following commissioning the ponds.
- Following significant seismic or extreme rainfall events or dam safety incidents.
- Reviewed as part of Comprehensive Safety Reviews of the ponds.
- Following re-commissioning in the event of structural or equipment failure.
- Following significant changes to the scheme including any significant change to the Control System logic.
- Following changes to either Resource Management Act or the Building Act.

2.0 Legislative Requirements

2.1 General Regulatory Environment for Dam Safety

All large dams in New Zealand are subject to the Resource Management Act and the Building Act. Requirements for dam safety are usually addressed in conditions to resource and building consents specific to a particular dam. Such consents often reference the New Zealand Dam Safety Guidelines, published by the New Zealand Society on Large Dams (NZSOLD), November 2015. Referred to herein as the NZ Dam Safety Guidelines.

The NZ Dam Safety Guidelines state that all dams should have a Dam Safety Management System (DSMS) and sets out the requirements for a DSMS.

The NZ Dam Safety Guidelines have been used as the basis for this Waimakariri Ponds DSMS.

The NZ Dam Safety Guidelines provide recommendations for design, construction and management of dams intended to reduce dam safety risks for the downstream population and environment. The guidelines include a tiered approach to design, construction and management of dams. This tiered approach recommends dams with higher potential impacts be designed and managed to a more stringent standard to provide a level of care appropriate to the consequences of failure.

2.2 Potential Impact Classification

The first step in design of any new dam is to perform a Potential Impact Classification (PIC). The PIC is primarily used to ensure that appropriate performance criteria are used in the design and safety evaluation of a dam, and that an appropriate level of care is reflected in operational procedures.

The Waimakariri Ponds are classified as “large” dams under the Building Act and the Potential Impact Classification (PIC) has been assessed as “MEDIUM” and “HIGH”. This follows the basic principle that different Potential Impact Classifications can be applied to discrete lengths of the pond embankment, as the downstream consequences of breach vary depending on the embankment section breached. It follows that a breach of the west embankment would have less consequence than a breach of any of the other embankments (refer Figure 1). PIC only reflects the potential impact that hypothetical failure of the dam could have on downstream people, property and the environment.

Figure 1 - PIC Classification for the Waimakariri Irrigation Storage Pond Embankments

3.0 Dam Structure And Purpose

3.1 Dam Location

The Waimakariri Ponds are located on the corner of Dixon and Wrights roads and adjacent to the existing Buffer Pond and main race MR4. The ponds are located about 12 km downstream of the Waimakariri intake at Browns Rock as shown in Figure 2.

Figure 2 - Detailed Location of Waimakariri Ponds

3.2 Dam Description

WIL operates a “run of river” scheme which diverts water from the Waimakariri River through a series of races for irrigation purposes. However, the volume of water extracted is subject to restrictions under resource consent conditions.

The storage ponds form an integral part of the Waimakariri irrigation scheme and will be operated by the current staff of a General Manager, Operations Manager and three Race men.

A general overview of the ponds is shown in Figure 3. Selected detailed general arrangement drawings are included in Appendix B.

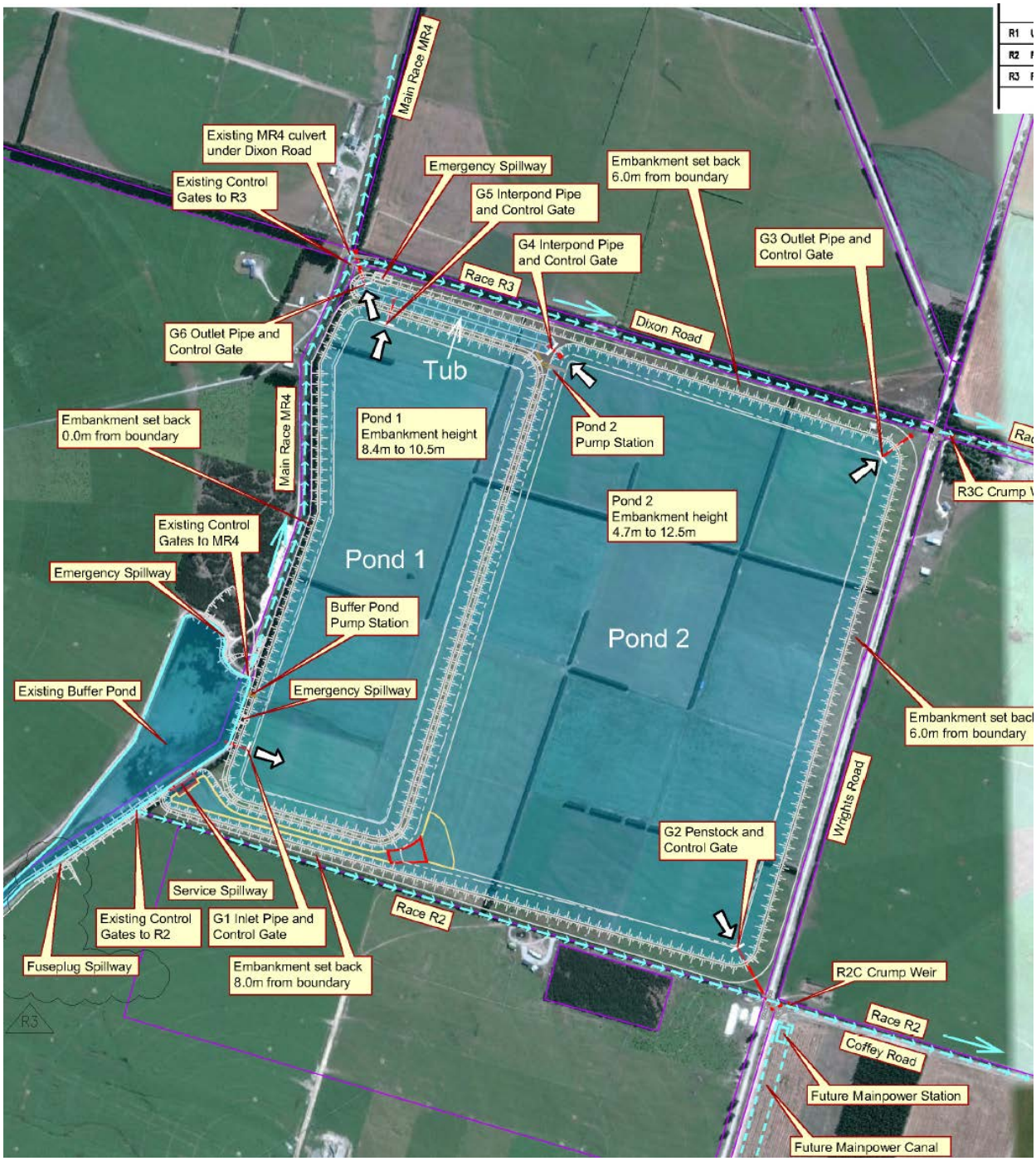

Figure 3 – Waimakariri Ponds and Appurtenant Structures

The key data for the Waimakariri Ponds is set out in Table 1.

Table 1 - Waimakariri Ponds Key Data

Parameter	Data			
Dam name	Waimakariri Storage Ponds 1 & 2			
Dam location (NZTM)	1534683mE, 5196928mN			
Dam type	Geo-membrane lined earth embankment			
Potential Impact Classification (PIC)	HIGH with some embankments being MEDIUM (see Figure 1)			
Construction period	Approximately 2 years			
	Pond 1	**Pond 2**	**Buffer Pond**	**The Tub**
Dam height (max)	8.4 to 10.5m	4.7 to 12.5m	2.7m	4.8m
Crest elevation	RL 227.7m	RL 224.0m	RL 224.0m	RL 224.0m
Full Supply Level (FSL)	RL 226.7m	RL 223.0m	RL 223.0m	RL 223.0m
Freeboard above FSL	1.3m	1.3m	1.3m	1.3m
Storage capacity of each pond	2 Mm^3	6.2 Mm^3	-	-
Type of spillway	Free Overflow			
Service spillway (S1) crest level	-	RL 222.5m		
Service spillway (S1) capacity	-	17.0 m^3/s		
Emergency spillway crest level	RL 227.2m (E1)	-	RL 223.5m (E2)	RL 223.5m (E3)
Emergency spillway capacity	-	-	17 m^3/s	17 m^3/s
Fuse plug spillway capacity			60 m^3/s	
Embankment slopes	Inside = 3H:1V Outside = 2.5H:1V = 2H:1V Pond 1 north embankment			

3.3 Project Components

The Waimakariri Ponds comprise a number of passive and dynamic components and their function is outlined in Table 2.

Table 2 - Project Components

Component	No.	Function
Passive		
Pond Embankments	1	To contain water within the two storage ponds.
Conveyance channel	1	To convey water from the Buffer Pond over the Service Spillway (S1).
Pond 1 inlet (G1)	1	To transfer water between the Buffer Pond to Pond 1.
Inter-pond gated inlet culverts (G4 & G5)	2	To transfer water between the Buffer Pond to Pond 1, between Pond 2 to the Tub and between Pond 1 to the Tub.
Gated outlet culverts (G2, G3 & G6)	3	To transfer water between Pond 2 to R2 race, between Pond 2 to R3 race and between the Tub to MR4 race.
Crump Weir	2	To measure flow release from Pond 2 on both R2 and R3.
Service spillway and chute (S1)	1	To transfer water from the Buffer Pond to Pond 2.
Emergency spillways	3	To allow water to safely discharge over the crest of the embankments in the event of uncontrolled flow into the ponds.
Fuse plug spillway	1	To fuse, if extreme rainfall runoff intercepted by the main canal upstream, surcharges the buffer pond, thus preventing further surcharging the Buffer Pond and Pond 2.
Standpipe piezometers	14	To allow monitoring of the static water level within the embankment.
Dynamic		
Inlet control gates (G1, G4 & G5)	3	To control the flow of water between the Buffer Pond to Pond 1, between Pond 2 to the Tub and between Pond 1 to the Tub.
Outlet control gate (G2, G3, G6)	3	To control flow between Pond 2 to R2 race, between Pond 2 to R3 race and between the Tub to MR4 race.
Pump stations	2	Buffer Pond pump station required to fill Pond 1 and Pond 2 pump station required to lift bottom water from Pond 2 into main race MR4 via the Tub and G6.
Control system	1	To control flows through gates on inlets and outlets to manage operation .
Ultrasonic flow measurement	1	On G6 culvert to measure flow into the main race MR4.

The component locations are shown in Figure 3 and Dwg WIL1125/30/1 and WIL1125/30/21-23 in Appendix B.

The main components of the Waimakariri Ponds are described in the following sub-sections

3.3.1 Embankments and Liner

The embankments, range in height up to a maximum of 12.5m, formed using compacted gravel excavated from the pond footprint.

The permeability of the gravels in the embankments and foundation requires a lining to control seepage from the ponds. This lining is placed over the base of each pond and extends up the full height of the pond embankments.

Sections through the ponds showing crest heights and full water levels are shown in Drawings WIL1125/30/21 to 23 in Appendix B.

3.3.2 Pond 1 Gated Inlet Culvert

Pond 1 is initially filled by gravity via the inlet gated culvert G1 (refer to Figure 3). Filling priority is to Pond 1 as it has the facility to augment water in the main race MR4.

Gated inlet culvert G1 is single barrel 1800mm diameter with concrete inlet and outlet transitions shown on Drawing WIL1125/30/101. Gate G1 is fully automated, managed by the control system to maintain the water level in the Buffer Pond. This ensures that there is always sufficient water in the Buffer Pond to supply the main race MR4.

- Initially, Pond 1 is filled by gravity until it reaches Buffer Pond water level.
- Gate G1 then closes and the Buffer Pond pump station pumps available flow from the Buffer Pond into Pond 1 until it reaches its full supply level RL 226.70m.

The service spillway to Pond 2 is designed to pass a maximum flow of 17.0m^3/s. It is a concrete lined channel. A concrete stilling basin is included to dissipate energy when Pond 2 is empty (Ref Drawing WIL1125/30/124 through 126).

Water then flows along the 245m long conveyance channel between the service spillway and Pond 2. The bottom of the conveyance channel is protected with 0.4 m thick riprap of Zone 1 material. At the end of the conveyance channel a 65 m long reinforced concrete chute, 0.2 m thick, passes water from RL 220.10m down to the 55 m long bed protection riprap of Pond 2 at RL 213.54m (refer Drawing WIL1125/30/123).

3.3.3 Emergency Spillways

The emergency spillway from Pond 1 into the buffer pond is required to protect Pond 1 should the Buffer Pond Pump Station fail to stop and as a consequence over fills Pond 1. The emergency spillway discharges water into the Buffer Pond (refer to Drawing WIL1125/30/120).

A grassed surface, over-flow spillway is also provided for the Buffer Pond to discharge up to 17m³/s into MR4 (refer to Figure 4.1 and Drawing WIL1125/30/122).

The third emergency spillway is provided from the Tub to the distribution race R3. This is required to protect the Tub, should the Pond 2 pump station pumps fail to shut off or gate G5 remains fully open due to a control system failure, in turn over filling the Tub. This spillway has a maximum capacity to discharge 14m^3/s (refer to Drawing 1125/30/121).

The emergency spillways discharging from the Ponds and the Tub are geomembrane lined channels and are detailed on Drawings WIL1125/30/120 through 122.

3.3.4 Inter-Pond Gated Culverts

There are two inter-pond gated culverts sized to convey inter-pond flows managed by the control system. They are G4; discharging water from Pond 2 to the Tub and; G5 discharging water from Pond 1 to the Tub. Both are single barrel gated culverts shown on Drawings WIL1125/30/113 through 116.

The inter-pond culvert transitions are designed to reduce through flow culvert head loss.

3.3.5 Pond Outlets

The pond outlets are designed for capacities that allow for future development of Ngai Tahu Land and the proposed MainPower NZ Ltd. Hydro-Scheme. The outlet to MR4 releases only the irrigation discharge of 3.63m^3/s from the Tub. Outlets to R3 and R2 discharge both irrigation and stock water up to a maximum of 4.54m^3/s and 5.26m^3/s respectively. The R2 discharge includes 4.00m^3/s for Ngai Tahu consented flow.

The maximum irrigation and stock water discharge with Ngai Tahu flow to R2 is 5.26m^3/s. The future hydroelectric discharge 14.0m^3/s (max) will also be through G2. G2 discharge into R2 will initially be controlled by the inlet gate. Subsequently, as part of power station construction, control will move to the valve located at the outlet to R2 (Ref Drawing WIL1125/30/106).

3.3.6 Crump Weirs

Two crump weirs are included on both R2 and R3 to measure the flow release from Pond 2. The crump weirs are designed to measure the canal flows for both R2 and R3.

Flow from the Tub to main race MR4 is through outlet G6 and is measured by ultrasonic flush mounted flow-meters installed on the RC culvert pipe walls, upstream of Dixons road.

3.4 Pond Access

The main access point to the toe of the pond embankments is from the end of Dixon Road near the corner of the Western and Northern embankments.

The crest width of the embankment is generally 4m wide and with no side protection. The crests have not been designed as access roadways and no vehicular traffic is permitted or required for general operation or maintenance. Normal operation access requirements relate to the following:

- Routine surveillance inspections and route marches for dam safety – these should be carried out on foot to ensure an adequate level of observance. Whilst walking along the crest of the embankments adjacent to the edge of the liner, the inspectors will require to take care to ensure that they do not slip down the face into the pond. Emergency exit ladders have been provided to assist in safe egress from the ponds.

- Grass cutting of the outer embankments will be carried out by mowers suitable for operating on the slopes of the embankment and by trained operators who have carried out an approved risk assessment prior to mowing the grass.

In the event of an emergency, access to the Tub and Pond 2 embankment crests can be gained from close to the main site access. The crest of Pond 1 embankments is gained from the crest of the Tub embankments or from the crest of the Buffer Pond embankments. All access points are shown on drawing WIL1125/30/5.

Future maintenance of the pond liner will require a specific contract to repair or replace the liner. These contracts will be required to develop specific health and safety plans for carrying out the work and it is anticipated that new access ramps will be formed to gain access into the ponds for this work when it is required.

4.0 Roles & Responsibilities

4.1 Management Team

Operation, maintenance, surveillance and emergency response of the Waimakariri Ponds shall be the responsibility of WIL management team consisting of the following. Named personnel and their roles and responsibilities are included in Appendix C and these must be kept up to date.

4.1.1 Dam Manager

WIL, the Dam Owner, shall appoint a Dam Manager. WIL shall ensure the Dam Manager is competent and has a thorough understanding of the ponds in the context of being large dams. The Dam Manager shall be fully familiar with the contents of this Dam Safety Management Plan and related documents.

The Dam Manager shall be trained and be proficient to manage operation, maintenance, surveillance and emergency response of the ponds in conformance with the NZ Dam Safety Guidelines pertaining to HIGH PIC dams.

Although the embankments surrounding the Tub have been defined as Medium PIC whilst the rest of the embankment are defined as High PIC, for the purposes of dam safety management all of the ponds and their embankments shall be treated as High PIC.

The Dam Manager should have access to specialist advice on repairs to structures, changes to equipment or operating regimes, interpretation of surveillance data, annual inspections and during an emergency.

4.1.2 Operation Manager

The Operation Manager is responsible for managing the daily operation of the ponds and is deputised to act as the Dam Manager if required. The Operation Manager will also take part in daily operation and surveillance tasks with the Racemen if necessary. See Section 4.1.3 for more detail on the Racemen tasks.

4.1.3 Racemen

The Racemen/Operations Manager shall carry out the daily operation of the ponds. A sufficient number of the Racemen should be trained to allow for holiday and sick cover and to allow continuity of surveillance in the vent of staff leaving WIL.

The Racemen/Operations Manager shall also undertake the role of surveillance technicians. The surveillance technicians carrying out surveillance functions shall be trained to a suitable level to ensure they are familiar with and implement the following in accordance with this plan:

- Routine inspections via a route march
- Observe and record surveillance data
- Safe operating practice
- Scheduled and unplanned maintenance procedures

- Emergency response procedures.

4.1.4 Dam Safety Advisor

The Dam Safety Advisor role is to:

- Review data recorded by the surveillance technicians
- Complete intermediate dam safety inspections, Comprehensive Safety Reviews (CSR) and provide advice in emergencies.

A suitable person for the Dam Safety Advisor role would be an experienced specialist dam safety engineer qualified in the design, operation and maintenance of HIGH PIC earth and gravel embankment dams.

4.1.5 Logger Technician

The Logger Technician shall maintain and support operation of the control system. As the Control System will be designed and installed by NIWA it is recommended that the Waimakariri Management contract with NIWA for supply of a qualified logger technician on an as needed basis.

4.1.6 Gates Engineer

The Gates Engineer shall support WIL on gate maintenance and operation. A suitable person for the Gates Engineer role would be a suitably experienced Mechanical Engineer qualified in the design, operation and maintenance of hydraulically operated slide gates.

4.2 The Management Structure

The WIL management structure and functions is shown in Figure 4.

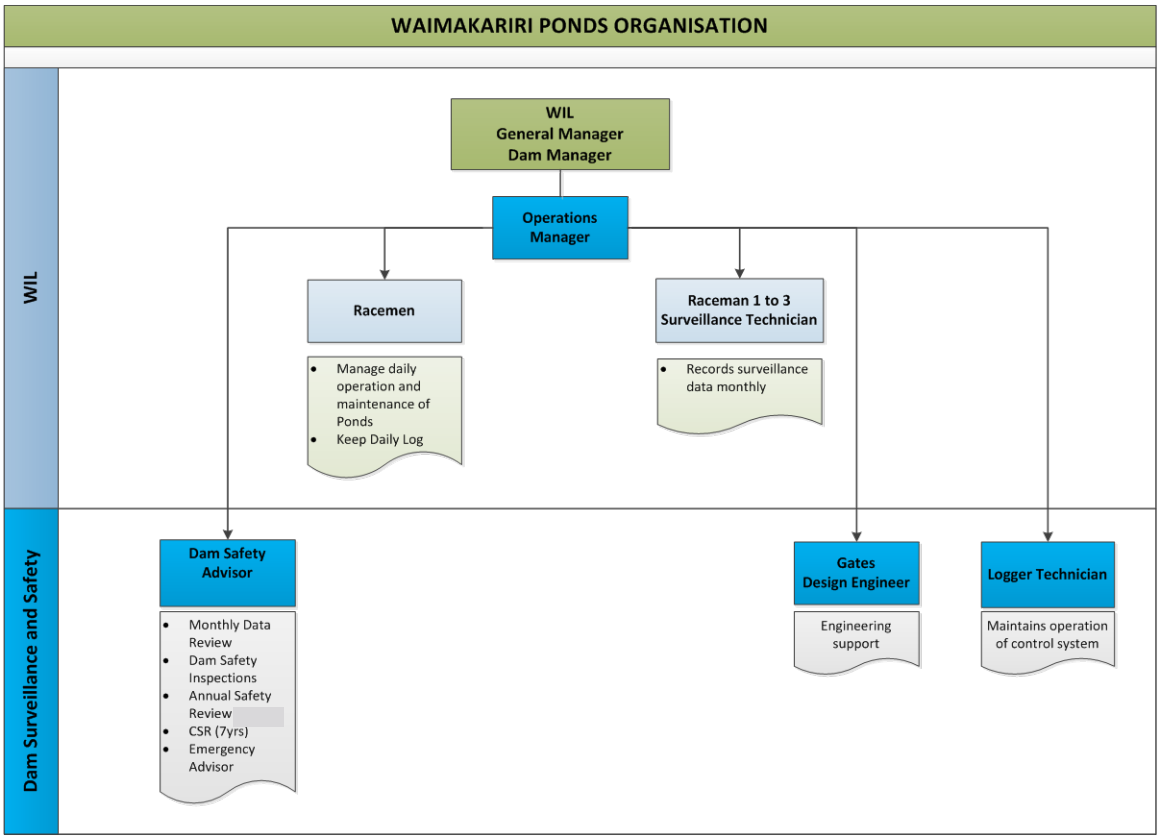

Figure 4 – Waimakariri Ponds Operation & Maintenance Management Structure

5.0 Operation Requirements

5.1 General

The control system for the pond will be integrated into and will extend the existing WIL control system which manages water into and through the WIL irrigation canal network.

The control system will control inflow to the storage ponds and drawdown of the storage ponds by supply to the main irrigation canals R2, R3 and MR4. The control system will:

- Monitor water levels in Ponds 1, 2 and the Buffer Pond.
- Monitor and maintain water levels in the ponds within pre-set limits.
- Open and close gated culverts to divert water into and out of the ponds as required.
- Control operation of the pumps.

Safety features are incorporated in the control system to prevent overfilling, rapid initial inflow when the pond water level is low and rapid drawdown of the ponds. The control system will limit the rate of initial opening of the gated culverts if the pond levels are very low. Under these conditions there is no tail water at the culvert outlets and rapid outflow could erode the lining ballast.

The control system is programmed to send alarms to indicate problems that need to be resolved quickly such as loss of power supply, loss of control communication, sensor failure or

overfull pond level. Such alarms will signal to mobile phones carried by the Racemen and Dam Manager.

The control system operation is addressed in greater detail in Appendix A.

5.2 Operation

Operation under Normal Conditions

Under normal operating conditions the Waimakariri Ponds are controlled by the automated control system based on downstream water demand as input by the Raceman. Where required the control system can be set for manual operation to facilitate commissioning, maintenance and inspections.

Operation under Unusual Conditions

Unusual conditions are events such as high wind, high rainfall and significant earthquakes. During these events the control system may require manual override. Such events require a surveillance route march inspection as detailed in Section 8.

Manual control is set out in the control system operation set out in Appendix A.

Operation under Emergency Conditions

An emergency operation is one that may require the ponds to be drawn down in order to prevent embankment failure or if enhanced safety management of the ponds is required. A situation may occur if there has been a significant earthquake and the liner has been damaged giving concerns of possible leakage through the embankments (Failure mode SM1 – Table 6).

The Waimakariri Ponds Emergency Action Plan (EAP), set out in Appendix E, shall be followed during emergency conditions. Identification of emergency conditions and initiation of the EAP is addressed subsequently in Section 8.2.

5.3 Control System

A control system is a computer managed system, controlled by input from the Racemen which automatically manages storage of water in the ponds and supply of water to the irrigation network when demand exceeds supply. The control system has been designed and installed by the National Institute of Water and Atmosphere (NIWA). Further detail of the control system is included subsequently in Appendix A.

5.4 Emergency Spillways

Whilst the service spillway between the Buffer Pond and Pond 2 will operate as part of normal operation, the emergency spillways are not to be used as part of normal operation.

Operation of the emergency spillways is automatic when the pond reservoir level rises above full supply level for each pond. Each spillway is designed for emergency spill in the event of an extreme rainfall event in combination with malfunction of the control system and no intervention within 8 hours of the initial control system alarm.

If water starts spilling over any of the emergency spillways then the inflows to the ponds from the MR2 race should be stopped as quickly as possible and the cause of the problem investigated.

6.0 Pond Storage Operation

6.1 Pond Storage Operation Filling

When Waimakariri River flows reach that permitted for water take, water will be discharged down the main race through the existing control gates at the downstream end of the buffer pond. Any excess water supplied down the main race will be discharged into the storage ponds via a pipe and control gate into Pond 1 and a gravity spill into Pond 2. The priority will be to fill Pond 1 as this pond can transfer water back into the main race as well as supplying water to the distributary races R2 and R3.

Pond 1 fills by gravity till the water level reaches RL 222.30m. When Pond 1 reaches RL 222.30m, Gate G1 closes and the three pumps located adjacent to G1 start to pump water from the Buffer Pond into Pond 1. The pumps continue to pump water into Pond 1 as long as excess water is available in the Buffer Pond. If the Buffer Pond level falls below RL 221.30m the pumps will stop operating.

The three pumps each have a capacity of 335 litres/sec. Assuming the pumps can operate continuously, Pond 1 will take 12 to 13 days to reach the maximum level of RL 226.40m from empty. The pumps are automated and the Buffer Pond water level will trigger the start of the pumps:

- Pump 1 will start when the buffer pond reaches RL 221.40.
- Pump 2 will start when the buffer pond reaches RL 221.50.
- Pump 3 will start when the buffer pond reaches RL 221.60.

The pumps are staged so that small amounts of excess water are captured without excessive start/stop scenarios. All pumps will cease operation when Pond 1 water level reaches Full Supply Level (RL 226.40m).

There is a service spillway between the Buffer Pond and Pond with a crest level of RL 222.30m. When water in the Buffer Pond exceeds this level then water spills into Pond 2. Pond 2 will continue to fill until the level in Pond 2 matches the RL 222.70m full supply level. The service spillway into Pond 2 will be designed to cope with a maximum flow of 17.0m³/sec.

6.2 Pond Storage Emptying

The storage ponds are designed to operate with three discharge outlets:

- Into the main race MR4.
- Into the Dixon Road race R3.
- Into race R2.

At full demand the two storage ponds can deliver approximately 9 days of storage at all three outlets with Pond 2 being able to supply all three outlets for 2 days.

With both ponds full, Pond 2 will initially supply storage water to all three outlets. Race 2 will be supplied via gate G2 low level outlet, Race 3 will be supplied via G3 low level outlet and MR4

will be supplied via gates G4 and G6. Gate G5 remains closed. At full demand there is sufficient stored water in Pond 2 to supply water to all three outlets for 2 days.

After 2 days, Gate G4 will close and water for MR4 is then supplied from Pond 1 through Gate G5.

When Pond 2 is at a low level and there is high demand for water in MR4 then Pond 2 pump station maintains the Tub water level at a sufficient height to provide the required water to MR4. The pumps are controlled by level probes set inside the Tub between G4 and G6. If the water level inside the Tub becomes too deep then the pumps will shut off. If the water level inside the Tub continues to drop even though both pumps are operating then gate G5 will open releasing water to maintain level within the Tub.

7.0 Maintenance And Testing

7.1 General

The maintenance routine identifies components of the ponds and associated structures which require maintenance, schedules these activities and records what is done, when and by whom.

Maintenance inspections are carried out at the same time as the dam safety surveillance inspections, described subsequently in Section 8.

Routine maintenance can typically be scheduled on the basis of time (e.g. weekly, monthly), usage (e.g. cycles or hours of operation), or observed condition from maintenance inspections (e.g. that identify excessive wear or corrosion). Routine maintenance may range from a simple lubricant change to a complete overhaul.

Even with effective preventative maintenance, WIL expects the need to undertake emergency maintenance at times. To mitigate the impact of these repairs, critical spare parts, tools, equipment and trained competent staff must be available as and when emergency maintenance is necessary.

7.2 Maintenance Needs for Waimakariri Ponds

The maintenance needs of the Waimakariri Ponds are typically identified by visual inspection of its outside surfaces and ancillary structures.

The following are typical evidence of maintenance needs:

- Concrete deterioration by cracking, spalling, erosion, cavitation, excessive joint leakage
- Potential for concrete joint deterioration indicated by leakage at joints or vegetation in joints
- Embankment crest erosion
- Damage to the geo-membrane lining
- Damage/corrosion to critical structures such as hydraulic rams and gates
- Damage/corrosion to non-structural items such as handrails, stairs, steps, walls, fencing embedded items, covers
- Blockage of drains, channels and in pond or race debris
- Overgrown vegetation on embankment or structures – can hide serious deterioration, deformation and seepage (which are failure mode indicators)
- Damage to reservoir level sensors
- Damage to power supply
- Damage to access road to crest of embankments.

Monthly routine maintenance inspections are appropriate to identify any maintenance needs and to assess an appropriate response. Additional inspections should be carried out after significant events such as gale force winds, earthquakes, extreme rainfall or malfunction resulting in a control system generated alarm or an emergency spill.

7.3 Maintenance Reporting

Maintenance inspections should be recorded and issues reported to the WIL Dam Manager for planning and implementation of the appropriate maintenance or repair activity. Records of all maintenance activities are to be kept to provide a cross reference with the initial maintenance inspection recommendation.

7.4 Testing of Flow Control Equipment

7.4.1 Equipment Included

This section covers the gates listed in Table 2, G1 to G6, and their supporting controls, communications and power supply.

7.4.2 Maintenance Requirements

Mechanical and electrical equipment require appropriate maintenance and testing. As recommended by the NZ Dam Safety Guidelines, the aim of a testing programme is to demonstrate the equipment is functional for normal and emergency operation and arrange for maintenance if there are any issues.

Table 3 summarises the inspection, maintenance and testing programme for equipment that has a dam safety function.

Table 3 - Programme of Inspection, Testing and Maintenance of Equipment with a Dam Safety Function

Equipment	Function	Test	Test Frequency
Gates, Actuators and Hydraulic Power Packs	Regulate inflows to Pond 1 and outflow from Pond 1 to the Tub, the Tub to MR4 and Pond 2 to R2 & R3 and the Tub	Opening and closing: • Unbalanced head test using normal and emergency power supply. • Record pressure of hydraulic operation and opening/closing times. • Check setting of hydraulic set relief valve. • Back- up power supplies. Because of frequent operation, NZ Guideline for 6 monthly testing of gate opening not required.	5 Yearly
Control Sensors	Monitor water levels in the ponds and at labyrinth and Crump weirs	• Check agreement with external staff gauge readings. • Water level sensor re-calibration and testing. Note – Agreement of staff gauge and sensor will be part of surveillance data review done monthly.	Yearly

Equipment	Function	Test	Test Frequency
Control System	To monitor and control water flows in and out of the ponds	Demonstrate remote control operation of gates. Note – Extent of opening must be limited dependant on upstream and downstream water levels, in order that test through flow does not cause damage immediately downstream of the gated culvert being tested.	Yearly
	Testing of backup power supply	Check backup power supply operational.	6 monthly
Pond 1 & Pond 2 Pumps	Lift water from Buffer Pond to Pond 1 and lift bottom water from Pond 1 to the Tub	For pumps and motors in accordance with manufacturers recommendations. Demonstrate remote control by control system operation.	Yearly

8.0 Surveillance

8.1 Introduction

Surveillance of the Waimakariri Ponds is carried out in conformance with Module 5 Section 4.2 of the NZ Dam Safety Guidelines.

Surveillance is a key activity of the Waimakariri Ponds Dam Safety Management System (DSMS). As explained in Module 5 of the NZSOLD, 2015 Guidelines, *"A robust surveillance process is the Owner's 'front line defence' for the safe operation of their dams and reservoirs. Surveillance provides the corner stone for effective management of dam safety and operational risks and includes routine visual inspections, instrument monitoring (including deformation surveys), data review and evaluation , and reporting on the safety of the dam".*

Other activities in the DSMS include Intermediate and Comprehensive Dam Safety Reviews, Emergency Action Plan, inspection and testing of appurtenant structures (including gates that contribute to reservoir safety), and resolution of dam safety deficiencies.

8.2 Surveillance Purpose and Philosophy

8.2.1 Surveillance Purpose

The purpose of Surveillance is to:

- Compile an accurate history of dam safety observations both visual and instrumented;
- Allow the performance of the dam to be regularly assessed and reported to facilitate the early detection and intervention addressing potential dam safety deficiencies or development of failure modes; and
- Fulfil legislative and regulatory requirements.

8.2.2 Surveillance Philosophy

During the design of the ponds the potential failure modes were identified (Waimakariri Irrigation Ponds Risk Assessment, Issue 3, July 2015, Damwatch). These failure modes are summarised in Table 4 of this plan along with an indication of the initiation event, key surveillance indicators and relevant instrumentation and monitoring systems for each failure mode. This table includes the failure modes that were considered to be not credible during the risk assessment process but have been included as in general they have similar surveillance requirements.

All of the credible failure modes and most of the non-credible failure modes require a leak through the pond liner followed by seepage through the embankment materials. The only exceptions to this relate to seismic events with the possible liquefaction of the foundations or a fault rupture through one of the embankments. Neither of these two failure modes were considered to be credible in the risk assessment study. However, in the event of an earthquake or fault movement sufficiently large to initiation these failure modes, the damage would be visually obvious and the reservoir could be drained.

The monitoring and surveillance system has been designed to allow early identification of the initiation of the other failure modes as described below.

The mechanism of failure in all of the credible failure modes is as follows:

- A hole forms in the liner (assumed 1m long tear)
- Water seeps through the liner into the embankment material
- Water seeps through the embankment material generally in a downwards direction into the foundation under the embankments
- Some of this seepage water may reach the downstream face of the embankment due to preferential flow paths along seismically induced cracks, along the outside of pipe culverts or along construction deficiencies such as through permeable layers (segregated layers) or along the top of less permeable layers (layers of finer material stopping downward drainage)
- This seepage may cause the finer material in the embankment to be eroded and removed from the embankment creating a larger flow path. This allows more flow through the embankment and more material can then eroded. Ultimately the sufficient material may be removed causing the embankment to collapse.

The time taken for this type of failure mode to move from the initiation of a hole in the liner to failure of the embankment is likely to be of the order of days or longer and therefore there is time for detection.

Surveillance shall consist of:

- Visual inspection of the pond embankments and structures
- Pond water level measurement
- Standpipe measurements to monitor rising groundwater and/or saturation of embankments
- Automatic crest failure alarm
- Deformation surveys
- Inflow and outflow measurement and water balance
- Testing of samples of the liner to detect premature aging or deterioration of the liner material.

Table 5 identifies the primary and back-up methods of detection of the failure mode indicators.

Routine inspections will follow a route march consisting of instruments to be measured and visual observations to be made as set out in the surveillance route march (see Table D1 in Appendix D). The frequency of the instrumentation readings and visual observations are also recorded in Appendix D.

Readings and observations will be carefully recorded by the WIL Racemen on prepared forms and reported to the WIL Dam Manager, who will manage assessment of the ponds and appurtenant structures performance based on the data recorded. A monthly surveillance report assessing the performance, any alarm conditions and intervention actions taken will be prepare by the WIL Dam Manager. This report will be filed for future reference in the event of dam safety incidents and will be reviewed as part of the intermediate and comprehensive inspections.

Anomalies or alarms raised during the routine or special inspections shall be treated as potential dam safety deficiency and shall be assessed in accordance with Table 8 and Figure 5.

Table 4 – Potential failure mode Indicators

No	Failure Mode	Initiation Event	Key surveillance indicators	Relevant Instrumentation/monitoring
N1	Seepage through a concentrated leak in liner leading to internal erosion through the embankment	• Deterioration over time • Impact puncture to liner	• Fall in water level in pond • Appearance of seepage on downstream face or toe • Visual damage to liner • Localised settlement on surface • Sinkhole on surface	• Visual inspections • Water level recorder • Piezometers • Annual topo surveys
N2	Seepage through a concentrated leak in liner leading to internal erosion through the embankment and into foundation	• Deterioration over time • Impact puncture to liner	• Fall in water level in pond • Visual damage to liner • Localised settlement on surface • Sinkhole on surface	• Visual inspections • Water level recorder • Piezometers • Annual topo surveys
N3	Seepage through a concentrated leak in liner leading to internal erosion at the corner due to damage at the lining interface with the penetrating conduit transition	• Deterioration over time • Impact puncture to liner	• Fall in water level in pond • Appearance of seepage at downstream end of conduit • Visual damage to liner • Localised settlement on surface • Sinkhole on surface	• Visual inspections • Water level recorder • Piezometers • Annual topo surveys
N4	*Seepage through a concentrated leak in liner leading to internal erosion along the pressurised conduit*	• *Deterioration over time* • *Impact puncture to liner*	• *Fall in water level in pond* • *Appearance of seepage at downstream end of conduit* • *Visual damage to liner* • *Localised settlement on surface* • *Sinkhole on surface*	• *Visual inspections* • *Water level recorder* • *Piezometers* • *Annual topo surveys*
N5	*Seepage through a concentrated leak in liner leading to internal erosion through the foundation*	• *Deterioration over time* • *Impact puncture to liner*	• *Fall in water level in pond* • *Visual damage to liner* • *Localised settlement on surface* • *Sinkhole on surface*	• *Visual inspections* • *Water level recorder* • *Piezometers* • *Annual topo surveys*
N6	*Seepage through a concentrated leak in liner leading to slope instability due to high piezometric*	• *Deterioration over time* • *Impact*	• *Fall in water level in pond* • *Visual damage to liner* • *Slips, slumps or cracks in the downstream*	• *Visual inspections* • *Water level recorder* • *Piezometers*

No	Failure Mode	Initiation Event	Key surveillance indicators	Relevant Instrumentation/monitoring
	level in embankment	*puncture to liner*	*slope of embankment*	• *Annual topo surveys*
SM1	Seepage through a concentrated leak in liner and seismic cracking causes internal erosion through the embankment	• Earthquake • Damaged liner	• Fall in water level in pond • Appearance of seepage on downstream face or toe • Visual damage to liner • Localised settlement on surface • Sinkhole on surface	• Visual inspections • Water level recorder • Piezometers • Annual topo surveys
SM2	Seepage through a concentrated leak in liner and seismic internal erosion near corner due to seismic induced transverse cracking	• Earthquake • Damaged liner	• Fall in water level in pond • Appearance of seepage on downstream face or toe • Visual damage to liner • Localised settlement on surface • Sinkhole on surface	• Visual inspections • Water level recorder • Piezometers • Annual topo surveys
SM3	*Seepage through a concentrated leak in liner and seismic cracking causes internal erosion near corner at penetrating conduit (soil structure interaction)*	• *Earthquake* • *Damaged liner*	• *Fall in water level in pond* • *Appearance of seepage on downstream face or toe* • *Visual damage to liner* • *Localised settlement on surface* • *Sinkhole on surface*	• *Visual inspections* • *Water level recorder* • *Piezometers* • *Annual topo surveys*
SM4	*Seepage through a concentrated leak in liner and seismic cracking causes internal erosion through the embankment and into the foundation*	• *Earthquake* • *Damaged liner*	• *Fall in water level in pond* • *Visual damage to liner* • *Localised settlement on surface* • *Sinkhole on surface*	• *Visual inspections* • *Water level recorder* • *Piezometers* • *Annual topo surveys*
SM5	*Seepage through a concentrated leak in liner and seismic cracking causes internal erosion through the foundation*	• *Earthquake* • *Damaged liner*	• *Fall in water level in pond* • *Visual damage to liner* • *Localised settlement on surface* • *Sinkhole on surface*	• *Visual inspections* • *Water level recorder* • *Piezometers* • *Annual topo surveys*
SM6	*Liquefaction of foundation zone leading to loss of freeboard and overtopping occurs*	• *Earthquake*	• *Depression on crest of embankment* • *Sand boils around toe of embankment*	• *Visual inspections*

No	Failure Mode	Initiation Event	Key surveillance indicators	Relevant Instrumentation/monitoring
SM7	*Fault rupture beneath embankment*	• *Earthquake*	• *Displacement of embankment* • *Damage to liner* • *Visible ruptures of ground adjacent to the embankment*	• *Visual inspections*

Note: Failure modes in italics were considered as not credible in the risk assessment carried out at design stage but have been included here for completeness.

Table 5: Failure Mode Surveillance

Failure Mode Indicator	Primary Surveillance Method	Back-up Surveillance Method
Hole in liner	• Routine (weekly and monthly) visual inspection with water in the ponds	• Annual inspection of liner with pond empty (1st 3 years) • Annual water balance calculation of inflow and outflow • 5 yearly testing of HDPE liner panels
Falling water levels in the ponds	• Automatic water level	• Gauge board readings • Annual water balance calculation of inflow and outflow
Seepage through the embankment	• Routine (weekly and monthly) visual inspection of outer slopes and toe with water in the ponds	• Piezometers standpipes to check for saturation of embankments
Seepage along the outlet pipes	• Routine (weekly and monthly) visual inspection of areas adjacent to the outlet pipes	• Annual inspection of liner around the outlet structure to identify any leakage points (1st 3 years)
Embankment deformation	• Routine (weekly and monthly) visual inspection	• Emergency or special inspections such as following earthquakes • TDR system • Deformation surveys (annual)
Failure of the embankment crest	• Routine (weekly and monthly) visual inspection	• Emergency or special inspections such as following earthquakes • TDR system • Automatic water level

8.3 Personnel

Routine surveillance inspections of the Waimakariri Ponds are carried out by WIL racemen with proficiencies consistent with those described in Section 2 of Module 5 of the NZ Dam Safety Guidelines. This includes specific on the job training with overview by appropriately qualified trainers. Training of the Racemen/surveillance inspector shall meet at least one of the levels listed below:

- Met the requirements of NZQA Unit Standard 15156 ‘Conduct hydraulic structures safety and surveillance inspections’, or
- Satisfactorily completed a surveillance inspector training course provided by suitably experienced dam engineers within the previous 5 years, or
- Been briefed by a person meeting at least one of the criteria above, or
- Been briefed by a suitably experienced dam engineer.

The Dam Safety Advisor that completes the assessment of the collected surveillance data should be a chartered professional engineer with 10 or more years' experience in dam safety and surveillance.

8.4 Surveillance Instrumentation

Instrumentation consists of:

- 14 Standpipe piezometers in the pond embankments (refer to drawing WIL1125/30/21)
- Water level sensors recorded by control system at the Buffer Pond, Pond 1 and 2 and the Tub
- 2 Crump weirs on R2 and R3 to measure the flow release from Pond 2
- Ultrasonic wall-flushed type flow-meters installed on the RC pipe walls, upstream of the outlets and Dixons road to measure flow from Tub to main race MR4 (controlled by Gate G6)
- 20 Survey monuments; located on the crest of the pond embankments (refer to drawing WIL1125/30/21)
- 4 Reservoir water level staff gauges located in the Buffer Pond, Pond 1, Pond 2 and in the Tub (read manually by surveillance inspector)
- 2 water level staff gauges located on the crump weirs in races R2 and R3.

For instrumentation locations refer to drawing WIL1125/30/21 in Appendix B.

For crump weir details refer to drawings WIL1125/30/107 and 127 in Appendix B.

8.5 Routine Inspections (Route march)

Routine inspections of the Waimakariri Ponds, including the Buffer Pond, shall include:

a) A **weekly visual inspection** of the exposed faces of the pond embankment, and

b) A **monthly route march** and measurement of the piezometers, the frequency being at least every 28 days and at least 12 routine inspections per year.

The purpose of the inspection is to confirm satisfactory behaviour of the ponds, and to identify any dam safety deficiencies or potential failure modes.

The **weekly visual inspection** of the embankment toe will specifically look for and monitor any potential issues with the pond liner, toe or downstream face seepages, unexpected operation of the spillways and check that the Pond 1 pump station intake screen is clean and operational.

The **monthly route march** shall take piezometer measurements and carry out a visual condition assessment of the Ponds, incoming and outgoing races and the pumping stations. The route march shall pay particular attention to the following items:

- Downstream embankment faces for erosion, seepage, deformation
- Upstream embankment faces for damage or displacement of the geo-membrane and deformation of slope
- Embankment crests for any erosion, local settlement or cracking

- Operation of the spillways when not expected
- Deterioration of concrete by cracking, spalling, erosion, excessive joint leakage
- Potential for concrete joint deterioration indicated by leakage at joints or vegetation in joints
- Damage/corrosion to mechanical components such as hydraulic rams and gates
- Damage/corrosion to non-structural items such as handrails, stairs, steps, walls, fencing embedded items, covers
- Blockage of drains, channels
- Overgrown vegetation on embankments (can hide more serious deterioration or failure mode indicators)
- Excessive debris in the pond (large floating objects will damage the geomembrane lining)
- Damage to reservoir level sensors
- Damage to power supply
- Damage to access road to crest of embankments.

A pro forma for the monthly route march is included in Appendix G.

8.6 Surveillance Alarms

8.6.1 Observation Alarms

Section 8.5 describes the scope of the observations to be made during the weekly and routine route marches. The results of these inspections are to be recorded on the Route March Form in Appendix G. The Surveillance Inspector should rate each item using the qualitative descriptors shown in Table 6 and repeated on the Route March Form. This allows each items performance to be effectively monitored.

Table 6 – Observation Alarm Levels

Indicator	Condition	Action
0	Condition good	None
1	Routine maintenance needed	Arrange for maintenance
2	Unusual condition observed	Contact WIL Dam Manager and investigate
3	Potential dam safety issue	Telephone WIL Dam Manager immediately and investigate
4	Emergency action required immediately	Contact WIL Dam Manager and take action where appropriate

If conditions are normal and the ponds are operating satisfactorily then Indicator level 0 is recorded. If there are any areas requiring general maintenance such as vegetation growth or debris in the pond then Indicator Level 1 is recorded and actions taken to have the maintenance carried out. If unusual conditions are observed such as deformation not previously seen but no obvious signs of distress then this is Indicator level 2 and an investigation is required to determine if it is a dam safety issue. Level 3 is recorded if it is obvious that the issue could relate to a dam safety issue but the indicators are small and it should be possible to manage the issue and prevent it becoming more serious. This would be the case if damp areas appear on

the embankment or there are small areas of clear seepage. Level 4 is when it is obvious that there is a serious dam safety incident that requires immediate attention.

In the case of levels 2, 3, and 4 it is important to provide a detailed description of the issue including the location and if possible photographs.

8.6.2 Instrument Reading Alarms

The surveillance instruments are listed in Section 8.4.

The key dam safety instrumentation are the piezometers. The water levels are expected to be below the base of the piezometers and therefore the normal reading expected would be a measurement of the full depth of the piezometer indicating that it is dry. The piezometer alarm levels are listed in Table 7. An indicator Level 0 should be recorded on the record form for Piezometers included in Appendix G. If it is not possible to read the piezometer because of a blockage or damaged top then this should be recorded on the form as a maintenance issue and arrangements made to repair the piezometer. If there are difficulties in taking readings due to bending or shearing of the piezometer standpipe then this could be an indication of movement of the embankment and should be investigated. It should be recorded as an Indicator Level 2 on the form. Any reading of water within the piezometer could be a sign of rising groundwater or saturation of the embankment and requires an investigation. The greater the depth of water in the piezometer the more serious the potential dam safety issue.

Table 7 – Piezometer Alarm Levels

Indicator	Condition	Explanation	Action
0	Piezometer dry		No action required
1	Not possible to read the piezometer due to blockage or damaged top	Maintenance of Piezometer needed	Arrange for maintenance to be carried out
2	Difficulty in reading the piezometer due to bending or movement of the standpipe	Investigation required to understand why the movement has taken place	Contact WIL Dam Manager and arrange for investigation
3	Reading > 0.3 m above Piezometer bottom RL	Potentially rising groundwater	Contact WIL Dam Manager and arrange for investigation
4	Reading > 1 m above Piezometer bottom RL	Potentially rising groundwater	Contact WIL Dam Manager and arrange for urgent investigation

Settlement Markers shall be level surveyed annually by a registered surveyor. The surveyors report shall list the survey method, reduced levels of each of the settlement markers and change from the initial level established prior to commissioning and form the previous set of readings. A typical level survey form is included in Appendix G.

The results of the survey should be reviewed by the WIL Dam Manager and settlement of more than 50mm within one year or more than 100mm since commissioning should be referred to the Dam Safety Advisor.

8.7 Data management and Review

All dam safety related documentation and records shall be maintained by WIL in one place within their information management system so that it is all readily available in the event of a dam safety issue or investigation and for the dam safety reviews.

The data that should be retained in this record should include but not be limited to the following:

- Details of the dam type, height and dimensions
- Details of the appurtenant structures and identification of the dam safety critical structures
- The design report, construction report and as built records
- Copies of the Resource Consent and conditions
- Copies of the Building Consent and Code Compliance Certificate
- The up to date assessment of the dam PIC
- The up to date assessment of failure modes and key indicators
- The dam safety management system and supporting documents
- Surveillance procedures, operating and maintenance procedures, gate/valve testing procedures, reservoir operating rules
- Copies of all studies relating to any modifications or issues during the life of the pond
- A register of all instrumentation, including maintenance and testing
- A register of all gate testing
- An auditable database of all dam safety issues including tracking of their status and decisions made
- Training schedules and records for all dam safety related staff, including managers, operators and Racemen

The dam safety management system should be internally audited at least every two years to ensure that the procedures are being followed. A record of this audit and its findings should be recorded in the dam safety records. It should be noted that the Resource Consent also requires that the system should be reviewed every 12 months for the first two years and after any emergency trigger event. These trigger events are events such as earthquakes greater than VII intensity on Modified Mercalli scale, if the emergency spillways operate or if significant leakage is detected on the downstream face of the embankment.

The dam safety management system should be reviewed as part of the CDSR process. However, the contact details in the system should be updated annually and the local emergency disaster management teams contacted annually to ensure that there are no changes that could affect the Emergency Preparedness Plan.

8.8 Intermediate Dam Safety Reviews

Intermediate Dam Safety Reviews (IDSR) of the Waimakariri Ponds shall be undertaken yearly by an experienced dam safety engineer (technical advisor) accompanied by Racemen / technicians familiar with the structures.

The purpose of the intermediate inspection is to confirm satisfactory behaviour of the pond embankments and identify any dam safety deficiencies or failure modes through visual examination and review of surveillance data. Refer to NZ Dam Safety Guidelines Module 5, Section 4.4. The scope of the IDSR shall include the following:

- An on-site inspection of the dam
- A review of the operation, surveillance, maintenance and testing records,
- An evaluation of the performance of the dam as indicated by the on-site inspection and review of the records since the last inspection
- Preparation of a report identifying any dam safety issues, changes to the monitoring or additional monitoring requirements.

8.9 Comprehensive Dam Safety Review

A Comprehensive Dam Safety Review (CDSR) shall be undertaken every five years by a dam engineer highly experienced in Comprehensive Safety Reviews and lined embankment dams, accompanied by Racemen/technicians familiar with the structures.

The purpose of the CDSR is to confirm satisfactory behavior of the dam, identification of deficiencies by a thorough onsite inspection; evaluation of data and applying current dam engineering best practice and understanding of the dam embankment, foundation and appurtenant structures. A CDSR report will assess the dam performance and identify any dam safety issues in accordance with the NZ Guidelines, Module 5, Section 4.5.

Ten A2 size coupons of the liner geomembrane material have been provided at the full supply level of the lining in Pond 1, for testing of a coupon sample every 5 years, commencing at end of year 10. The coupons are to be tested for tensile and tear resistance and if these samples show a greater than 20% decrease from the design parameters then the two samples on the base of the pond shall be tested to determine if the liner should be replaced. The engineer carrying out the review will specify the appropriate tests required to assess the condition of the liner and its ability to perform to its design criteria. This testing and liner assessment shall be included as part of the Comprehensive Dam Safety Review.

A detailed scope of works for the Comprehensive Dam Safety Review is included in the NZ Dam Safety Guidelines but in general will include:

- A review of previous inspections and surveillance reports
- A thorough visual inspection of the Waimakariri Ponds and associated structures
- A review of the piezometer data and water levels
- Inspection and witness of equipment operation such as gates to identify any deficiencies
- A review of results from deformation survey of the survey marks located on the embankment crest
- A review of the potential impact classification (PIC)
- A review of the design failure modes analysis and known or potential hazards

- A review of the dam safety management system and emergency preparedness plan
- Discussion with the WIL Dam Manager on the operation, maintenance and surveillance of the dam and any matters of potential significance
- Testing and reporting on the condition of the liner
- An assessment of the dam and its appurtenant structures to safely perform to current acceptability criteria for all loading conditions
- Preparation of a detailed report.

8.10 Special Inspections and Dam Safety Reviews

Special dam safety inspections and dam safety review, shall be carried out following unusual events, observations or emergencies. These may be undertaken by the WIL Raceman with any anomalies reported to the WIL Dam Manager for further investigation. Such events and emergencies should be evaluated to determine whether they have resulted in any noticeable changes, damage that requires attention, whether any special safety measures or follow-up investigations need to be implemented and whether the dam performance continues to be in accordance with design expectations. Unusual events, observations and emergencies relevant to the WIL Ponds may include:

- Adverse surveillance observations, for example, seepage from an outer embankment, or a piezometer reading above alarm level
- Extreme rainfall
- Strong winds
- Major earthquake (with intensity at the site greater than VII on the Modified Mercalli Scale).

8.11 Identification of a Dam Safety Deficiency

A dam safety deficiency is an issue which if not remediated could lead to an uncontrolled release of reservoir water. These can be either identified through the normal course of surveillance route marches and instrumentation reviews or through a recommendation process as part of on-going dam safety reviews such as the Intermediate and Comprehensive Dam Safety Reviews. The status of dam safety recommendations is reported in the Intermediate Dam Safety Review reports and the Comprehensive Dam Safety Review reports.

If a dam safety deficiency is observed during day to day operations, or surveillance inspections, the WIL Dam Manager is to be notified immediately.

While some dam safety deficiencies require immediate response (e.g. active embankment piping), others are non-immediate in nature and require longer timeframes to investigate, assess and resolve (e.g. dam appears to fail stability criteria). Such deficiencies are managed using the following planned process:

- review to assess whether the potential dam safety deficiency is a dam safety deficiency
- plan the evaluation process
- identify and use appropriate advisors
- develop the applicable dam safety acceptance criteria
- identify treatment alternatives that meet the dam safety acceptance criteria

- identify and consider non-technical risks
- implement and manage the treatment to address the dam safety deficiency in a manner appropriate to the nature of the risk and the likelihood of occurrence
- review the effectiveness of the treatment through ongoing surveillance and reviews

WIL maintains a register of dam safety deficiencies that allows their investigation, assessment and resolution to be prioritised and monitored.

Dam safety deficiencies are most likely to be related to one or more of the identified potential failure modes (refer to Waimakariri Irrigation Ponds Risk Assessment, Damwatch, Issue 3, July 2015). These are listed in Table 6 below along with the likely initiation events, key surveillance indicators and relevant instrumentation or monitoring task.

Identification of any of the surveillance indicators in Table 4, the occurrence of a felt earthquake at the site, extreme rainfall or inflow malfunction, or an incident that leads to the puncture of the liner, should be reported immediately to the WIL Dam Manager for review.

For all identified concerns or dam safety deficiencies, the WIL Dam Manager, with advice from the Dam Safety Advisor, will classify the event in accordance with Table 8 below. The WIL Dam Manager will then arrange for the appropriate notifications and actions to be carried out. All incidents shall be registered and monitored in the pond incident database. Figure 5 provides an overview flow chart of the process for the management of an incident.

If the initial assessment leads to an Alert Level of 1 or 2 then the Dam Manager will organise the appropriate internal notifications and response. Refer to the Emergency Action Plan (Appendix E) for actions expected by the Dam Manager to manage and record an Alert Level 1 or 2 Incident.

Alert Level 3 or 4 requires notification of the event to the Emergency Services and implementation of warnings and emergency actions in accordance with the actions outlined in the Emergency Action Plan contained in Appendix E herein.

A Time Domain Reflectometry (TDR) system is installed in the dam crest around the embankment perimeter (refer to drawing WIL1125/30/25). This system is capable of providing an alert if the TDR cable is sheared, indicating a large magnitude slope failure. Figure 5 shows how the TDR alerts are managed under the Emergency Action Plan.

Table 8 – Alert Level Classification

Alert Level	Description	Safety State	Consequences	Initiating Event	Notifications
1	Unusual Event	Controlled	None expected	Seepage change Earthquake Extreme rainfall	File Notification Report
2	Isolated incident or alarm	Increased dam safety awareness	Potential incident	Increased leakage, seepage or turbidity, embankment deformation, punctured liner	Notify WIL management team, arrange investigation
3	**Potential dam failure situation, rapidly developing**	**Threat to dam safety controllable if action taken swiftly**	**Injury or safety of public or property endangered**	• **Increasing leakage, seepage or turbidity,** • **embankment deformation**	• **Manage corrective measures** • **Notify Police and of Alert level 3**
4	**Urgent, dam failure appears imminent or in progress**	**Evacuation needed Serious threat to pond embankment**	**Downstream damages expected**	• **Uncontrollable turbid seepage;** • **Significant or increasing crest settlement leading to overtopping**	• **Alert Police of Alert Level 4 with recommend-ation to evacuate residents in inundation area**

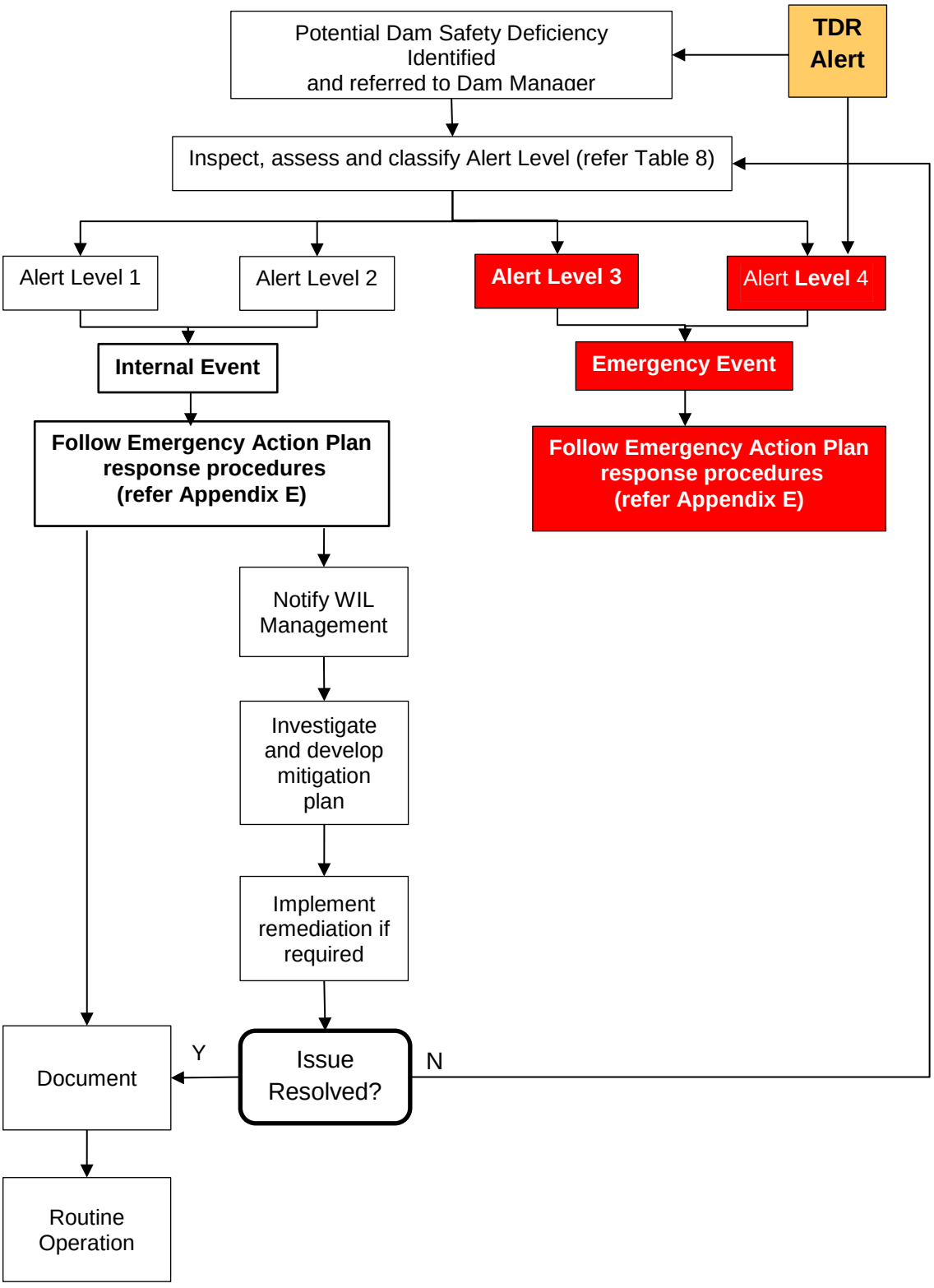

Figure 5- Emergency Action Plan Implementation Chart

Appendix A – Control System

[DETAILS TO BE CONFIRMED]

Appendix B – Drawings

The register of As Built drawings is set in Table on next page followed by selected drawings to support this Dam Management Plan.

[DETAILS TO BE CONFIRMED]

Appendix C – Personnel Roles & Responsibilities

The WIL team responsible for the day to day Operation, Maintenance and Surveillance of Waimakariri Ponds are:

WIL General Manager / Dam Manager

- Name: TBA
- Affiliation: Waimakariri Irrigation Ltd
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Overall responsibility for operation, maintenance and surveillance.
  - Overall management and implementation of the Emergency Action Plan.

Operation Manager

- Name: TBA
- Affiliation: Waimakariri Irrigation Ltd
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Monitor piezometers and embankment deformations and communicate data to relevant parties.
  - Visual inspections of canals, embankments and appurtenant structures.
  - Reading staff gauges as required.
  - Manual override of gates as required.

Raceman Surveillance Technician 1

- Name: TBA
- Affiliation: Waimakariri Irrigation Ltd
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Monitor piezometers and embankment deformations and communicate data to relevant parties.
  - Visual inspections of canals, embankments and appurtenant structures.
  - Reading staff gauges as required.
  - Manual override of gates as required.

Raceman Surveillance Technician 2

- Name: TBA
- Affiliation: Waimakariri Irrigation Ltd
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Monitor piezometers and embankment deformations and communicate data to relevant parties.
  - Visual inspections of canals, embankments and appurtenant structures.
  - Reading staff gauges as required.
  - Manual override of gates as required.

Raceman Surveillance Technician 3

- Name: TBA
- Affiliation: Waimakariri Irrigation Ltd
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Monitor piezometers and embankment deformations and communicate data to relevant parties.
  - Visual inspections of canals, embankments and appurtenant structures.
  - Reading staff gauges as required.
  - Manual override of gates as required.

Logger Technician

- Name: TBA
- Affiliation: NIWA
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Maintains operation of control system

Gates Engineer

- Name: TBA
- Affiliation: TBA
- Contact Details:
  - Work: TBA
  - Mobile: TBA
  - Home: TBA
- Role & Responsibilities:
  - Gate maintenance advice

Dam Safety Advisor

- Name: Damwatch Engineering Ltd.
- Contact Details:
  - Work: 04 381 1300
  - 1st Contact: TBA
  - 2nd Contact: TBA
- Role & Responsibilities:
  - Emergency dam safety advice

Appendix E – Emergency Action Plan

[BOUND SEPARATELY]

Appendix D – Monitoring Schedule

General

This schedule sets out surveillance to be carried out during operation of the ponds.

Summary of Instrumentation

Instrumentation consists of:

- 14 Standpipe piezometers in pond embankments (refer to drawing WIL1125/30/21);
- Water level sensors recorded by control system at the Buffer Pond, Pond 1 and 2 and the Tub;
- 2 Crump weirs on R2 and R3 to measure the flow release from Pond 2 and associated staff gauges;
- Ultrasonic wall-flushed type flow-meters installed on the RC pipe walls, upstream of the outlets and Dixons road to measure flow from Tub to main race MR4 (controlled by Gate G6).
- 20 Survey monuments; located on the crest of the pond embankments (refer to drawing WIL1125/30/21);
- 4 Reservoir water level staff gauges located in the Buffer Pond, Pond 1, Pond 2 and in the Tub and two water level staff gauges located in the crump weirs in races R2 and R3 (read manually by surveillance inspector)

Monitoring Route March and Observations

- Inspect outside perimeter of the ponds on a weekly basis, record observations at observation points monthly – establish observation points in areas of leaks;
- Inspect Intake Race and adjacent Main Race sections;
- Inspect Outlet Race, Crump Weirs and adjacent Main Race sections;
- Inspect Crest (8 observation points) for:
    - Crest conditions;
    - Embankment conditions;
    - Lining conditions;
    - Floating debris, logs, etc.;
    - Emergency spillways.

The observation details are summarised in Table D1

Table D1 – Observation Details

Item	Component	Read/Observe	Monitoring frequency
1 Intake Race and Buffer Pond			
	Embankments	Observe embankments external perimeter settlement, slumping or seepage	Monthly
2 Ponds 1, 2 and Tub			
	Embankment toe	Observe outside embankment perimeter and particularly toe area for seepage	Weekly and include in monthly inspection
	Embankment crest and pond lining	Observe Crest and inside embankment slope for settlement, slumping or damage to liner	Weekly and include in monthly inspection
	Pond water level	Record staff gauge reading and time	Monthly
	Standpipe Piezometers	Read piezometers with dipmeter	Monthly
	Settlement markers	Survey level	Yearly
3 R2, R3 and MR4 at Outlet Transitions			
	Embankments	Observe embankments external perimeter settlement, slumping or seepage	Monthly
	Crump Weir	Observe crump weirs for operation and embankment seepage Record staff gauge reading and time	Monthly

Reporting

Weekly inspections and monthly routemarch observations and instrumentation readings will be recorded in the surveillance database and the results reviewed by the Dam Safety Advisor.

If any seepage, erosion or damage to lining observed – communicate immediately to Design Engineer providing details including: approximate seepage flow rate; whether discoloured; whether increasing, and provide photographic record.

Appendix F – Resource Consent Conditions

[DETAILS TO BE CONFIRMED]

Appendix G – Forms

ROUTE MARCH FORM

Date ……	**Time Start……..Finish……**
Observed by:	**Weather:**
Water Levels:	**Buffer Pond:** **Tub:** **Pond 1:** **Pond 2:**

Item	Component	Reading/Observation	Alarm
1	Buffer pond, intake race and Service spillway	Floating Debris Embankment Seepage Embankment Slump	
2	Outside embankment perimeter of Pond 1	Seepage Slump	
3	Crest and Inside Slope Conditions of Pond 1	Misalignments/depressions Lining Conditions Floating debris in pond Emergency Spillway conditions	
4	Outside embankment perimeter of Pond 2	Seepage Slump	
5	Crest and Inside Slope Conditions of Pond 2	Misalignments/depressions Lining Conditions Floating debris in pond Emergency Spillway conditions	
6	Outlet gates, The Tub Crump Weirs and adjacent races	Floating Debris Embankment Seepage Embankment Slump	

Other observation

Alarm	Condition
0	No action required
1	Routine maintenance needed
2	Urgent maintenance required
3	Emergency developing
4	Emergency action required forthwith

RECORD FORM FOR PIEZOMETER AND GAUGE BOARD READINGS

Date:……	**Time:** Start……..Finish……
Frequency: **Daily**	Readings to nearest millimetre
Temperature: (Celsius)	Observed by:
Weather Conditions:	Signature:

Condition	Code
Very sunny	0
Sunny	1
Partly cloudy	2
Cloudy	3
Light rain	4
Heavy rain	5

Piezometer Reference	Dip Reading, A (m)	Capped Piezometer Level, B (RL m)	Piezometer Water Level =B-A (m)	U/S Pond No.	U/S Water Level (m)	D/S Pond No.	D/S Water Level (m)	Bottom of Piezometer (RL m)	Comments
Buffer Pond	**Comment:**						**Gauge Board Reading:**		
Tub	**Comment:**						**Gauge Board Reading:**		
U/S Toe Pond 1	**Comment:**						**Gauge Board Reading:**		
D/S Toe Pond 2	**Comment:**						**Gauge Board Reading:**		
WIL OW 1 W		TBA						TBA	
WIL OW 1 N		TBA						TBA	
WIL OW 1 E1		TBA						TBA	
WIL OW 1 E2		TBA						TBA	
WIL OW 1 E3		TBA						TBA	
WIL OW 1 S		TBA						TBA	
WIL OW 2 S1		TBA						TBA	

Piezometer Reference	Dip Reading, A (m)	Capped Piezometer Level, B (RL m)	Piezometer Water Level =B-A (m)	U/S Pond No.	U/S Water Level (m)	D/S Pond No.	D/S Water Level (m)	Bottom of Piezometer (RL m)	Comments
WIL OW 2 S2		TBA						TBA	
WIL OW 2 N1		TBA						TBA	
WIL OW 2 N2		TBA						TBA	
WIL OW 2 N3		TBA						TBA	
WIL OW 2 E1		TBA						TBA	
WIL OW 2 E2		TBA						TBA	
WIL OW 2 E3		TBA						TBA	

Pond water levels should be recorded from both the manual gauge boards and the automatic water level recorders. Any differences in water levels between the two systems should be investgated.

1. **If Piezometer water level ≥ Pond water level on either side, call Damwatch.**
2. **All results to be forwarded to Damwatch on a daily basis.**

Piezometer Behaviour

- Piezometers are located in the foundation under the dividing embankments.
- Existing groundwater level is greater than 10m below ground level.
- On filling the ponds the ground water is not expected to rise between the ponds.
- Piezometric water level above bottom of piezometers should be communicated to Damwatch Design Engineer.

Commissioning Piezometric Levels

- During commisioning the piezometer level should be reported to the design engineer along with the water levels in the ponds on both sides. The design engineer will consider the levels and responses.
- However, if the level in the piezometer rises to the same level as one of the ponds then this probably indicates a leak in the liner.
- Water level should be drawn down until the piezometer level drops back to original ground level. If this is done in stages then it may help in locating the level of the leak.
- Reading of water level and piezometers during commisioning – daily.

RECORD FORM FOR SURVEY MARKS/BENCH MARKS

Frequency: Weekly	Readings to nearest millimetre

Mark	Date	Time	RL (m)

Observed by:	Signature:

1. **If the Survey Mark RL moves by more than 50mm to previous RL reading call Damwatch.**
2. **Results to be forwarded within 24hr of survey to Damwatch on a weekly basis.**