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Piako River scheme: Service level review

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- Hugh MacMurray for undertaking the hydraulic modelling and preparing the report

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Executive summary

The Piako River and its major tributary, the Waitoa River, have a combined catchment area of 1590km^2 and can be split into three distinct zones: Delta zone, Middle zone, and Upper catchment zone. The Delta zone consists of drained swamp lands and the Kopuatai Peat Dome Conservation area, the Middle zone consist of the area between Morrinsville, Matamata and north to where they join, while the Upper zone contains the mountainous lands south of Morrinsville and Matamata (Figure 1).

The Piako River flood protection scheme provides protections to Ngatea and Pipiroa townships, farmland, and several roads of national significance. A key Level of Service of the scheme is that it is designed to control the effect of a flood event, up to a specific size.

In general the service levels are:

- 100 year (1% annual exceedance probability or AEP) tide event, from the sea to Kaihere.
- 1:50 year event: All of river south of Kaihere excluding the ponding zones
- 1:10 or 1:20 year event: Ponding & Spillway banks.

See **Table 7** in section 9.1 for more specific details.

Scheme Review Findings

Using surveys of the actual heights of the stopbanks and spillways, river cross section surveys and extreme weather information from the ministry for the environment, and NIWA this scheme review has looked first at whether the integrated flood protection scheme meets the existing performance levels of service. It then reviewed how the existing scheme would perform with future projected weather extremes caused by climate change.

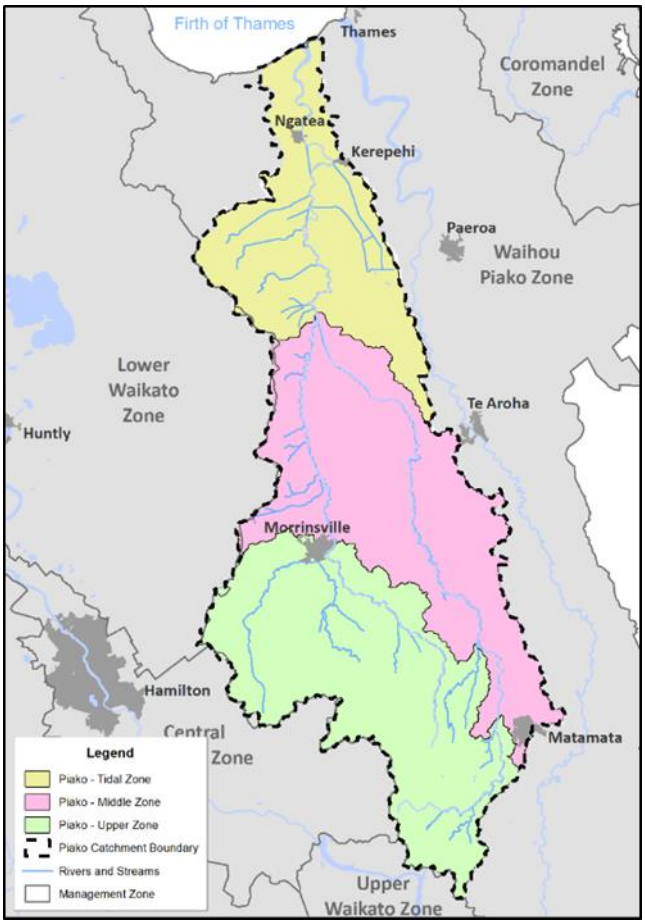

Figure 1: Piako Catchment Area

For the main tidal zone flood protection scheme area the following was noted:

- Under the current climate scenario, 91% of stopbanks meet the current performance requirements, whereas 9% provide marginal protection.

For the non-tidal zone flood protection scheme area:

- Under the current climate scenario, 84% of stopbanks meet the current performance requirements, whereas 16% provide marginal protection.

See the Appendix 6 for the details of where the stopbanks are / are not high enough.

Recommendations

1. That service levels for each major stopbank and spillway are adopted (**Table 7**).
2. The design standard is formalised as follows:
    - A 3.0m level is adopted as the 100 year tide level for the purposes of design of tidal zone stopbanks.
    - The current design freeboard of 0.50m be retained for the foreshore and tidal river stopbanks.
    - First Emergency Ponding Zone - spillway stopbank levels are set at a 1:10 year river flow event with zero freeboard.
    - Second Emergency Ponding Zone - spillway stopbank levels are set at a 1:20 year river flow event, with zero freeboard.
3. Stopbank renewals are prioritised over the next 7 years for the 9% that are a performance grade of 4 or 5, with priority given to stopbanks protecting urban areas. These are:

    Tidal Zone

    - Main eastern and western foreshore stopbanks – 0.82km
    - Piako river between mouth and Kaihere Ferry (both left and right Banks) –6.19km
    - Awaiti Canal and Tee Head stopbanks (left bank and right bank) – 0.87km

    River Zone

    - Northern Canal, Carters Block Cutoff and Kerepehi Block No 2 Cutoff – 0.93km
    - Whakahoro Rd West stopbank – 200m
    - Otway stopbank – 240m
    - Brickells stopbank – 246m
4. The policy regarding tolerances on spillway crest levels be reviewed.
    - Spillway renewals are prioritised over the next 7 years for the 9 spillways out of 11 that have an activation performance grade of 4 or 5, with priority given based on the frequency and extent of overtopping.

1 Introduction

The Piako River and its major tributary the Waitoa River have a combined catchment area of 1590km². The Piako catchment area is divided into three zones, namely the Delta Zone, Middle Zone and Upper Zone.

The Piako River Scheme is an integrated flood protection scheme comprising stopbanks, spillways, floodways' and flood storage ponding zones, drainage outlets, pump stations and channel enlargement and clearance works. This report presents a review of service levels for the Piako River Scheme main stopbanks and spillways. An overview of the scheme is shown in Figure 2 below.

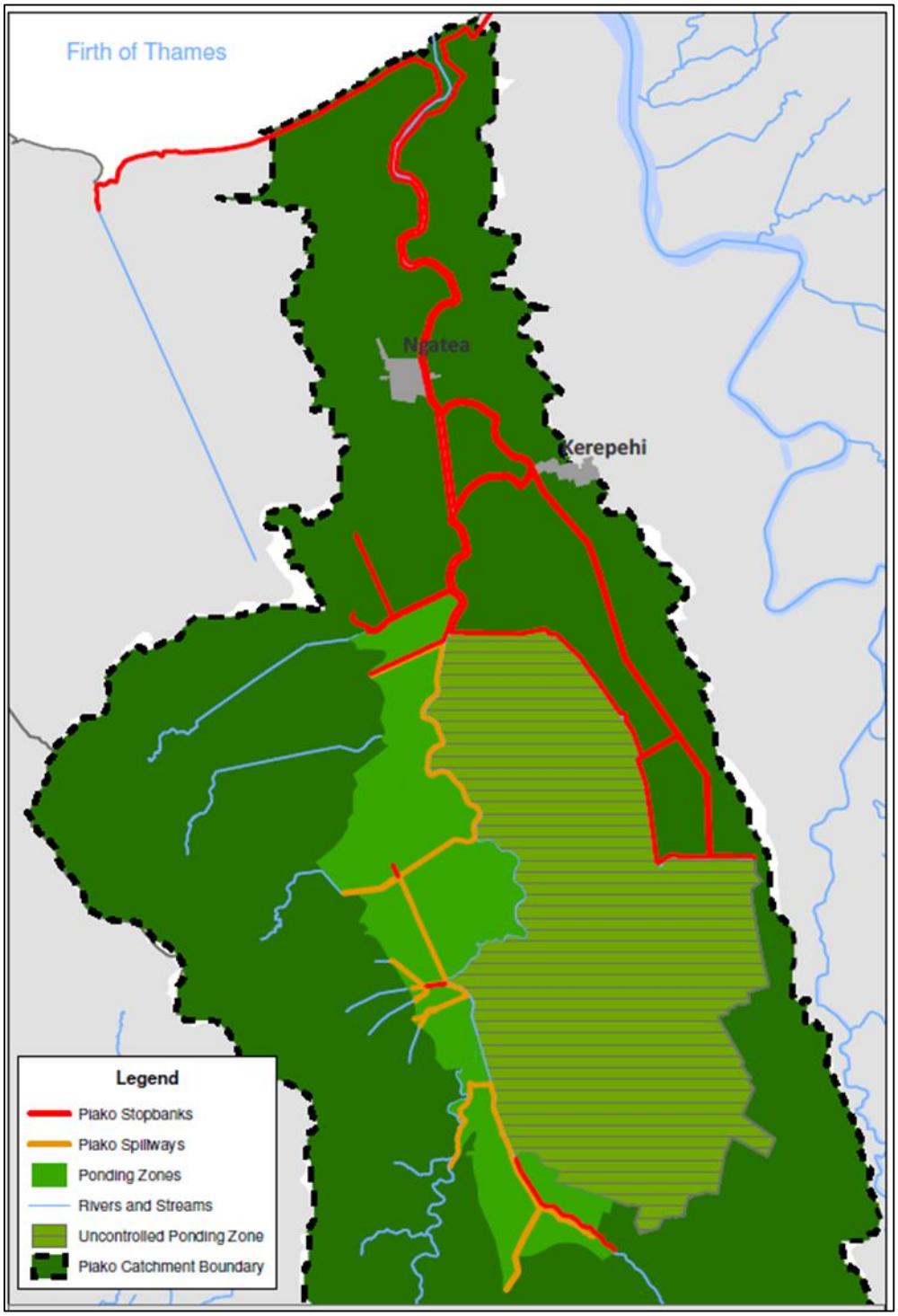

Figure 2: Piako River Flood Protection Scheme Overview

The majority of the scheme works and assets are located within the Delta zone, which extends from the mouth of the Piako River near Pipiroa to the confluence of the Piako and Waitoa Rivers. The scheme provides protection from both the sea and tides and flood flows coming down the Piako River. There are 126.8km of stopbanks within the scheme and 45.9km of spillways. The spillways are primarily associated with the First and Second emergency ponding zones.

The whole area comprising the ponding zones up to Paeroa Tahuna Road was not part of the Original Piako River Scheme approved in 1960. This area was a ponding area serving as an attenuation medium to reduce flood flows and levels downstream. In 1970, a request for extension of the scheme to provide a level of flood protection within this area without compromising the protection standard of the main scheme downstream was approved. Accordingly, the scheme was extended and three level of protection in a staged manner were provided within this reach. The main reason was to ensure that these areas maintain their storage and attenuation properties while receiving flood protection against the more frequent events (e.g. 5 – 20 year events)

The Delta zone is former swamp land, which has been drained and developed, (except for the area of the Kopuatai Peat Dome). The river through this reach has an almost flat gradient. Much of the shallow peat in the area has disappeared and the deeper peats have settled appreciably. Large areas of land are only one to two metres above mean sea level, presenting significant drainage difficulties.

The Middle zone extends from the confluence to Morrinsville (on the Piako River) in the west and Matamata (on the Waitoa River) in the east. In this zone the main works have been the construction of intermittent stopbanks along the Piako and Waitoa Rivers up to the Paeroa-Tahuna Road and clearance of vegetation from the channels. The area also includes the excavated channel extending along the Waitoa River to a point just downstream of Waitoa Township and up the Piako River to Whakahoro Road.

The Upper zone extends south and west from Morrinsville and south from Matamata to cover the remaining area of the catchment. In this zone is mainly farmland and the Te Miro and Richmond Down reserves.

2 Scope of Scheme Review

The scope of this study was to review whether the actual level for all the stopbanks and spillways of the scheme meet the current service levels.

The review has maintained the existing 100 year ARI tidal water level to be 3.0m as per previous designs. A frequency analysis of extreme tides for the Firth of Thames since 1965 suggests that this is slightly conservative.

2.1 Exclusions

The following aspects are not included in this review:

- Reviewing the service levels of floodgates and pumps is not included in the scope of the project, nor were river management activities reviewed – such as silt trap management.
- Reviewing the risk and or extent of land inundation from tidal or river flooding events is not included in the scope of the project.
- The ABCD flaxblock wildlife reserve has been incorporated in the modelling, however specific issues regarding the management of the reserve have not been considered in this study

- Review of time to clear the water spilt into the ponding zones (return of ponding zone water to the river) has not been considered.

3 Drivers for Activities

Scheme Reviews are conducted periodically either at the request of the catchment committee or when the morphology or characteristics of the area have substantially changed, e.g. in lieu of a flood event, change in river course, or change in land use. The last review was undertaken in 2009.

This scheme review was commissioned in 2016 as a routine review of the Piako scheme functionality, but was delayed in being finalised after the 2017 weather events resulted in new information that improved the understanding of how the scheme would perform.

4 Service Requirements

As specified in the Zone plan and Regional Asset Management Plan, Flood protection assets are required to control the effect of a flood event by ensuring that the integrated flood protection scheme is designed to meet agreed annual exceedance probability (AEP) levels and customer expectations. For the Piako scheme these are (Table 1):

Table 1: Overarching Service Level Requirements

Annual Exceedance Performance (AEP)	**Scheme Areas designed to meet AEP levels**
1% AEP tidal event, with a 50% AEP river flow event	From the river mouth to Kaihere. Awaiti and Tee Head Canals
2% AEP river flow event, with a mean high water spring tide (MHWS)	All areas outside the main tidal zone excluding the ponding zones
5% AEP river flow event, with a mean high water spring tide (MHWS)	20 year ponding areas (Second Emergency Ponding Zone) spillway banks
10% AEP river flow event, with a mean high water spring tide (MHWS)	10 year ponding areas (First Emergency Ponding Zone) spillway banks

Within the Piako region there are both normal stopbanks and stopbanks that act as spillways. While both may physically look the same, they provide different functions during a flood or coastal inundation event, and thus have different levels of service requirements. These are explained in **Table 2** table below.

Table 2: Stopbank and Spillway Service Level Requirements

Asset Type	Service Level Required
Stopbank	• Contain flood flows within the main floodway to protect floodplain areas, (including both infrastructure and farmland against river flooding). • Protect tidal zone areas, (infrastructure and farmland) against tidal flooding
Spillway	• To protect the ponding zone areas up to a moderate flood level (10 - 20 year ARI event) and once this level is exceeded spill in to the ponding zones • Provide preferential overtopping point for a controlled spill into recognised designated ponding areas and to relieve pressure on the other parts of the scheme

5 Performance Measures

The performance measures used for the stopbanks and spillways are aimed at ensuring the level of service provided meets customer's reasonable expectations, and is sustainable in terms of scheme income.

The performance requirements for both stopbanks and spillways are expressed as either the Average Recurrence Interval (ARI) or the Annual Exceedance Probability (AEP). These are expressed as 1:xx rain event or a % respectively. This is then used to calculate the Design Level of Service (designed flood level, DFL) for the stopbank or spillway.

5.1 Stopbanks

Performance is determined by the ability of the stopbank to protect against all flood events less than or equal in magnitude to the Design Level of Service (designed flood level).

Stopbanks have an additional freeboard added above the designed flood level to allow for uncertainty in the estimation of design flood levels, or build errors when constructing and maintaining stopbanks. The amount of freeboard is not a service level element; but rather it is a safety margin to allow for uncertainties such as:

- Uncertainty in hydrological modelling
- Uncertainty in hydraulic modelling
- Wind and wave setup on the water surface
- Super-elevation on the water surface at bends
- Settlement of stopbanks over time
- Construction tolerance

The Designed Flood level (DFL) + the Designed Freeboard (DFB) = Designed Crest Level (DCL).

For stopbanks, it is of no consequence if actual crest levels are higher than design, it simply adds an additional element of conservatism to the protection standard.

5.2 Spillways

The performance requirements for spillways are more stringent than that for stopbanks. If spillway crests are higher than design, the spillway capacity may be compromised, and likewise if they are lower than design they will start spilling earlier. The key performance requirements for spillways are:

- Spillway should provide protection up to the activation level for the spillway (i.e. the spillway should not spill prematurely).
- Once the activation level for a spillway is exceeded, the overflow capacity of the spillway must be sufficient to ensure that it performs its spilling function adequately up to the design level of service.
- Spillways have negative freeboard under the design level of service to ensure that the required spilling capacity is achieved.

The performance measures for spillways are set out in **Table 3**.

5.3 Performance Expectations

For the following events the system is expected to perform in the following manner (**Table 3**).

Table 3: Hydraulic Performance Expectations for Stopbanks and Spillways

Event	Desired Outcome	
	Stopbank	**Spillway and ponding area**
Flood smaller than designed size	Not overtopped	Spillway not overtopped
MHWS tide only	Not overtopped	Spillway not overtopped
50% AEP river flow & 1% AEP high tide	Not overtopped	Spillway activates if level at "activation event" level
Flood less than designed flood height & MHWS tide	Not overtopped	Spillway overtops at activation flood level Storage in ponding zones attenuated flood peak in main channel
Flood larger than designed flood height & MHWS tide	Potentially overtops	Spillway overtops at activation flood level Storage in ponding zones attenuated flood peak in main channel

6 Performance Grades

Current performance has been assessed against the design performance standard based on most recent stopbank crest level survey data and the results of hydraulic modelling for design events.

Performance measurement is calculated on the basis of the actual crest level relative to the design crest level. Stopbank performance is classified with 5 grades. Performance grades 1 and 2 are acceptable, 3 requires medium term upgrade (within 10 years), while grades 4 and 5 indicate remedial measures are required in the short term (3 years).

6.1 Stopbanks

The performance of earthen structures (stopbanks and detention dams) is assessed by comparing the current crest level against the design crest level (DCL). The assessment is done at every 100m length or link of stopbank, where the calculated current lowest crest level is compared to DCL.

Each link is assessed and graded applying the criteria set out in **Table 4**. The worst grade of any link of the stopbank represents the overall performance grade of the stopbank.

Table 4: Stopbank Condition Assessment

Condition Grade	Crest Level Measure
1	Actual crest level > design crest level for entire section
2	Actual crest level > target level for entire section
3	Actual crest level < target level at any point
4	Actual crest level < half (target level + design flood level) at any point
5	Actual crest level < design flood level at any point

DFL = Designed Flood Level
DCL = Designed Crest Level = DFL + Freeboard
Target = DFL + ½ Freeboard

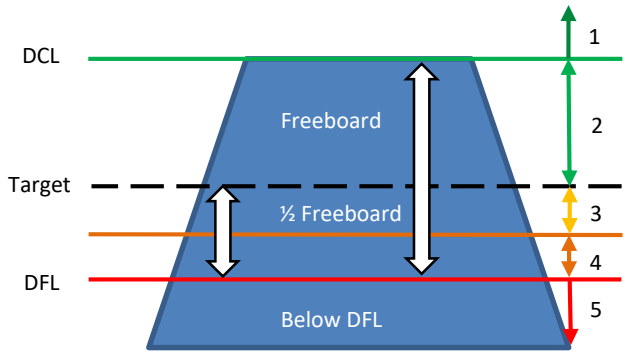

Figure 3 Condition Assessments for Stopbanks

6.2 Spillways

Key Points:
Actual Freeboard (AFB) = Actual Crest Level (ACL) – Design Flood Level (DFL)
Design Freeboard (DFB) = Design Crest Level (DCL) – Design Flood Level (DFL)

Table 5: Spillway Performance Assessment

Performance Grade	Activation Criteria A= Min (AFB – DFB)	Capacity Criteria R = Average (AFB / DFB)
1	A ≥ -0.050m	R ≥ 1
2	-0.050m > A ≥ -0.100m	0.90 ≤ R < 1
3	-0.100m > A ≥ -0.150m	0.50 ≤ R < 0.9
4	-0.150m > A ≥ -0.200m	0.25 ≤ R < 0.5
5	0.200m > A	0.25 > R

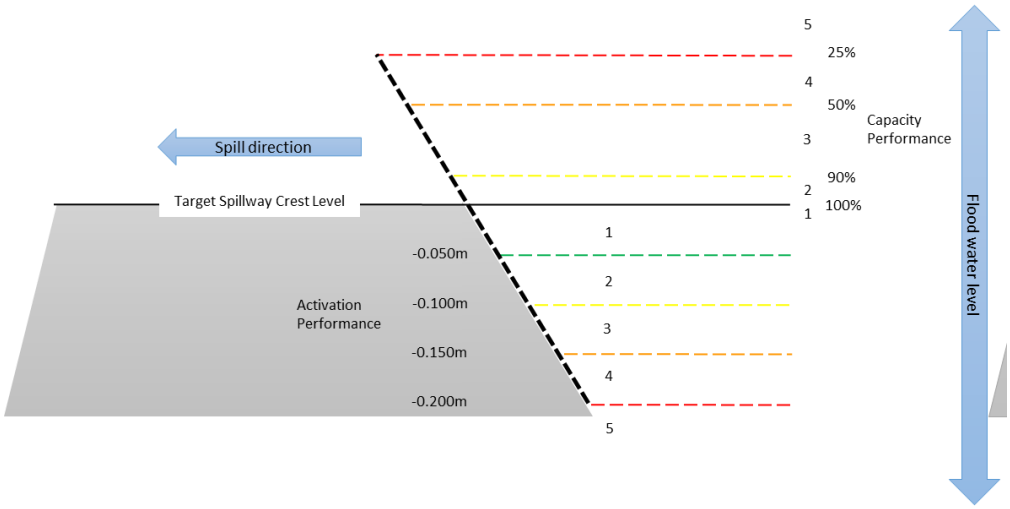

Figure 4: Performance Assessments for Spillways

7 Service Level Options

As part of the service level review process, consideration has also been given to potential changes in service levels.

7.1 Status Quo

- Keep the current service levels at the original design standards

When completing this analysis it was noted that there are a number of stopbanks and spillways within the Piako scheme where the original design standard is unclear. Judgement has been used to infer design standards based on the best information available.

7.2 Ponding Zone Spillways Protected to Full 50 Year ARI Standard

- Keep the current service levels for the stopbanks.
- Change the spillway service levels, upgrading the first and second emergency ponding zones to provide for protection against a uniform 50 year river flow event with 0.0m freeboard

The implication of this option is that controlled use of storage within the ponding zones will be eliminated for events up to the 50 year ARI event, and there would be a requirement for all non-tidal stopbanks and spillways to be raised to offset the rise in river levels resulting from this loss in storage.

Analysis of the effect of applying this option showed that upgrading the ponding zone spillways to a 50 year standard would require raising their height by an average of 0.70m over a total length of 50.3km. A broad scale estimate is that the cost of such an upgrade would be in the order of $11 – 14 Million.
Adoption of this option would result in significant scheme rate increases for landowners in the ponding zone areas.

7.3 Climate Change to 2090

- Keep the current service levels for the stopbanks and spillways (refer Appendix 1 for scheme review process) which includes current state climate change
- Apply Ministry for the Environment calculations of expected flood and coastal inundation events

This option involved allowing for climate change through to the year 2090. The impact of this option in terms of increased stopbank and spillway levels has been assessed, however the option has not been taken further or adopted in accordance with a recent council decision.

Subsequent to the undertaking of this scheme review climate change has been adopted by Council through the infrastructure strategy and the Climate Change guidance note:

“Climate Change Guideline ICM - FINAL Sept 2017.docm”
(https://discover.wairc.govt.nz/otcs/llisapi.dll?func=ll&objaction=overview&objid=11048382)

8 Performance Assessment

8.1 Hydrological and Hydraulic Assessment

For a given Design Flood Standard, the design discharges and resulting design flood levels for the main rivers and tributaries are established through hydrological and hydraulic analysis.

Barnett and MacMurray undertook a full review of the flood hydrology and hydraulics of the Piako and Waitoa River catchments, and from this a computer model was constructed to model water levels and flows throughout the scheme based on rainfall.

The modelling considered all three options discussed in the previous section, i.e. the current situation (status quo); expected future floods allowing for climate change up to the year 2090; and the current situation with all spillways raised to full 50 year height.

In general, the modelling also looked at what the water levels and flows would be for different sized floods (ARI).

The various scenarios modelled are shown in **Table 6** .

Table 6: Modelled Scenarios

Scenario	Source of Flooding	Spillway Crest Levels Scenario	ARI (years)
Status Quo			
1	River Flooding	Existing Spillway Levels	2
2	River Flooding	Existing Spillway Levels	10
3	River Flooding	Existing Spillway Levels	20
4	River Flooding	Existing Spillway Levels	50
5	River Flooding	Design Spillway Levels	2
6	River Flooding	Design Spillway Levels	10
7	River Flooding	Design Spillway Levels	20
8	River Flooding	Design Spillway Levels	50
9	River Flooding	Full Height Spillways – No spill	10
10	River Flooding	Full Height Spillways – No spill	50
11	Tidal Surge	Design Spillway Levels	10
12	Tidal Surge	Existing Spillway Levels	100
13	Tidal Surge	Design Spillway Levels	100
Climate Change to 2090			
14	River Flooding	Existing Spillway Levels	50
15	River Flooding	Design Spillway Levels	50
16	Tidal Surge	Existing Spillway Levels	100
17	Tidal Surge	Design Spillway Levels	100

The design standard for the main Piako River stopbanks against tidal surge is the 1% Annual Exceedance Probability (AEP) or 100 year Average Recurrence Interval (ARI) event. The current design tide level for the scheme is based on the estimated level of the 1938 tidal surge the highest in recorded memory), with the presumption that this event had an approximate ARI of 100 years. Frequency analysis of the Thames tide gauge annual maximum levels indicates that the 100 year ARI tide level is somewhat less than 3m (2.71m +/- 0.16m at the 95% confidence

limit range), however the annual maxima series is relatively short, and does not include the 1938 event. A 3.0m level is adopted as the 100 year tide level for the purposes of design.

For the purpose of assessing the effect of rising sea levels due to climate change on future tide levels an additional 0.8 metres has been added to the status quo values, in line with the recommendations of MFE. The climate change design tide level is therefore 3.8m.

It is also proposed that the current design freeboard of 0.50m be retained for the foreshore and tidal river stopbanks.

9 Results

Thematic maps of stopbank and spillway performance grades are shown in , **Figure 11** and **Figure 12**

9.1 Stopbank and Spillway Level of Service

The table below (**Table 7**) is the recommended stopbank Level of Service and design freeboard for each of the stopbanks and spillways in the Piako Scheme.

Table 7: Piako River Scheme Stopbanks and Spillways - Levels of Service

Asset grouping	**Asset Description**	**Source of Flooding**	**Design Freeboard** (m)	**ARI** (years)
Foreshore	West Foreshore SB	Tidal Surge	0.50	100
	East Foreshore SB	Tidal Surge	0.50	100
Piako River Left	Mouth to Pipiroa Left SB	Tidal Surge	0.50	100
	Pipiroa to Ngatea Left SB	Tidal Surge	0.50	100
	Ngatea to Puhunga Canal Bridge LB SB	Tidal Surge	0.50	100
	Puhunga Canal Bridge to Ferry Rd Bridge LB SB	Tidal Surge	0.50	100
	Ferry Rd Bridge to Kaihere LB SB	Tidal Surge	0.50	100
Ngarua Canal Left	02B) Ngarua Canal Left SB	Tidal Surge	0.50	100
	03) Waikoura Left SB	River	0.30	50
Piako River Right	Mouth to Pipiroa Right SB	Tidal Surge	0.50	100
	Pipiroa to Ngatea Right SB	Tidal Surge	0.50	100
	Ngatea to Puhunga Right SB	Tidal Surge	0.50	100
	Puhunga Canal Right SB	Tidal Surge	0.50	100
	Puhanga to Kaihere Right SB	Tidal Surge	0.50	100
	Kaihere to Elstow Right SB	Tidal Surge	0.50	100
Elstow Canal	Elstow Canal Right SB	Tidal Surge	0.50	100
Kerepehi Loop	Kerepehi Loop Left SB	Tidal Surge	0.50	100
	Kerepehi Loop North Right SB	Tidal Surge	0.50	100
	Kerepehi Loop South Right SB	Tidal Surge	0.50	100
Awaiti Canal / Tee Head	Awaiti Canal Right SB	Tidal Surge	0.50	100
	Awaiti Canal Left: Ferry Rd to Reservoir Canal SB	Tidal Surge	0.50	100
	Awaiti Canal Left: Reservoir Canal to Tee Head SB	Tidal Surge	0.50	100
	13) Tee Head West SB	Tidal Surge	0.50	100
	12) Tee Head East SB	Tidal Surge	0.50	100
Kerepehi Block No.2 / Northern Canal Left	Kerepehi Block No 2 Cutoff SB	River	0.30	50
	Northern Canal Left SB	River	0.30	50
	Carters Block Cutoff SB	River	0.30	50

Asset grouping	Asset Description	Source of Flooding	Design Freeboard (m)	ARI (years)
Carters Block Cutoff/Northern Canal Right	Northern Canal Right SB	River	0.30	50
Piako River Upstream of SH27	Whakahoro Road West SB	River	0.00	20
Waitoa River Upstream Paeroa Tahuna Rd	13) Brickells SB	River	0.00	50
	12) Otway SB	River	0.00	50
EP1	Ngarua Canal Right SB	River and Tide	0.00	10
	Kaihere to Central Left SB	River and Tide	0.00	10
	Central Drain Left SB	River and Tide	0.00	10
	Central Drain Right SB	River and Tide	0.00	10
	Central to Waikaka Left SB	River and Tide	0.00	10
	Waikaka Canal Left SB	River	0.00	10
	Waikaka Canal Right SB	River	0.00	10
	Maukoro Line SB	River	0.00	10
	Maukoro Landing Road Left SB	River	0.00	10
	Carters Outlet Left SB	River	0.00	10
	Waikaka North Wingbank SB	River	0.00	10
EP2A	Whakahoro Canal Right SB	River	0.00	20
	Chatfield Cookson SB	River	0.00	20
EP2B	Boardmans to West Road Right SB	River	0.00	20
	Boardmans SB	River	0.00	20
	Boardmans SB (Waitoa)	River	0.00	20
	Clarke Left SB	River	0.00	20
	Whakahoro Canal Left SB	River	0.00	20
EP2C	Ohinekaua Stream Left SB	River	0.00	20
	Ohinekaua Stream Right SB	River	0.00	20
	Pouruiri Stream Right SB	River	0.00	20
	Maukoro Landing to Hart Road Left SB	River	0.00	20
	Hart Road Stream Left SB	River	0.00	20
	Hart Road Stream Right SB	River	0.00	20
EP2D	Clarke Right SB	River	0.00	20
	Russell SB	River	0.00	20
	Pitts Road Stopbank	River	0.00	#N/A
Maukoro Canal	Maukoro Canal Right SB	Tidal Surge	0.50	100

9.2 Main Tidal Zone Stopbanks

The stopbanks within the main tidal zone (Gulf of Thames to Kaihere) were originally designed to protect against a 100 year tidal surge event. The assets consist of a total of some 109km of stopbanks as follows:

- The main Eastern and Western foreshore stopbanks
- The Maukoro Canal right bank stopbanks
- The Piako river stopbanks between the river mouth and Kaihere Ferry
- The Kerepehi Loop Stopbanks
- Awaiti Canal and Tee Head stopbanks

- Elstow Canal Stopbanks

The scheme was tested during the recent extreme tide levels of January 2018, and the tidal reach stopbanks performed satisfactorily. The tide level of 2.9 metres, was the highest since 1938, and only 0.1m below the design 100 year tide.

Plots of design flood levels against actual crest levels are shown in Appendix 6

A summary of the lengths of Piako River Scheme main tidal zone stopbanks within each performance class is shown in **Figure 5**.

Since the completion of the review data the following banks have already been upgraded. Ngatea to Pauls Wharf 1.7km, Puhunga to Kaihere 970m.

9.3 River Zone Stopbanks

The assets consist of a total of some 10km of stopbanks as follows:

- Northern Canal Right and Left stopbanks
- Carters Block Cutoff stopbank
- Kerepehi Block No 2 Cutoff stopbank
- Central Drain Left and Right stopbanks
- Whakahoro Road West stopbank
- Pitts Road stopbank
- Otway stopbank

River flooding is the critical design condition for all these banks.

Plots of design flood levels against actual crest levels are shown in Appendix 6.

A summary of the lengths of Piako River Scheme river zone stopbanks within each performance class is shown in Figure 6.

Since the completion of the review data the following banks have already been upgraded. Pitts Road 950m and Takos 900m. These were necessary as they were identified as an issue during the March/April 2017 flood events.

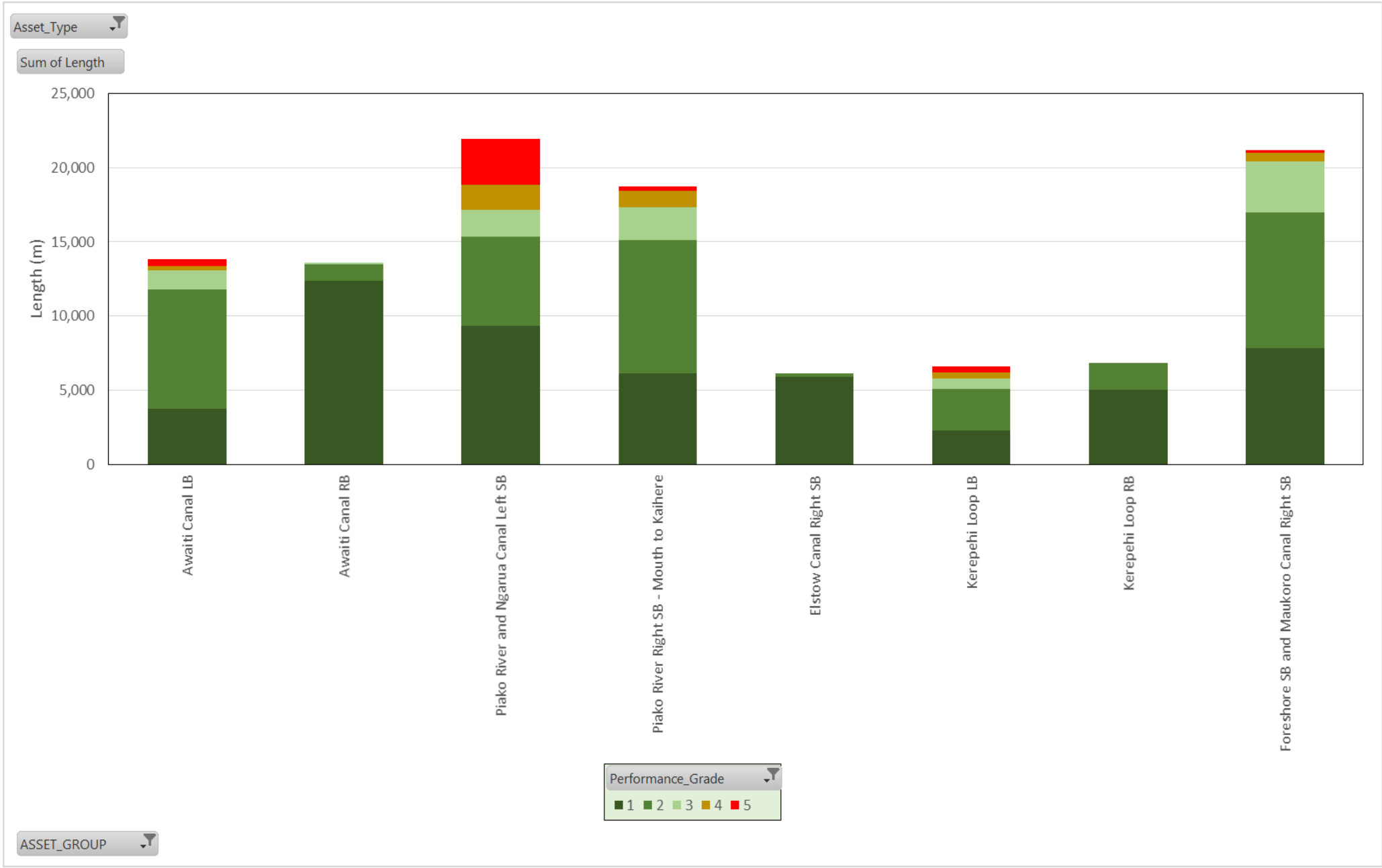

Figure 5: Summary of Performance for Tidal Zone Stopbanks

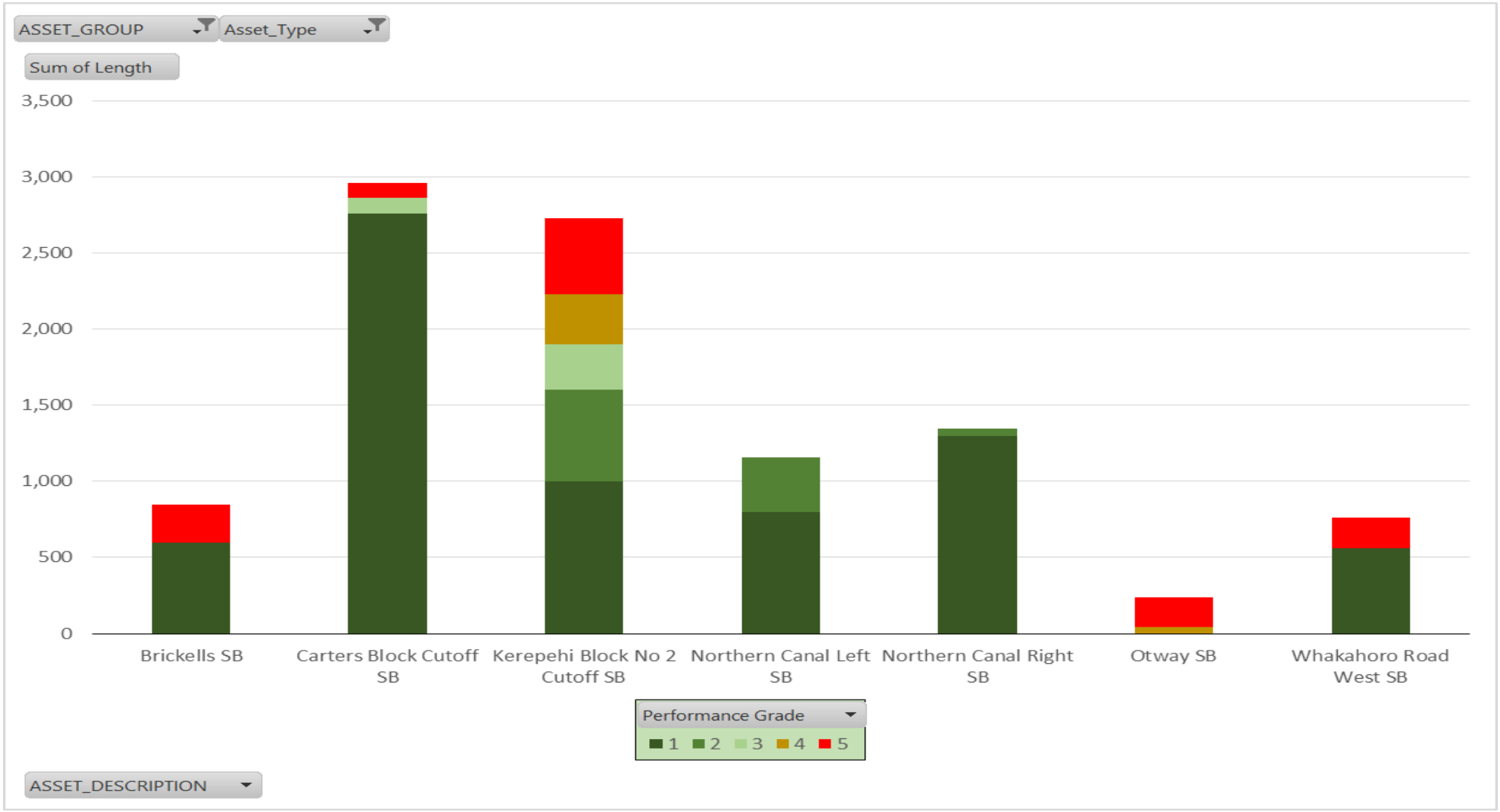

Figure 6: Summary of Performance for River Zone Stopbanks

9.4 Scheme Ponding Zones (Spillways)

The location of the main scheme ponding zones is shown in **Figure 7**. The events at which overtopping first occurred to each ponding zone have been assessed by Barnett and MacMurray (2010) from the design runs. This information together with the flows at which overtopping occurred in this and larger events is shown for each ponding zone. This can vary from event to event, and in the lower river is also dependent on the tidal effect on water levels.

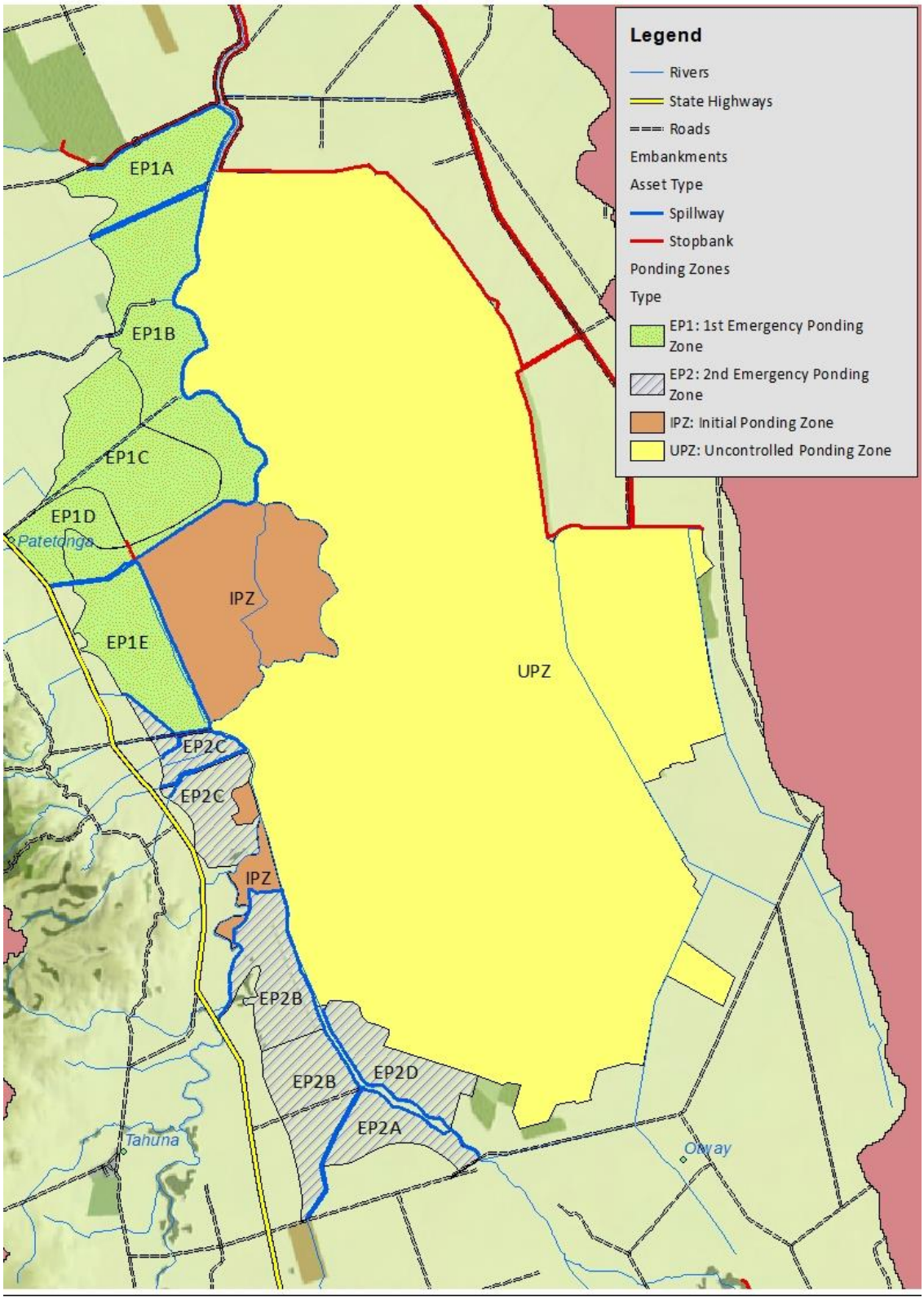

Figure 7: Piako River Scheme Ponding Zones

Table 8: Ponding Zone Overtopping Thresholds (After Barnett and MacMurray)

Zone	Ponding Zone	Overtopping Criteria	Overtopping Threshold Values	
			Current	Design
EP1	EP1A	Ngarua Canal Flow	$10m^3/s$	$59m^3/s$
	EP1B	Piako River Level [1]	3.04m	3.25m
	EP1C	Piako River Level [1]	3.10m	3.25m
EP2	EP2A	Waitoa River Flow [3]	$26m^3/s$	$96m^3/s$
	EP2B	Waitoa River Flow [3]	$26m^3/s$	$96m^3/s$
	EP2C	Piako River Level [2]	2.98m	3.49
	EP2D	Waitoa River Flow [3]	$50m^3/s$	$96m^3/s$

[1] Measured at Maukoro Landing
[2] Measured at Paeroa Tahuna Rd
[3]Measured at Mellon Rd

9.4.1 First Emergency Ponding Zone

The original scheme design provided for the first emergency ponding zone to overtop when flows in the river exceeded $142m^3/s$ (5,000 cusecs), which equated to approximately a 5-10 year return period event. It is therefore proposed that the design standard for the spillways of this zone be a 10 year event. Zero freeboard is proposed so that the banks overtop in greater than 10 year events and provide relief to the wider scheme.

The First Emergency Ponding Zone (1EP) overtopped during the July 2008 and the April 2017 flood events. These events had estimated recurrence intervals of 10 years and 20 years respectively.

The current performance of the first emergency ponding zone spillways, in terms of spillway activation are shown in **Table 9**

Table 9: Performance of First Emergency Ponding Zone Spillways

Asset Group	**Asset Description**	**Performance Grade**	
		Activation	**Capacity**
EP1A	Central Drain left bank	3	3
	Central Drain right bank	5	3
EP1A/B/C/D: Kaihere to Waikaka Canal	Ngarua Canal Right SB	5	1
	Kaihere to Central Left SB	2	4
	Central to Waikaka Left SB	5	1
	Waikaka Canal Left SB	5	3
EP1E Waikaka to Carters Outlet	Carters Outlet left Stopbank	1	5
	Waikaka Canal Right SB	1	5
	Maukoro Line SB	1	4
	Maukoro Landing Road Left SB	1	5

Notes

1. A poor activation performance grade for a spillway (i.e. grades 4 or 5) indicates that the spillway operates more frequently than designed for.

2. A poor capacity performance grade for a spillway (i.e. grades 4 or 5) indicates that the spillway capacity is significantly less than design.

9.4.2 Second Emergency Ponding Zone

The original design standard for the second emergency ponding areas was established as being a 10-20 year event. For this ponding area the model predicted overflows during the 2008 reasonably well, or was slightly conservative in predicting them to occur at lower levels. The modelled overtopping events for these areas range from a 10 year event to a 50 year event, and it is proposed that a uniform standard of a 20 year event be adopted for the whole of the 2nd emergency ponding zone. Again, zero freeboard is proposed so that the banks overtop in greater than 20 year events and provide relief to the wider scheme.

The current performance of the 2nd emergency ponding zone spillways, in terms of spillway activation are shown in **Table 10**

Table 10: Performance of Second Emergency Ponding Zone Spillways

Asset Group	Asset Description	Performance Grade	
		Activation	Capacity
EP2A: Whakahoro Canal RB to Chatfield Cookson	Whakahoro Canal Right SB	5	1
	Chatfield Cookson SB	5	1
EP2B: Waitoa at SH 27 to Whakahoro Canal LB	Boardmans to West Road Right SB	5	1
	Boardmans SB	5	1
	Boardmans SB (Waitoa)	5	1
	Clarke Left SB	5	1
	Whakahoro Canal Left SB	5	1
EP2C: Hart Rd Stream RB	Hart Road Stream Right SB	5	3
EP2C: Ohinekaua Stream RB to Hart Rd Stream LB	Ohinekaua Stream Right SB	5	1
	Pouruiri Stream Right SB	5	1
	Maukoro Landing to Hart Road Left SB	5	1
	Hart Road Stream Left SB	4	1
EP2C: Pouriri Stream RB to Ohinekaua Stream LB	Ohinekaua Stream Left SB	5	3
EP2D: Clarke and Russell RB	Clarke Right SB	5	1
	Russell SB	5	1

Notes

1. A poor activation performance grade for a spillway (i.e. grade 4 or 5) indicates that the spillway operates more frequently than designed for.

2. A poor capacity performance grade for a spillway (i.e. grades 4 or 5) indicates that the spillway capacity is significantly less than design.

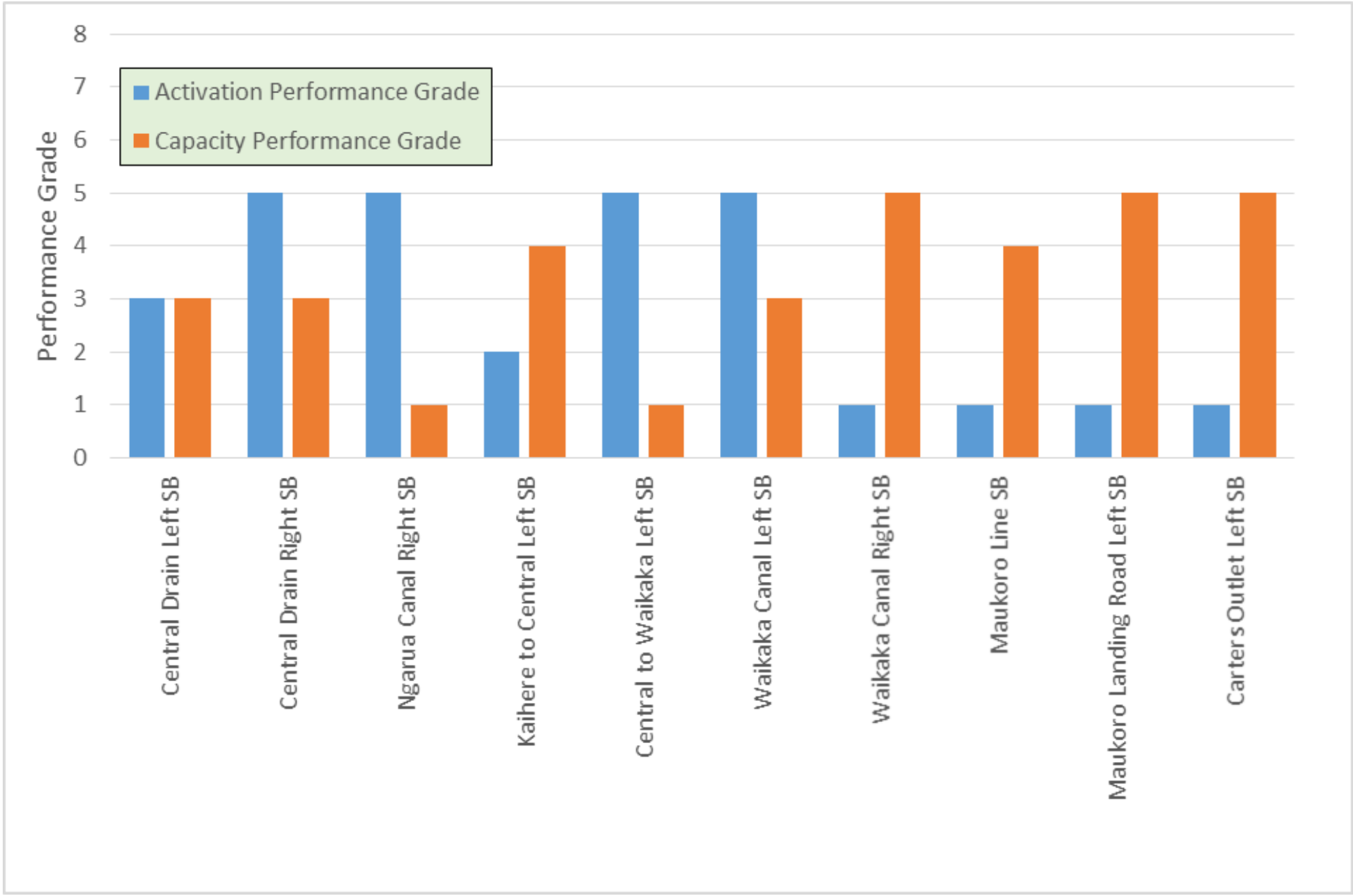

Figure 8: 1st Emergency Ponding Zone Performance

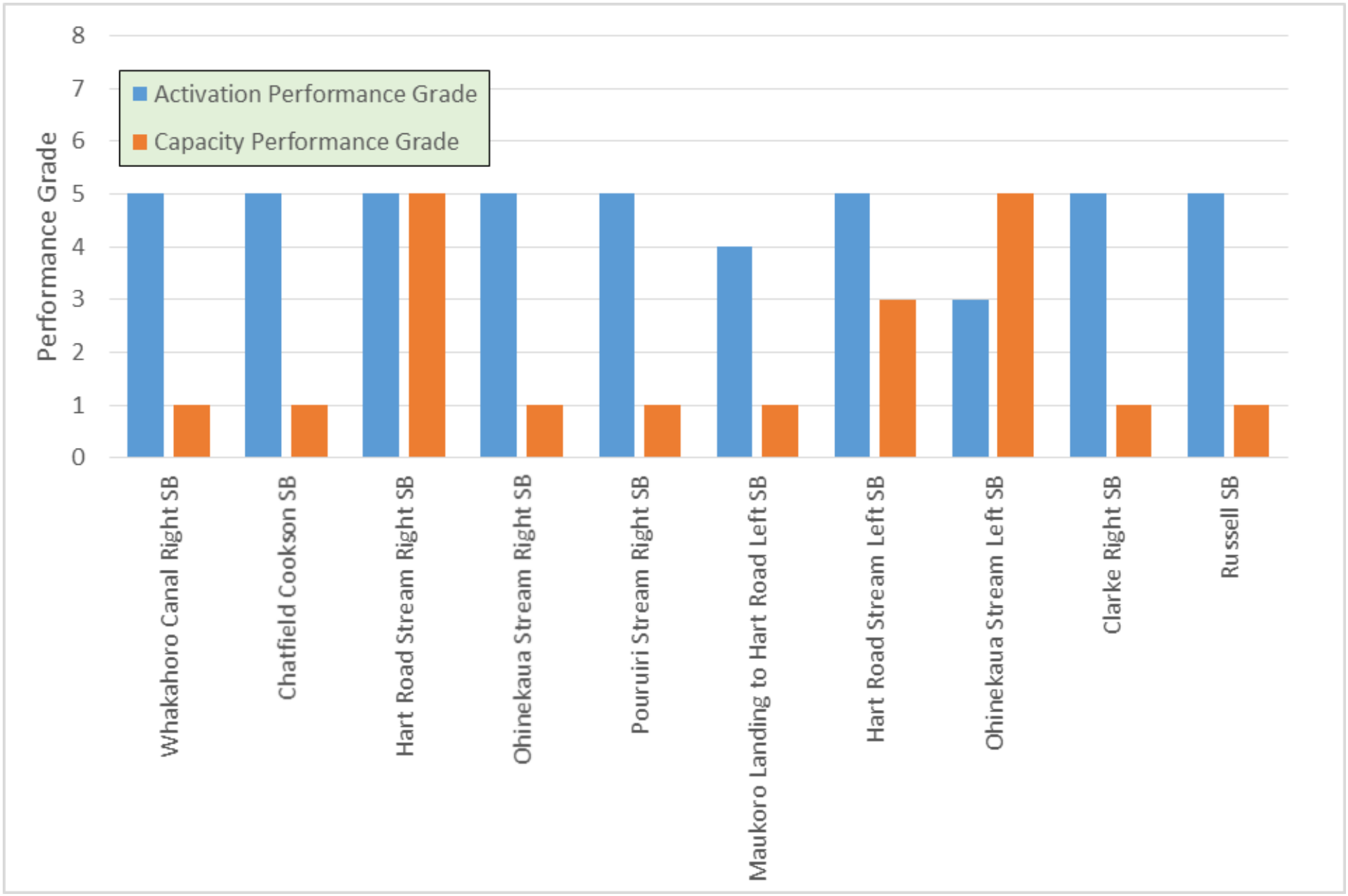

Figure 9: 2nd Emergency Ponding Zone Performance

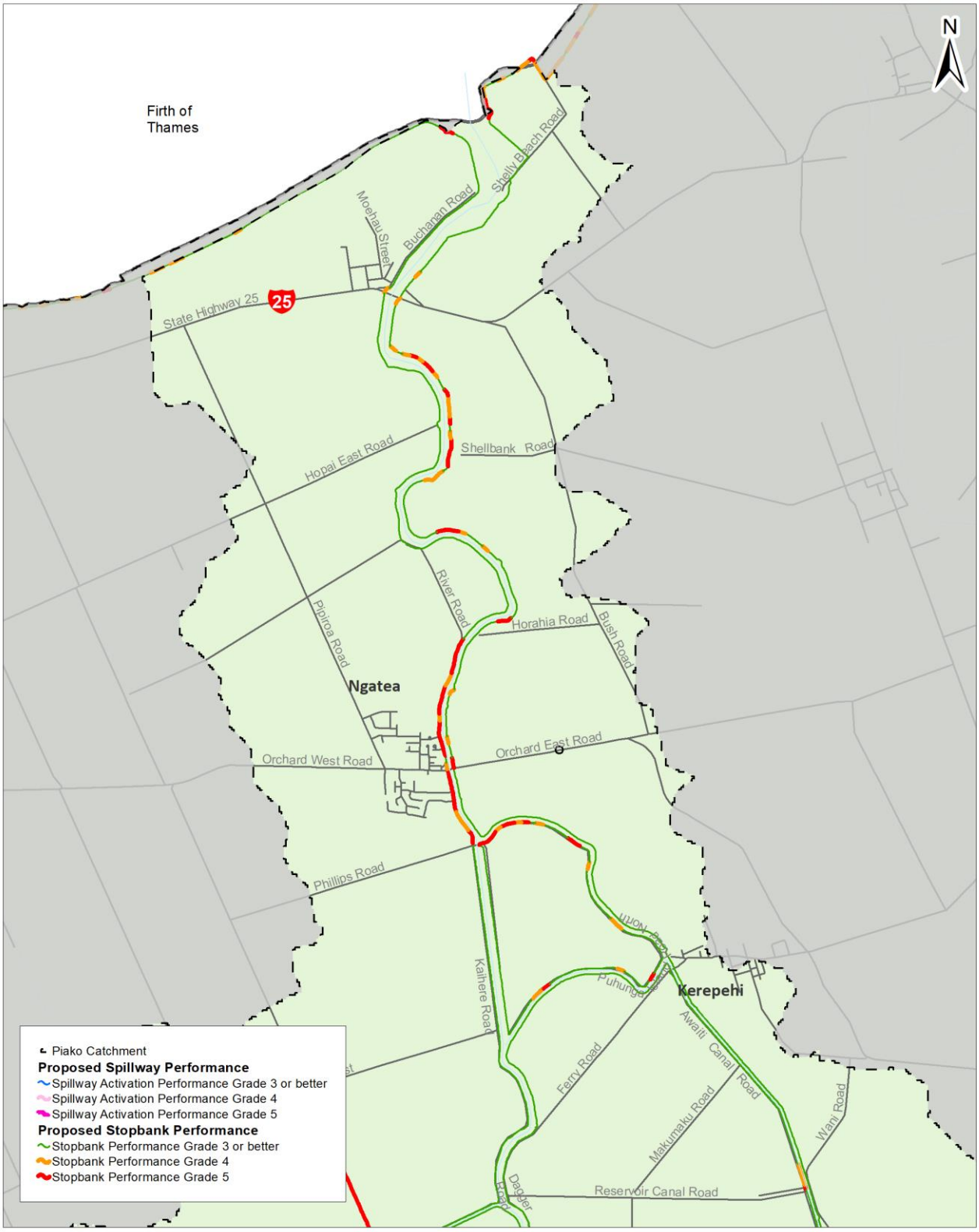

Figure 10: Stopbank Performance - Firth of Thames to Kaihere

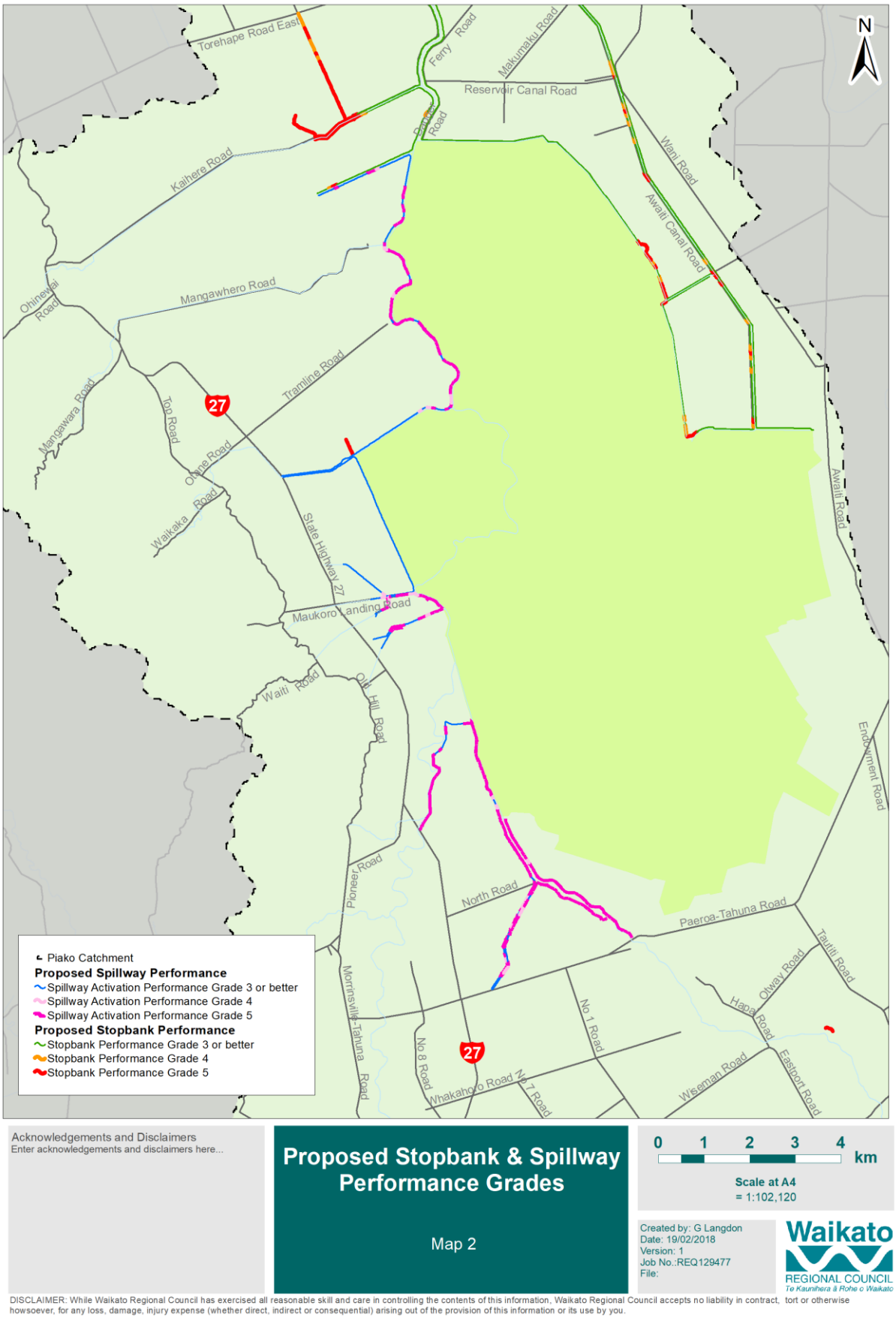

Figure 11: Stopbank and Spillway Performance - Kaihere to Paeroa Tahuna Rd

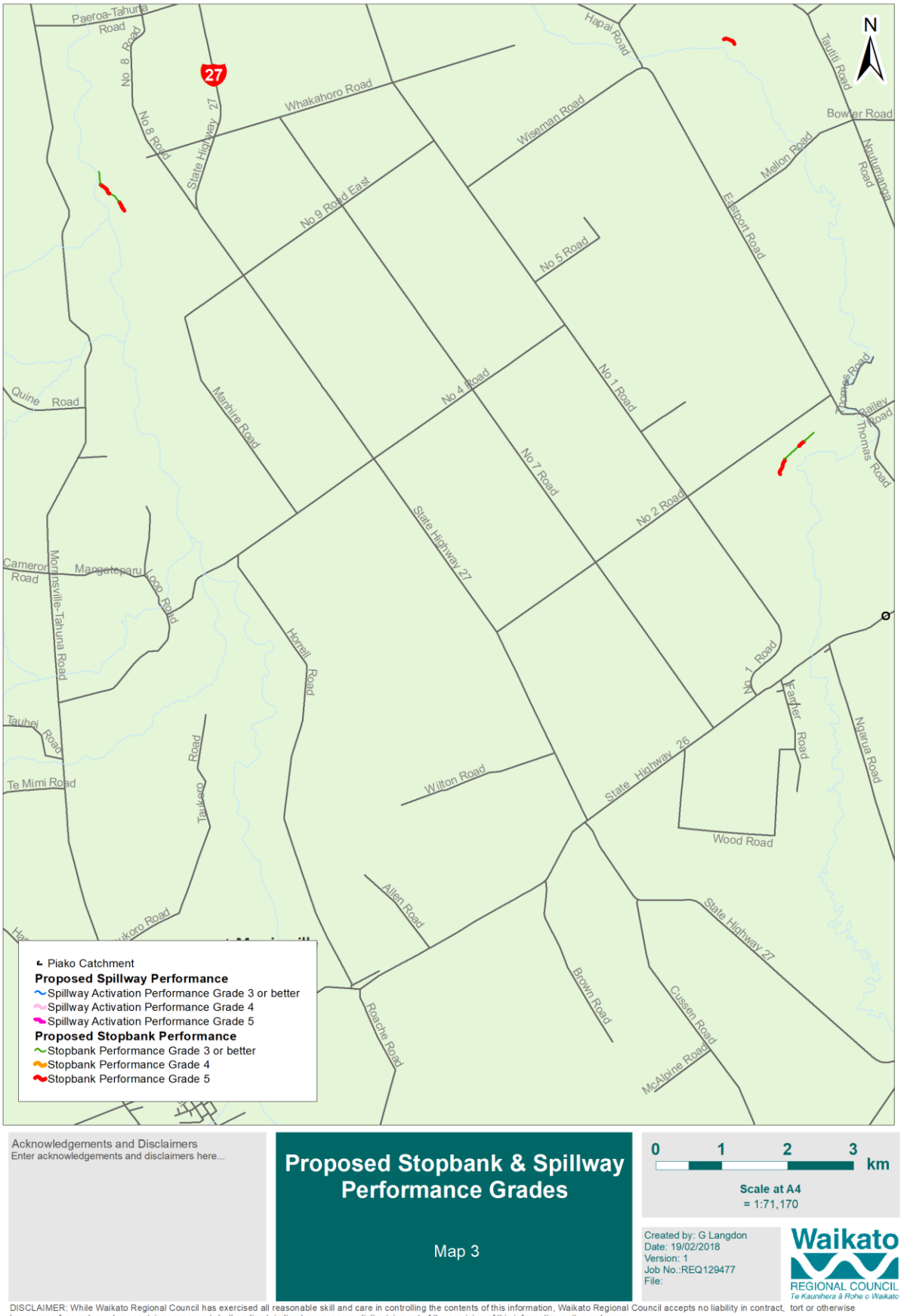

Figure 12: Stopbank and Spillway Performance –Paeroa Tahuna Rd to Waitoa

10 Conclusions

Tidal zone stopbanks

Performance of the Piako River Scheme main tidal zone stopbanks is generally acceptable under the current climate scenario, although 9% (9.7km) are currently graded as being 4 or 5. These elements require topping up.

In general adequate capacity is available for the Awaiti Canal stopbanks to provide protection against a 3m 100 year ARI high tide event with 0.5m freeboard, except for a 0.78km section on the left bank.

River zone stopbanks

The River Zone stopbanks currently have 1.6km (16%) graded as being 4 or 5. The Kerepehi Block No 2 Cutoff stopbank is the highest priority as it overtopped for a significant period during the April 2017 flood event.

Spillways

In general the ponding zone spillways need to be raised at low points to prevent frequent overtopping. An exercise to prioritise spillway upgrades will be completed to provide a forward works programme.

Levels of Service

The proposed revised levels of service/design standards for the scheme main stopbanks are as shown in **Table 7**

The climate change scenario results in a significant increase in the lengths of stopbank which fail to meet a performance grade of 4 or 5. This is due to the effect of increases in tide levels in the lower reaches, and to the effect of increased discharges in the upper and middle catchments.

Next steps

- Investigation of frequent ponding issues for the Bancroft/Elstow area
- Return of water ponded in the ponding zones to the river
- Management issues in regard to the ABCD flax block
- Investigation into the effects on scheme of western catchment streams
- Review of pump station and floodgate invert levels

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Appendices

Appendix 1: Scheme Review Process Schematic

Appendix 2: Data Inputs

Appendix 3: Hydraulic and Hydrological Modelling

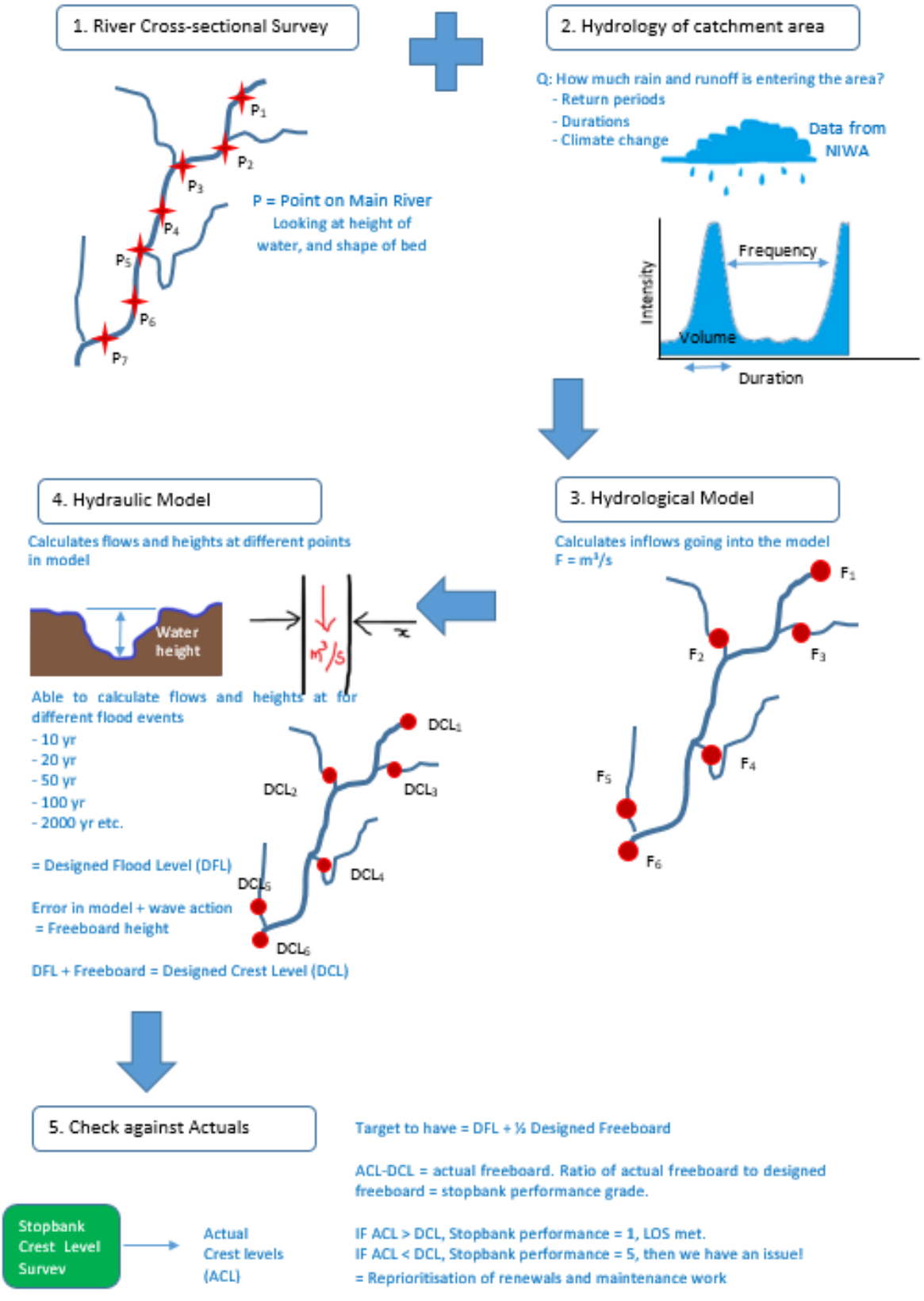
Appendix 4: Performance Grade Results

Appendix 5: Piako River and Waitoa River Longitudinal Sections

Appendix 6: Stopbank and Spillway Longitudinal Sections

Appendix 1: Scheme Review Process Schematic

High level process followed to do a review of stopbank and spillway service levels



Appendix 2: Data Inputs

The service level review is dependent on a range of data inputs as outlined in the following sections.

Stopbank Crest Levels

The source of stopbank crest level data used in the performance assessment is shown in **Table 11**. The LiDAR survey was flown in 2015.

Table 11: Stopbank Crest Level Surveys

Asset ID	ASSET DESCRIPTION	Survey ID
25218	Awaiti Canal Right SB	LiDAR
23774	Awaiti: Ferry Road to Reservoir Canal Road SB	LiDAR
41290	Awaiti: Reservoir Canal Road to Tee Head SB	LiDAR
23050	Boardmans SB	LiDAR
26720	Boardmans SB (Waitoa)	LiDAR
25220	Boardmans to West Road Right SB	LiDAR
24476	Brickells SB	2003
25968	Carters Block Cutoff SB	2009
27872	Carters Outlet Left SB	2011
23775	Central Drain Left SB	2011
33377	Central Drain Right SB	2011
34489	Central to Waikaka Left SB	2011
34489	Central to Waikaka Left SB	LiDAR
27474	Chatfield Cookson SB	LiDAR
25223	Clarke Left SB	LiDAR
25975	Clarke Right SB	LiDAR
23048	East Foreshore SB	LiDAR
25969	Elstow Canal Right SB	2009
41151	Ferry Rd Bridge to Kaihere LB SB	LiDAR
25971	Hart Road Stream Left SB	2003
23458	Hart Road Stream Right SB	2003
27472	Kaihere to Central Left SB	LiDAR
26717	Kaihere to Elstow Right SB	LiDAR
28545	Kerepehi Block No 2 Cutoff SB	2009
23778	Kerepehi Loop Left SB	LiDAR
23779	Kerepehi Loop North Right SB	LiDAR
33394	Kerepehi Loop South Right SB	LiDAR
46582	Maukoro Canal Right SB	2012
23049	Maukoro Landing Road Left SB	2011
25972	Maukoro Landing to Hart Road Left SB	LiDAR
26716	Maukoro Line SB	2011
25973	Mouth to Pipiroa Left SB	LiDAR
23777	Mouth to Pipiroa Right SB	LiDAR
25974	Ngarua Canal Left SB	2006
33375	Ngarua Canal Right SB	2006
26719	Ngatea to Puhunga Canal Bridge LB SB	LiDAR
27473	Ngatea to Puhunga Right SB	LiDAR

Asset ID	ASSET DESCRIPTION	Survey ID
34487	Northern Canal Left SB	2009
24473	Northern Canal Right SB	2009
25631	Ohinekaua Stream Left SB	2003
25219	Ohinekaua Stream Right SB	2003
28164	Otway SB	2003
28164	Otway SB	2013
28164	Otway SB	LiDAR
23780	Pipiroa to Ngatea Left SB	2011
23780	Pipiroa to Ngatea Left SB	LiDAR
25222	Pipiroa to Ngatea Right SB	LiDAR
27858	Pouruiri Stream Right SB	2003
28163	Puhunga to Kaihere Right SB	LiDAR
41152	Puhunga Canal Bridge to Ferry Rd Bridge LB SB	LiDAR
24475	Puhunga Canal Right SB	LiDAR
24477	Russell SB	LiDAR
25970	Tee Head East SB	2009
23047	Tee Head West SB	2009
26718	Waikaka Canal Left SB	LiDAR
33379	Waikaka Canal Right SB	2011
23481	Waikaka North Wingbank SB	2011
25221	Waikoura Left SB	2006
24474	West Foreshore SB	LiDAR
25976	Whakahoro Canal Left SB	2003
24879	Whakahoro Canal Right SB	2003
23776	Whakahoro Road West SB	2003

River Channel Cross Sections

The sources of cross section data used to construct the hydraulic model are shown in **Table 12**.

Table 12: River Cross Section Data Used in the Hydraulic Model

River/Stream	Count of Cross Sections						
	Survey						Total
	2013	2014	2015	2016	2017	LIDAR 2007/2008	
Awaiti Canal				32			32
Carters Block Cutoff			37				37
Carters Outlet		17					17
Central Drain			7				7
Elstow Canal (North)		40				2	42
Elstow Canal (South)			5			9	14
Hart Road Stream			10				10
Kaihere Canal	18						18
Kerepehi Block No 2			29			2	31
Kerepehi Loop				8			8
Koromatua North						6	6
Koromatua South						5	5
Northern Canal			5				5

River/Stream	Count of Cross Sections						
	Survey						Total
	2013	2014	2015	2016	2017	LIDAR 2007/2008	
Ohinekaua Stream			4				4
Otway Drain						12	12
Piako River				73	13		86
Pouriri Stream		6	2				8
Tee Head Canal East			3				3
Tee Head Canal West			5				5
Tributary of Hart Rd Strm			1				1
Waikaka Canal			4	7			11
Waitoa River				21	20		41
Whakahoro Canal			11			3	14
Total	18	63	123	141	33	39	417

Hydrological Data

Hydrological data (**Table 13**) from a number of water level recorder and rainfall recorder sites within and around the Piako River Catchment were used for the purpose of model calibration.

Table 13: Hydrological Data Used in the project

River	Site	Measurement	Use
Piako River	Kiwitahi	Flow, Level	Rainfall Runoff Model Calibration
	Paeroa Tahuna Rd	Flow, Level	Rainfall Runoff Model and Overall Calibration
	Maukoro Landing	Water Level, Rainfall	Overall Calibration
Waitoa River	Whaharoa Control	Flow, Level	Rainfall Runoff Model Calibration
	Mellon Rd	Flow, Level	Rainfall Runoff Model and Overall Calibration
Carters Block Cutoff	Carters Block Weir	Flow, Level	Peat Dome Rainfall Runoff Model Calibration
Rain Gauges	Tamihana	Rainfall	Rainfall Runoff Model Calibration
	Te Aroha	Rainfall	Rainfall Runoff Model Calibration
	Pokaiwhenua	Rainfall	Rainfall Runoff Model Calibration

Design rainfalls for the catchment were sourced from the HIRDS high intensity rainfall estimation website operated by NIWA. This provides rainfall as a function of duration and return period for sites in terms of geographic coordinates.

Frequency Analyses has been performed on historical flood data as a means of calibrating and validating the hydraulic model, and in the case of Thames Tide, has been used to confirm appropriate design tidal levels for the scheme.

A summary of the frequency analyses which have been performed is shown in **Table 14**.

Table 14: Summary of Frequency Analyses

		Peak Flows (m^3/s)				Peak Water Levels (m)	
		Waitoa at Waharoa Control	Waitoa at Mellon Rd	Piako at Kiwitahi	Piako at PT Rd	Piako at Maukoro Landing	Thames Tide +/- 95% Confidence Interval
Catchment Area (km2)		409.7	122.5	108.2	537.1	1131.7	N/A
N (Years)		34	62	38	66	65	49
ARI	2	21.3	32.0	30.9	82.4	2.620	2.162 ± 0.035
	5	32.3	49.8	50.4	131.5	2.931	2.308 ± 0.063
	10	39.6	65.0	65.1	172.0	3.137	2.405 ± 0.085
	20	46.6	82.9	80.7	218.2	3.335	2.498 ± 0.107
	50	55.6	112.1	103.4	291.0	3.591	2.618 ± 0.136
	100	62.4	139.4	122.3	357.0	3.783	2.708 ± 0.158
	200	69.1	172.4	143.1	434.5	3.974	2.798 ± 0.180
	500	78.0	226.8	173.7	558.3	4.226	2.917 ± 0.210

Note: Annual Maxima series have been extended by correlation with nearby gauges where appropriate.

The estimated 100 year tide level for the Thames tide site is 2.708m. The analysis does not however include the largest tide recorded of 2.85m – 3.00m recorded in 1938. The 95% confidence evel upper limit for the 100 year level is 2.867. It is therefore deemed prudent to adopt 3.00m as the 100 year tide level for design purposes for the Gulf of Thames.

Appendix 3: Hydraulic and Hydrological Modelling

Location	Distance (m)	Discharges (m^3/s)			
		Current Climate			Future Climate (2090)
		10 Year	20 Year	50 Year	50 Year
Piako at Paeroa Tahuna Rd	49,545	203	282	371	
Piako at Maukoro Landing	35,600	159	199	373	
Piako at Kaihere	19,245	169	178	220	
Piako at Ngatea	12,735	206	222	241	
Waitoa at Paeroa Tahuna Rd	7,773	76	104	141	
Waitoa at Piako Confluence	0	54	63	70	
Awaiti at Tee Head	12,369	6	7	8	
Kerepehi Loop	0	11	13	15	

Appendix 4: Performance Grade Results

Table 15: Performance for Tidal Zone Stopbanks

ASSET GROUP	ASSET DESCRIPTION	Sum of Length (m)					
		Performance Grade					Total
		1	2	3	4	5	
Awaiti Canal LB	Awaiti: Ferry Road to Reservoir Canal Road SB	2,175	1,200	200	100	100	3,775
	Awaiti: Reservoir Canal Road to Tee Head SB	1,100	6,200	900	200	100	8,500
	Tee Head West SB	500	600	200	0	240	1,540
Awaiti Canal RB	Awaiti Canal Right SB	11,193	1,100	100			12,393
	Tee Head East SB	1,200					1,200
Piako River and Ngarua Canal Left SB	Mouth to Pipiroa Left SB	1,400	1,500			100	3,000
	Pipiroa to Ngatea Left SB	3,300	2,096	1,500	1,300	900	9,096
	Ngatea to Puhunga Canal Bridge LB SB	0	232	200	200	500	1,132
	Puhunga Canal Bridge to Ferry Rd Bridge LB SB	2,063	1,900	100			4,063
	Ferry Rd Bridge to Kaihere LB SB	1,174	100				1,274
	Ngarua Canal Left SB	1,400	200		200	792	2,592
	Waikoura Left SB					759	759
Piako River Right SB - Mouth to Kaihere	Mouth to Pipiroa Right SB	1,600	1,800	262		0	3,662
	Pipiroa to Ngatea Right SB	1,340	4,200	2,000	1,100	300	8,940
	Ngatea to Puhunga Right SB	1,000	90				1,090
	Puhunga Canal Right SB	791	1,900				2,691
	Puhanga to Kaihere Right SB	1,400	971				2,371
Elstow Canal Right SB	Kaihere to Elstow Right SB	1,329	200				1,529
	Elstow Canal Right SB	4,600					4,600
Kerepehi Loop LB	Kerepehi Loop Left SB	2,300	2,800	700	400	400	6,600
Kerepehi Loop RB	Kerepehi Loop North Right SB	2,426	1,400				3,826
	Kerepehi Loop South Right SB	2,619	400				3,019
Foreshore SB and Maukoro Canal Right SB	Maukoro Canal Right SB	4,600	900				5,500
	West Foreshore SB	2,300	6,800	1,800	300	0	11,200
	East Foreshore SB	903	1,500	1,600	300	200	4,503
Grand Total		52,712	38,089	9,562	4,100	4,391	108,854

Table 16: Performance for River Zone Stopbanks

ASSET GROUP	ASSET DESCRIPTION	Sum of Length (m)					
		Performance Grade					Total
		1	2	3	4	5	
Carters Block Cutoff/Northern Canal	Northern Canal Right SB	1,300	47				1,347
	Carters Block Cutoff SB	2,760		100		100	2,960
Kerepehi Block No 2/Northern Canal	Northern Canal Left SB	800	359				1,159
	Kerepehi Block No 2 Cutoff SB	1,000	600	300	328	500	2,728
Minor Stopbanks	Brickells SB	600				246	846
	Otway SB				40	200	240
	Whakahoro Road West SB	560				200	760
Grand Total		**7,020**	**1,006**	**400**	**368**	**1,246**	**10,040**

Table 17: Performance for 1st and 2nd Emergency Ponding Zone Spillways

ASSET GROUP	ASSET DESCRIPTION	Length (m)	Performance Grade	
			Activation	Capacity
EP1: 1st Emergency Ponding Zone	EP1A Central Drain	4,370	5	3
	EP1A/B/C/D: Kaihere to Waikaka Canal	15,685	5	2
	EP1E: Waikaka to Carters Outlet	6,678	1	5
EP2: 2nd Emergency Ponding Zone	EP2A: Whakahoro Canal RB to Chatfield Cookson's	4,431	5	1
	EP2B: Waitoa at SH 27 to Whakahoro Canal LB	9,768	5	1
	EP2C: Hart Rd Stream RB	714	5	3
	EP2C: Ohinekaua Stream LB to Hart Rd Stream	1,723	5	1
	EP2C: Ohinekaua Stream RB to Hart Rd Stream LB	1,922	5	1
	EP2C: Pouriri Stream RB to Ohinekaua Stream LB	892	3	3
	EP2D: Clarke and Russell RB	4,071	5	1

Appendix 5: Piako River and Waitoa River Longitudinal Sections

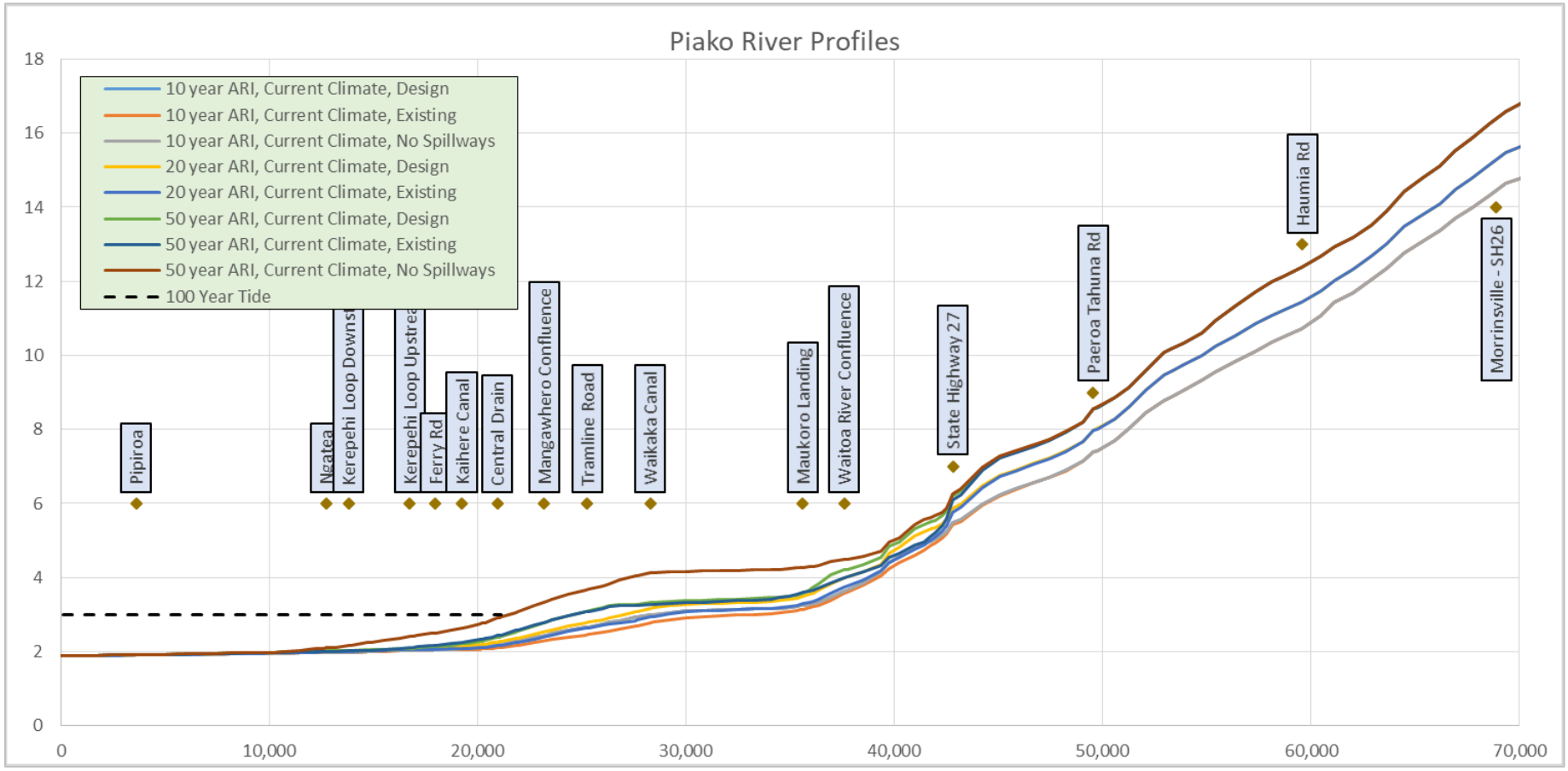


Figure 13: Piako River Water Level Profiles

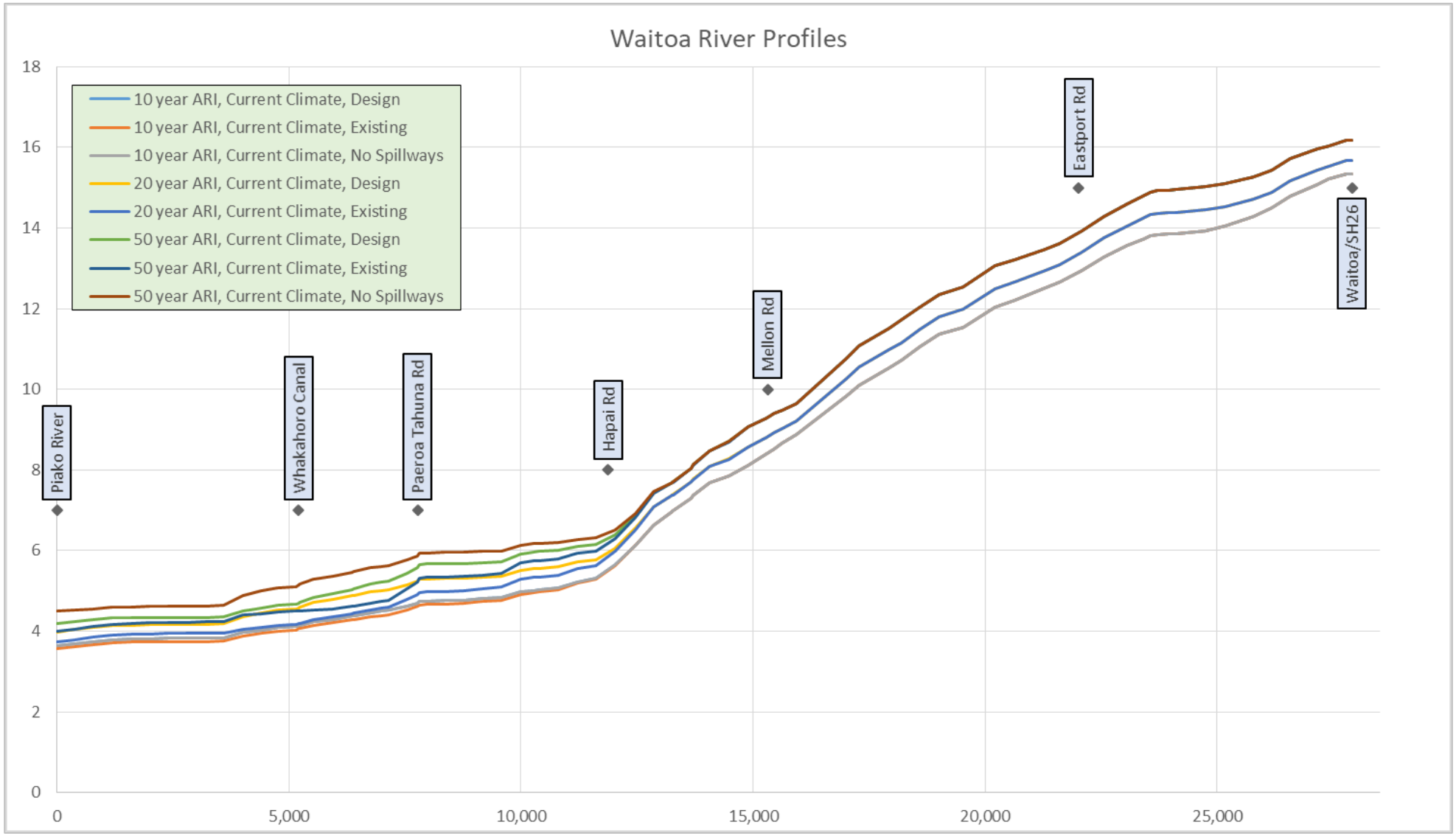


Figure 14: Waitoa River Water Level Profiles

Appendix 6: Stopbank and Spillway Longitudinal Sections

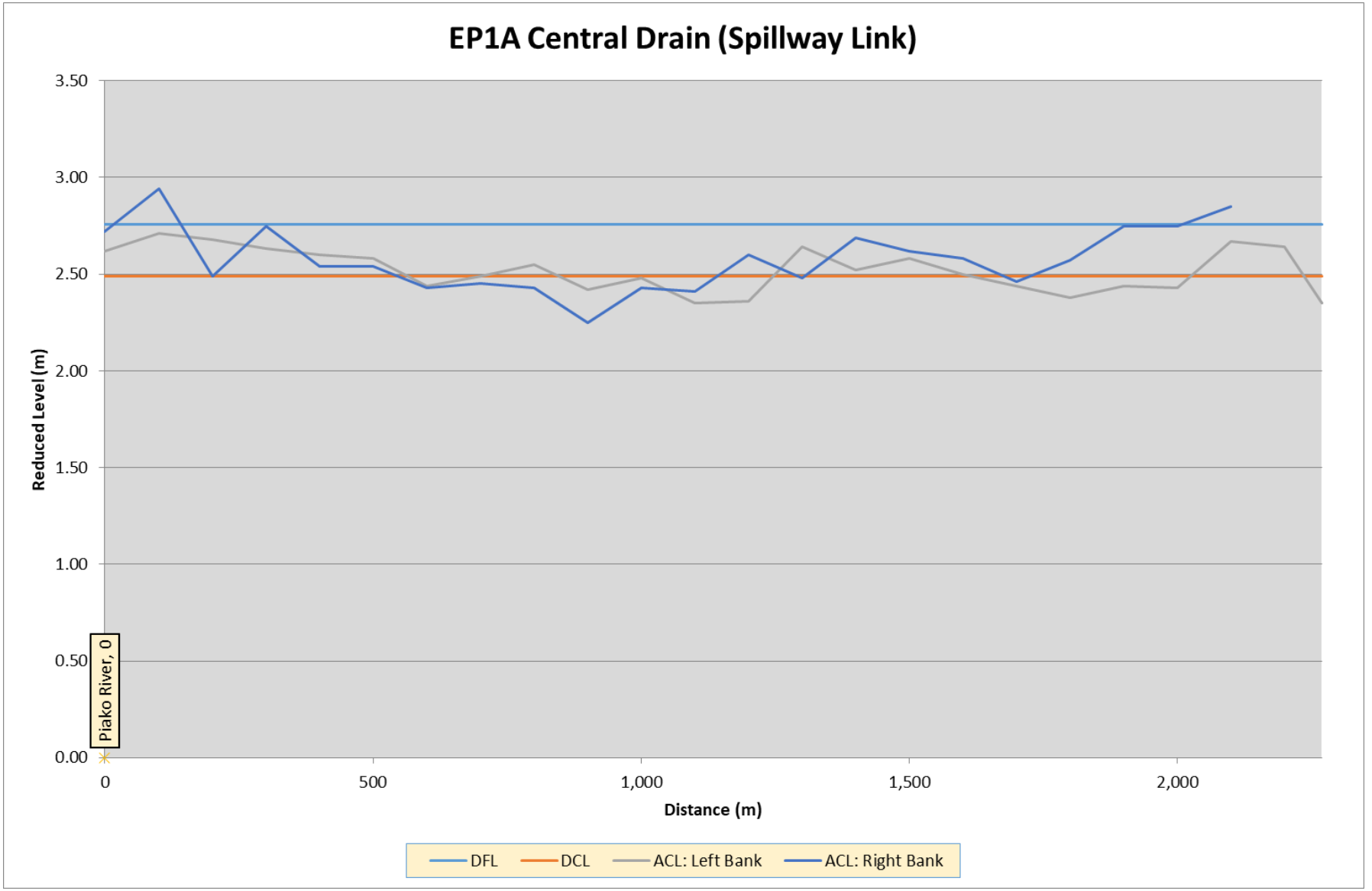


Figure 15: Central Drain stopbank profiles

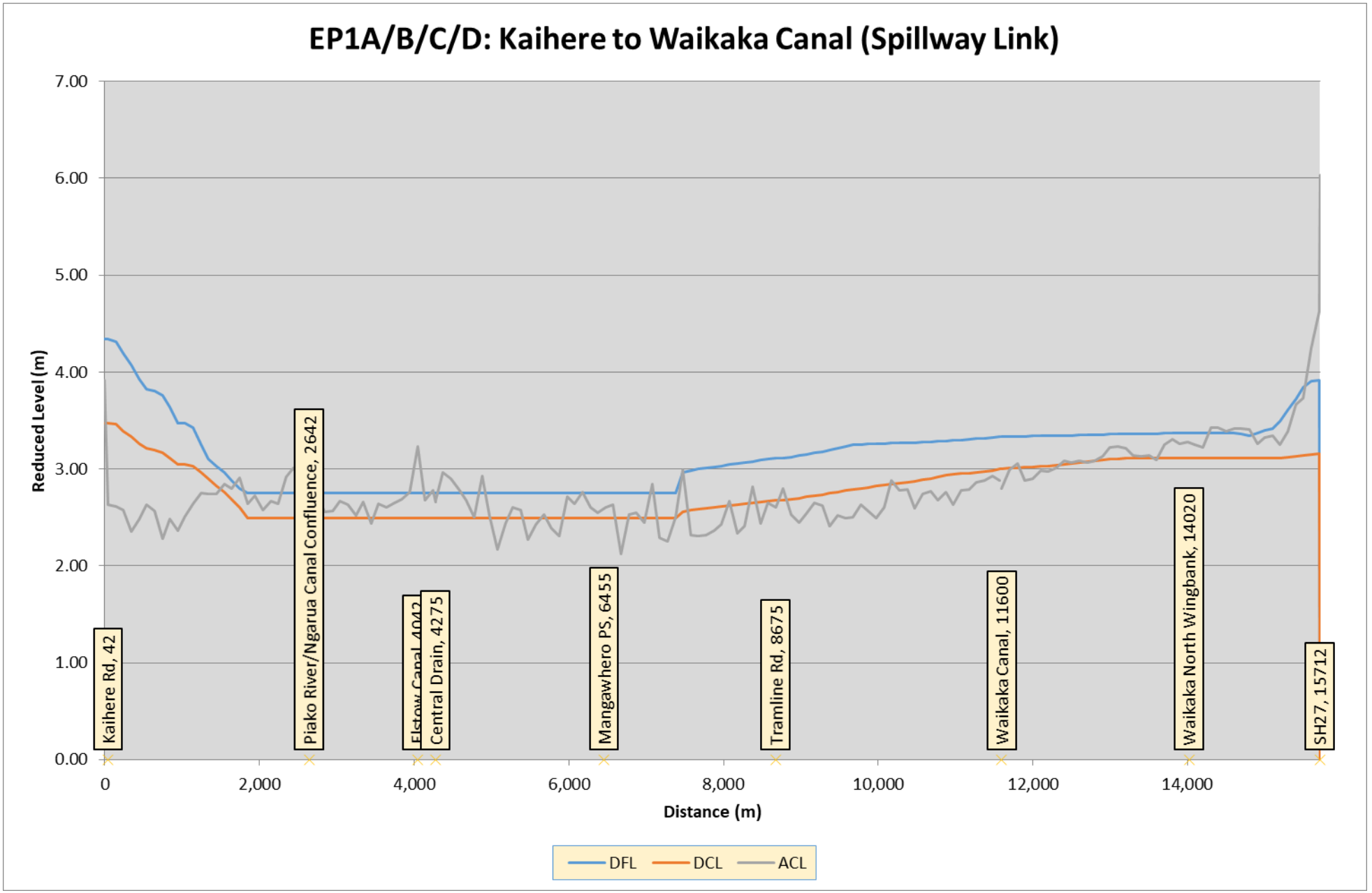


Figure 16: 1st Emergency Ponding Zone - Kaihere Rd to State Highway 27 stopbank profile

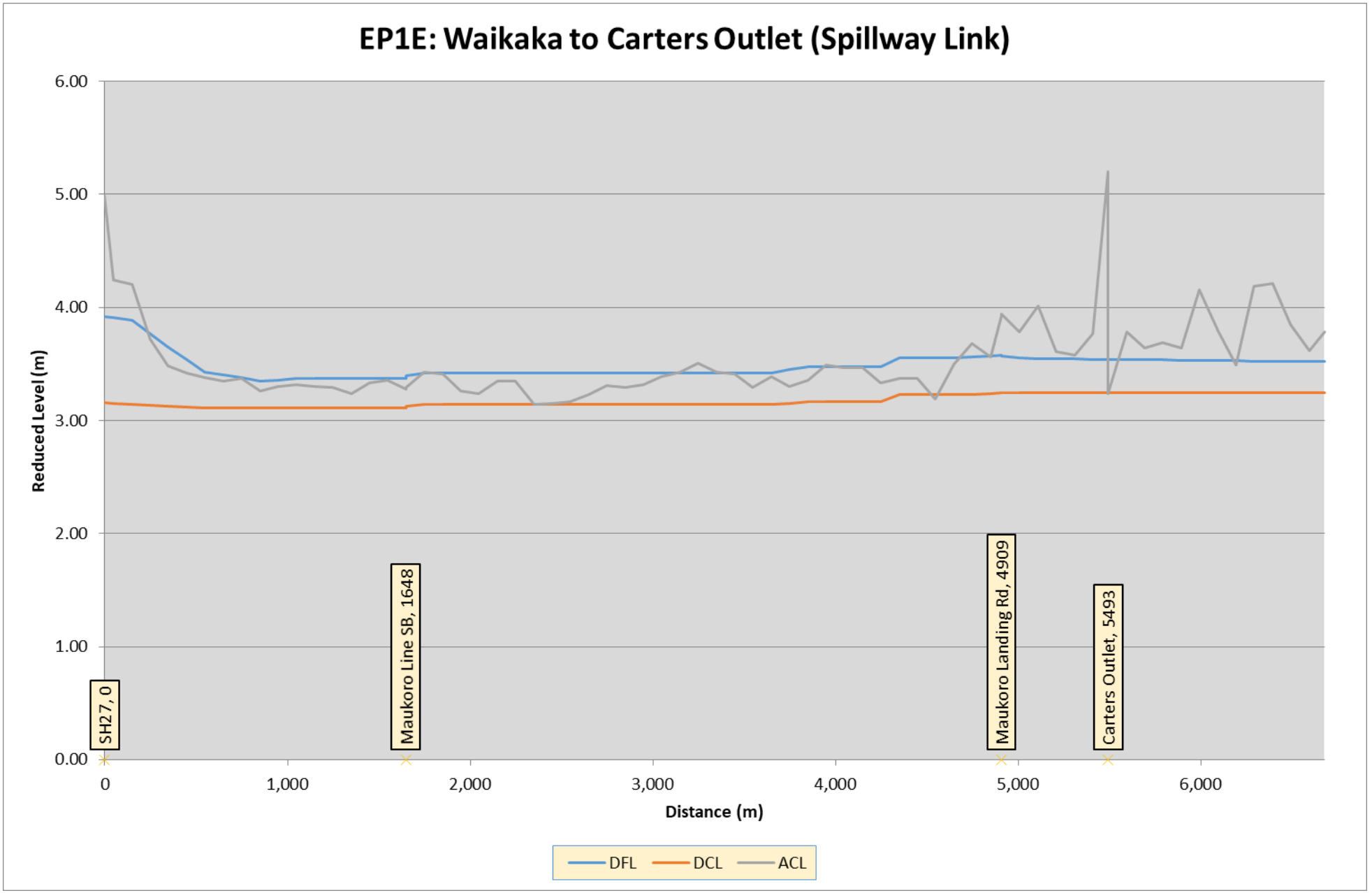


Figure 17: 1st Emergency Ponding Zone - State Highway 27 to Carters Outlet stopbank profile

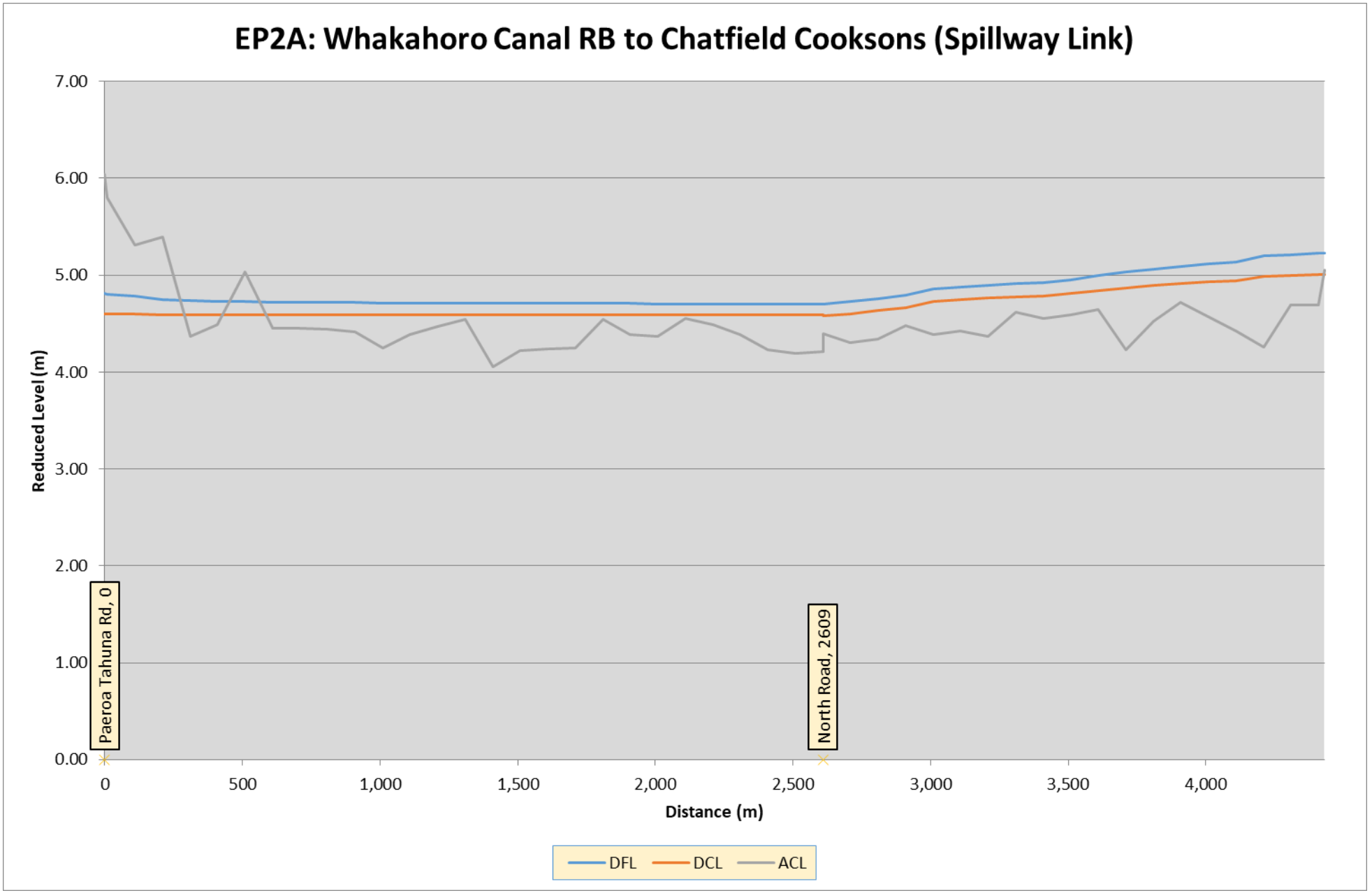


Figure 18: 2nd Emergency Ponding Zone - Paeroa Tahuna Rd to Chatfield Cooksons stopbank profile

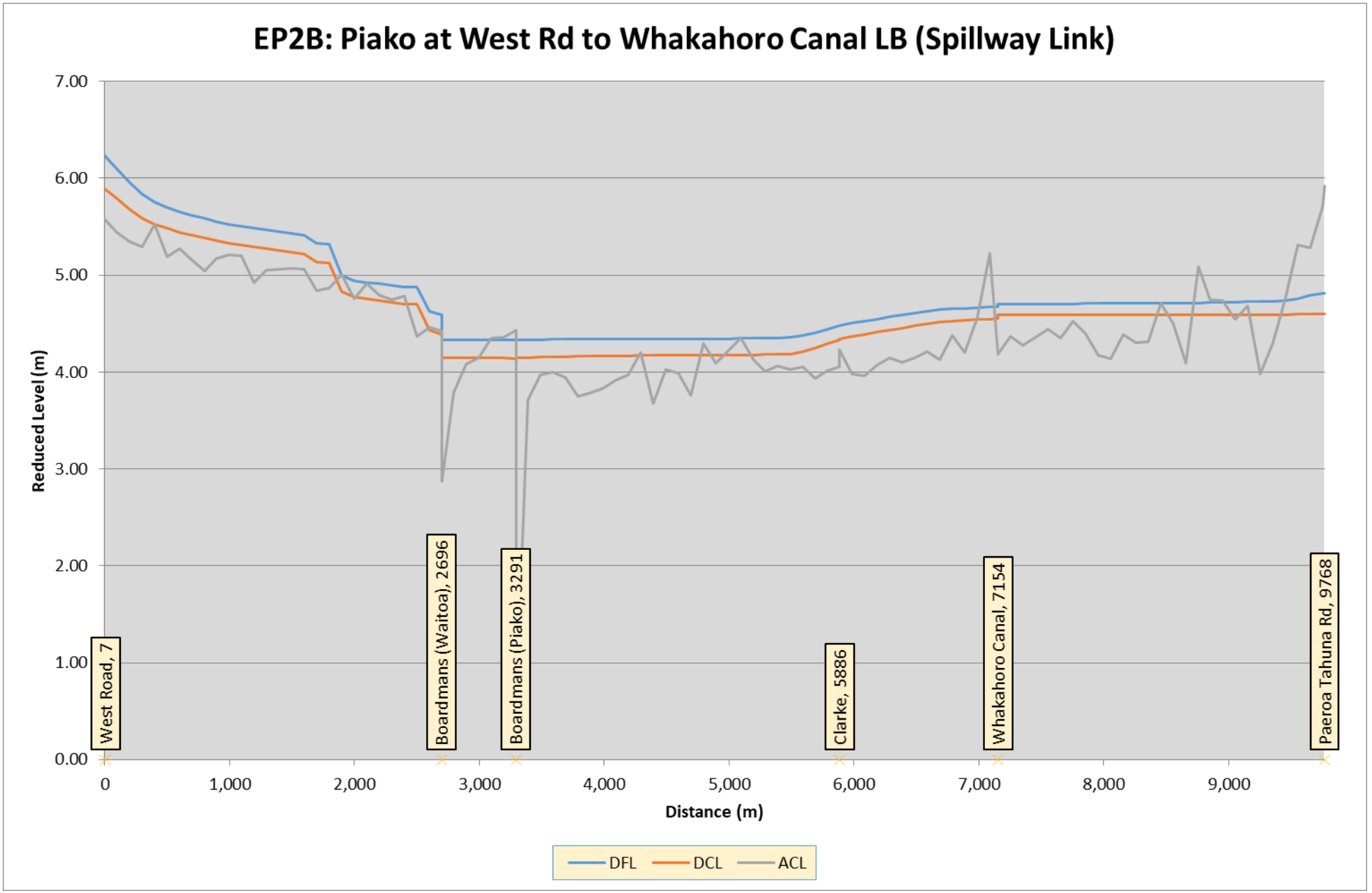


Figure 19: 2nd Emergency Ponding Zone - West Rd to Paeroa Tahuna Rd stopbank profile

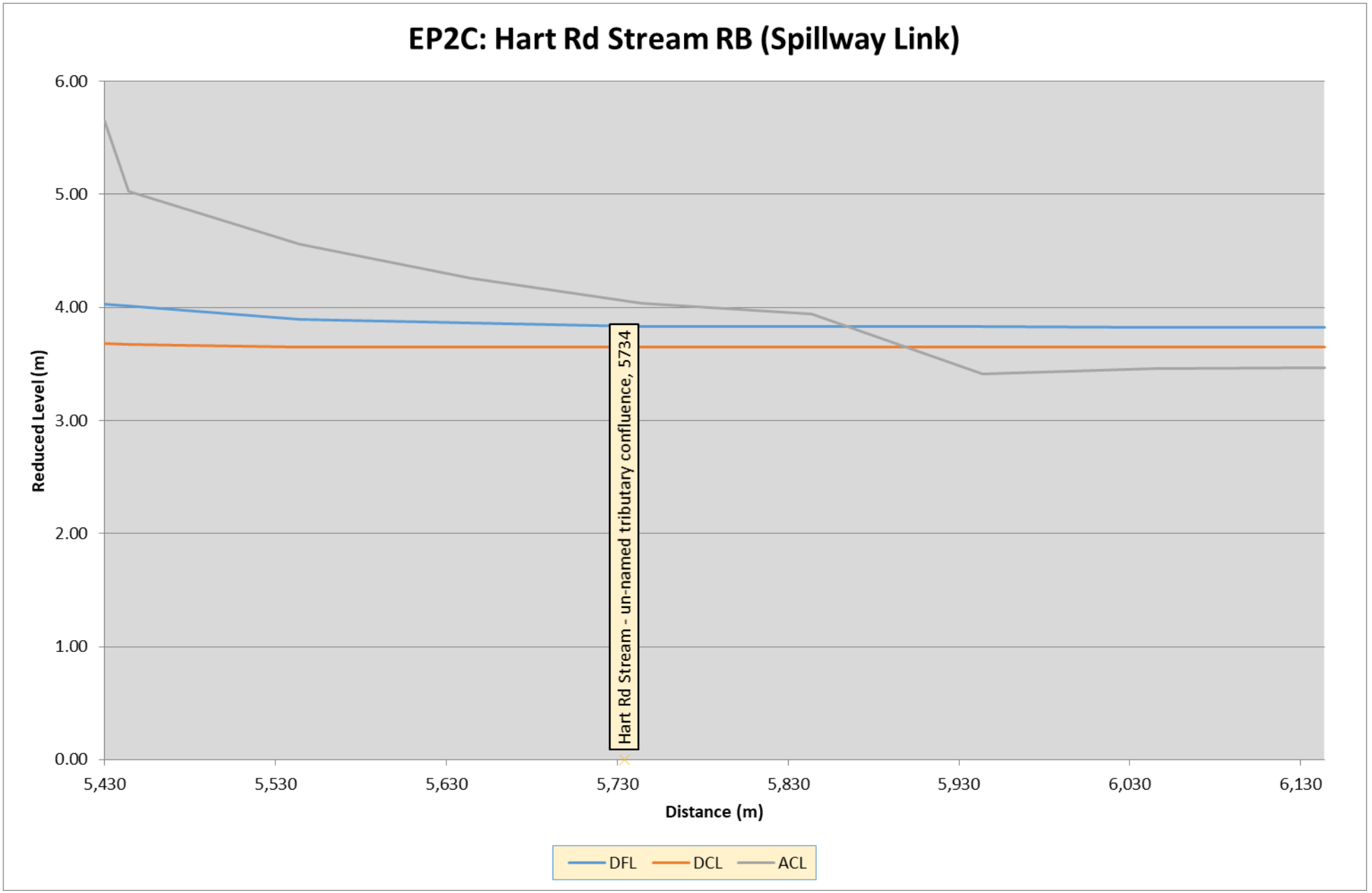


Figure 20: 2nd Emergency Ponding Zone - Hart Rd Stream right bank stopbank profile

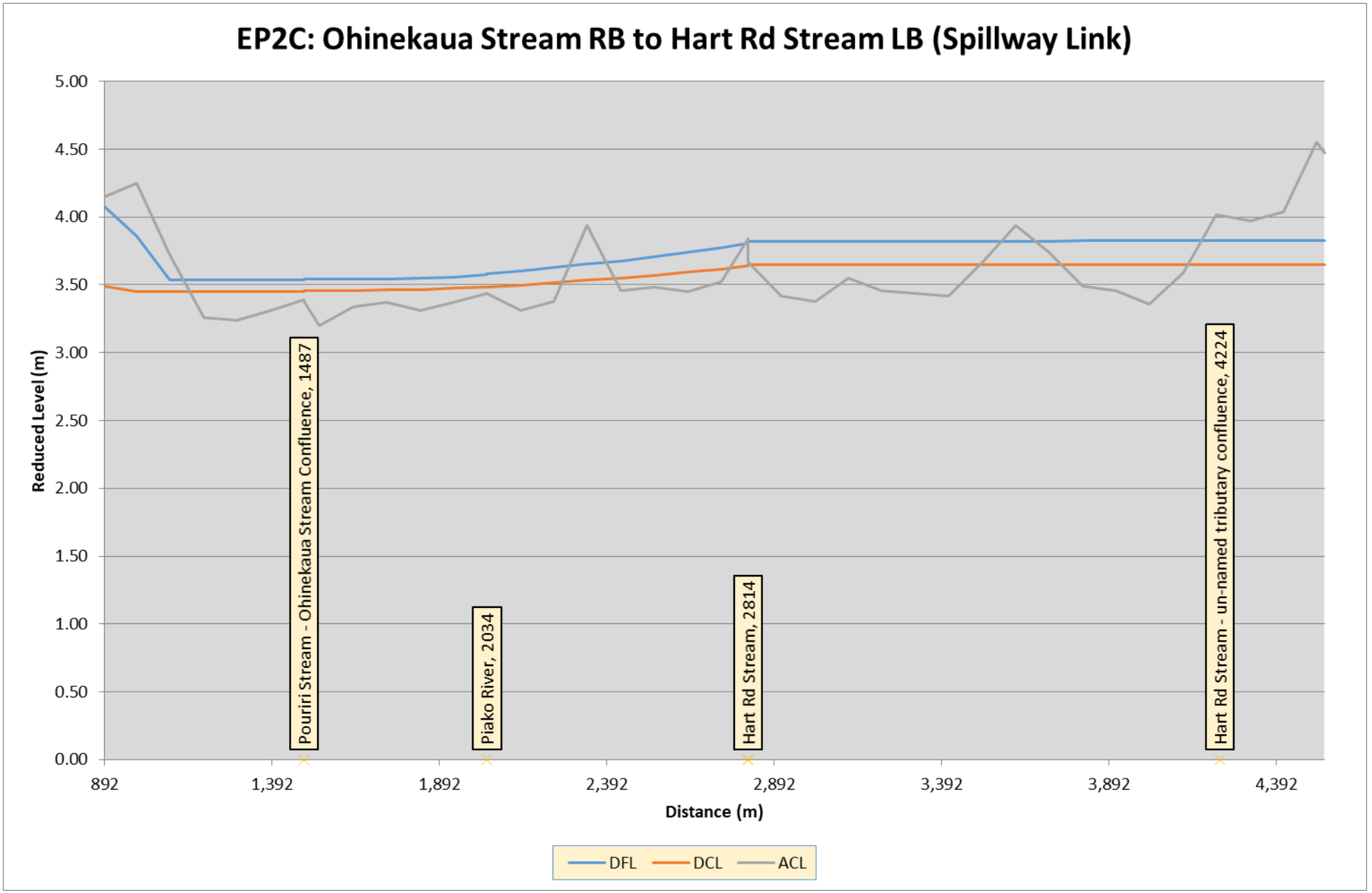


Figure 21: 2nd Emergency Ponding Zone - Ohinekaua Stream right bank to Hart Rd Stream left bank stopbank profile

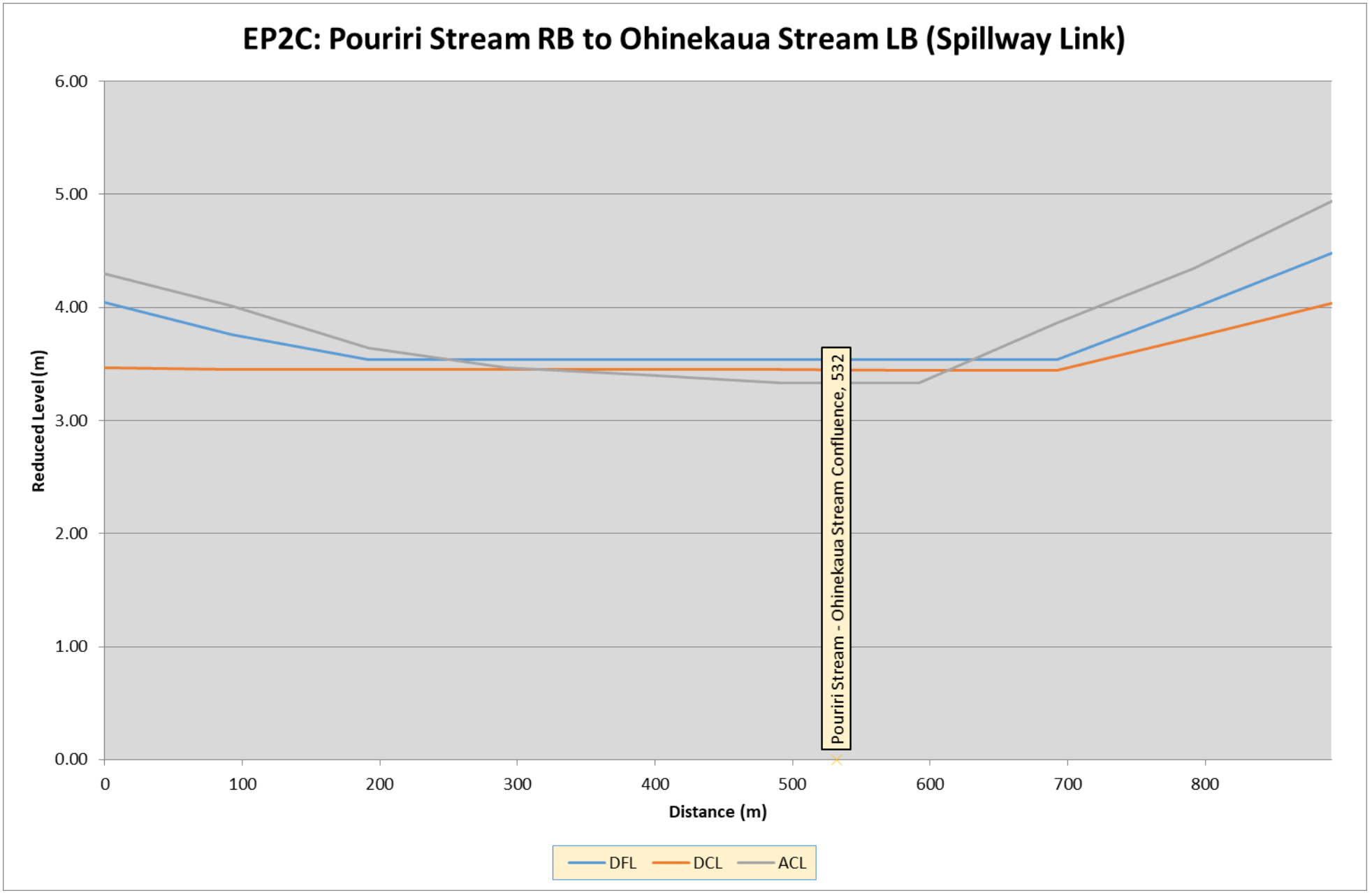


Figure 22: 2nd Emergency Ponding Zone - Pouriri Stream right bank to Ohinekaua Stream left bank stopbank profile

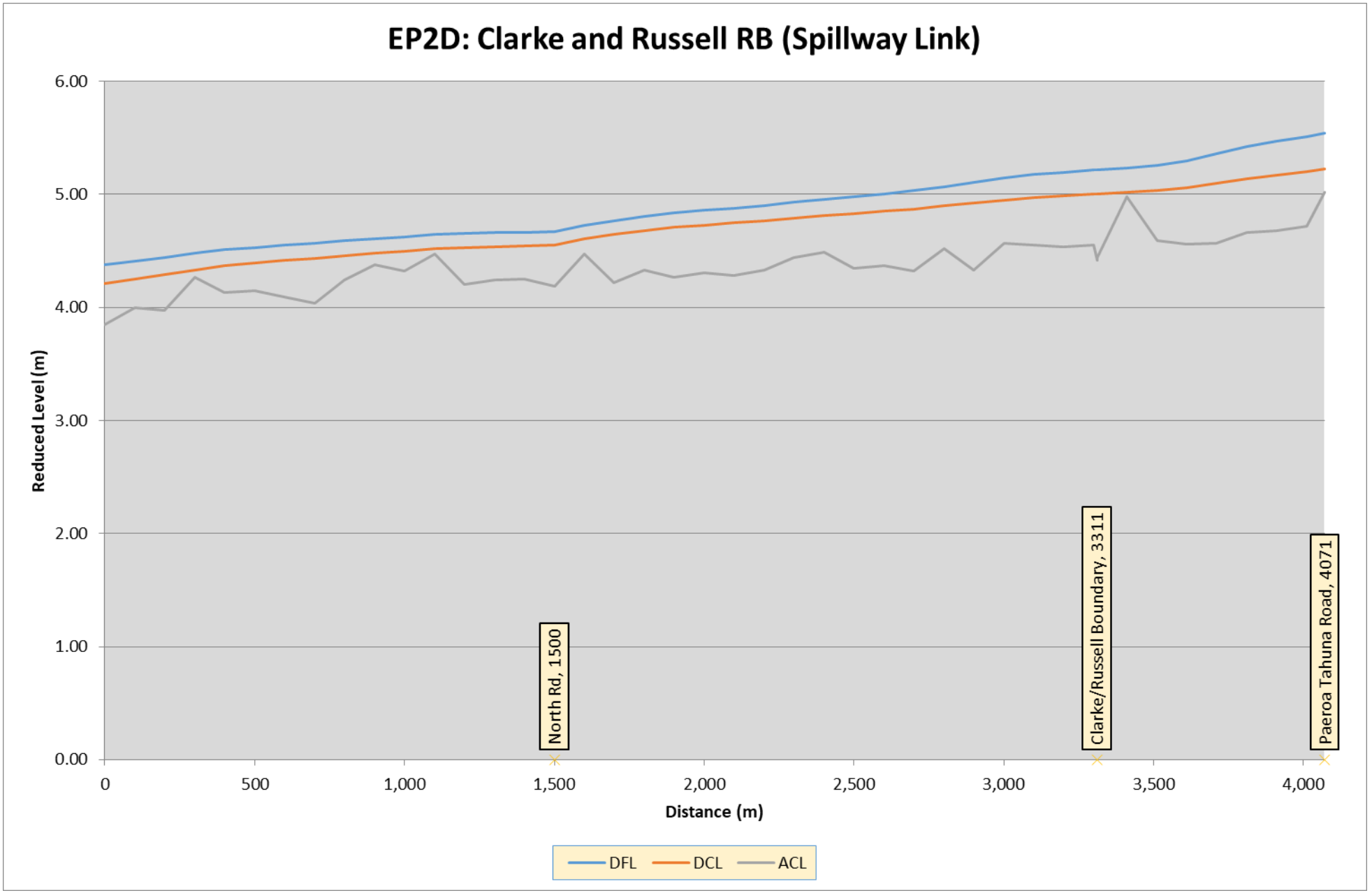


Figure 23: 2nd Emergency Ponding Zone – Waitoa River right bank Clarke to Paeroa Tahuna Rd stopbank profile

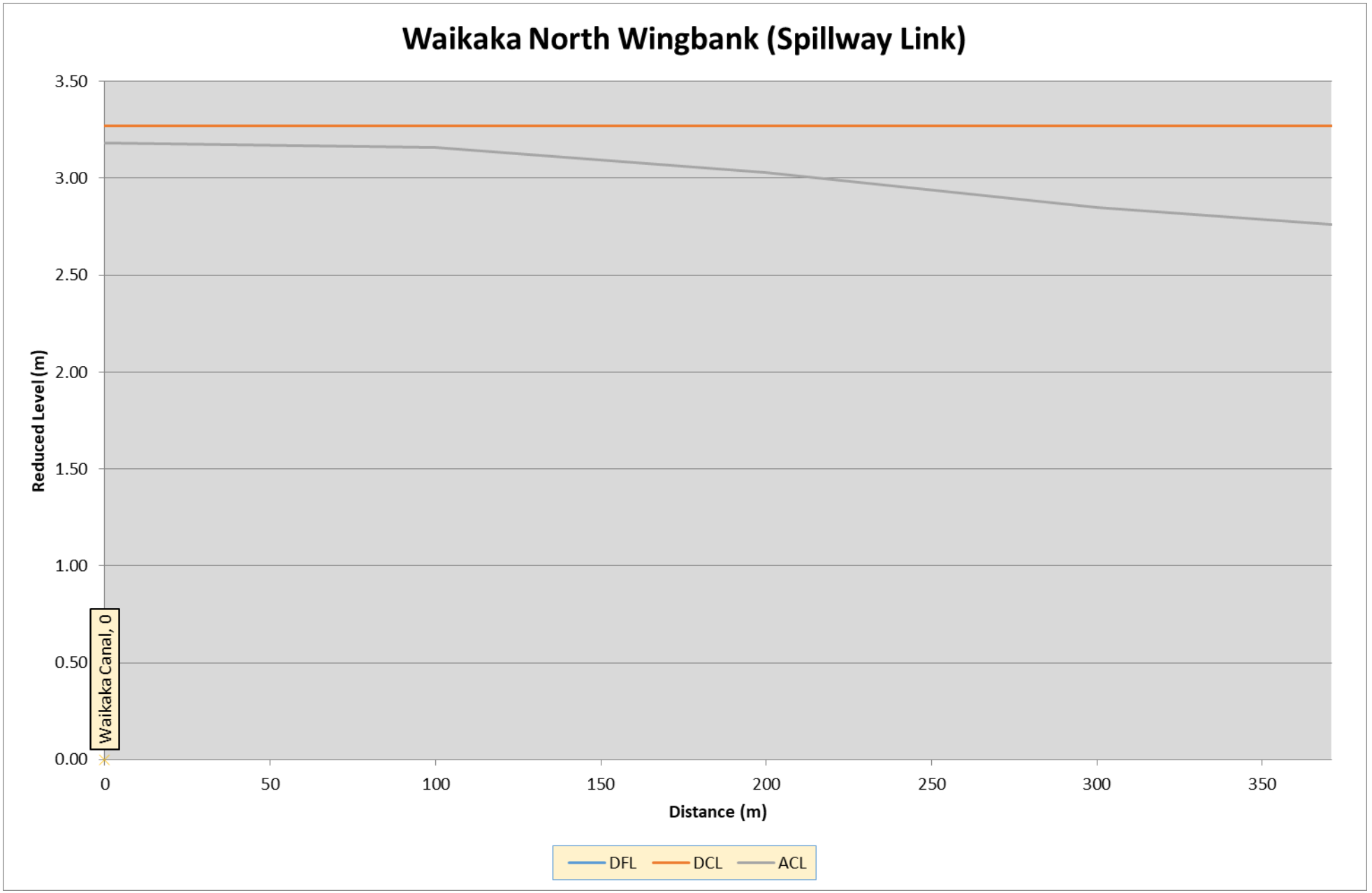


Figure 24: Waikaka North Wing Bank stopbank profile

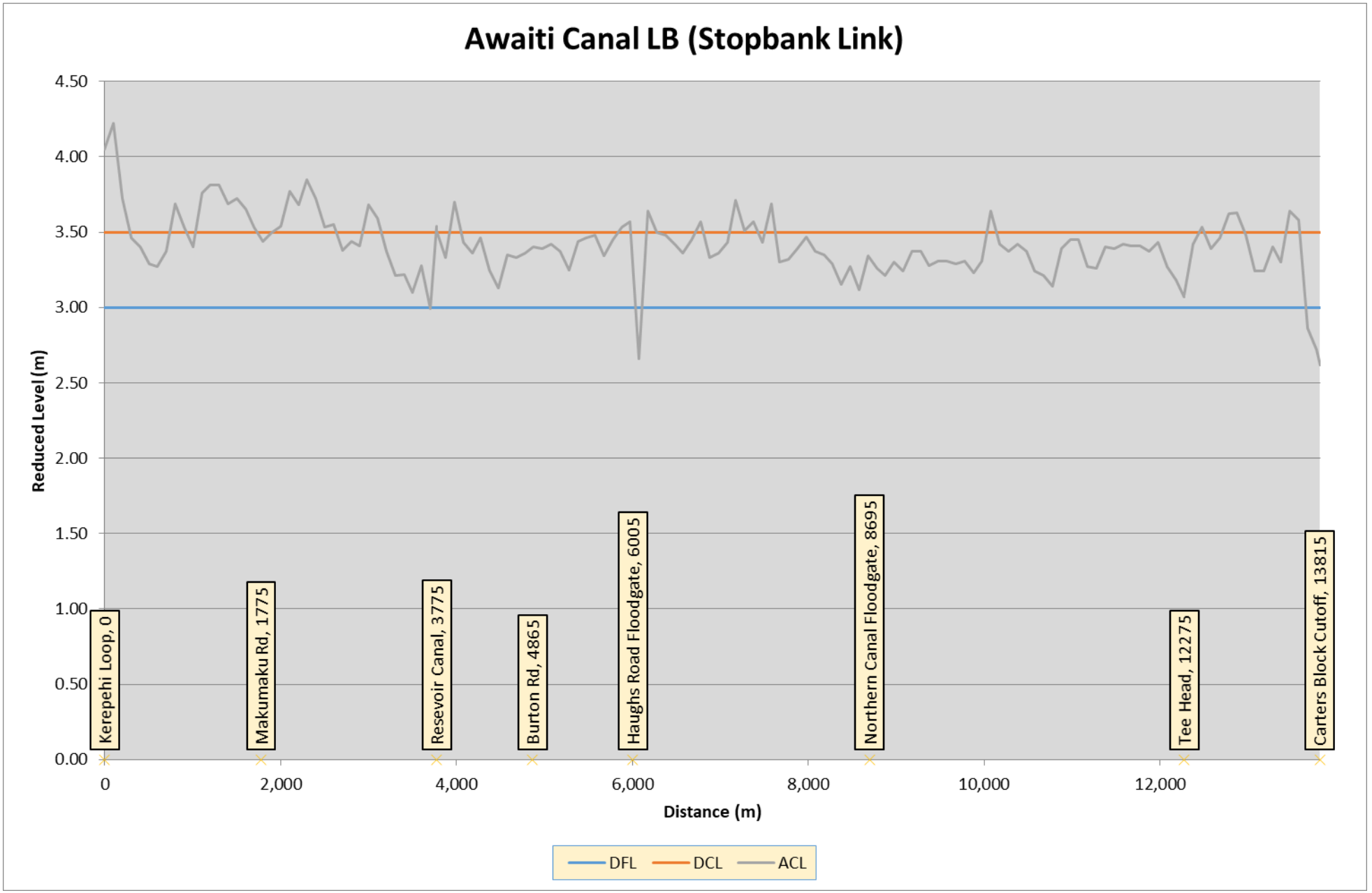


Figure 25: Awaiti Canal left bank stopbank profile

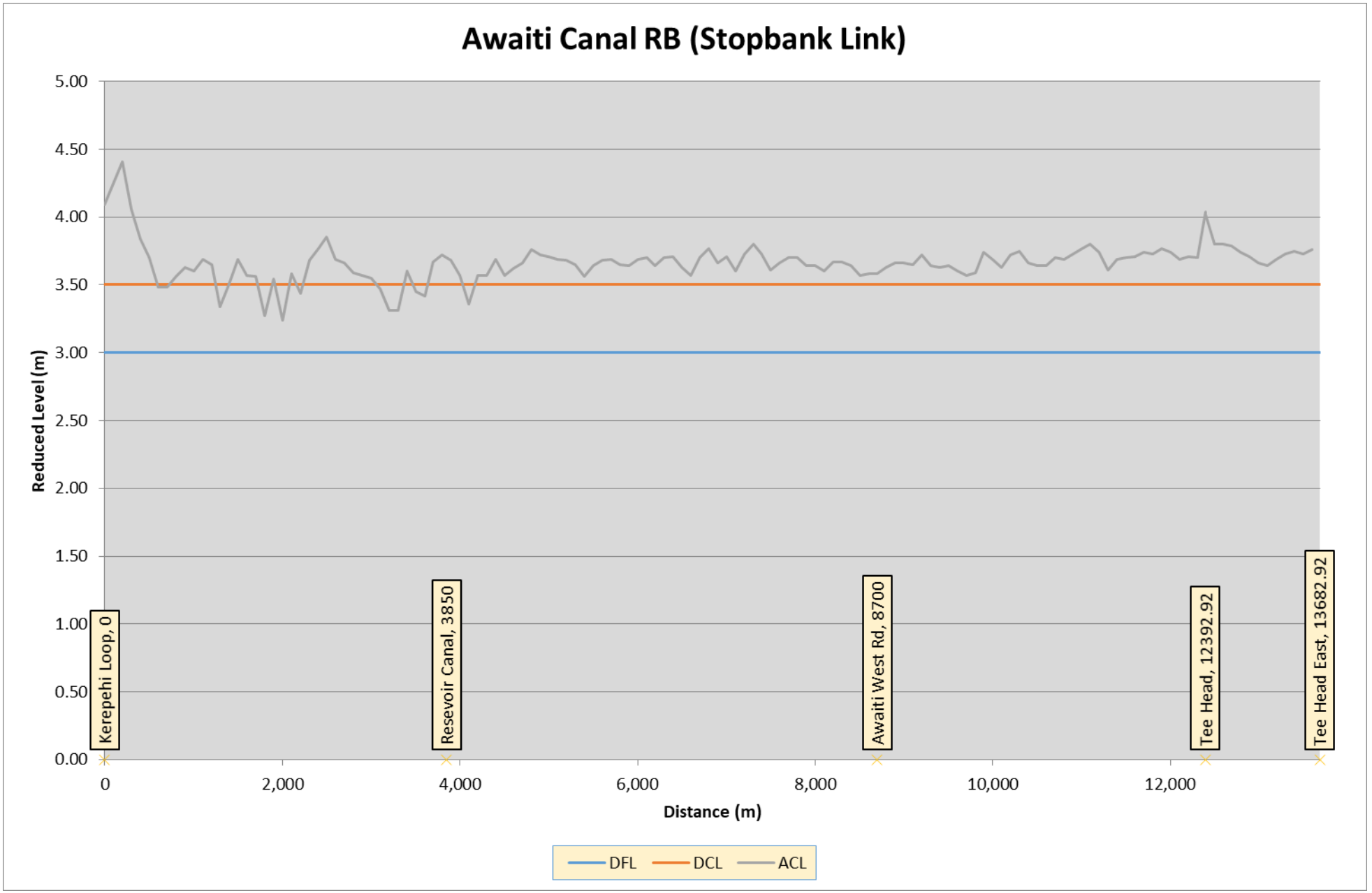


Figure 26: Awaiti Canal right bank stopbank profile

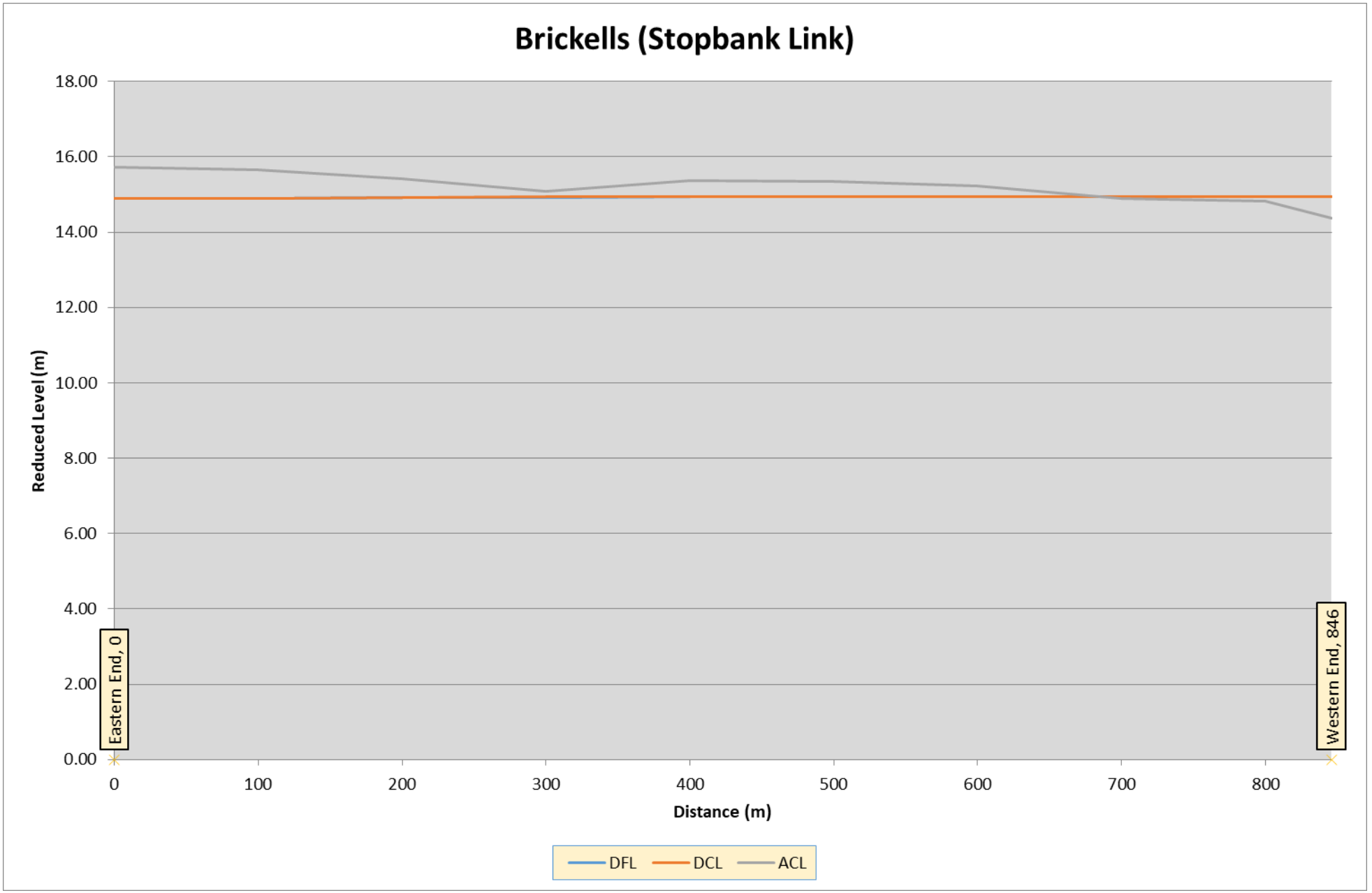


Figure 27: Brickells Stopbank (Waitoa River left bank)

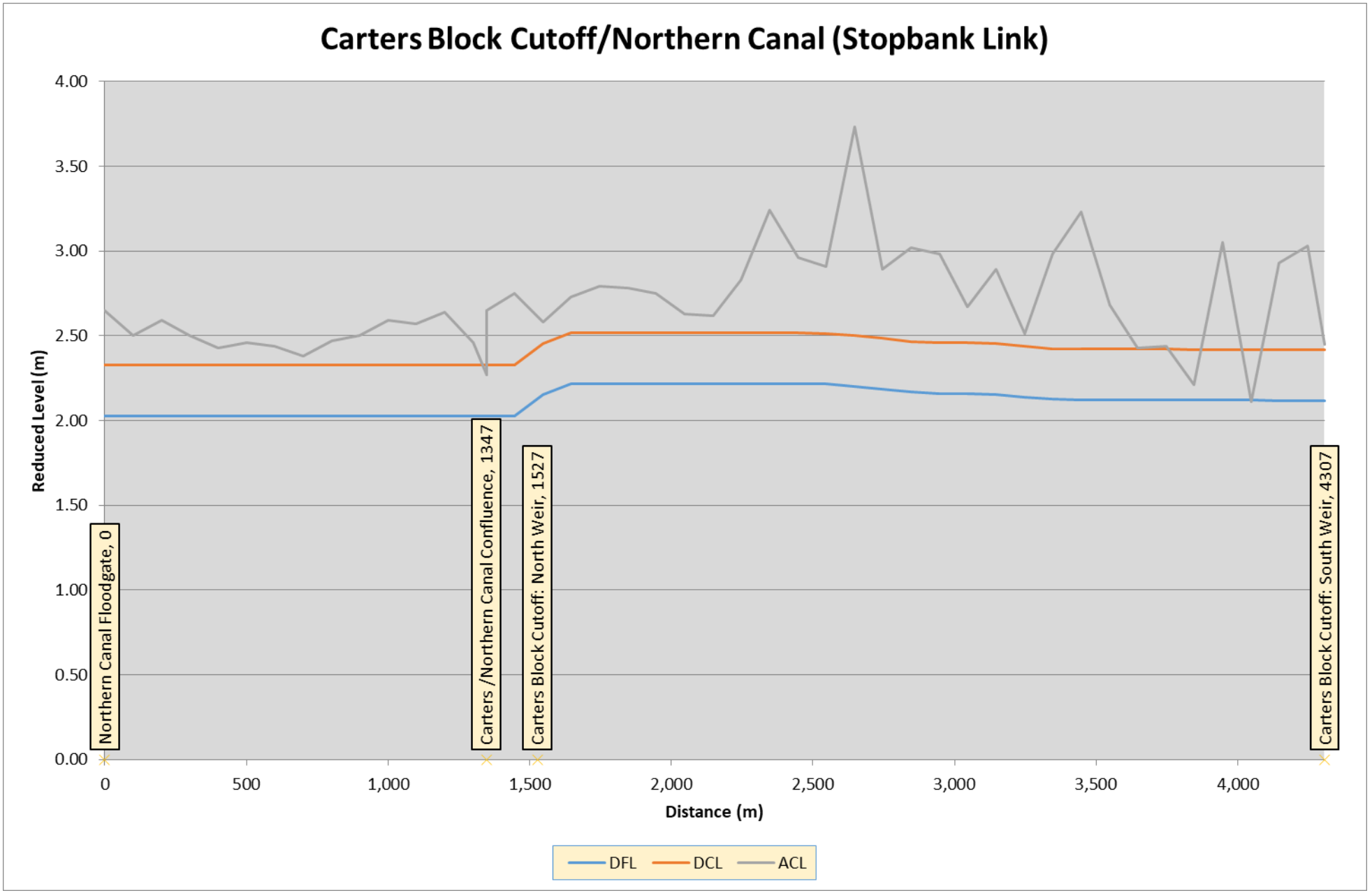


Figure 28: Carters Block Cut-off/Northern Canal right bank stopbank profile

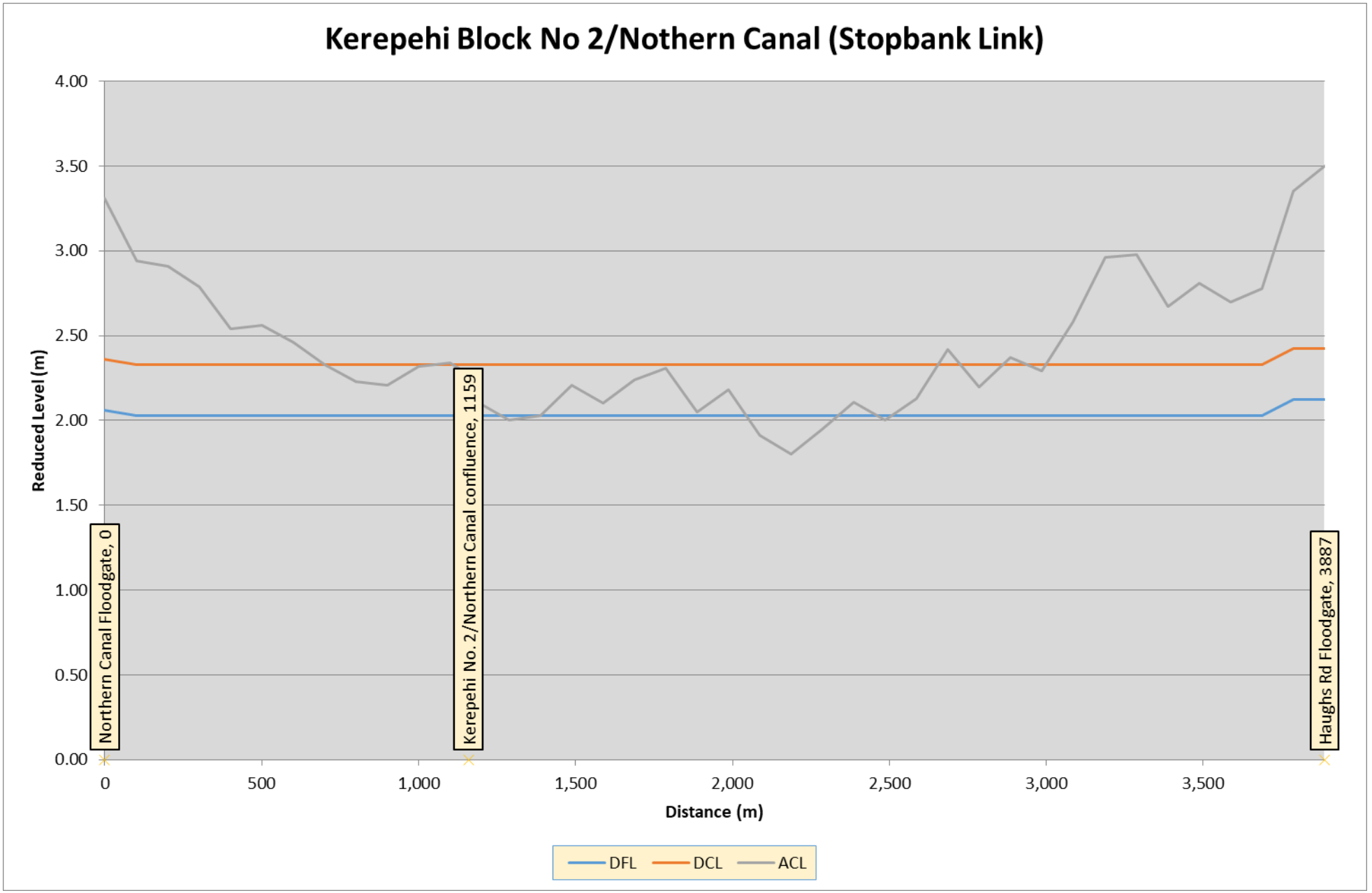


Figure 29: Kerepehi No 2 Cutoff and Northern Canal left bank stopbank profile

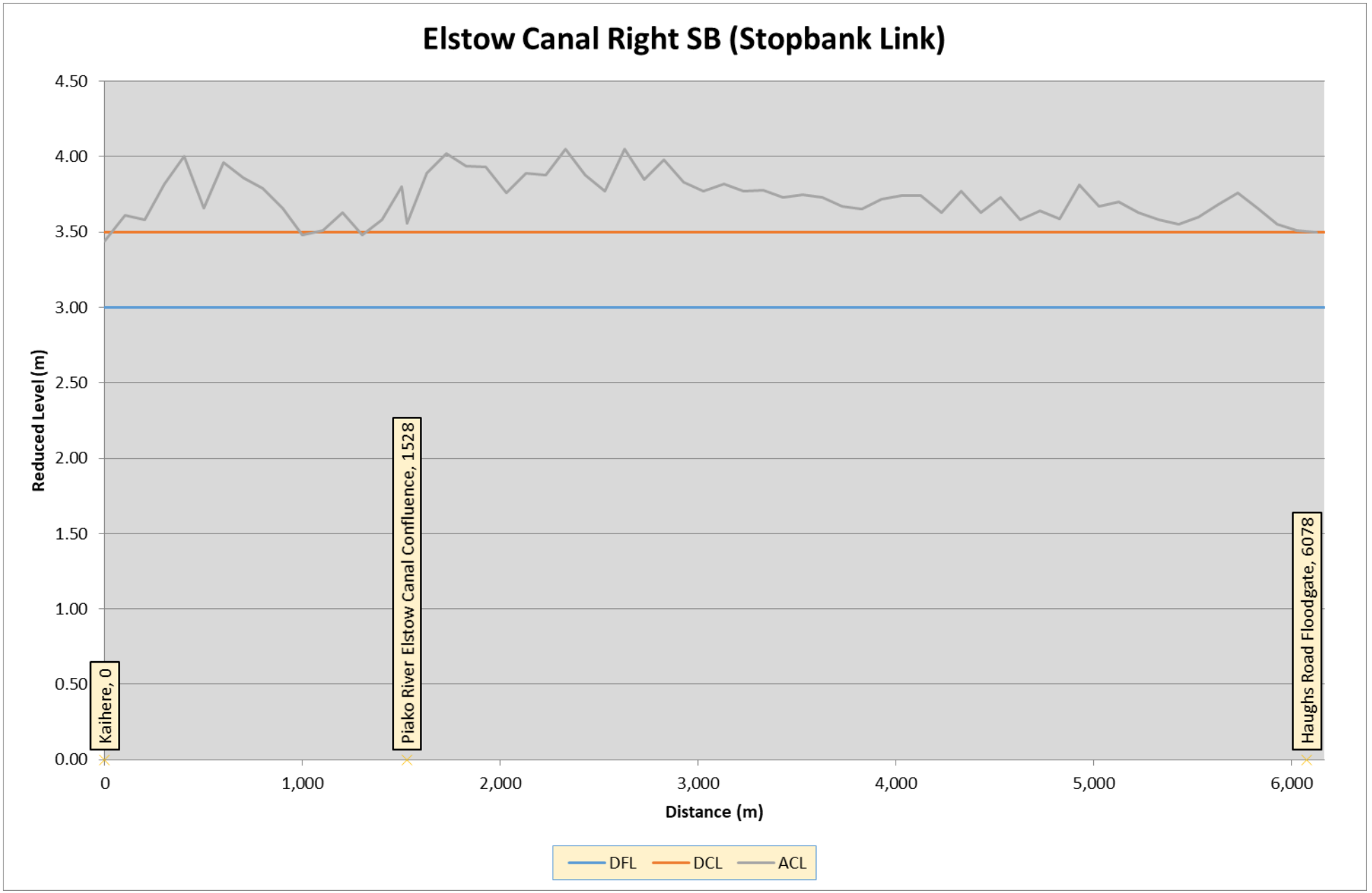


Figure 30: Elstow Canal right bank stopbank profile

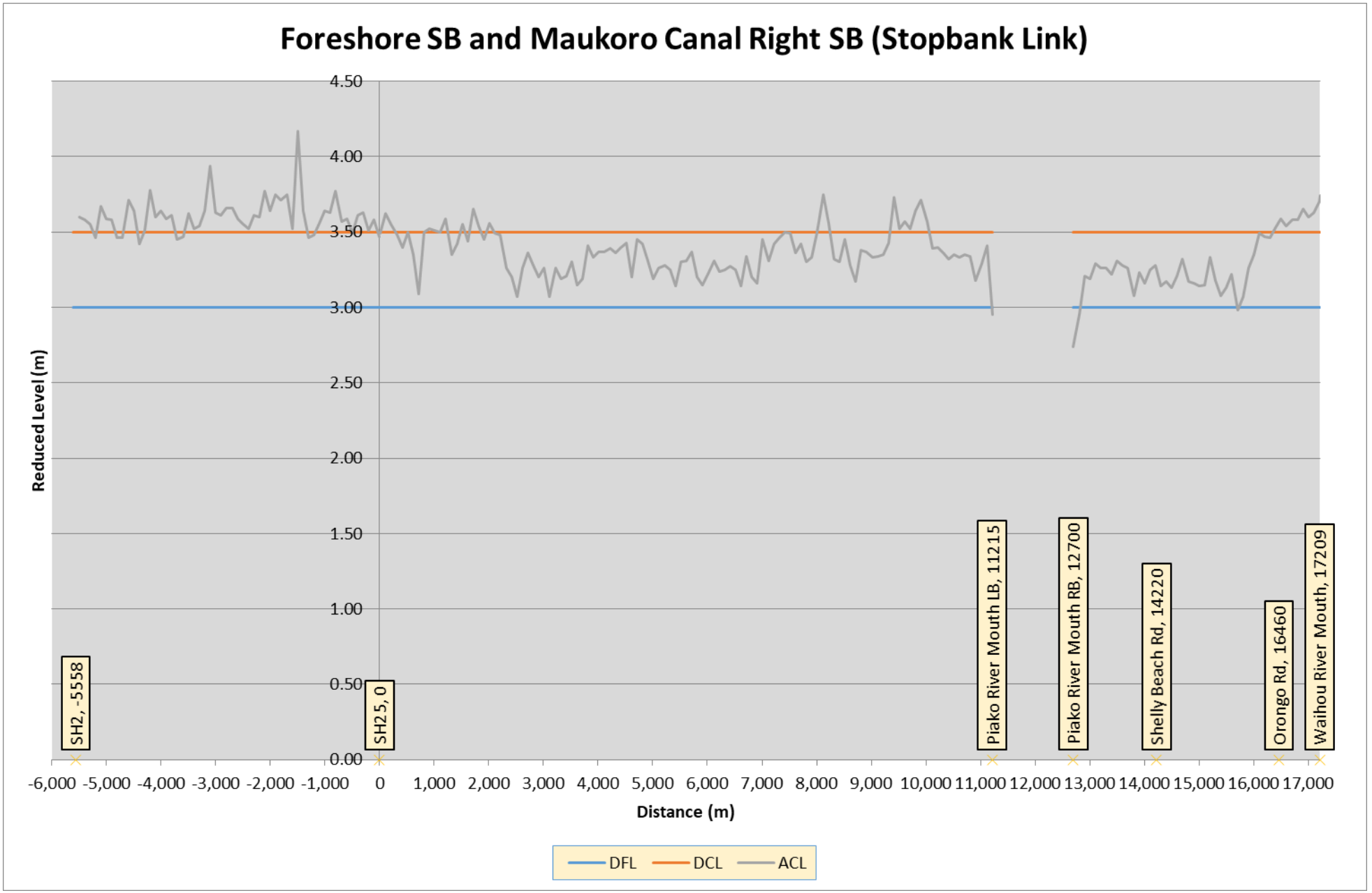


Figure 31: Maukoro Canal right bank and Piako Foreshore Stopbank Profile

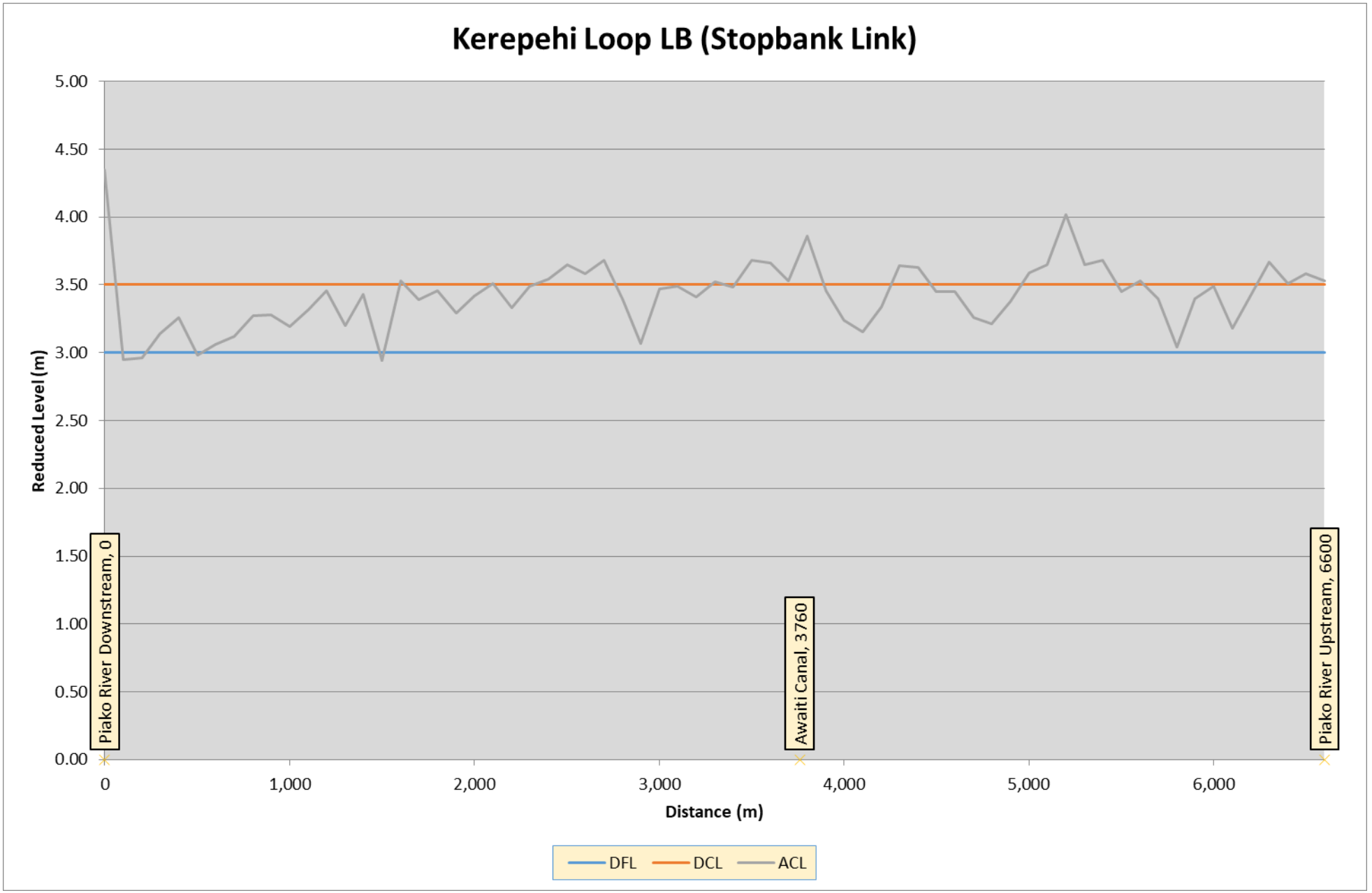


Figure 32: Kerepehi Loop left bank stopbank profile

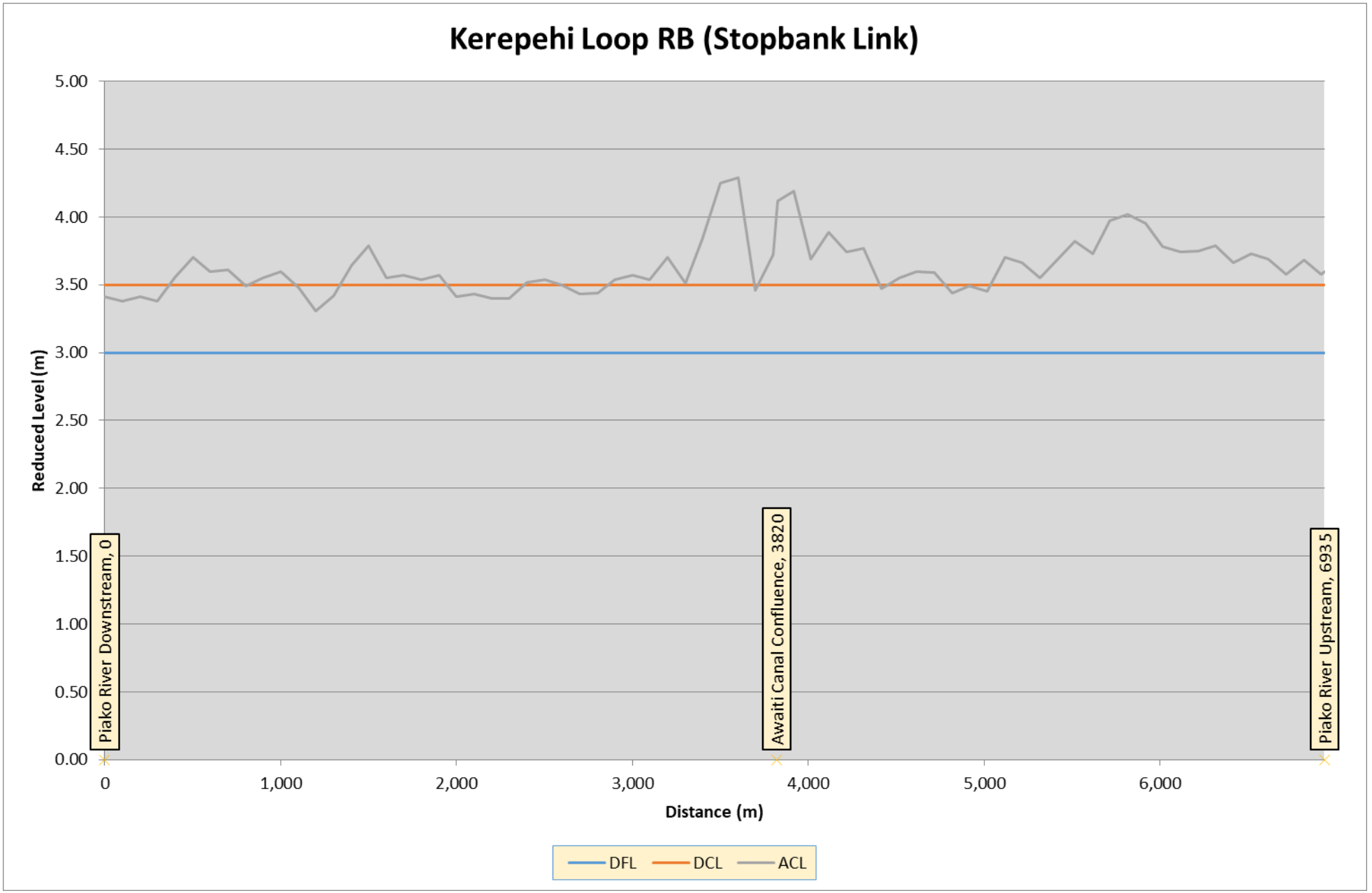


Figure 33: Kerepehi Loop right bank stopbank profile

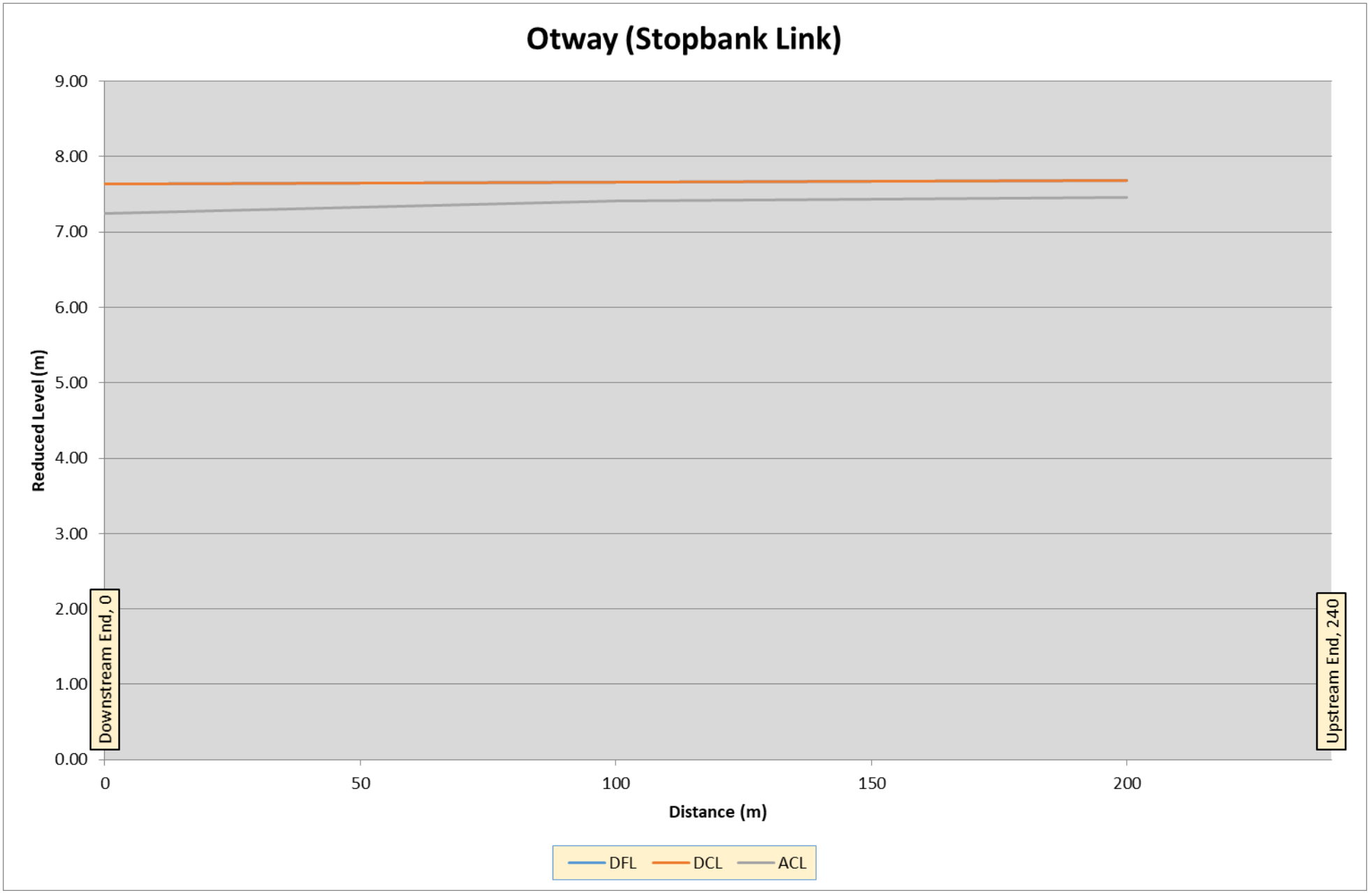


Figure 34: Otway Stopbank (Waitoa River right bank) profile

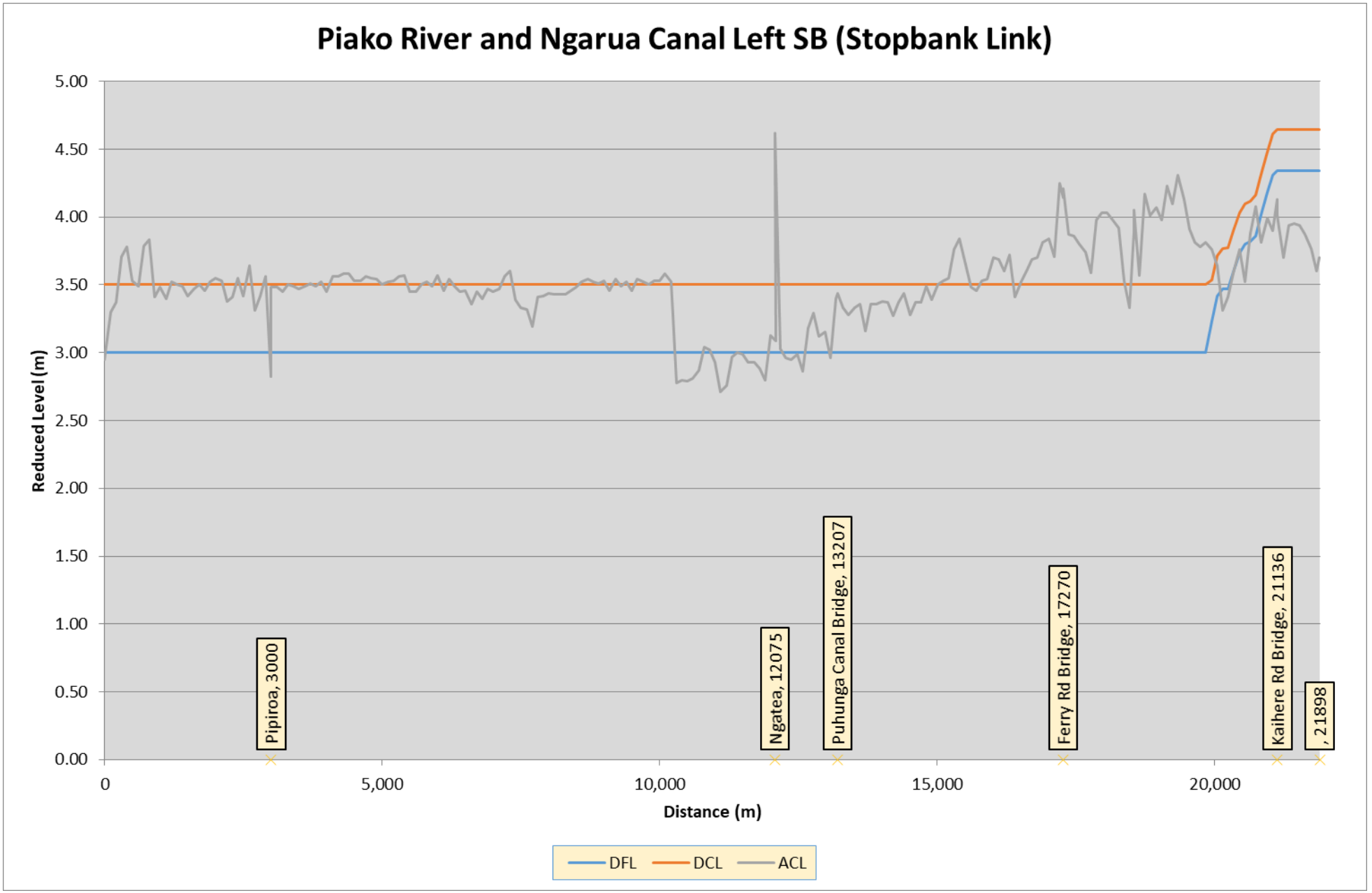


Figure 35: Piako River and Ngarua Canal left bank stopbank profile

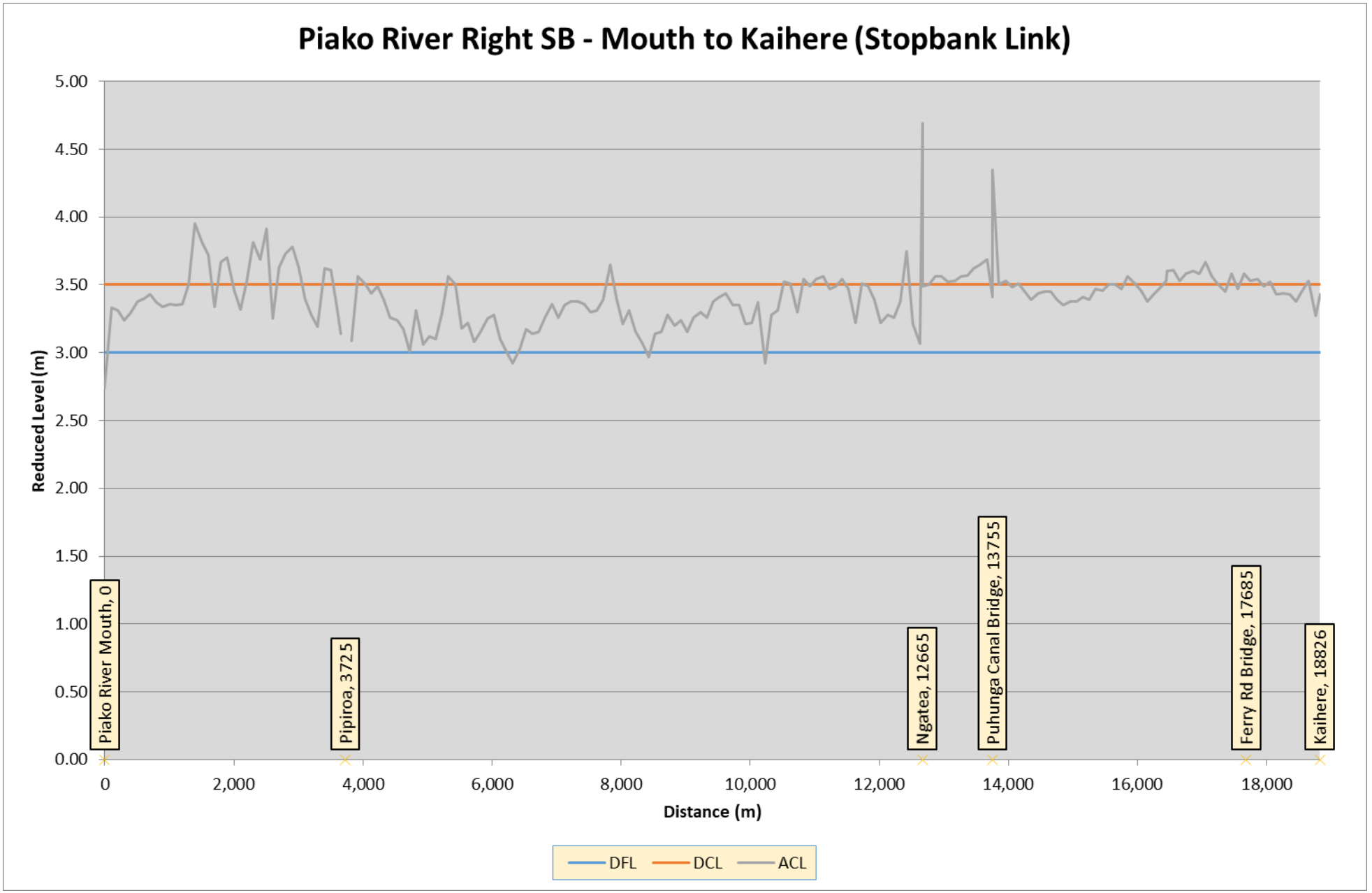


Figure 36: Piako River right bank stopbank profile

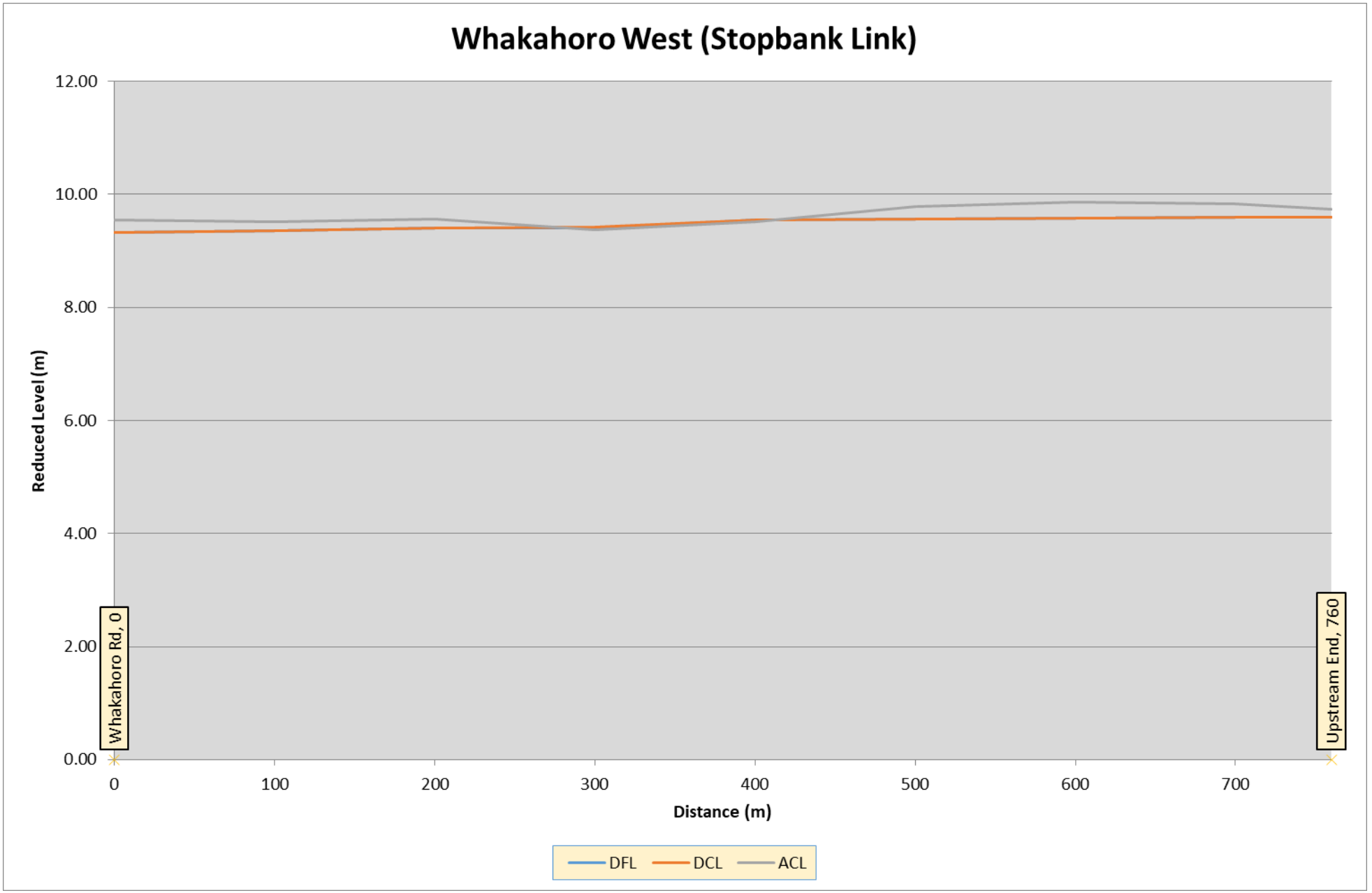


Figure 37: Whakahoro West Stopbank (Piako River right bank) profi