

Flooding and Stormwater Issues – Feasibility Study

Proposed New Stadium Awatea Street Site

1. Introduction

The proposed new stadium site is close to the Otago Harbour and has the Leith Stream on the SW side of the site. Opoho Stream is conveyed through a double barrelled culvert beneath the site that is land reclaimed from the upper harbour. Local stormwater from the site and stadium buildings themselves also has to be disposed of. See attached plan (Figure 1.1) that shows the flooding threats.

A minimum floor level for the ground floor facilities is required to be established.

2. Required Standards

The BIA issued Approved Document for New Zealand Building Code: Surface Water Clause E1 has requirements relating to performance:

“**E1.3.1** Except as otherwise required under the Resource Management Act 1991 for the protection of other property, surface water, resulting from an event having a 10% probability of occurring annually, and which is collected or concentrated by buildings or site work, shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property.”

“**E1.3.2** Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings.” [This clause applies to Housing, Communal Residential and Communal Non-residential buildings. The stadium falls into the latter category – refer BIA Clause A1 Classified Uses paragraph 4.0.2]

DCC building requirements for a commercial building normally would not require the 2% standard to be applied but the BIA definitions do kick in for a stadium (non-residential building).

ORC recommend a standard of an annual exceedance probability (AEP) of 1% for buildings on floodplains.

3. Existing Waterway Design Standards

3.1 Water of Leith

The Water of Leith has been subject to a recent design review of the channel. This has been undertaken by Opus for the Otago Regional Council. The Opus report “Lower Leith Hydraulic Modelling report dated October 2004 details the capacity of the various sections of channel. The catchment is 45 km² and the design 100 year ARI flood event is calculated as 171 m³/s (Log Pearson 3 type frequency distribution).

Highest astronomical tide level corresponds to a level of 101.36m (Otago datum)

The soffit level of the bridges as shown in Table 2.1 of the Opus report are shown as Table 3.1.

Bridge	Model Chainage (m)	Soffit Level (m)			Deck Level (m)
		Left Bk	Apex	Right Bk	
Forth Street (overflow channel)	636	104.13	-	104.13	105.1
Anzac Avenue	960	104.10	-	104.28	not known
South Island Main Trunk Railway Bridge	1317	102.90	-	102.90	not known

Table 3.1: Part Opus Table 2.1 Road bridges crossing Water of Leith below Lindsay Creek confluence

Opus assumed a harbour water level of RL101.0m and the 100 year flood was able to pass by the proposed stadium site with substantial freeboard. There is potential in larger events (Opus modelled 200 and 500 year ARI flood events) for some overflows above the Union and Forth Street bridges. An inspection of the terrain would indicate that this would not be a major breakout. Flows in the lower reaches of the Water of Leith channel past the proposed stadium site would also become super-critical under low to medium tidal conditions

Opus Figure 6.1a (Figure 3.1) below shows the backwater profile from the Union St Bridge to the harbour. The blue dashed line in the latter figure represents the backwater profile in the secondary overflow channel below the Forth Street Bridge.

There are a number of bridges in this reach. Table 5.1 from Opus below (Table 3.2) compares the actual freeboard at each bridge with the existing channel geometry against the design flood event and the recommended freeboard values. Negative freeboard values indicate surcharging on the deck beams on the upstream side of the bridge.

Bridge	Recommended Design Freeboard (m)	Actual Freeboard for Existing Channel (m)
Dundas St	0.6	-1.08
University Footbridge at St Davids St	0.6	-0.25
Union St	0.75	0.65
Leith St footbridge	0.9	1.26
Clyde St	0.75	-0.45
Forth St	0.6	0.00
Anzac Ave	0.6	2.30
Railway	0.6	1.80

Table 3.2: Opus Table 5.1 Summary of freeboard values for the 100 year ARI design flood event for bridges along the Water of Leith between the Lindsay Creek confluence and the harbour

Water of Leith and Lindsay Creek - Design Philosophy for Achieving Minimum Design Flood Standard

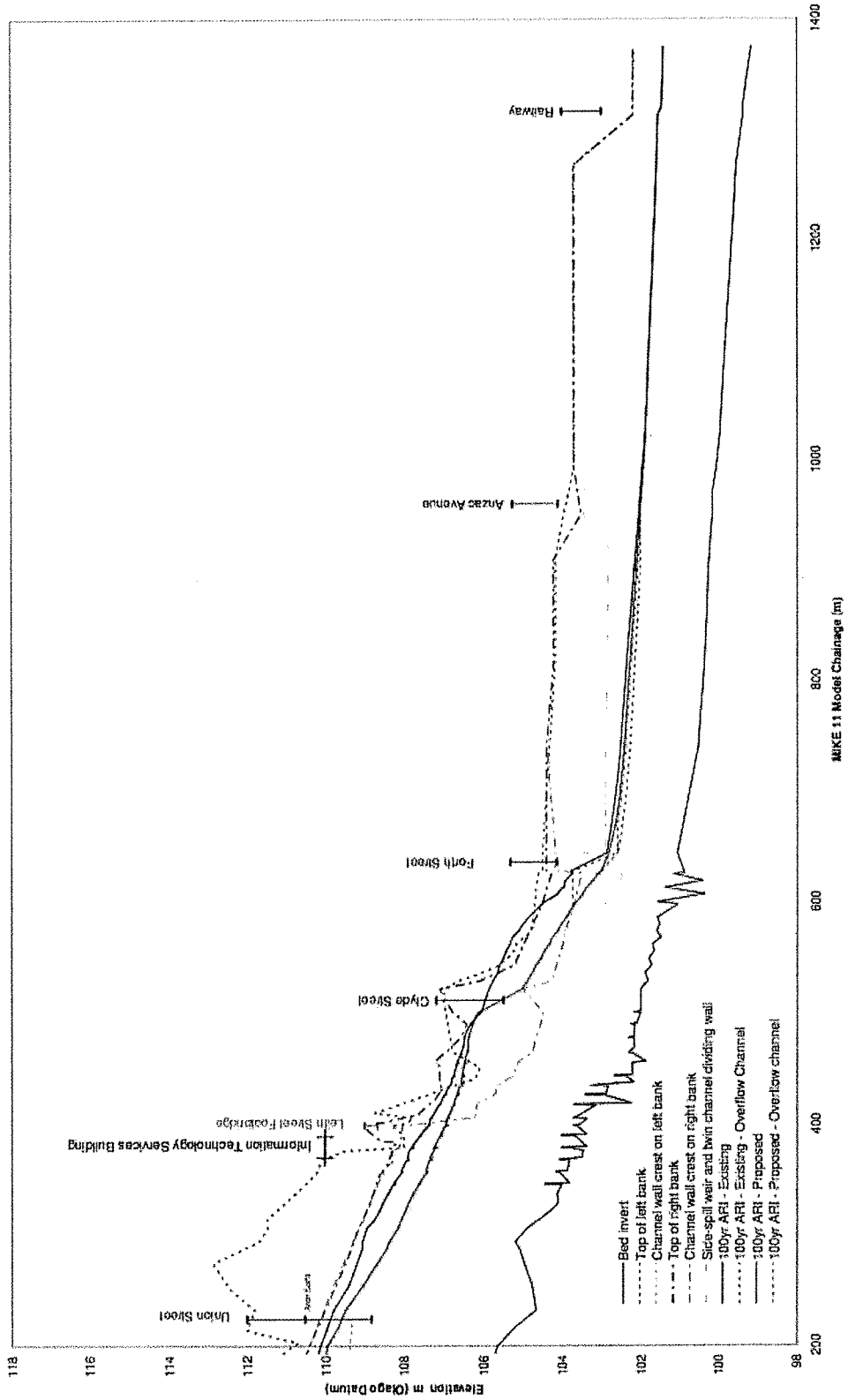


Figure 6.1a 100 year ARI flood profiles of the Water of Leith from the Harbour to the Union St Bridge

Figure 3.1: Figure 6.1a from Opus (2004)



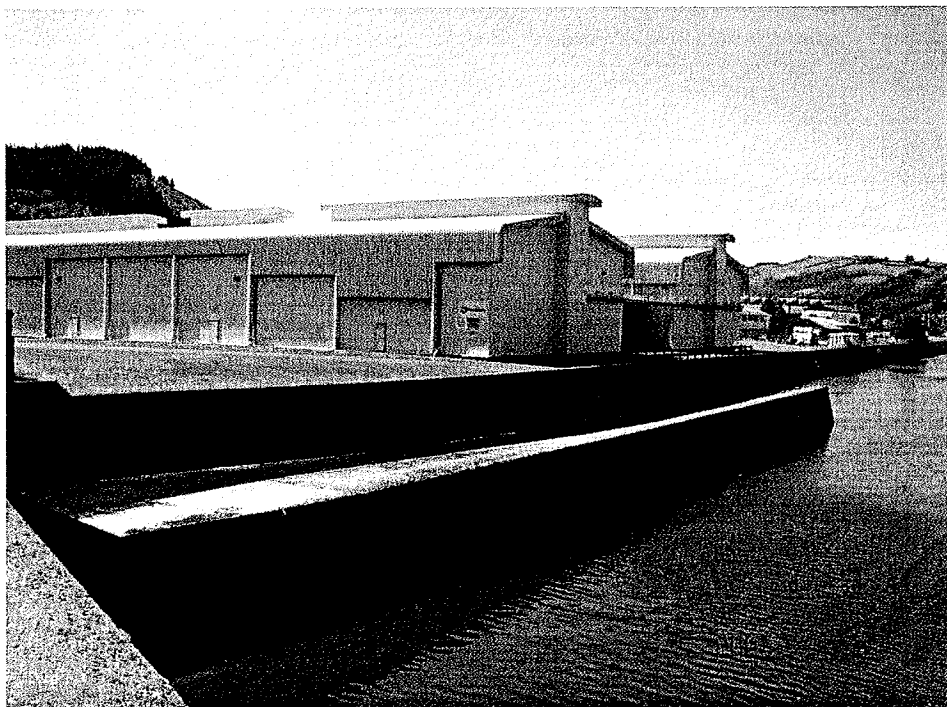


Figure 3.2: Photo looking east from Anzac Ave bridge down water of Leith & site

3.2 Opoho Creek

The existing double-barrelled culvert extends from Logan Park corner through to the water of Leith between the railway bridge and the boat harbour. The longsection and cross section of the culvert have been provided by DCC. The plans are dated 1926 that coincides with the Dunedin Exhibition of that year that was held on newly reclaimed land at Logan Park.

The culvert is 337 m (1106 ft) long and the invert gradient over most of the length is at 1 in 1000 ($S=0.001$). Culvert barrels are 2.59m wide by 2.285m high (8'6" wide by 7'-6" high) with chamfered corners. Total combined waterway cross section is 11.35 m² for this culvert.



Figure 3.3: Photo of entrance to Opoho Creek culvert upstream of Ravensbourne Rd. Concrete wall level on right at ~RL102.6m

Culvert hydraulic capacity without surcharging is calculated to be about $8\text{ m}^3/\text{s}$ per barrel or a total of $16\text{ m}^3/\text{s}$ (This has assumed a Mannings $n = 0.018$ that is relatively rough for a concrete culvert but the condition of the floor and walls would need to be inspected to confirm a roughness factor). This flow is considered reasonable as the culvert is expected to have a free outfall (i.e not drowned) as the downstream soffit is RL 101.64m (Otago datum) that is higher than the highest astronomical tide of RL 101.36m (Opus).

The side walls of the culvert upstream appear to be about RL 102.6m, based on the 1926 plan upstream soffit level of RL 102.0m, slightly lower than the adjacent Logan Park ground.

The Opoho Creek catchment extends from sea level up to an altitude of about 403m asl. Total catchment area is 271 ha. It is substantially rural in character but includes part of Logan Park and the Logan Park High School and a small residential area along Signal Hill Road at Opoho. Catchment cover includes pasture, native bush, scrub and gorse, and pinus radiata plantations. Soils are primarily silty clay and silt loam. The Q_{100} design flood has been assessed as in the range $12\text{-}15\text{ m}^3/\text{s}$ (see below). The culvert is therefore of sufficient capacity for the 1% AEP event.

The floor of Logan Point Quarry of Blackhead Quarries Ltd on the corner of Butts Rd and Ravensbourne Road is now substantially below ground level with its own catchment. This water is pumped out to the Opoho Creek culvert from time to time though a relatively small pipe. They do not need to pump at times of flooding in Opoho Creek.

3.3 DCC Stormwater Pipes

In addition to Opoho Creek there are stormwater mains running along Union Street East that collect from the Polytech and student flatting areas as well as Logan Park and feed into the Opoho Creek culvert downstream of the double culvert entrance. The main size is 1500mm diameter from Union St East. The invert level is RL100.344 on the north corner of Butts Rd/Ravensbourne Rd corner. Approximate maximum flow from this culvert without surcharging is $2.0\text{ m}^3/\text{s}$.

Should these surcharge or there be a spill overflow from the Water of Leith under superdesign flood conditions Logan Park playing fields can act as a temporary flood detention area. The levels of Logan Park (from 2m contour intervals supplied by SKM are as low as RL102.0m in places near Harbour Terrace. More detail on the ground levels would be desirable but it is assumed that much of the ground is about RL 102.8 and ponding up to RL103.1m could be accommodated in the superdesign situation if it occurred now. The stadium would not exacerbate this.



*Figure 3.4:
Photo 10
December 2006.
Ravensbourne
Road looking
east with site on
right*

3.4 Local hydrological data

ORC provided this tabular data (Table 3.1) in their Hydrologic & Hydraulic Guidelines, 2006. Only the closest relevant catchments are shown.

Otago Region Hydrological Sites Mean and Median Annual Floods							
Siteno	River	Sitename	Map Reference NZMS 260	Mean Annual Flood m ³ /s	Median Annual Flood m ³ /s	Catchment Area km ²	Mean Annual Flood as Specific Discharge m ³ /s/km ²
73105	Waikouaiti Sth Br	Lawsons	I43:196044	47.9	46.4	74.1	0.65
73501	Leith	University Foot Br	I44:169798	46.4	47.3	45	1.03
73507	Lindsays Ck	North Rd Br	I44:176811	12.2	11.8	11.7	1.04
74324	Silverstream	Taieri Depot	I44:021783	61.9	65.7	92	0.67

Table 3.1: Local hydrological stations summary data

Based on these figures one would expect a mean annual flood for the Opoho Creek to be about 1.3 to 1.5 m³/s/km² or 3.6 to 4.2 m³/s. A figure of 4 m³/s is adopted.

Regional Flood Estimation (McKerchar & Pearson "Flood Frequency in New Zealand")
Figure 4.9 shows a ratio of 3.0 ± 28% for q₁₀₀. This would give a Q₁₀₀ of 12 m³/s ± 3.4 m³/s.

4. High Intensity Rainfall Design Figures

4.1 Time of Concentration

The duration of the rainfall event to choose should match the time of concentration for the catchment. This is the time for water to travel from the farthest point in the catchment to the site of the modification. Its determination requires knowledge of the catchment characteristics (channel slope, flow length, catchment area, elevation difference) and can be calculated by a

number of methods (Ramser-Kirpich, Bransby-Williams, US Soil Conservation Service, Nomographs). BIA Document E1/Verification Method VM1 includes two of these methods.

A time of concentration of 30 minutes has been adopted for the catchment to the entrance of the Opoho Creek double barreled culvert under the proposed stadium site.

A minimum time of concentration of 10 minutes is used for on-site works at the stadium.

4.2 Raineffects Ltd Update for DCC

Following high intensity rainstorms in February 2005 and April 2006 the DCC has sought an update for rainfall intensity design curves for Dunedin. Raineffects Limited has undertaken this work.

The design curves for sea level Dunedin are shown as Figure 4.1. The methodology uses a series of graphs for different elevations. It is understood to make provision for increased intensities associated with climate change. This methodology has not yet been published. The details of this need to be clarified.

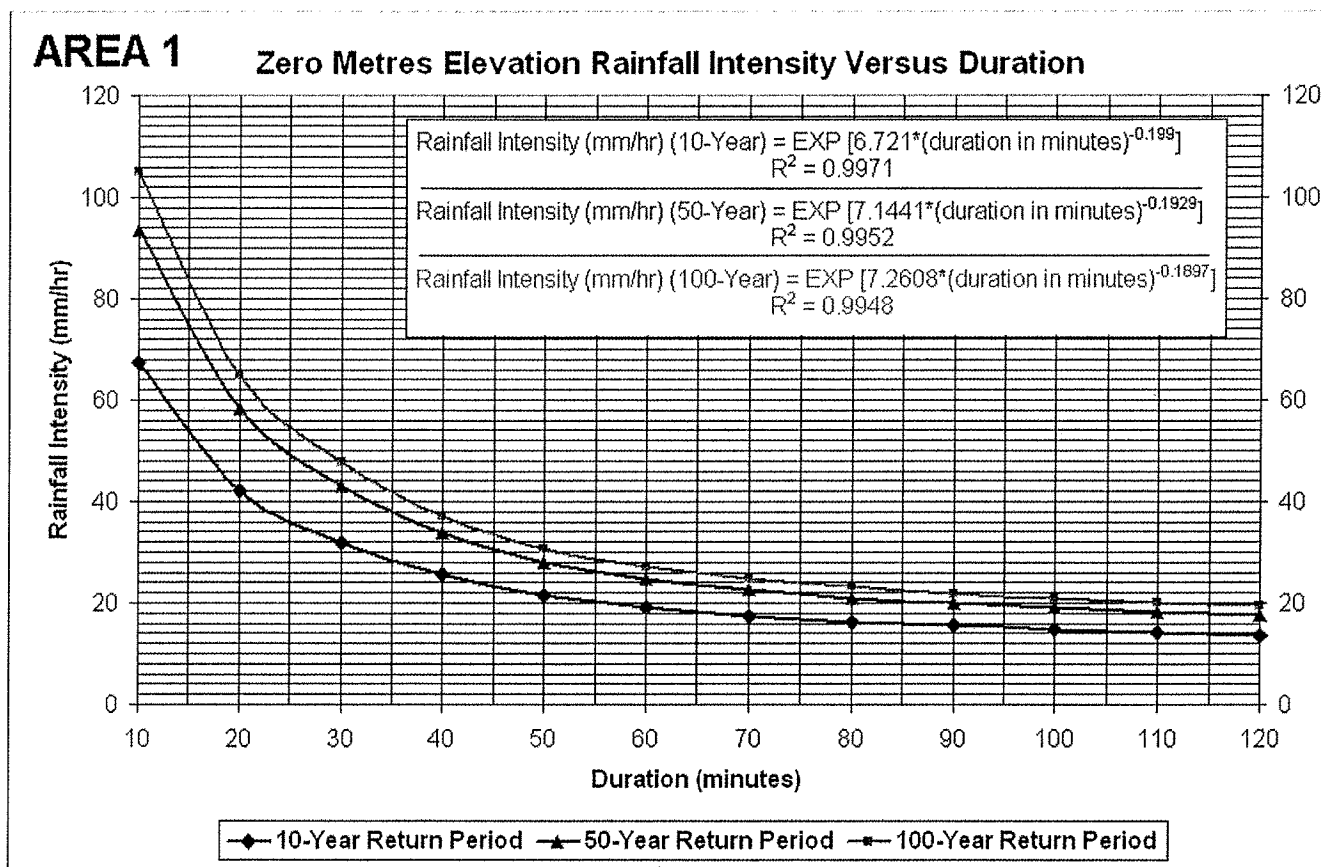


Figure 4.1. The 10 minute 50 year rainfall intensity is 93mm/hr. The 10 minute 10 year local stormwater design figure is 67 mm/hr.

4.3 Design Flood Standard Opoho Creek - Rational Formula

The derived Q₁₀₀ design flow for Opoho Creek using the Rational Formula and the new DCC rainfall intensity curve method for average catchment rainfall intensity yields a flow of 14.96 m³/s, say 15 m³/s. This compares reasonably with the Regional Flood Estimation technique. The Regional Flood estimation technique is based on historic data approach whereas the new

high intensity rainfall curves for Dunedin City make an allowance for climate change higher intensity rainfalls. (CHECK!).

4.4 Stadium Site Stormwater

The Dunedin City updated design rainfall figures are shown in the following table with the associated runoff coefficient C

	10 year ARI	50 yr ARI
Design rainfall figure i (10 minutes)	67 mm/hr	93 mm/hr
Roof areas Runoff Coefficient C	0.90	0.90
Asphalt or Concrete Paved Runoff Coefficient C	0.85	0.85
Playing area if open Runoff Coefficient C	0.30	0.30

Table 4.1: Recommended design parameters for on site works

The above table can be used with the Rational formula provided in BIA Acceptable Solutions E1 Surface Water to determine design stormwater runoff for the site.

5. Otago Harbour

NIWA (2005) has undertaken an analysis of extreme sea level based on historic events. Based on this information that is summarised in the Appendix the 100 year extreme sea level for Otago Harbour is RL 101.90m.

Climate change impacts of 0.3-0.5m by 2100 have been recommended for mean sea level impacts. The addition of 0.5m makes the design figure for the stadium for maximum water level without wave action as RL 102.4m. To this freeboard must be added. At the stadium proposed location the site has protection provided by:

- Boat harbour breakwater at ~ RL 102m [Maybe slightly higher]
- Main Trunk Railway line at ~ RL 104.0m [needs checking]
- Vertical walls on Water of Leith channel crest levels at ~ RL 103.7m.

A study carried out by Tonkin & Taylor Ltd for ORC in 1997 also assessed likely tsunami risk. A far field tsunami (South America) was estimated to produce a still water tsunami level of RL 101.7m at Dunedin (allows for 0.2m climate related sea level rise and to occur at high spring tide) as there is a dampening effect as a wave propagates up the harbour. The return period for such an event is 350 years for the tsunami and 4000 years for the tsunami to coincide with high tide.

It is considered that a design freeboard of 1.0m should be used for the marine hazards.

6. Combined events

It would be worthwhile to look at the probabilities of a storm surge occurring at the same time as the peak discharge from the Opoho Creek culvert. The height of the Water of Leith sidewalls at about RL 103.7m will generally contain a combined Water of Leith flood and storm surge.

7. Recommended Minimum Floor Level for the new stadium

The following table summarises the information derived from the sources identified above.

Hazard	Design WL RLm (Otago Datum)	Recommended freeboard m	Recommended Minimum floor level based on threat RL m (Otago Datum)
Water of Leith Q100 level at Anzac Ave	102.0	0.6	102.6
Opoho Creek culvert inlet design flow Q100	102.0	0.6	102.6
Potential surcharge in Logan Park if Leith water exits left bank upstream or local stormwater pipes surcharge in superdesign event	103.1	0.6	103.7
Otago Harbour Storm surge incl 0.5m climate change	102.4	1.0	103.4
Otago Harbour Tsunami incl 0.5m climate change	102.0	1.0	103.0

Table 7.1: Derived minimum floor levels from different hazards

A **minimum floor level of RL 103.7m** is considered sufficient to provide at least an 0.6m freeboard for floods of an annual exceedance probability of 1% from all the various sources. Such a floor level would also permit gravity drainage to the Water of Leith for local stormwater.

This level is below some of the existing ground at the site and assumes that if this minimum level is used that site work will provide adequate site drainage for on-site stormwater. A higher floor level can of course be used.

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References

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David Hamilton & Associates Ltd (June 2006) "Otago Regional Council Hydrologic & Hydraulic Guidelines", 49p.

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Wild, Bell & Walsh (NIWA 2005) "Otago Extreme Sea Level Analysis"

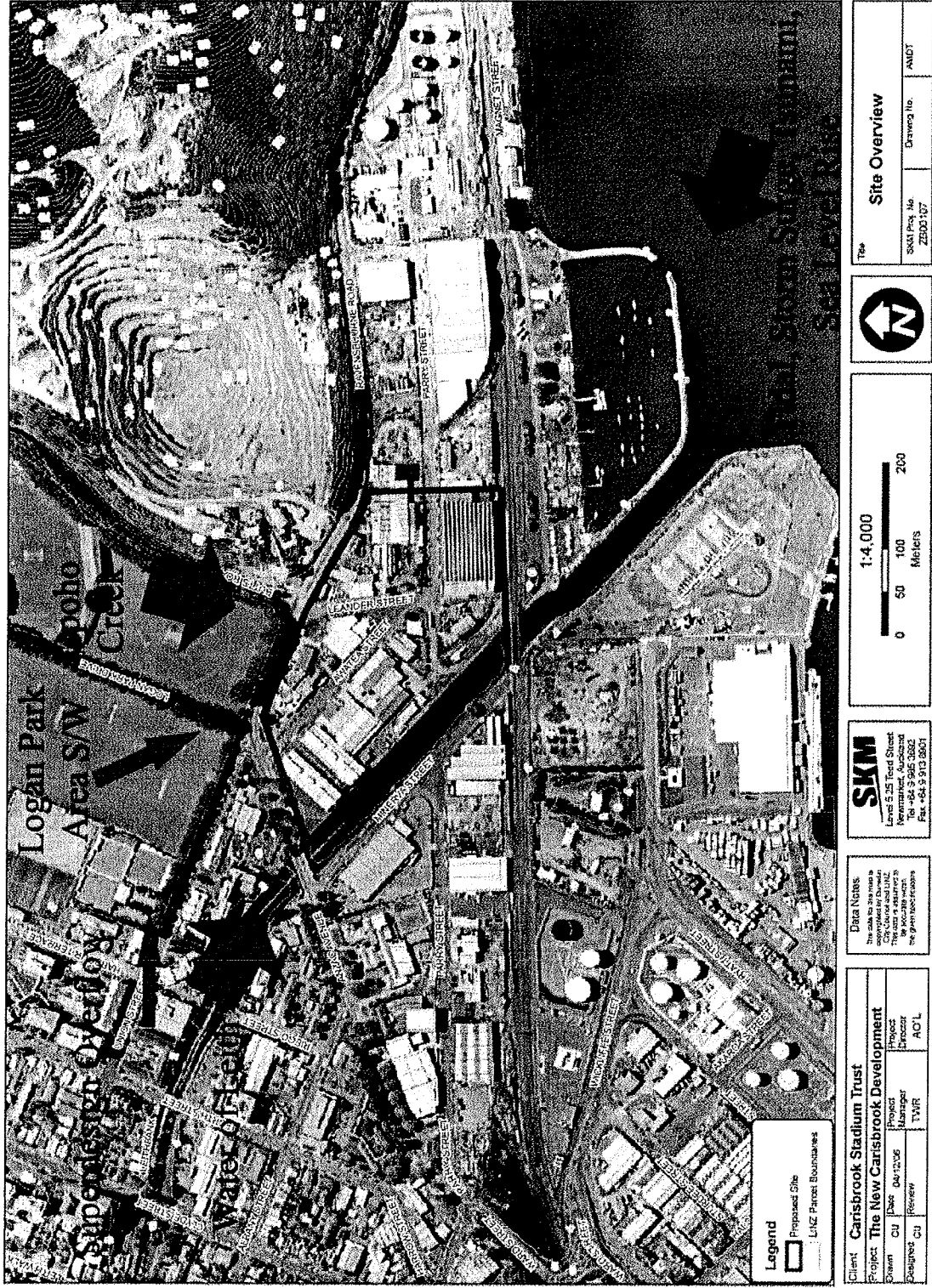
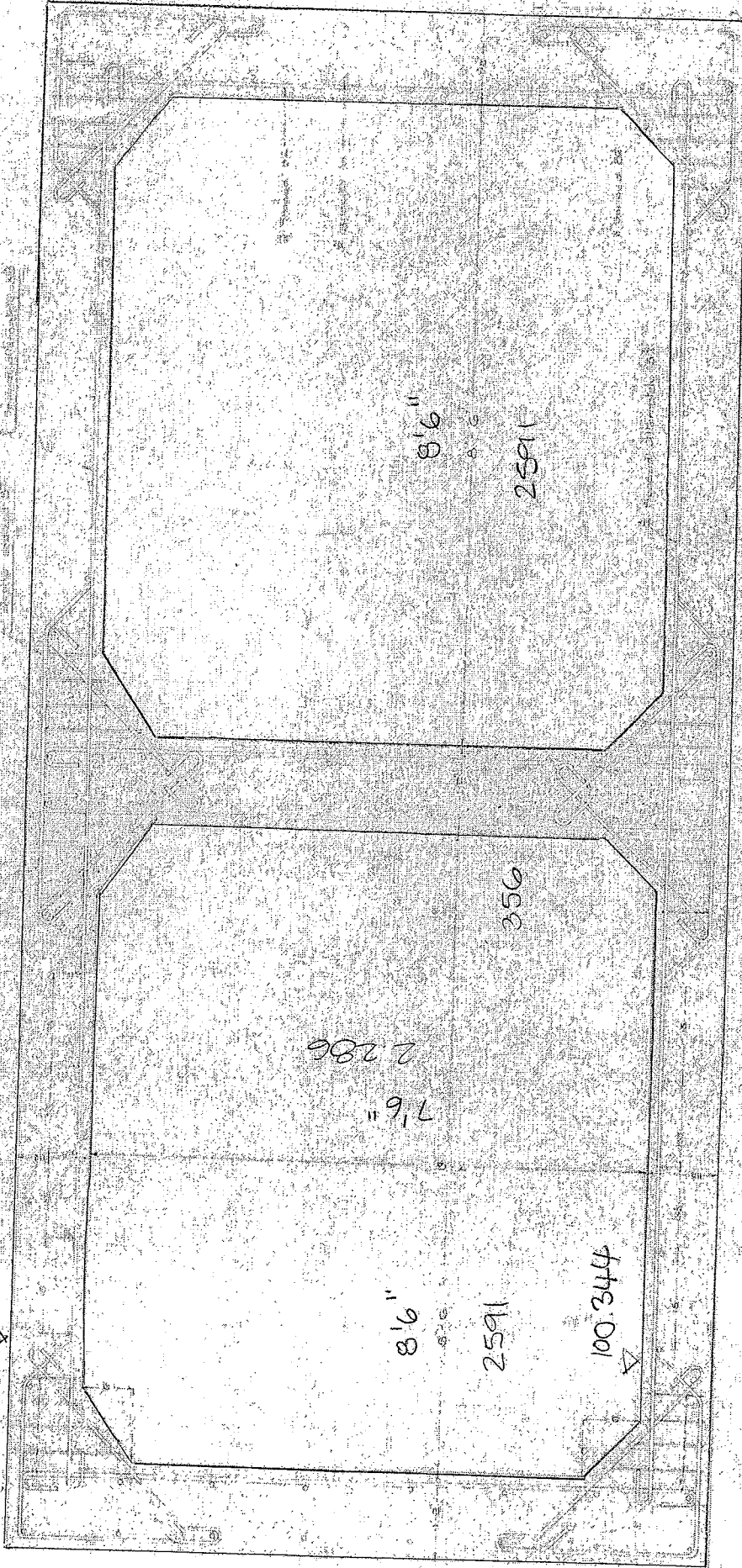


Figure 1.1: Site Overview Plan modified to show flooding threats



102.935
 30

356
 1'2"

7'6"
 2.286

8'6"
 2.591

356

8'6"
 2.591

1'2"
 356

30

(6.250)

OPHO CREEK DOUBLE CULVERT

6.250 x 2.896

6.3 x 2.9

(2.896)