

Waitakere main dam hydraulic structure



Schedule of Contents

Schedule of Contents	2
Summary	4
Geology	4
Summary of Geology	5
Catchment and Reservoir	5
Potential Impact Classification	6
Determination Of Assessed Damage Level	6
Determination of Dam Clasification.....	6
Embankment	7
Materials.....	7
Crest.....	7
Ground Anchors	7
Internal Drainage	8
External drainage	8
Abutment Vegetation	8
Spillway	8
Spillway inlet.....	8
Spillway Dissipater.....	8
Valve Tower	9
Valve tower structure	9
Valve tower tunnel access	9
Valve tower equipment	9
Scour discharge.....	9
Performance Instrumentation.....	10
Lake Level	10
Rainfall	10
Visual Inspection	10
Log Boom.....	11
Communication And Control Systems	11
Basic Warning Systems.....	11
Emergency Communications.	11
Telecom Landline Network	12
Telecom Cellphone Network.....	12
VHF Radio.....	12
Satellite Phones.....	12
Control Communications.....	12
Power Supply	12
Primary Power Supply	12
Back Up Power Supplies	13
Access to the Dam	13
Waitakere Dam Hydraulic Structures Hydrological Data (L&S Datum)	14
Waitakere Dam Original Construction Data	16
Seismic Spectra.....	17
Recommended Class B Smoothed Spectra for SEE ¹ Motions	18
Spillway Rating.....	18
Failure Mechanisms	19
Surveyed Spillway Levels	21
Waitakere Main Dam Spillway Rating	22
Cross-section of Dam	24
Bathymetric Plan	25
Waitakere Dam Site Location	26
Schedule of Drawings.....	28
Contents of Waitakere Dam Data Books	36

Schedule of Reports39

Summary

The Waitakere Main dam was constructed between 1907 and 1910 and was raised approximately 5 m in 1927. The Saddle dam was constructed in 1927 to allow the raising of the reservoir to its current height. They are located some 13 kms northwest of Titirangi and dam the Waitakere Stream. The dams are owned and operated by Watercare Services Ltd and are part of a network of 16 dams used for impounding water for Auckland's water supply.

A notable feature of the main dam is its position above a 95 m high waterfall.

Geology of the main dam foundation

The Waitakere dam is founded in the Piha Formation which consists of interbedded fine and coarse pyroclastic deposits which dip gently to the north east.

The dam site is intersected by two sets of major joints. One set parallel to the dam axis, the other perpendicular. These major joints show up as lineations on aerial photographs and several are exposed in the cliff face below the dam.

The alternating layers of agglomerate and tuff beds are exposed at the waterfall escarpment downstream of the dam. This geological formation consists of pyroclastic rock, ranging from fine grained siltstones and sandstones known as tuff, to beds and lenses of gravel and boulder sized andesitic and mudstone clasts in a sand / silt matrix, referred to as agglomerates. At the main dam's location, the bedding planes within the Piha Formation dip between 5 to 15 degrees to the east.

Both abutments of the dam are deeply weathered, particularly the right abutment. The boundary between extremely and highly weathered rock and the moderately less weathered rock is significant in terms of the stability of the dam. Weathered rock above the boundary is weak and defects in this weathered rock are open and permeable. Below this boundary, the rock is of higher strength and is relatively impermeable.

The depth of the extremely/highly weathered zone is 17.5 metres deep on the right abutment and 10.5 metres deep on the left.

This weathered zone daylights on the lower abutments at approximately RL 194 m. Below this level the rock exposed in the stream channel at the toe of the dam is moderately or less weathered. This weathering profile indicates that development of a deep weathering profile has not kept pace with down cutting of Waitakere Stream.

The agglomerate and fine grained tuffs appear to be equally susceptible to weathering. In the agglomerate the sand/silt matrix weathers in preference to the clasts. In the intermediate stage of weathering the matrix is extremely weathered and the clasts are highly to moderately weathered. In the less weathered rock at depth, defects have weathered rinds adjacent to the joints suggesting that a "weathering front" extends out from the joint surfaces into the rock.

The extremely and highly weathered rock on both abutments is extremely low-very low strength with unconfined compressive strength values from approximately 0.4 – 2 MPa. In general only the higher strength sections of core in these zones were suitable for testing and as a result the test results give higher strength values than is considered appropriate for core as a whole, hence the difference between estimated and measured strength values.

The rock strength increases markedly in the moderately and less weathered zone and ranges from low-high strength UCS values from 12 – 39 MPa but typically low-medium strength UCS values 12 – 20 MPa.

Two potential foundation concerns were noted in the first Review.

- Seepage flows initiating joint controlled rock falls in the upper right abutment; and
- Large scale joint controlled rock falls on the cliff face affecting the tramline and undermining the lower right abutment of the dam

Geology of the Saddle dam foundation

The saddle dam foundation is founded on a deeply weathered ridge of Piha Formation tuff and agglomerate. The interface between the fill and dam slopes downstream at up to 10°. The residual soil consists of silt, medium to high plasticity with minor weathered gravels. Upstream of the core wall the upper 1.2 m of the silt is soft. Below this level and downstream of the core wall the residual soil is firm to stiff consistency. At 4m depth the residual soil grades into extremely weathered Piha Formation and the soil strength increases with depth. The residual soil is massive and of low permeability. The underlying Piha Formation is of higher permeability because of defects in the weathered rock.

Catchment and reservoir

The Waitakere Dam is located at the northern end of the Waitakere Ranges west of metropolitan Auckland. The catchment is approximately 4 km long by up to 3 km wide, covering an area of some 820 ha. The reservoir area at top water level is approximately 27.8 ha. The dam impounds a reservoir of 1,850,000 cubic metres storage.

The catchment is bounded by the Scenic Drive to the east, the Cutty Grass Track to the south which divides this catchment from the Nihotupu catchment; the Ridge Road Track to the west which divides the catchment from the headwaters of the Anawhata Stream and the Fenceline track and dam to the north.

The Gleeson, Waiatarua and Waitakere Streams are all of approximately 2 km length and discharge into the southern end of the reservoir. The slopes of the catchment are predominantly moderate to steep and bush covered. The highest point in the catchment is approximately 340 m above sea level. The maximum operating level of the reservoir is 209.7 m, giving total relief of 130 m. The reservoir is a ribbon shape, and measures 1.4 km in length and is 400 m wide at its widest part. The surface area of the reservoir is approximately 28 hectares (0.28 km²).

Potential Impact Classification

Determination of assessed damage level

Damage Level	Specified Categories				
	Residential Houses ¹	Critical or major Infrastructure ²		Natural environment	Community Recovery time
		Damage	Time to restore to operation ³		
Catastrophic	More than 50 houses destroyed	Extensive and widespread destruction of and damage to several major infrastructure components	More than 1 year	Extensive and widespread damage	Many years
Major	4 to 49 houses destroyed and a number of houses damaged	Extensive destruction of and damage to more than 1 major infrastructure component	Up to 12 months	Heavy damage and costly restoration	Years
Moderate	1 to 3 houses destroyed and some damaged	Significant to at least 1 major infrastructure component	Up to 3 months	Significant but recoverable damage	Months
Minimal	Minor damage	Minor damage to major infrastructure component	Up to 1 week	Short term damage	Days to weeks

Determination of dam classification

Assessed Damage Level	POPULATION AT RISK (PAR)			
	0	1 - 10	11 to 100	More than 100
Catastrophic	High potential impact	High	High	High
Major	Medium potential impact	Medium./High (see note 4)	High	High
Moderate	Low potential impact	Low/Medium/High (see notes 3 & 4)	Medium/High (see note 4)	Medium/High (see notes 3 & 4)
Minimal	Low potential impact	Low/Medium/High (see notes 1,3 & 4)	Low/Medium/High (see notes 1,3 & 4)	Low/Medium/High (see notes 1,3 & 4)

Embankment

Materials

Waitakere (main) Dam is a single curvature, concrete gravity dam with a maximum height of 26 metres and a crest length of 175 metres. The crest width is 2.6 m. It is located in the Waitakere Ranges above a 110 metre high cliff. The dam has an uncontrolled overflow spillway with 8 bays along approximately 42 metres of crest.

The dam has a volume of 25,200 cubic metres of concrete. The dam has additional strengthening from 55 ground anchor cables secured in the rock below the dam's foundations. These were installed in 1992/93.

Reinforcing dowels have been installed to strengthen the dam by providing a better bond between the original concrete and the raised dam body.

Crest

As part of the upgrade in 1992/1993, the upstream handrail has been replaced by a concrete wall at the right abutment to ensure that overtopping does not occur at this location, which could lead to erosion around the abutment.

On the dam right abutment the upstream parapet wall limits the amount of flow that can overtop the dam. The left abutment does not have an equivalent level of protection. However it does appear that there would need to be significant erosion before the dam toe is exposed. Works Consultancy (1996) in their safety review noted that some lining protection on the left abutment may be required.

Ground anchors

Following the recommendations of the 1988/1989 Safety Evaluation review, structural upgrading was undertaken in 1992/1993 comprising the installation of 55 vertical post tensioned rock anchors to increase the main dam's resistance against sliding and overturning. They typically range between 30 and 60 metres in length, and the majority consisted of 28, 15mm (0.6 inch) diameter strands. Double corrosion protection was provided by individually greased and sheathed strands contained in a grouted smooth wall HDPE sheathing in the free length. In the anchor length, the basket woven strand bundles are contained within a corrugated HDPE sleeve. The anchors have the facility for load monitoring and re-stressing throughout the entire life of the structure.

The dam has been in service at its current height since 1927. The concrete dam stability was enhanced with post-tensioned cables during 1992/93. The driver for installing the cables was to ensure adequate stability for extreme earthquake load and PMF conditions. It was however noted that under usual loads tension could exist at the heel of the dam, and in this respect the dam would not have met usual stability criteria prior to post-tensioning. In fact, if base cracking had developed along any tension zone, then the stability of the dam was well below accepted standards for both usual loads and PMF loads. The post-tension works are an important element in ensuring adequate stability under all load combinations, and not just extreme earthquake loads. Hence the importance of continuing stress monitoring and inspection of corrosion protection elements at the anchor heads at regular intervals to demonstrate effectiveness of the cable loads.

Internal drainage

There is no internal drainage gallery in the Waitakere Main Dam

External drainage

Seepage flows at the main dam are monitored at the following locations:

- The main stream pipe (MSTRM), slightly downstream of the stilling basin, which primarily reflects an historic spring in the foundation of the basin, but would also capture any left abutment seepage which flowed to the stilling basin.
- The main dam toe weir (WTOE) which captures any seepage from the right abutment area in addition to the main stream pipe flow.

Both monitoring points have been flooded for the majority of the review period as a result of the dam spilling and the release of compensation flows; a solution is currently being sought by Watercare.

Abutment vegetation

Both abutments rise steeply and are covered in native bush.

Spillway

Spillway inlet

A simple ogee weir type overflow type spillway is located centrally in the concrete dam structure. The water flows over the downstream face of the dam into a plunge pool.

The dam has a free overflow ogee spillway with a crest level of RL210.7m. It has eight openings. Six of the openings are approximately 5.5m wide and two are approximately 4.5m wide. A 2.6m wide bridge deck is supported on piers across the free overflow crest.

The estimated PMF of 301 cumecs would be passed with approximately 700mm overtopping of the dam deck.

Spillway Dissipater

At the foot of the spillway is 2 m deep plunge pool which absorbs the energy from the released flow. The plunge pool overflows through a narrow channel then flows over the cliff face. This was installed just after 2000 to prevent further erosion beneath the spillway.

Valve Tower

Valve tower structure

The valve tower was formed integral with the upstream face of the dam. A 2 m high by 1 m wide access tunnel runs from the downstream toe of the dam to the base of the tower.

Valve tower tunnel access

A 760 mm diameter cast iron supply pipeline passes through the dam from the valve tower. This pipeline then narrows to 500 mm in diameter and follows the tram track on the eastern side of the waterfall.

A semi-circular concrete valve tower on the upstream face of the gravity dam houses the delivery pipework system for the water supply reservoir. Access to the valve tower is either through a hatch at the dam crest, or via the tunnel at the base of the dam that connects the base of the valve tower to the spillway face at the toe of the dam.

Water is drawn through valve intakes to a central standpipe which feeds an embedded pipe at the base of the dam. Water is piped to the Waitakere Filter Station which controls the flows. Inlet valves require manual operation.

Valve tower equipment

From the valve tower the delivery passes against the right hand wall of the tunnel to the downstream portal and from there past the valve chamber to the bench extending to Kelley's Tunnel. The standpipe within the valve tower and watermain within the tunnel is a 500 mm diameter epoxy lined mild steel pipe.

Beyond the valve chamber, the main reverts to the original cast iron main.

The scour valve within the tunnel is a 600 mm diameter epoxy lined mild steel pipe laid within the original 760 mm cast iron main. The annulus between the two has been grouted.

Both mains feed into the valve chamber.

Scour discharge

A reinforced concrete valve chamber sited below the right hand side of the plunge pool houses the free discharge valve and the maintenance flow control valve. Both discharge valves can draw from either the raw water supply main or the scour intake.

The scour intake is expected to provide the coolest source of water for discharge to the stream. Additionally, the constant use of the valve reduces the potential for a build up of silt at the upstream base of the valve tower.

The maintenance flow discharges into a weir that spills into the Waitakere Stream. The free discharge Valve discharges into the plunge pool at the base of the main spillway.

Performance Instrumentation

Lake Level

The lake level is monitored principally by a shaft encoder located on top of the valve tower. The data is recorded both on a local data logger, and also forwarded via SCADA to servers in Auckland.

The data logger is downloaded monthly, and verified against the electric plumb bob reading.

A comparative recording is provided with an electric plumb bob monitoring the water level in the same stilling well.

These are both capable of reading to 1 mm.

A further reference is the tide gauge attached to the outside of the valve tower. This gauge is capable of reading to 50 mm or less in fine weather with little or no wind.

Unverified data from SCADA is forwarded weekly to Damwatch Services Ltd.

Verified data collected by the Data Technician is stored in a Hydstra database and available for review at any time.

Rainfall

An automated raingauge and a manual check gauge are installed on the right abutment above the dam for monitoring the local rainfall.

The automated rainfall is forwarded to the InTouch screens and the PI server via SCADA. This is used for real time viewing.

The check gauge is used to calibrate the automated recording on a monthly basis when the data recorder attached to the raingauge is downloaded.

Unverified data from SCADA is forwarded weekly to Damwatch Services Ltd.

Verified data collected by the Dam Technician is stored in a Hydstra database and available for review at any time. This verified data is used if ever the SCADA data is in question.

Visual inspection

Eleven visual observation points are monitored during routine inspections by the caretakers and loaded onto the Psions for transfer to Damwatch. These cover the:

- Lake, crest, upstream and downstream faces and downstream toe (5).
- Upstream and downstream left and right abutments (4)
- Valve tower and tunnel (2)

- Saddle dam drains (3)

Porewater pressure monitoring

Seepage flows

Survey monuments

Log boom

There is no log boom in place at the Waitakere Dam

Communication and control systems

Basic Warning Systems

The Operations Controller is notified of alarms directly and from displays on emergency computer screens. Alarms on the emergency screens include:

- High lake level;
- Valve availability;
- Loss of power; and
- Alert levels on the vibrating wire piezometers,
- Intense rainfall records are notified to the Control Rooms by fax from the Metservice.

The Operations Controller will provide information regarding any alarms received and any communications or control outages prior to any person proceeding to site.

Emergency communications

The communication channels linking Newmarket Control centre and Waitakere are:

- Control and indication: - Radio network;
- Speech: - Telecom phones, VHF radio, and cell phones.

Normal communication methods available are:

- Telecom landline phone network;
- WSL VHF Radio network.

The VHF radio is the primary means of communication in an emergency.

Telecom landline network

This is used for speech and fax only. Watercare use a Vodaphone telecommunications system over the Chorus lines

Vodaphone cellphone network

The Telecom cellphone network uses a radio link repeater from Orams Road. There is a further repeater at Cowan Road in Hunua. It is vulnerable to saturation from public use.

VHF radio

This utilises a network of radio repeaters to link the WSL sites. The system is the most robust terrestrial system available

Satellite phones

There are no satellite phones in use. Recent trials have shown their performance in the Hunua and Waitakere valleys to be inconsistent at best.

Control communications

Control communication links comprise.

- A radio bearer signal from Waitakere Dam to a repeater station at Ruatowhenua,
- From Ruatowhenua, the signal is beamed to both Khyber Pump Station and the Mangere wastewater treatment plant,
- There are two separate fibre optic cables from Khyber to Newmarket (Vector and Telecom). There are dual radios with dual power supplies,
- If the Khyber system fails, then the information can arrive via Mangere along a Vector cable.

The intake valves and free discharge valve can be controlled either remotely from the Newmarket control centre, Huia and Waitakere water treatment plants, or locally from the individual valves.

Power Supply

A three phase 11KV power supply line is run aerially down the access road from Scenic Drive, with feeds from both Swanson and Titirangi. An 11KV/400V transformer is located on a pole beside the depot.

Primary power supply

The main power supply to the intake valves and free discharge valve is 24 volt battery unit charged by locally generated power at a wind turbine and solar panel units on site. The

battery unit consist of 12, 2 volt 570AHr batteries and is located in the valve tower of the dam.

Backup power supplies

A connection is provided in the valve tower for a portable standby generator to be brought to site and connected to the power supply.

Access to the dam

Public access to the dam is provided off Scenic Drive and approximately 1.4 m down the private sealed road to the dam. The Scenic Drive may be accessed from Swanson, Henderson, Glen Eden or Titirangi.

An alternative access is by road from Swanson to the Waitakere water treatment plant, then metaled access up to the start of Georges Tunnel. A 2 ft gauge tramline then travels alongside the watermain to just past Kelly's Stream. Access from this point to the dam is by pedestrian track.

Regional Park's tracks are also available from Anawhata Road and Cascades Park

Waitakere dam hydraulic structures hydrological data (L&S datum)

Hydraulic Structure	Waitakere Dam	
Structures		
Levels	Lands & Survey Datum	
Top of dam core		
Dam crest	212.085	
PMF peak level	212.30	
Top of spillway crest	210.677	
Top of auxiliary spillway crest		
Intake No 1	207.840	
Intake No 2	200.920	
Intake No 3	195.404	
Intake No 4		
Intake No 5		
Intake No 6		
Scour intake	190.670	
Freeboard at PMF	-0.215	
Discharges		
Maximum Capacity of supply to treatment	22,000 m³/day (less during normal ops)	
Maximum flow capacity spillway crest		
Maximum capacity IFDV		
Maximum capacity EFDV	1.9 m3/s	
Catchment		
Water Source	Waitakere Stream	
Catchment area (ha)	815	
Surface area of full lake (ha)	25.12	
Live Storage at full volume (m³)	1,761,000	
Storage between spillway and crest (m³)	363,000	
Hydrology		
Return Period	Q (m³/s)	
	Inflow	Outflow
Mean Annual Flow	36	
5year	48	
10 year	58	
20 year	67	
100 year	88	
500 year		
1000 year		
PMF	244	234

Survey Benchmark	
Valve tower benchmark	RL 212.088
Hydraulic Structure	Waitakere Dam
Background	
Location	On Waitakere Stream
Water source	Waitakere Stream
Purpose	Water supply
Date Built	1907 – 1910 (raised 4m 1926 – 1927), upgraded 1992 (ground anchors etc)
Dam engineering	Auckland City Council
Dam construction	Thomas Billington & Sons Ltd
Dam Construction	
Structure	Concrete gravity dam with ground anchors into foundation rock, plus Saddle Dam
Height (m)	25.3
Crest length (m)	175
Crest width (m)	4.000
Dam volume (m3)	25,200
Valve tower	Cast into gravity dam
Spillway type	Ogee weir
Auxiliary spillway	
Scour Valves	
Valve type located outside dam	Gate valves
Size (mm diameter)	450
Installation date	1990
Condition	Good
Method of operation	Manual
Maximum scour flow rate (m3/sec)	
Maximum scour rate off the intakes (m3/sec)	1.9
Valve type located within dam	
Size (mm diameter)	
Installation date	
Condition	
Method of operation	
Maximum scour flow rate (m3/sec)	
Maximum scour rate off the intakes (m3/sec)	
Notes	

Waitakere dam original construction data

Catchment area	850 ha
Reservoir area	15.5 ha
Dry weather yield	13,636 m ³ /day
Reservoir storage	1,000,000 m ³
Width dam crest	1.067 m
Width dam base	13.665 m
Height of dam above foundation	19.51 m
Height of dam above stream bed	16.15 m
Radius of curvature	116.4 m
Height of wing walls	0.915 m
Weir length	16.3 m
Tender sum	£29,112 11s 8d
Contractor May 1907 to Dec 1908	Thomas Billington & Sons Ltd
Contractor Dec 1908 to Dec 1910	John Schiska
Supply officially opened	10 May 1907
Opening by:	Mayor A. M. Myers
City Engineer to March 1906	A A Wrigg
City Engineer from March 1906	W E Bush
ACC Waterworks Engineer	James Carlaw
ACC Foreman	A Wilkins
Project Engineer	H Munro Wilson
Project completed	Mid December 1910
	No official opening

Seismic spectra

GNS (2006) presents a recalculation of the seismic hazard at the Waitakere and Hunua dam sites using both probabilistic seismic hazard analysis and a deterministic approach. The spectra have been developed for class B rock sites, which is appropriate for Waitakere dam.

Spectra are produced for High PIC dams (10,000 yr return period), Medium PIC dams (2,500 year return periods). For a low PIC dam in the Auckland region the recommended motions are based on a minimum design earthquake motion ($2/3^{\text{rd}}$ of the 84-percentile motions for magnitude 6.5 at 20 km).

NZSOLD recommends that 150 year earthquake motions be used for the Operating Basis Earthquake. GNS indicate that these motions are less than 0.6 times the minimum design earthquake motions in NZS 1170.5:2004 and recommend the latter be used for the OBE. We concur with this GNS approach as it provides consistency with other structures where NZS 1170.5:2004 applies.

The outcome with respect to peak ground acceleration is as follows:

1. High PIC Safety Evaluation Earthquake (Waitakere Dam) = 0.19g
2. Low PIC Safety Evaluation Earthquake (Saddle dam) = 0.12g
3. Operating Basis Earthquake(both dams) = 0.07g

GNS has supplied smoothed response spectra for each of the above situations. These are appropriate for most applications. However, if a modal analysis was ever being considered for the Waitakere dam, then we would recommend that the raw spectra produced by GNS be used as these give higher response in the period range of 0.08 second to 0.30 seconds, which will be critical for the dam. Waitakere dam will have a first mode period of approximately 0.10 seconds when reservoir and foundation interactions are considered. The modal approach in NZS1170.5:2004 also increases spectra value in this period range relative to smoothed spectra.

Recommended Class B smoothed spectra for SEE¹ motions

(Reference Report 4128 from GNS dated May 2006)

Period(s)	Hunua			Waitakere		
	High PIC 10,000 years	Med PIC 2,500 years	Low PIC MinDe motions ²	High PIC 10,000 years	Med PIC 2,500 years	Low PIC MinDe motions ²
0.0	0.28 (g)	0.19 (g)	0.12 (g)	0.19 (g)	0.12 (g)	0.12 (g)
0.075	0.66	0.43	0.29	0.44	0.31	0.29
0.1	0.66	0.43	0.29	0.44	0.31	0.29
0.15	0.66	0.43	0.29	0.44	0.31	0.29
0.2	0.66	0.43	0.29	0.44	0.31	0.29
0.25	0.66	0.43	0.29	0.44	0.31	0.29
0.3	0.66	0.43	0.29	0.44	0.31	0.29
0.35	0.59	0.39	0.26	0.40	0.27	0.26
0.4	0.53	0.35	0.23	0.36	0.25	0.23
0.5	0.45	0.30	0.20	0.31	0.21	0.20
0.75	0.33	0.22	0.15	0.23	0.16	0.15
1.0	0.27	0.18	0.12	0.18	0.13	0.12
1.5	0.20	0.13	0.09	0.13	0.09	0.09
2.0	0.15	0.10	0.07	0.11	0.07	0.07
3.0	0.10	0.07	0.04	0.07	0.05	0.04

¹SEE Motions – Safety Evaluation Earthquake (or Maximum Design Earthquake) motions

²MinDe motions – Minimum Design Earthquake motions (2/3 of 84-percentile motions for magnitude 6.5 earthquake at 20 km) govern rather than 500 year return period motions

Failure mechanisms

A failure event modes analysis (FEMA) workshop was held on 16 February 2011 facilitated by Damwatch Services Ltd to establish potential failure modes relevant to the Waitakere Concrete Dam. This report presents the results of that workshop. It identifies the relevant potential hazards and the potential failure modes for the Waitakere Concrete Dam. A brief review of the workshop discussions are presented and the identified risk reduction measures. The potential failure modes are then used to objectively evaluate the performance of the dam, particularly safety evaluations and evaluation of monitored data during routine surveillance. The identification of potential failure modes does not indicate that the dam may be unsafe.

A separate FEMA workshop for the Waitakere Saddle Dam was conducted and the identified potential failure modes reported on separately in Waitakere Saddle Dam Potential Failure Modes Report, Damwatch Services Ltd., June 2011.

During this workshop eleven (11) potential failure modes were identified and eight (8) of these were discounted as unlikely failure scenarios. The following three (3) scenarios were considered credible potential failure modes at the Waitakere Concrete Dam by the workshop team.

PMF 1: Right Abutment Failure

PFM 2: Sliding Foundation at Dam Interface

PFM 3: Sliding within Deeper Foundation

The key performance parameters identified during the workshop for the credible potential failure modes are:

PMF 1: Right Abutment Failure, key performance parameters:

- Surveillance to identify movement.
- Monitoring of groundwater levels.
- Monitoring of slope deformation.
- Measurement of seepage.

PFM 2: Sliding Foundation at Dam Interface, key performance parameters:

- Measurements of foundation uplift pressures.
- Surveillance to identify deformation movement.
- Monitoring of seepage
- Visual observation of the dam.
- Anchor testing results.

PFM 3: Sliding within Deeper Foundation, key performance parameters:

- Deformation Survey to identify movement of the waterfall limits.

- Piezometric pressures at depth.
- Visual observation of the waterfall area.

The general risk reduction measures such as ongoing surveillance monitoring measures, post earthquake inspections, post flood inspections, continued removal of brush and trees in the dam vicinity and reservoir, and ongoing maintenance practices should be continued.

Recommendations of assessments required to improve management of risks identified in this report are:

Potential Failure Mode 1: Right Abutment Failure:

- Obtain a rock mechanics opinion on the right abutment.
- Consider reinstating the groundwater monitoring in the right abutment area.
- Consider survey network enhancements in the right abutment area.

Potential Failure Mode 2: Sliding Foundation at Dam Interface:

- To improve the uplift monitoring network, consider installation of more piezometers at the foundation interface.
- Obtain anchor designs if available from the ARA

Potential Failure Mode 3: Sliding within Deeper Foundation:

- Obtain a rock mechanics expert review of the waterfall area.

While other potential failure modes have been discounted there are three recommendations relating to features of the dams and the site:

- The Western Scour should be made safe by casting the guard valve in concrete and plugging the upstream scour pipe as recommended in the 2001 CSR.
- Further to the rock mechanics expert assessment of the waterfall area required for Failure Mode 3, reassess Discounted Potential Failure Mode 5: Waterfall Regression, following the rock mechanics assessment.
- Obtain a structural assessment of the valve tower.

Surveyed spillway levels

These levels are the L&S levels to the local datum as used in May 1995



Memorandum

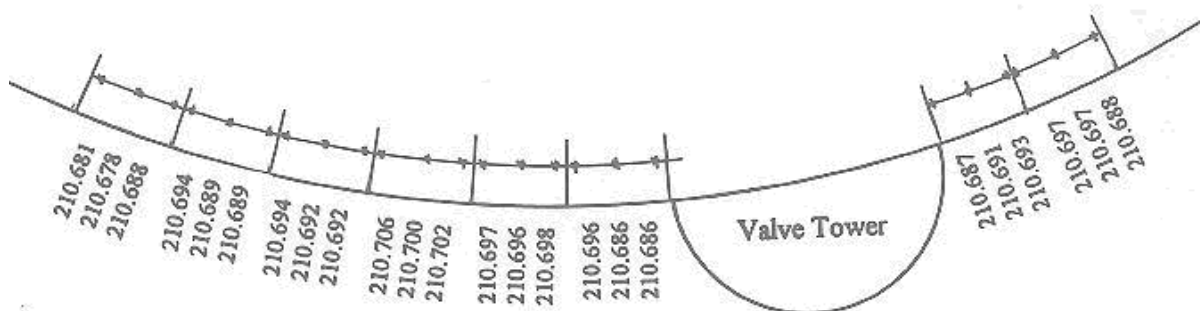
TO: Wallace McQuarrie
FROM: Phil Salmon
SUBJECT: Waitakere Catchments -- Dam Spillway Levels
(to show construction variation)
DATE: 12 May 1995 FILE:

The Spillway crest levels quoted are relative to the Bench Marks located on the top of each respective Valve Tower. The Bench Mark values were derived from reciprocal vertical angle observations, see memo dated 20/02/86, copy attached.

WAITAKERE DAM

Spillway Crest Levels

Sketch only :- Not to Scale
Levels spaced at 2m intervals in each bay

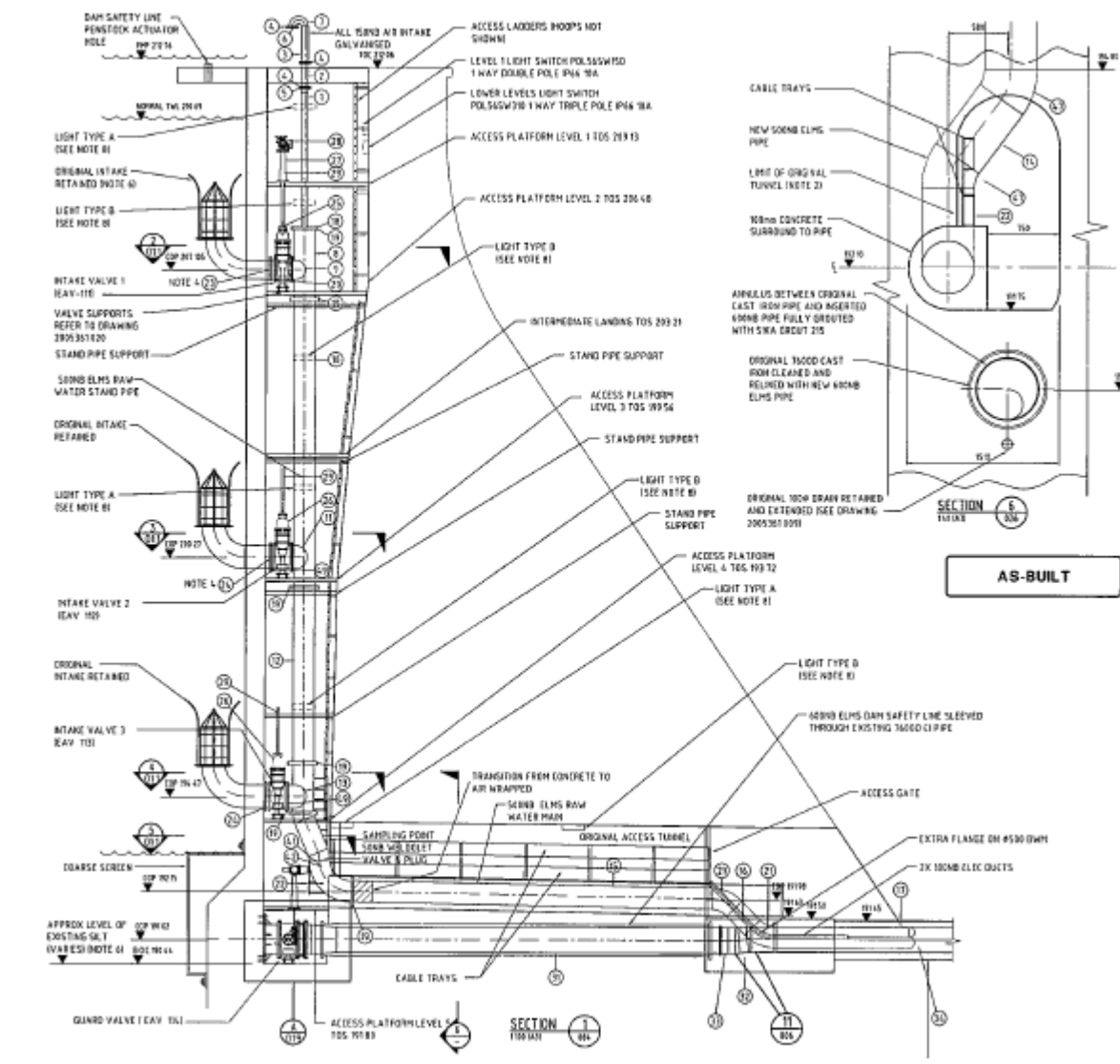


Waitakere main dam spillway rating

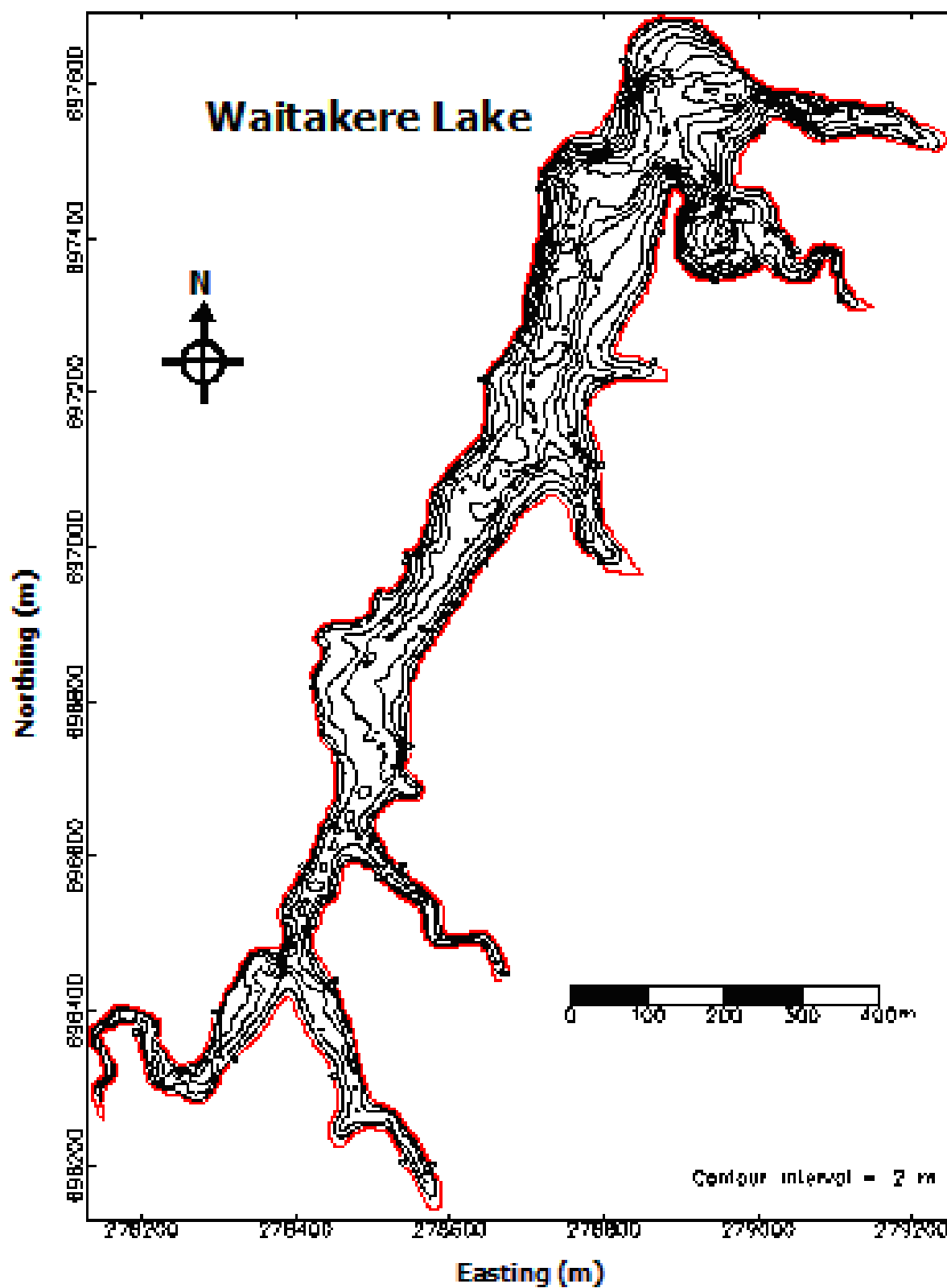
Water Level	Gauge Level	Head Over	Total Discharge
(m RL)	(m)	Crest (m)	(m3/s)
210.678	19.803	0	0
210.6785	19.8035	0.0005	3.2E-05
210.679	19.804	0.001	9.05E-05
210.6795	19.8045	0.0015	0.000166
210.68	19.805	0.002	0.000256
210.6805	19.8055	0.0025	0.000358
210.681	19.806	0.003	0.000471
210.6815	19.8065	0.0035	0.000626
210.682	19.807	0.004	0.000816
210.6825	19.8075	0.0045	0.001032
210.683	19.808	0.005	0.001271
210.6835	19.8085	0.0055	0.001529
210.6845	19.8095	0.0065	0.002099
210.6855	19.8105	0.0075	0.002732
210.6865	19.8115	0.0085	0.003488
210.6875	19.8125	0.0095	0.004534
210.6885	19.8135	0.0105	0.005911
210.6895	19.8145	0.0115	0.007748
210.6905	19.8155	0.0125	0.010068
210.6915	19.8165	0.0135	0.012766
210.6925	19.8175	0.0145	0.015925
210.6935	19.8185	0.0155	0.019639
210.6945	19.8195	0.0165	0.023919
210.6955	19.8205	0.0175	0.028809
210.6975	19.8225	0.0195	0.040382
210.6995	19.8245	0.0215	0.055062
210.7015	19.8265	0.0235	0.072355
210.7035	19.8285	0.0255	0.092069
210.7065	19.8315	0.0285	0.125664
210.7105	19.8355	0.0325	0.177473
210.7155	19.8405	0.0375	0.251668
210.7215	19.8465	0.0435	0.352967
210.7285	19.8535	0.0505	0.486935
210.7365	19.8615	0.0585	0.657338
210.7455	19.8705	0.0675	0.866718
210.7555	19.8805	0.0775	1.120689
210.7665	19.8915	0.0885	1.425679
210.7785	19.9035	0.1005	1.796395
210.7915	19.9165	0.1135	2.22807
210.8055	19.9305	0.1275	2.715078
210.8205	19.9455	0.1425	3.27822
210.8405	19.9655	0.1625	4.116436
210.8705	19.9955	0.1925	5.473596
210.9105	20.0355	0.2325	7.505449
210.9505	20.0755	0.2725	9.696036
210.9905	20.1155	0.3125	12.18069
211.0305	20.1555	0.3525	14.80596

Water Level		Gauge Level	Head Over	Total Discharge
211.0705		20.1955	0.3925	17.62107
211.1105		20.2355	0.4325	20.62379
211.1505		20.2755	0.4725	23.82376
211.1905		20.3155	0.5125	27.21253
211.2305		20.3555	0.5525	30.77259
211.2705		20.3955	0.5925	34.50031
211.3105		20.4355	0.6325	38.39368
211.3505		20.4755	0.6725	42.45313
211.3905		20.5155	0.7125	46.66924
211.4305		20.5555	0.7525	51.01688
211.4705		20.5955	0.7925	55.48379
211.5105		20.6355	0.8325	60.09332
211.5505		20.6755	0.8725	64.85817
211.5905		20.7155	0.9125	69.77347
211.6305		20.7555	0.9525	74.85298
211.6705		20.7955	0.9925	80.10017
211.7105		20.8355	1.0325	85.50202
211.7505		20.8755	1.0725	91.06666
211.7905		20.9155	1.1125	96.77273
211.8305		20.9555	1.1525	102.5375
211.8705		20.9955	1.1925	108.3346
211.9105		21.0355	1.2325	114.5144
211.9505		21.0755	1.2725	123.0116
211.9905		21.1155	1.3125	132.9567
212.0305		21.1555	1.3525	143.926
212.0705		21.1955	1.3925	155.7568
212.1105		21.2355	1.4325	168.3794
212.1505		21.2755	1.4725	181.7527
212.1905		21.3155	1.5125	195.7991
212.2305		21.3555	1.5525	210.4145
212.2705		21.3955	1.5925	225.5494
212.3105		21.4355	1.6325	241.2608
212.3605		21.4855	1.6825	261.7554
212.4105		21.5355	1.7325	283.1039
212.4605		21.5855	1.7825	305.2478
212.5105		21.6355	1.8325	328.1355
212.5605		21.6855	1.8825	351.6955
212.6105		21.7355	1.9325	375.9118
212.6605		21.7855	1.9825	400.7585
212.7105		21.8355	2.0325	426.2113

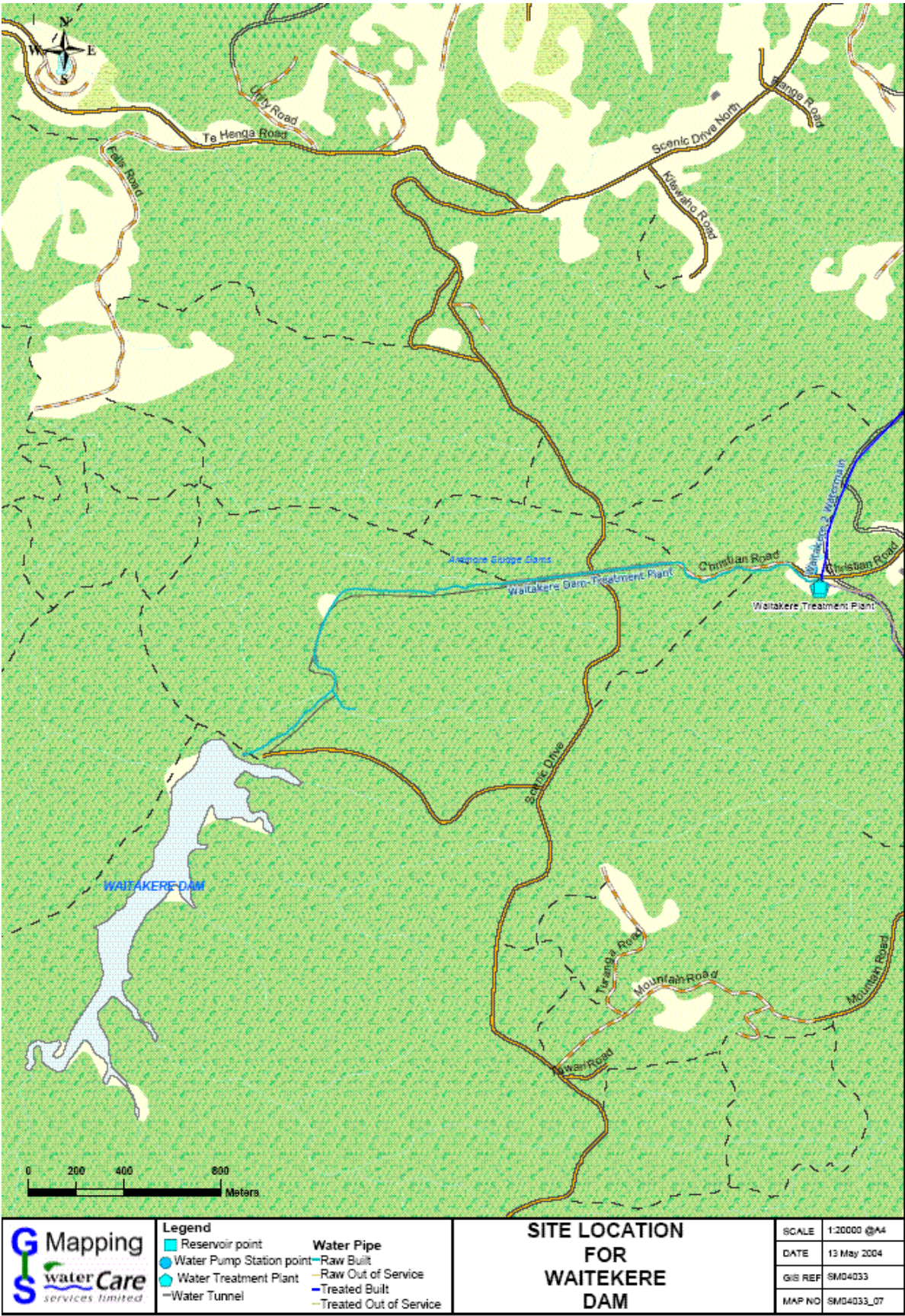
Cross-section of dam



Bathymetric plan



Waitakere dam site location



Schedule of drawings

Plan record No.	Group	Subject
315151.001	Access Roads & Bridges	Waitakere Tramline Plan
315151.007	Access Roads & Bridges	Pipe Track Henderson Road To Bp Reservoir Transverse And Longitudinal S
315151.008	Access Roads & Bridges	Pipe Track Plan And Longitudinal Section 1905
315151.009	Access Roads & Bridges	Pipe Track Plan Longitudinal And Cross Sections 1905
0315151.010;A	Access Roads & Bridges	Spot Heights On Tramway And Access Road 1974
315151.011	Access Roads & Bridges	Tramline Cliffs Open Drain Sealing Plan And Section Sump
315154.001	Civil Service	Kelly's Creek Weir Water Gate Plan Elevation Section
0315154.002;B	Civil Service	Kelly's Creek Weir Water Shute Details
2000841.001;H	Control System	Overview And Drawing List As Built
2000841.002;E	Control System	Alternating Current Supply Schematic As Built
2000841.003;C	Control System	SCADA Cubicle Equipment Layout As Built
2000841.004;H	Control System	SCADA Cubicle Power Supply Schematic As Built
2000841.005;C	Control System	SCADA Cubicle Moscad Digital Output Card Slot No4 Schematic As Built
2000841.006;D	Control System	SCADA Cubicle Moscad Digital Input Card Slot No3 Schematic As Built
2000841.007;H	Control System	Moscad Plc Layout As Built
2000841.008;J	Control System	Terminal Block Layout And Field Wiring Sheet No1 As Built
2000841.009;F	Control System	Rain Gauge Schematic As Built
2000841.010;C	Control System	Security System Wiring Schematic As Built
2000841.011;C	Control System	Security System Field Wiring As Built
2000841.012;C	Control System	Ft-011 Waitakere Flowmeter Schematic As Built
2000841.013;C	Control System	Ft-021 Kelly's Creek Flowmeter Schematic As Built
2000841.014;B	Control System	Flow Transmitter Cubicle Layout As Built
2000841.015;D	Control System	Piezometer Schematic As Built
2000841.016;D	Control System	Modbus Network As Built
2000841.017;C	Control System	Piezometer Cabinet Layout As Built
2000841.018;C	Control System	Eav-111 Intake No1 Isolation Valve 230v Ac Rotork Valve Schematic As Built
2000841.019;C	Control System	Eav-112 Intake No2 Isolation Valve 230v Ac Rotork Valve Schematic As Built
Plan record No.	Group	Subject
2000841.020;C	Control System	Eav-113 Intake No3 Isolation Valve 230v Ac Rotork Valve Schematic As Built
2000841.021;C	Control System	Eav-114 Eastern Guard Valve 230v Ac Rotork Valve Schematic As Built
2000841.022;C	Control System	Eav-123 Dam Safety Valve 24v Dc Rotork Valve Schematic As Built
2000841.023;C	Control System	Fit-121 Compensation Flow Flowmeter Instrumentation Schematic As Built
2000841.024;C	Control System	Fcv-121 Compensation Flow Control 24v Dc Rotork Valve Schematic As Built
2000841.025;C	Control System	Pit-122 Dam Safety Valve Line Pressure Instrumentation Schematic As Built
2000841.026;C	Control System	Compressor House Control Panel Schematic As Built
2000841.027;C	Control System	Compressor House Control Panel Layout As Built
2000841.028	Control System	Valve Tower Security System As Built
2002140.001	Control System	Three Phase 11kv Supply Line To Dam Schedule Of Due Maintenance Work August
2003964.001	Control System	Emergency Pipeline Pump Cabinet Layout
2003964.002	Control System	Emergency Pipeline Pump Control Schematic
315151.002	Dam	Plan And Longitudinal Section 1905
315151.004	Dam	Georges Tunnel Plan And Longitudinal Section Tunnel Section
315153.001	Dam	Plan And Longitudinal Section Of Dam Face
315153.003	Dam	Raising Of Waitakere Dam Plan And Section Of Dam Face
315153.008	Dam	Cross Sections Of Dam Wall

315153.009	Dam	Cross Sections Of Dam Wall
315153.012	Dam	Raising Of Waitakere Dam Detail Of Earthen Dam And Core Wall Plan Longitudinal
315153.014	Dam	Penstock Platform As Built
315153.016	Dam	Details Of Core Wall As Built
315153.017	Dam	Details Of Core Wall As Built
315153.018	Dam	Penstock Valve Platform
315153.023	Dam	Dam Plan And Longitudinal Section 1907
315153.024	Dam	Cross Sections
0315153.032;A	Dam	Dam Site Contours 1987 Sheet No1
315153.033	Dam	Dam Contours 1987 Sheet No2 1987
315153.036	Dam	Right Abutment Surface Water Drain Plan Sections
0315153.061;A	Dam	Saddle Topographical Survey 1990
315153.063	Dam	As Built Survey For Stressing Cable Design
315153.069	Dam	Stressing Contract Survey Control
0315153.071;A	Dam	Location Of Piezometer As Built
0315153.072;D	Dam	Location Of Piezometer Design Layout
315153.073	Dam	Silt Survey Plan As At 10th June 1986
315153.074	Dam	Silt Sounding Plan February 2007
Plan record No.	Group	Subject
315154.005	Dam	Kelly's Creek Weir Plan Elevation And Section
0315155.001;A	Dam	Strengthening Remedial Works Scheme No1 Anchor Layout
0315155.002;A	Dam	Strengthening Remedial Works Scheme No1 Anchor Details
0315157.001;A	Dam	Strengthening Drawing Index As Built
0315157.002;A	Dam	Strengthening General Structural Note As Built
0315157.007;A	Dam	Strengthening Concrete And Handrail Demolition Elevation As Built
0315157.008;A	Dam	Strengthening Downstream Elevation Of Dam Ground Anchor As Built
0315157.009;A	Dam	Strengthening Post stressed Ground Anchors Layout As Built
0315157.010;A	Dam	Strengthening Cross Section And Tendon Detail As Built
0315157.011;A	Dam	Strengthening Spillway Ground Anchor Cable Layout As Built
0315157.012;A	Dam	Strengthening Slab Top And Ground Anchor Cable Pit Detail As Built
0315157.014;B	Dam	Strengthening Cut Off Wall And Handrail At Eastern End Of Dam As Built
0315157.017;A	Dam	Strengthening Precast Bridge Deck And Infill Slab As Built
0315157.018;A	Dam	Strengthening Precast Deck Unit Layout And Reinforcement Sheet No1 As Built
0315157.019;A	Dam	Strengthening Precast Deck Unit Layout And Reinforcement Sheet No2 As Built
0315157.020;A	Dam	Strengthening Precast Deck Unit Layout And Reinforcement Sheet No3 As Built
0315157.022;A	Dam	Strengthening Bridge Abutment Reinforcement Detail Sheet No1 As Built
0315157.023;A	Dam	Strengthening Bridge Abutment Reinforcement Detail Sheet No2 As Built
0315157.024;A	Dam	Strengthening Handrail Details As Built
0315157.025;A	Dam	Strengthening Saddle Dam Remedial Works Sheet No1 As Built
315157.029	Dam	Downstream Elevation Of Dam Borehole Strata Material Strength As Built
315157.03	Dam	Vertical Anchor Detail Supplied By Construction Techniques Limited As Built
0315157.031;B	Dam	Vertical Anchor Cable Records March 1993 April 1993 Sept 1994 Dec 1994 D
315157.032	Dam	Proposed Anchor Servicing Platform Cross Section At Spillway
2000853.001	Dam	Saddle Dam Remedial Work Site Locality Plan
2000853.002	Dam	Saddle Dam Remedial Work Trench Drain
2000951.002	Dam	Typical Section Diagrammatic Display Intake Tower As Built
2001071.001;F	Dam	Waitakere Saddle Dam Survey Monitor For Movement
2001071.002;B	Dam	Waitakere Saddle Dam Survey Monitoring For Movement Spread Sheet Yr1999
2001071.003;B	Dam	Waitakere Saddle Dam Crest Settlement Monitor Survey Yr2001
2001173.001;E	Dam	Waitakere Dam Survey Monitor Dam And Adjacent Country September Yr1999
2001173.002;B	Dam	Waitakere Dam Survey Monitoring Detail
2001955.001	Dam	Road Barrier Extension Elevation And Detail
2002643.019	Dam	Waitakere Dam Site And Road Access Layout Plan Yr1999 For Visitor Information
2002643.02	Dam	Waitakere Dam Site Layout Plan Yr1999 For Visitor Information
Plan record	Group	Subject

No.		
2003130.011	Dam	Waitakere Dam Lake Contour Plan Yr2000
2004823.001	Dam	Western Dams Compliance Project
2005361.001;B	Dam	Resource Consent Upgrade Valve Tower Upgrade Dam Safety Valve Const As Built
2005361.002;B	Dam	Resource Consent Upgrade Valve Tower Upgrade Dam Safety Valve Drawi
2005361.003;B	Dam	Resource Consent Upgrade Valve Tower Upgrade Dam Safety Valve Site L Safety Hazard Areas Indentified As Built
2005361.006;C	Dam	Resource Consent Upgrade Dam Safety Valve Area Chamber Compensation
2005361.007;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Valve Chamber Layout F Built
2005361.008;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Valve Chamber Section
2005361.009;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Tunnel Section From V Valve Chamber Sections Sheet No2 Of3 As Built
2005361.010;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Dam Safety Valve Char Sheet No3 Of 3 As Built
2005361.026;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Concrete Slab Reinforc
2005361.027;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Standard Reinforcing De
2005361.028;A	Dam	Resource Consent Upgrade Dam Safety Intake Screen As Built
2005361.029;B	Dam	Resource Consent Upgrade Temporary Intake Blanking Plate Details As Built
2005361.030;C	Dam	Resource Consent Upgrade Cofferdam On Upstream Dam Face Details She
2005361.031;C	Dam	Resource Consent Upgrade Dam Safety Intake Sealing Plate As Built
2005361.032;B	Dam	Resource Consent Upgrade Cofferdam On Upstream Face Details Sheet No
2005361.033;B	Dam	Resource Consent Upgrade Valve Stem Blanking Plate Details As Built
2005392.002	Dam	Saddle Dam Plan Instrumentation Drainage
315153.035	General	Automatic Water Level Recorder Details
315153.037	General	Public Toilet Sealed Vault Type Plan Section Detail
2000657.001	General	Waitakere Dam Scenic Drive Car Park Topographical Plan
2005392.001	General	Instrument Layout Plan
2005408.001	General	Inundation Map For Waitakere Dam
315158.001	Houses	Caretakers Residence
315158.002	Houses	Caretakers Residence
311151.003	Lake	Raising Of Waitakere Dam Old And New Reservoir Contours
315151.003	Lake	Pipe Track Georges Tunnel To Waitakere Falls Longitudinal And Cross Secti
315151.005	Lake	Pipe Track Georges Tunnel To Waitakere Falls 1905
315151.006	Lake	Transverse And Longitudinal Section 1905
315153.021	Lake	Upper Dam And Impounding Area Cross Sections
Plan record No.	Group	Subject
315153.022	Lake	Old New Reservoir Contours Sheet No4
315153.053	Lake	River Mapping Sheet Layout
315153.054	Lake	River Mapping Sheet No1 Of 7
315153.055	Lake	River Mapping Sheet No2 Of 7
315153.056	Lake	River Mapping Sheet No3 Of 7
315153.057	Lake	River Mapping Sheet No4 Of 7
315153.058	Lake	River Mapping Sheet No5 Of 7
315153.059	Lake	River Mapping Sheet No6 Of 7
315153.06	Lake	River Mapping Sheet No7 Of 7
315154.004	Monitor Service	Kelly's Creek Weir Dam Raw Water Main Magnetic Flow Meter Installation Pi Detail Elevation Flange Detail
0315153.002;A	Plans & Sections & Surveys	Raising Of Waitakere Dam Details Of Earthen Dam On Saddle Plan And Sec
315153.004	Plans & Sections & Surveys	Raising Of Waitakere Dam Details Of Earthen Dam On Saddle Sheet No3
315153.005	Plans & Sections & Surveys	Impounding Dam At Waitakere Falls Cross Sections Type Section Wing Wall
315153.006	Plans & Sections & Surveys	Impounding Dam At Waitakere Falls Details Of Valve Well

315153.007	Plans & Sections & Surveys	Impounding Dam At Waitakere Falls Details Of Valve Well
315153.01	Plans & Sections & Surveys	Spillway Details Cross Sections
315153.011	Plans & Sections & Surveys	Proposed Ventilation Of Valve Well
315153.013	Plans & Sections & Surveys	Plan And Sections Of Raised Portion At RI686
315153.015	Plans & Sections & Surveys	Details Of Core Wall As Built
315153.019	Plans & Sections & Surveys	Intake Penstock Platform Details
315153.02	Plans & Sections & Surveys	Detail Plan Top Of Tower As Built
315153.025	Plans & Sections & Surveys	Raising Scour Pipe Platform Leakage Information
315153.026	Plans & Sections & Surveys	Raising Brackets For Rod Operating Penstock

Plan record No.	Group	Subject
315153.027	Plans & Sections & Surveys	Raising Details Pipes Intake screen Guide Rods
0315153.028;A	Plans & Sections & Surveys	Raising Pelton Nozzle Regulator
0315153.029;A	Plans & Sections & Surveys	Raising Extension To Scour Valve Spindle
0315153.030;A	Plans & Sections & Surveys	Valve Wheel Details 1989
0315153.031;C	Plans & Sections & Surveys	Topographical Site Plan Dam Face 1986
0315153.038;A	Plans & Sections & Surveys	Piezometer Reading Heads Housing 02 Units
315153.039	Plans & Sections & Surveys	Piezometer Reading Head Housing 04 Units
315153.04	Plans & Sections & Surveys	Survey Monuments Construction Details
315153.041	Plans & Sections & Surveys	Refer Report 4395 Phase 01 Investigation Safety Evaluation Report
315153.042	Plans & Sections & Surveys	Phase 02 Investigation May 1989 Investigation Instrumentation Of The Saddle
315153.043	Plans & Sections & Surveys	Phase 02 Investigation Instrumentation Of The Saddle
315153.044	Plans & Sections & Surveys	Break Study River Cross Section
315153.045	Plans & Sections & Surveys	Break Study River Cross Section
315153.046	Plans & Sections & Surveys	Phase 02 Investigation June 1989 Investigation Instrumentation Of
315153.047	Plans & Sections & Surveys	Manufacturers Drawings Tramway Cliff Cross
315153.048	Plans & Sections & Surveys	Manufacturers Drawings Cross
315153.049	Plans & Sections & Surveys	Manufacturers Drawings Elevation Typical
315153.05	Plans & Sections & Surveys	Manufacturers Drawings Geology Plan
315153.051	Plans & Sections & Surveys	Manufacturers Drawings Waterfall Longitudinal Cross
Plan record No.	Group	Subject
315153.052	Plans & Sections & Surveys	Valve Tower Service Decks
315153.062	Plans & Sections & Surveys	Saddle Dam Section Through Dam And Gully
315153.064	Plans & Sections & Surveys	Saddle Raising Of Details Of Earthen On Saddle
315153.065	Plans & Sections & Surveys	Upgrading Contractors Storage Areas
315153.066	Plans & Sections & Surveys	Bridge Over Stream At Base
315153.067	Plans & Sections & Surveys	Composite Contour Topographical Plan
2000901.001	Plans & Sections & Surveys	Seepage East Abutment Topographical Survey Along Tram Line
2003859.001;H	Process And Instrumentation Diagram	Discharge Piping And Instrumentation Diagram Revision I Added As Sheet N
2003859.002	Process And Instrumentation Diagram	Dam Aeration P&ID MMIP

2003859.003	Process And Instrumentation Diagram	Instrument Block Diagram P&ID MMIP
315153.068	Site	Cliff Contours Showing Rock Overhang Yr1995 Plan And Section
0315154.003;A	Site	Kelly's Creek Weir Dam Topographical Site Plan Locality And Layout Plan Sp Elevation
0315157.003;A	Site	Strengthening Locality And Site Plan As Built
0315157.006;A	Site	Strengthening Topographical Site Plan As Built
2000668.001	Site	Public Lookout Topographical Site Plan East Abutment
2000784.001	Site	Lookout And Information Board Layout Plan Walkway And Viewing Platform
2000784.002	Site	Lookout And Information Board Site And Locality Plan Concrete Step Paving
2000827.001	Site	As Built Under Ground Power Supply To Compressor Shed Waitakere Dam F Caretaker
2000906.001	Site	Waitakere Dam West Abutment Access To Saddle Dam Topographical Survey
2001327.001	Site	Access Road Guardrail Detail
2001489.001	Site	Waitakere Dam Proposed Supply Pipe Tunnel Topographical Survey
2002096.001	Site	Waitakere Dam Topographical Survey Proposed Toilet
2002096.002	Site	Waitakere Dam Public Toilet Block Site Layout Plan And Sub Floor Framing F
Plan record No.	Group	Subject
2002096.003	Site	Waitakere Dam Public Toilet Block Elevation And Section Detail
0315157.013;B	Spillway	Strengthening Spillway Reinforcement Anchor Head Pit As Built
0315157.015;A	Spillway	Strengthening Reconstructed Bridge Over Spillway As Built
0315157.016;A	Spillway	Strengthening Spillway Bridge Pier As Built
0315157.021;A	Spillway	Strengthening Bridge Unit At Abutments As Built
315157.026	Spillway	Strengthening Setting Out Survey Data (Renumbered As Sheet .027)
0315157.027;B	Spillway	Strengthening Spillway Survey Setting Out Data Pier Position As Built
0315157.028;A	Spillway	Not Used
2002946.001;A	Spillway	Waitakere Dam Spillway Reinforced Concrete Plunge Pool As Built McQuarrie Cross Sections Amended Waitakere Dam Spillway Reinforced Concrete Plunge Pool As Built McQuarrie And Opus International Limited As Built
2002946.002;A	Spillway	Resource Consent Upgrade Dam Spillway Area Plan Environmental And Safety As Built
2005361.004;B	Spillway	As Built
2004641.295	Survey Information	Working Folder Deformation Survey
2004641.296	Survey Information	Working Folder Tramline Seepage Points And Kelly's Dam
2004641.297	Survey Information	Working Folder Waitakere Dam And Saddle Dam Monitoring Survey
2004641.298	Survey Information	Working Folder Waitakere Dam Monitoring Survey
2004641.299	Survey Information	Working Folder Waitakere Saddle Dam Monitoring Survey
2004641.3	Survey Information	Working Folder Waitakere Saddle Dam And General Dam Monitoring
2004641.301	Survey Information	General Working Folder Waitakere Dam Including Installation Of Tilt Meter
2004818.65	Survey Information	Waitakere Dam Benchmark Location Assumed Bearings
2004818.653	Survey Information	Waitakere Saddle Dam Topographic
2004818.656	Survey Information	Waitakere Dam As Built Measurements For Stressing Cables
2004818.659	Survey Information	Waitakere Dam Contractors Storage Area Plan Only No Levels
2004818.668	Survey Information	Waitakere Dam Topographic Rangers House Septic Tank Irrigation
2004818.669	Survey Information	Free Waitakere Dam Deformation Monitoring
2004818.67	Survey Information	Waitakere Dam As Built Tunnels Scour And Supply In Main Dam
2004818.682	Survey Information	Waitakere Dam Bench Marks And Survey Control
2004818.683	Survey Information	Waitakere Dam Spillway Measure Up
2004818.709	Survey Information	Waitakere Dam Observation Deck Topographic
2004818.711	Survey Information	Waitakere Dam Scenic Drive Car Park Topographic
2004818.717	Survey Information	Waitakere Saddle Dam Monitoring Survey Plan
2004818.718	Survey Information	Waitakere Dam Monitoring Survey
2004818.722	Survey Information	Waitakere Saddle Dam Topographic Survey On Crest
2004818.726	Survey Information	Waitakere Dam Tramline Seepage Points
Plan record No.	Group	Subject

2004818.727	Survey Information	Waitakere Dam Access Road West Abutment
2004818.748	Survey Information	Waitakere Dam Monitoring Calculations Saddle Dam
2004818.755	Survey Information	Waitakere Dam Photo Control Points Cliff Mapping
2004818.757	Survey Information	Waitakere Dam Supply Pipe Diversion Tunnel Topographic
2004818.768	Survey Information	Waitakere Dam Topographic For Toilet Block East End Of Dam
2004818.784	Survey Information	Waitakere Dam Topographic Picnic Area
2004818.828	Survey Information	Raingauge Survey And Diagram Waitakere Dam
2004818.86	Survey Information	Waitakere Dam Saddle Dam Location Settlement Marks
2004818.864	Survey Information	Waitakere Dam Sonar Survey Of Lake Bed
2004818.885	Survey Information	Kelly's Dam Digitised Plan Of 315154.003
2004818.927	Survey Information	Waitakere Dam And Saddle Dam
2005360.018	Survey Information	Survey Order Waitakere Dam Topographical Survey At Base Of Dam A Stew
0315153.034;A	Valve Tower	Valve Tower Access Tunnel Plan Section Elevation
315153.07	Valve Tower	Hatch Cover 1996 Detail
2000041.001	Valve Tower	New Platform And Ladder
2000042.001	Valve Tower	Intake Screen Lifting Gantry General Arrangement 1991
2000042.002	Valve Tower	Intake Screen Lifting Gantry Bearing Pedestal Detail
2000866.001	Valve Tower	General Assembly Of Valve Position Indicator Sprocket Orientation
2000866.002	Valve Tower	Component No1 No2 No3 No4 No5 And No6 Terminal Box Mounting Plate Li End
2001521.001	Valve Tower	Intake Screen Component No1 Inlet Screen No1 Component No2 Inlet Scree
2001521.002	Valve Tower	Intake Screen Inlet Bend Component No1 Inlet Bend No1 Component No2 In
2001521.003	Valve Tower	Intake Screen Lifting Gantry Assembly And Component No4 Top Bearing No
2001521.004	Valve Tower	Intake Screen Lifting Gantry Component No1 Lifting Arm Inlet No1 And No2 C
2005361.005;C	Valve Tower	Resource Consent Upgrade Valve Tower And Access Tunnel General Arrang
2005361.011;B	Valve Tower	Resource Consent Upgrade Dam And Valve Tower Sections Showing Raw V
2005361.012;C	Valve Tower	Resource Consent Upgrade Valve Tower Elevation Internal Pipework As Buil
2005361.013;C	Valve Tower	Resource Consent Upgrade Valve Tower Roof Plan As Built
2005361.014;D	Valve Tower	Resource Consent Upgrade Valve Tower Plan Of Level No1 RL 209.13m As
2005361.015;D	Valve Tower	Resource Consent Upgrade Valve Tower Plan Of Level No2 RL 206.74m Inta
2005361.016;D	Valve Tower	Resource Consent Upgrade Valve Tower Plan Of Level No3 RL 199.56m Inta
2005361.017;D	Valve Tower	Resource Consent Upgrade Valve Tower Plan Of Level No4 RL 193.72m Inta
2005361.018;C	Valve Tower	Resource Consent Upgrade Valve Tower Plan Of Base RL 191.80m As Built
2005361.019;B	Valve Tower	Resource Consent Upgrade Intake Valve Adaptor Plate Details Dam Safety Details Sheet No1 Of2 As Built
Plan record No.	Group	Subject
2005361.020;C	Valve Tower	Resource Consent Upgrade Intake Valve Supports Ladder With Safety Cage
2005361.021;B	Valve Tower	Resource Consent Upgrade Work Areas And Site Access As Built
2005361.022;B	Valve Tower	Resource Consent Upgrade Work Area Construction Access Pedestrian Publ
2005361.023;B	Valve Tower	Resource Consent Upgrade Dam Safety Valve Area Valve Chamber Reinfor As Built
2005361.024;B	Valve Tower	Resource Consent Upgrade Dam Safety Valve Area Valve Chamber Reinfor As Built
2005361.025;C	Valve Tower	Resource Consent Upgrade Valve Tower Roof Slab And Platform Steelwork
311151.001		Lake Plan And Cross Section
311151.002		Upper Dam And Impounding Area Waitakere River Cross Section And Survey
311151.004		Lake Contours
311151.005		Lake Contours
315157.004		Strengthening Original Sheet 01
315157.005		Strengthening Original Sheet 02
2005361.026;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Concrete Slab Reinforc
2005361.027;B	Dam	Resource Consent Upgrade Dam Safety Valve Area Standard Reinforcing De
2005361.028;A	Dam	Resource Consent Upgrade Dam Safety Intake Screen As Built
2005361.029;B	Dam	Resource Consent Upgrade Temporary Intake Blanking Plate Details As Buil
2005361.030;C	Dam	Resource Consent Upgrade Cofferdam On Upstream Dam Face Details She

2005361.031;C	Dam	Resource Consent Upgrade Dam Safety Intake Sealing Plate As Built
2005361.032;B	Dam	Resource Consent Upgrade Cofferdam On Upstream Face Details Sheet No
2005361.033;B	Dam	Resource Consent Upgrade Valve Stem Blanking Plate Details As Built
2005392.001	General	Instrument Layout Plan
2005392.002	Dam	Saddle Dam Plan Instrumentation Drainage
2005392.003	Survey Information	Saddle Dam Plan Topographical Survey Measured 11th December Yr2009 A
2005392.004	Survey Information	Saddle Dam Plan Topographical Survey Measured 11th December Yr2009 A
2005408.001	General	Inundation Map For Waitakere Dam
2007315.007	General	Vegetation Control For Survey Lines Aerial Photo Plan
2007315.016	General	Vegetation Control For Survey Lines Aerial Photo Plan Trig Control
2007316.001;A	General	Fish Trap And Haul Locality Plan
2007316.002;A	General	Fish Trap And Haul Layout Details Transition Tray Layout
2007316.003;A	General	Fish Trap And Haul Trap Box Plan And Section
2007316.004;A	General	Fish Trap And Haul Trap Box Reinforcement
2007316.005;A	General	Fish Trap And Haul Trap Box Lid Plan And Sections
2007316.006;A	General	Fish Trap And Haul Fish Pass Section Details
Plan record No.	Group	Subject
2009517.001	Survey Information	Saddle Dam Topographical Survey Measured 11th December 2009 And 11th

Contents of Waitakere dam data books

Note that since January 2005, all documentation re dam safety has been stored in the ProjectWise data base instead of separate hard copy data books

Volume	Item	Page No
1	Correspondence	
	Characteristics	5
	Geology of the Waitakere Ranges fields trip notes	6
	Seismograph at Waitakere dam – memo from Riley Consultants	30
	Tunnel excavated through Waitakere Dam –Riley Consultants	33
	Concrete core sampling & testing - Geotechnics	35
	Waitakere Dam access tunnel blasting Riley Consultants	52
	Concrete core sampling & testing - Geotechnics	56
	Waitakere Dam Site Visit – Riley Consultants	63
	Waitakere Dam –Valve Tower Access Tunnel – Riley Consultants	64
	Waitakere Dam –Valve Tower Access Tunnel – Riley Consultants	67
	Waitakere Dam –Tunnel to Intake Tower– Riley Consultants	71
	Waitakere Dam –Tunnel Excavation Shape – Riley Consultants	73
	Waitakere Dam –Design Flood Proposal for PMF – Riley Consultants	75
	Hydrological assessment of the Waitakere River – BCHF for WCC	81
	Waitakere concrete and earthfill saddle dam, examination report	87
	Waitakere reservoir volume survey	110
2	SEED Report	
	Waitakere Dam Safety Evaluation Stage 1 – Riley Consultants	5
	ARC Bulk Water Supply Dams Seismic Hazard Study Engineering Geology Ltd	98
	Probable Maximum Floods for 10 water supply dams - Works	130
	Probable maximum Precipitation in NZ Addendum	174
2A	SEED Report (Stages 1 & 2) 1989/1990	
	Waitakere Dam Safety Evaluation Stage 2 – Riley Consultants	5
2B	SEED Report 1990/91 Waitakere Dam Construction	
	Conditions of Contract for Upgrade	5
	Waitakere Dam Strengthening Anchor Stressing Records - Contech	256
2C	SEED Report 1993/94 Post Construction	
	The Rehabilitation of the Waitakere Dam	5
	Waitakere dam outline Design Notes Draft	18
	NZSOLD Newsletter May 1992	21
	Waitakere Dam Geological Completion Report	47
	Waitakere Dam – Load monitoring and restressing	220
	Waitakere dam Tramway Stability Review	226

Volume	Item	Page No
2D	SEED Report 1996	
	Tonkin & Taylor Comprehensive Safety Review June 2001	5
	Waitakere Dam 1996 SEED Examination	154
	Waitakere dam Risk Assessment Report	205
2E	Investigations	
	Waitakere raw watermain geological Implication of the undercut cliff – Tonkin & Taylor April 2000	
	Waitakere Dam Plunge Pool & Abutment Stabilisation Feasibility Study November 1998 Opus	84
	Waitakere Dam Plunge Pool AEE - Opus	146
	Waitakere Dam Plunge Pool Outline Plan of Works - Opus	187
	Pneumatic & Hydraulic Piezometer Review	231
3 & 3A	Photographic Record Prior to upgrading & construction works during upgrade	
	Index	5
	Dam	7
	Saddle Dam	13
	Discharge Valve	17
	Miscellaneous	20
	Photographic Record Prior to upgrading & construction works during upgrade	
	Construction photograph Index	24
	Pre-construction	28
	Drilling work on the dam	33
	Transvers anchors and transverse dowels	41
	Demolishing & rebuilding the deck and spillway	51
	Re-construction of the spillway crest, abutment & deck	61
	Drilling & grouting pre-stressing cables	66
	Stressing Anchor cables	74
	Dam upstream flood wall	80
	Completed dam	82
4 & 4A	Drawings Prior To Upgrade & Construction Works During Upgrade	
	Dam Characteristics	5
	Index of Drawings	6
	Anchor cable records	7
	Site layout	8
	Site & road access layout	9
	Reservoirs and dam site	10
	Dam and valve Tower	18
	Saddle Dam	44
	Miscellaneous	52
	Waitakere Dam construction works Index	58
	General	59
	Reconstruction of the main dam	66
	Saddle Dam	88
	Electrical & Mechanical	91

Schedule of reports

Report No.	Title	Corp Author	Publ. Date
210	Waitakere Concrete And Earthfill Saddle Dam - Examination Report 1985	Law & Gulliver	22/11/1985
327	Engineering Geological Survey Of Waitakere Dam Raw Water Pipeline Georges Tunnel And Little Tunnel	Auckland University	5/02/1990
337	Waitakere Dam Concrete Core Report No 90/45	Hotham / Works Consultancy	1/06/1990
384	Phase 2 Investigation And Instrumentation Waitakere Dam	Riley Consultants	1/06/1989
385	Waitakere Dam Phase No2 Investigation And Instrumentation Saddle Dam	Riley Consultants	1/05/1989
386	Waitakere Dam Break Analysis Report	Webby / Works Consultancy	1/11/1989
1118	Waitakere Dam Safety Evaluation 1988	Riley Consultants Ltd	6/10/1988
1196	Waitakere Dam Upgrade	Parker	1/06/1990
2053	Pneumatic And Hydraulic Piezometers Evaluation And Maintenance Waitakere Upper Huia Lower Huia Cosseys Wairoa Mangatangi Dam	Opus Central Laboratories	24/07/1997
2067	Waitakere Dam Annual Safety Review 2000 To 2001	Alaa Ahmed-Zeki	20/09/2000
2166	Copy Waitakere Raw Water Main Geological Implication Of The Undercut Cliff Near The Dam	Tonkin And Taylor	20/04/2000
2194	Waitakere Dam Assessment Of Environmental Effects	Water	30/03/2001
2195	Waitakere Ranges Infrastructure Huia And Nihotupu Catchments Assessment Of Environmental Effects	Water	30/03/2001
2419	Waitakere Dam Annual Dam Safety Review 2002	Gordon Euinton	20/03/2002
2445	Flow Requirements For Native Fish Habitat Below Waitakere Upper Nihotupu Upper Huia Dam Reservoirs	NIWA	20/03/2001
2461	Waitakere Dam Piezometer Upgrade Completion Report	Gordon Euinton	20/07/2002
2578	Waitakere Dam Tramway Review And Tunnel Study Draft No2	Tonkin And Taylor Limited	20/03/2000
2610	Annual Dam Safety Review Of Waitakere Dam 2002 To 2003	Gordon Euinton	28/02/2003
2750	Annual Dam Safety Review 2003 To 2004 Waitakere Dam	Gordon Euinton	20/10/2003
2760	Vibrating Wire Piezometers Operation And Maintenance Data	Gordon Euinton	20/07/2002
2859	Comprehensive Safety Review June 2001	Tonkin And Taylor Ltd	20/10/2001
2908	Tramway Stability Review Waitakere Dam	Tonkin And Taylor	20/07/1995
2969	Response Testing Of Piezometers Waitakere Dam January 1999	Richard Body	20/02/1999
3091	Stage No1 Safety Report Tramway And Pipeline Bench Sited On Rock Ledge	Tonkin & Taylor Ltd	20/02/2000
3093	Plunge Pool And Abutment Stabilisation Feasibility Study Including Geological And Ecological Report	Opus	20/11/1998
3178	Copy Documentation Of Dam Scour Valve For Hunuas And Waitakere	Watercare Services Ltd	12/12/1997
3263	Intermediate Dam Safety Review Inspection Date 8th November 2004	Damwatch Services Ltd	20/01/2005
3404	Dam Deformation Survey Report 25th November 2004	Energy Surveys Ltd	25/11/2004

Report No.	Title	Corp Author	Publ. Date
3503	Dam Deformation Survey Report Waitakere Dam 24 November 2005	Energy Surveys Ltd	24/11/2005
3783	Waitakere Intermediate Dam Safety Review Inspection Date: 1st Of November 2005	Damwatch Services Ltd	7/04/2006
3836	Waitakere Dams Discharges Equipment Control Systems Monitoring And Reporting Feasibility Brief	Watercare Services Limited	21/10/2005
4027	Failure Potential Models For The Waitakere Dams		
4041	Waitakere Dam Post Earthquake Observations Draft	WSL	20/11/1998
4395	Waitakere Dam Safety Evaluation 1989 Repaired For Auckland Regional Authority	Riley Consultants Ltd	30/01/1989
4468	Intermediate Dam Safety Review 2006 1st November To 31st October 2006 Final	Damwatch	19/02/2007
4469	Comprehensive Safety Review September 2006	MWH NZ Ltd	20/01/2007
4576	Dam Data Book Volume No1 Correspondence	Watercare Services Ltd	
4577	Dam Data Book Volume 2 S E E D Report	Watercare Services Ltd	
4578	Dam Data Book Volume 2a Seed Report Stage No1 No2 1989 To 1990	Watercare Services Ltd	
4579	Dam Data Book Volume 2b Seed Report 1990 To 1991 Construction	Watercare Services Ltd	
4580	Dam Data Book Volume 2d Seed Report 1996	Watercare Services Ltd	
4581	Dam Data Book Volume 2e Investigations	Watercare Services Ltd	
4582	Dam Data Book Volume 3a 3b Photographic Record To Upgrading And Construction Work	Watercare Services Ltd	
4583	Dam Data Book Volume No4 No4a Drawings Prior To Upgrading And Construction Work	Watercare Services Ltd	
4584	Dam Data Book Volume No6 Annual Dam Safety Review	Watercare Services Ltd	
4820	Waitakere Dam Intermediate Dam Safety Review 2006 Period No1 November 2006 To 31st October 2006 Final	Damwatch Services Ltd	19/02/2007
5064	Waitakere Dam Intermediate Dam Safety Review 2007 Period 1st November 2006 To 31st October 2007 Final		25/01/2008
5068	Dam Data Book Volume 2c Seed 1993 To 1994 Post Construction	Watercare Services Ltd	1/03/1994
5245	Dam Crest Spillway Bridge Assessment	Maunsell AECOM	22/07/2008
5403	Intermediate Dam Safety Review 1st November 2007 To 31st October 2008	Damwatch Services	18/12/2008
5487	Deformation Survey Report Waitakere Dam 21st January 2009	Energy Surveys	21/01/2009
6257	Waitakere Dam Water Operations Caretakers Inspection Sheet Template		
6595	Intermediate Dam Safety Review Period 1st November 2008 To 31st October 2009	Damwatch	20/01/2010
6931	Copy Waitakere And Lower Huia Dams 11kv High Voltage Spur Line Inspection Report February 2010	Team Power Ltd	8/02/2010
6944	Waitakere Dam Resource Consent Upgrade	SKM	1/07/2009
6968	Waitakere Dam Resource Consent Upgrade Final Design Report	Sinclair Knight Merz	17/03/2010
Report No.	Title	Corp Author	Publ. Date
7239	Deformation Survey Report March 2010	Damwatch-Energy Surveys	12/03/2010

7380	Piezometer Installation And Concrete Core wall Inspection Waitakere Saddle Dam January 2011 Issue 1.0	Damwatch	11/01/2011
7515	Request For Quotation For The Manufacture And Supply Of A Dam Safety Valve At Waitakere Dam	SKM	9/11/2007
7541	Pre CDSR Intermediate Dam Safety Review Period 1st November 2006 To 31st October 2010	Damwatch	8/12/2010
7804	Waitakere Dam Uplift Considerations	Damwatch	20/06/2009
7989	Control Survey Report Waitakere Scheme Dams Lower Huia Upper Huia Lower Nihotupu Upper Nihotupu 9 12 March 2010	Damwatch	9/03/2010
7990	Deformation Survey Report Waitakere Dam 24 25 November 2010	Damwatch ESL	24/11/2010
8002	Comprehensive Safety Review CDSR Waitakere Dam March 2011 WSL	Watercare Services Limited	20/03/2011
8017	Inspection Report High Voltage Lines Periodic Annual WSL Western Dam Headworks 11 Kv Overhead Electric Lines Supplying Waitakere Dam Lower Huia Dam Lower Nihotupu Dam Parau Depot March April 2011	Team Power Ltd	7/04/2011
8074	Contingency Plan Development Waitakere Dam Pipeline 17703.001 July 2002 Tonkin And Taylor WSL Draft	Tonkin And Taylor	20/07/2002
8075	Tramway Stability Review Waitakere Dam Revised Edition July 1995 12358 Taylor And Tonkin Includes Drawings Photos Surveys And Maps	Tonkin And Taylor	20/07/1995
8093	Waitakere Concrete Dam Potential Failure Modes Report Final June 2011 PFMA FEMA	Damwatch	22/06/2011
8362	Geotechnical Risk Assessment Of Waitakere Dam Tramline Waitakere	Ormiston Associates	2/07/2010
8364	Environmental Monitoring Report Waitakere River December 2010 To July 2011	Tonkin And Taylor	20/09/2011
8385	Intermediate Dam Safety Review 1st November 2010 To 31st October 2011 Waitakere Dam	Damwatch	3/02/2012

Schedule of calculations

Calc. No.	Title	Corp Author	Contract No.
247	Waitakere Dam Overflow Capacity	Law	
415	Waitakere Reservoir Account 93713n Calculations 1611	Wright	1611
1116	Waitakere Dam Upgrade	Parker	FILE 11/18/15
1179	Waitakere Dam Road Bridge	Parker	1642
1213	Waitakere Dam Slab Across Spillway Bridge Structural Check	Wright	
1265	Waitakere Dam Kelly's Creek Water Chute		
1406	Kiosk And Information Seat Structures	Goldwater	
1417	Waitakere Dam And Hunua Dam Signage	Goldwater	
1439	Dam Strengthening	Gallagher	