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Muriwai Downs Golf Project: Water Supply Assessment for Proposed Reservoir Sites Q and J

The Bears Home Project Management Limited

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Muriwai Downs Golf Project: Water Supply Assessment for Proposed Reservoir Sites Q and J

Prepared for

The Bears Home Project Management Limited

June 2021

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This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by The Bears Home Project Management Limited and others (not directly contracted by PDP for the work), including the National Institute of Water and Atmospheric Research (NIWA), Auckland Council, and Landcare Research New Zealand Limited. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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Executive Summary

The Bears Home Project Management Limited (BHPM) is proposing to develop a golf course at Muriwai Downs, approximately 3 km north east of Muriwai Beach Township. The proposed course requires a water supply for irrigation of approximately 49.5 ha at rates up to 5 mm/day using pop-up sprinklers.

PDP has been engaged to carry out hydrological analyses and a supply-demand water balance assessment for the golf course to determine the available water supply at 3 different surface water abstraction sites and to size the storage reservoir to achieve a highly reliable irrigation supply for maintaining the turf under 3 different supply scenarios. Potential water sources in the area include Okiritoto/Raurataua Stream, its tributaries and abstraction from groundwater.

The supply scenarios are the outcome of earlier options assessment carried out for 12 different sites across the property. All except one have been ruled out as being too small for the project needs or have wetlands constraints. The existing quarry site was added to the remaining viable option after determining that the quarry operator was supportive of rehabilitating quarried out areas for water storage. The 3 potential surface water sources are generally adjacent to these sites.

The 3 potential surface water abstraction sites are part of the Okiritoto Stream Catchment and the supply of water at each abstraction point (Site C, E and A) depends on the flow and allocation regime set in the Auckland Unitary Plan and flow time series. The reliable, core allocation is fully allocated and therefore only the high flow allocation was assumed to be available for irrigation and refill of the storage reservoir. Based on initial groundwater investigations it was assumed that a maximum seasonal volume of approximately 25,000 m^3 can be abstracted from the groundwater resource.

To estimate flows at the potential abstraction points, a regression analyses was undertaken using the nearby long-term continuous flow record for the Kaipara River at Waimauku. Auckland Council previously used regression analyses with this long-term recorder site to estimate flows at several different locations throughout the Okiritoto catchment as described in their TP102 report. Statistics of the resulting long-term synthetic flow series for the three potential abstraction sites were compared with estimates from a catchment flow model developed by Williamson Water & Land Advisory (WWLA, 2021)). Comparison of the flow statistics between the two methods indicates that estimated flows for the 7DMALF (7-Day Mean Annual Low Flow) and 10 percentile flows are generally similar. However, estimated flows from the lower quartile (25th percentile) upwards are significantly greater for the catchment flow modelling (WWLA, 2021).

The results of the water supply-demand modelling show that the following amounts of storage are required to achieve 95 - 99% reliability for the potential abstraction point and the associated storage reservoirs:

- Potential abstraction point E, reservoir Q (The Quarry):
  - Catchment model (WWLA) flow series: 284,500 - 340,000 m^3.
  - TP102 (PDP) flow series: 515,000 - 580,000 m^3.
- Potential abstraction points A + E, reservoir Q (The Quarry):
  - Catchment model (WWLA) flow series: 137,000 - 172,000 m^3.
  - TP102 (PDP) flow series: 177,500 – 210,500 m^3.
- Potential abstraction point C, reservoir J:
  - Catchment model (WWLA) flow series: 132,000 – 169,000 m^3.
  - TP102 (PDP) flow series: 177,500 – 210,000 m^3.

Given the uncertainties in water demand for the golf course, stream flows, and the volume of water available from streams and groundwater, it is recommended that the modelling will be updated once further information becomes available. This includes the following:

- Continuous flow data from the recently established flow recorder sites in the catchment;
- Available flow and volume of water from groundwater following further pump testing work (planned to be completed in June 2021);
- Finalising the golf course design including the irrigable area; and
- Determining the amount of left-over water from the core allocation currently allocated to one downstream user.

It is also recommended further work be undertaken to establish soil PAW values at the site and determine expected rooting depths for the varieties of turf grass to be grown at the proposed golf course.

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1.0 Introduction

The Bears Home Project Management Limited (BHPM) is proposing to develop a golf course at Muriwai Downs, approximately 3 km north east of Muriwai Beach Township. The proposed course requires a water supply for irrigation of approximately 49.5 ha of turf green at rates up to 5 mm/day using pop-up sprinklers (Steve Marsden, Turf Services).

Potential water sources in the area include Okiritoto Stream, its tributaries and abstraction from groundwater. These supplies are to be coupled with a storage reservoir to achieve a high reliability water supply capable of maintaining the turf.

PDP has been engaged to carry out hydrological analyses and a supply-demand water balance assessment for the golf course to determine the following:

- the available water supply at 3 different surface water abstraction sites; and
- the required storage reservoir size to achieve a highly reliable irrigation supply for irrigation under 3 different supply scenarios.

2.0 Background

Prior to the supply-demand options assessment detailed as part of this report, PDP previously undertook an initial, desk-top study exploring a number of combined surface water and groundwater supply options on the property; including 12 'long-listed' water storage locations ranging in size from 9,000 m^3 to 100,000 m^3 (PDP, 2020). Preliminary storage locations identified are shown in Figure 1.

Of the 12 sites, 9 were located on-stream and had insufficient reservoir size potential for the project needs. All were less than 30,000 m^3. The existing natural lake at the western side of the site, Lake Okaihau, was assessed to have an insufficient catchment resource and is a significant ecological/cultural feature, making it unsuitable. Two sites on the eastern side of the property (Site J and Sites F and H together) had potentially sufficient storage volume capacity (around 100,000 m^3) to be taken forward for further consideration. Subsequent mapping of the presence and extent of wetlands across the property has ruled out Sites F and H, due to constraints under the recently operative National Environmental Standards for Freshwater which prohibit earthworks and other activities in natural wetlands.

In addition, since the Options Report, further enquiry has revealed that the existing quarry, Site Q on Figure A1, located just upstream from site G, could be a viable reservoir site option. The quarry operator is supportive of the use of quarried out areas of his site to be rehabilitated for water storage. This site meets the minimum storage volume size criteria used for sites in the Options Report.

This report focusses on reservoir sites in the vicinity of Sites F and Q with water sources that feed them from adjacent streams, together with a developed groundwater supply.

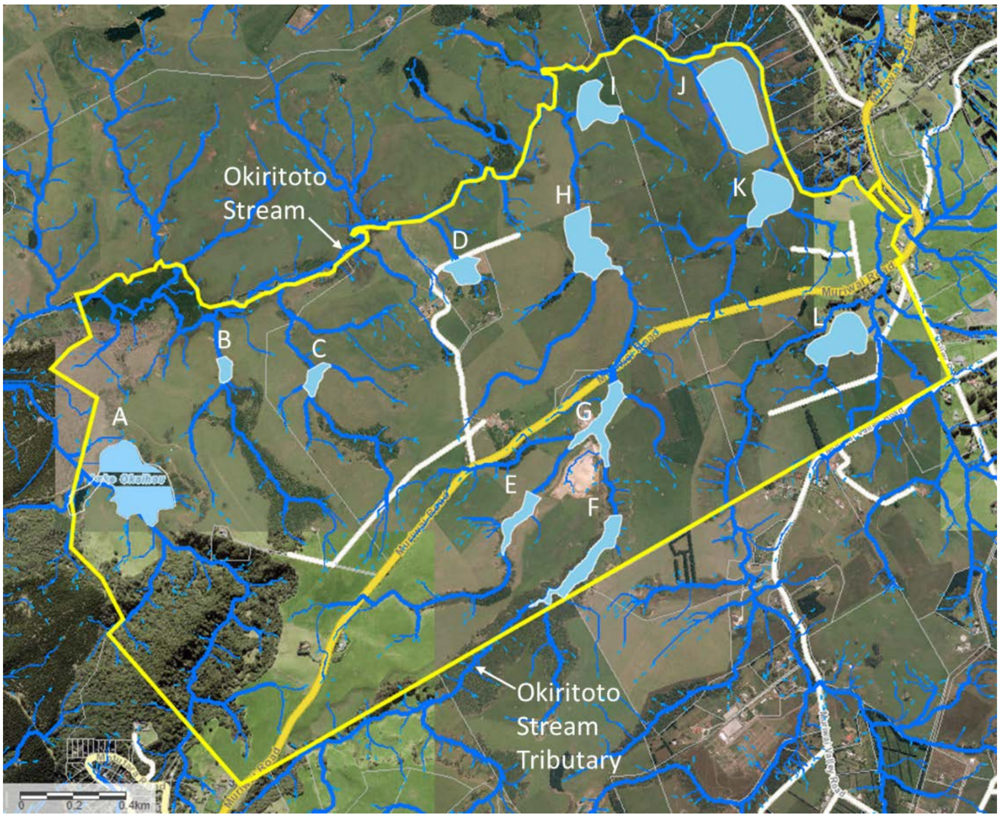

Figure 1: Potential Storage Locations A to L (taken from PDP, 2020)

3.0 Hydrology

3.1 Sites

The location of the 3 potential surface water abstraction sites (E, A, and C) is shown alongside the two potential storage reservoir locations in Figure A1, Appendix A. If site C is utilised as a water supply, it is expected the storage reservoir would be constructed in the vicinity of the location marked reservoir J, whereas if site E or A is utilised the storage reservoir would be constructed near or at the location marked reservoir Q (The Quarry).

The model results are not dependent on the reservoir location itself but rather the reservoir size and the water source locations. Ongoing assessment will lead to refinement of the reservoir location and layouts according to broader assessment criteria including access, landuse and economic aspects.

The 3 potential surface water abstraction sites are part of the Okiritoto Stream Catchment. The catchment area at each potential abstraction point has been estimated as follows:

- **Site C:** 13.1 km^2
- **Site E:** 1.8 km^2
- **Site A:** 9.0 km^2

3.2 Available Allocation

The supply of water at each location (Site C, E and A) depends on the flow and allocation regime and flow time series. The Auckland Unitary plan sets the flow and allocation regime for the Okiritoto Stream Catchment as follows:

<u>Core Allocation:</u>

- Minimum Flow: 85% of the 7DMALF (7 - Day Mean Annual Low Flow[1])
- Allocation: 30% of 7DMALF

<u>High Flow Allocation:</u>

- Minimum flow: Median
- Allocation: Total take does not exceed 10% of the flow, when the flow is greater than the median

Based on the 7DMALF estimate discussed in section 2.3 below and the current allocation of the stream there is no core allocation available. There is currently one existing surface water take (Muriwai Golf Club Inc., Permit 21123) which takes water from Okiritoto Stream in the lower reaches of the catchment. The maximum rate of take for this water permit is 25 L/s with a maximum daily volume of 1,150 cubic metres.

At the time of writing this report, no high flow allocation has been consented and BHPM can apply for a consent to abstract high flow water.

In addition to the surface water take it was assumed that a maximum seasonal volume of 25,000 m^3 of groundwater is available at a maximum flow rate of 20 L/s. The groundwater resource availability estimate is based on flow testing results from a 200 m deep exploratory bore located within a dyke of pillow lava

[1] The average stream flow during times of 'low flow'. The lowest seven day flow for each year is averaged across recorded years to estimate the 7- Day Mean Annual Low Flow (7DMALF).

exposed in the middle of the site. An update on the groundwater resource availability will be forthcoming once a full-scale production well is constructed and tested.

3.3 Regression Analyses

To estimate flows at the potential abstraction points a regression analyses was undertaken using a nearby long-term continuous flow record. This methodology was previously used by Auckland Council in their TP102 report (Bowden, 1999) to estimate flows at several different locations throughout the Okiritoto catchment. Regression analysis was undertaken using the available gaugings for Raurataua Creek at Valley Road and the mean daily flows from the Auckland long-term flow recorder site Kaipara River at Waimauku (refer to Appendix A, Figure A2). The resulting regression plot is shown below.

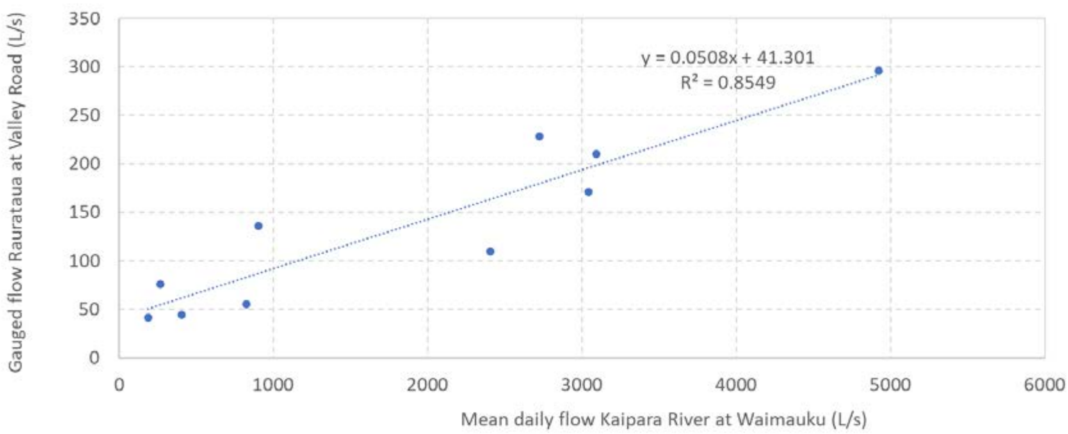

Figure 2: Regression for Okiritoto Stream at Valley Road and Kaipara River at Waimauku

3.4 Flow Statistics

Using the regression equation derived above, flow statistics can be calculated and a long-term synthetic flow record can be derived for the Okiritoto Stream at Valley Road. This site is essentially the same location as potential abstraction point C. For potential abstraction points A and E, the flow record created at point C was scaled based on catchment area.

Williamson Water & Land Advisory (WWLA) previously estimated flows at these locations using a catchment flow model. Flow statistics using the TP102 methodology and flow statistics from the catchment flow model are summarised in Figure 1 below with the key statistics that determine the core and high flow minimum flow and allocation highlighted in **bold (7DMALF and Median).** When comparing the flow statistics from the TP102 methodology and the catchment flow modelling it is clear that estimated flows for the 7DMALF and 10 percentile flows are generally similar. However, estimated flows from the lower quartile (25th percentile) upwards are significantly greater for the catchment flow modelling. These differences in flow estimates will have an effect on the required storage volumes as detailed in section 4.0 below. As a comparison, the 7DMALF estimate for site C was 47.2 L/s from TP102 which compares to an estimated 7DMALF for the TP102 methodology (with updated flows) and catchment flow model of 50 L/s and 42.4 L/s respectively.

3.5 Core Allocation

The Muriwai Golf Club Inc. currently holds consent for a maximum daily take of 1,150 m^3/day, at maximum instantaneous take rate of 25 L/s (Permit 21123). It is noted that this take location (situated in the lower reaches of the Okiritoto Stream), has a reported 7DMALF of approximately 66 L/s (TP102 report). Based on this estimate, the maximum available core allocation at this location is approximately 20 L/s. It is therefore likely that the Orikitoto Stream catchment core allocation is fully allocated, however this will need to be confirmed with Auckland Council.

With a maximum daily take of 1,150 m^3/day (approximately 13 L/s), there is likely to be periods of time when the Muriwai Golf Club does not fully utilise its maximum instantaneous take allowance. This 'left over' water allocation may be available to BHPM. Any such allocation sharing will require an agreement with the existing consent holder (who will need to retain priority of take at all times), installation of real-time telemetry at their offtake and approval from Auckland Council.

Abstraction data and modelling of the potential available 'left over' water is required to determine the benefits (i.e. reduction of required storage volume) of shared allocation. The outcome of this assessment will inform whether this is worth pursuing and to determine the next steps (i.e., discussions with Muriwai Golf Club Inc. and Auckland Council).

Table 1: Flow Statistics

	Site C		Site A		Site E	
Statistic	**TP 102 (PDP)**	**Catchment Flow Model (WWLA)**	**TP 102 (PDP)**	**Catchment Flow Model (WWLA)**	**TP 102 (PDP)**	**Catchment Flow Model (WWLA)**
90th percentile	419.3	1086.7	285.9	581.7	57.4	118.6
75th percentile	218.8	526.2	149.2	285.8	30.0	60.5
Mean	198.7	423.8	135.5	231.8	27.2	50.0
Median	**108.4**	**187.5**	**73.9**	**110.7**	**14.9**	**27.3**
25th percentile	66.0	93.1	45.0	56.1	9.0	15.7
10th percentile	52.3	53.6	35.6	32.7	7.2	10.0
7DMALF	**50.0**	**42.4**	**34.1**	**26.1**	**6.8**	**8.5**

4.0 Supply and Demand Modelling

4.1 Demand Model Overview

Irrigation water demand was modelled in Python (a programming language widely used in scientific and engineering research and design) using a daily water-balance approach. The daily water balance tracks the change in water content within the root zone of a representative soil profile. Water inputs to the soil profile include rainfall and irrigation, while losses include runoff, evapotranspiration and drainage to groundwater. The demand model behaviour is shown schematically in Figure 1.

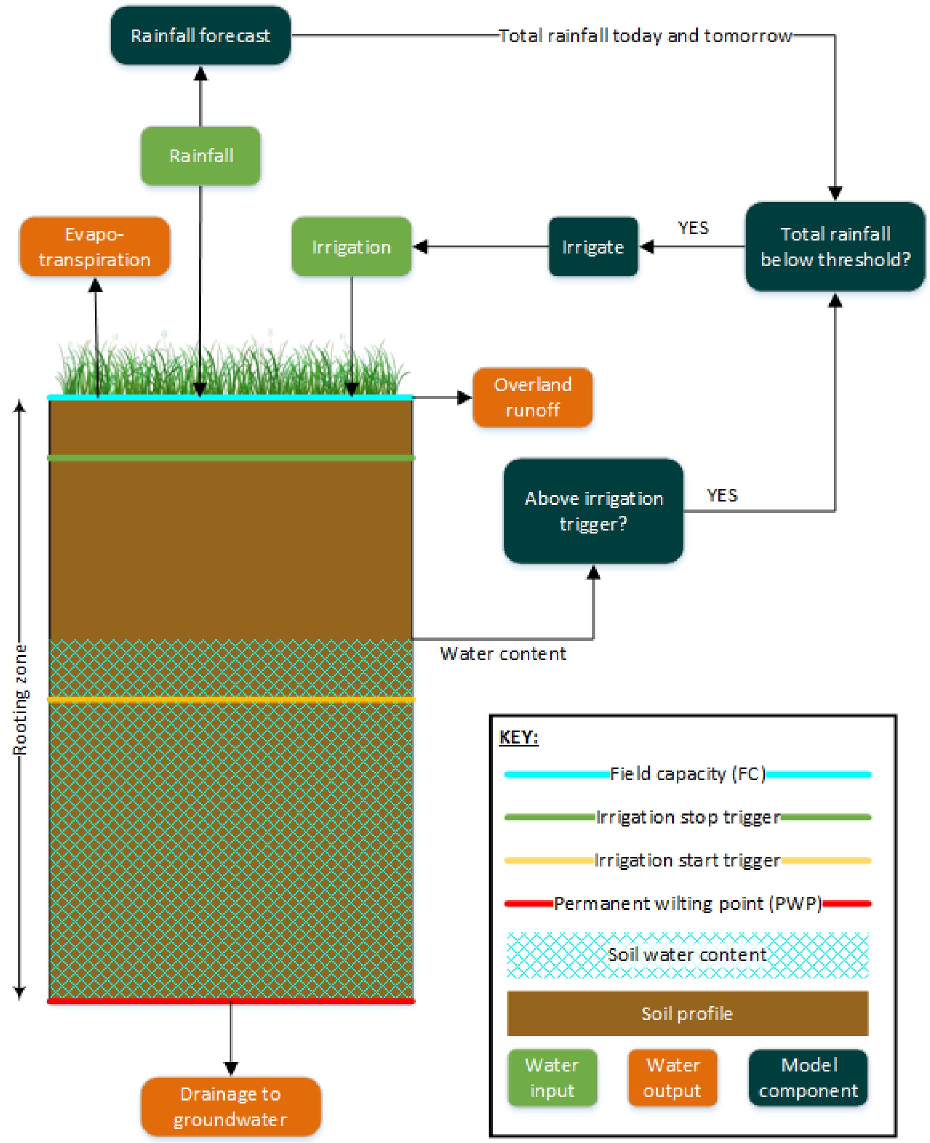

Figure 3: Schematic of Irrigation Demand Model

During each day of the irrigation season the model considers the demand for irrigation based on the current moisture content of the soil profile. If the soil moisture content falls below a set trigger level, irrigation is applied until the soil moisture content reaches a specified stop trigger level.

The model also tracks rainfall several days in advance to simulate making irrigation decisions based on the rainfall forecast. In the model, an irrigation event can be postponed if the rainfall over the current day and the next exceeds specified thresholds. Heavy rainfall can also generate overland runoff, so the model allows for an effective rainfall threshold to be set. Rainfall above this threshold is assumed to not contribute to the final soil moisture level of the soil profile.

4.2 Supply Model Overview

The demand model predicts the amount of irrigation water required each day, but this does not account for restrictions in water supply for irrigation. The supply component of the Python model incorporates this restriction by determining the water available from surface-water abstraction, groundwater abstraction, and storage ponds each day.

For this assessment, the relevant supplies are:

- Abstraction from site E (see Figure A1, Appendix A). Assumed up to 20 L/s intake capacity based on sensitivity analysis of available flows.
- Abstraction from site A (see Figure A1, Appendix A). Assumed up to 50 L/s intake capacity based on sensitivity analysis of available flows.
- Abstraction from site C (see Figure A1, Appendix A). Assumed up to 80 L/s intake capacity based on sensitivity analysis of available flows.
- Abstraction from groundwater of up to 20 L/s with an annual maximum take of 25,000 m³.
- The proposed storage reservoir.

The model assigns the following priorities to use of water from these water supplies, with 1 having the highest priority and 4 having the lowest priority:

1) Water taken from stream supplies for irrigation (A, E and C).
2) Water taken from groundwater for irrigation. Note the groundwater abstraction is assumed to only be available for irrigation, and only when the level of the storage reservoir falls below 75%, so that the annual abstraction limit is not reached too early in the season and opportunities for refilling storage from surface water throughout the season are fully utilised.
3) Water taken from the storage reservoir for irrigation.
4) Water taken from stream supplies for refill of the storage reservoir.

The model accounts for seepage and evaporation losses from storage reservoirs. Seepage rates from the storage reservoir were assumed to be a constant 0.212 L/s/ha consistent with an HDPE lined pond installed with good-quality control measures (MWH, 2015).

For the purposes of this assessment, the following supply scenarios are being considered:

- Groundwater + site E + storage reservoir Q
- Groundwater + site E + site A + storage reservoir Q
- Groundwater + site C + storage reservoir J

4.3 Model Inputs Summary

- Irrigation area of 49.5 ha.
- PAW (Profile Available Water[2]) of 75 mm (based on New Zealand Fundamental Soil Layer (FSL, Landcare Research New Zealand Limited). It is noted that no detailed soil information is available for the proposed golf course area. It is therefore recommended that further work will be undertaken to establish soil PAW values at the site and to determine expected rooting depths for the varieties of turf grass to be grown at the proposed golf course.
- Daily rainfall and potential evapotranspiration (PET) from the NIWA Virtual Climate Station Network. The nearby VCSN station 21835 (average annual rainfall of 1,290 mm/year and average annual PET of 1,030 mm/year) was chosen to use for this assessment.
- 5 mm/day irrigation applied by pop-up sprinklers during the irrigation season (assumed 1 September – 30 April).
- Sprinklers assumed to be 80% efficient to account for losses due to spray drift and bypass flow to deeper groundwater. Value assumed is within accepted ranges for solid set inground sprinklers of 70-85% (Rogers, et al., 1997) and 70-80% (Solomon, 1988).
- Effective rainfall threshold of 50 mm/day (rainfall above this level does not reach the soil profile and is lost as overland runoff).
- Rainfall forecast threshold of 15 mm (rainfall above this level over the current day and the next day will pause irrigation).
- Irrigation starts when soil moisture drops to 50% of PAW and continues until soil reaches 90% of PAW.

[2] Profile Available Water (PAW) is the amount of water potentially available to plant growth that can be stored in the soil to the rooting depth of a crop. PAW is expressed in millimeters of water.

- Evapotranspiration modelled using curve number of 5 and crop factor of 0.8. A crop factor of 0.8 was selected based on mid-season time-averaged coefficients ranging from 0.75-0.85 for carefully managed turf grass varieties (Allen, Pereira, Raes, & Smith, 1998).
- Seepage rate of 0.212 L/s/ha from the storage reservoir.
- Site A maximum intake capacity of 50 L/s.
- Site E maximum intake capacity of 20 L/s.
- Site C maximum intake capacity of 80 L/s.
- Groundwater abstraction of 20 L/s utilised when the storage pond falls below 75%, up to an annual maximum of 25,000 m^3.
- Run period from 6 October 1978 to 30 January 2021 (dictated by climate and flow data availability at the time of modelling). Note this period spans 43 years, but only 41 years have complete irrigation seasons.

5.0 Modelling Results and Discussion

The model was run for all combinations of allocation flow series (rainfall-runoff model as generated by WWL, or TP102 methodology as generated by PDP) and run of river supply scenarios (site E, site E+A, or site C). Each run assumed the groundwater supply and storage reservoir would be available. In each case the size of the storage reservoir was adjusted to achieve varying levels of irrigation reliability. In the model, reliability is quantified as the ratio of volume supplied to volume demanded. The resulting reliabilities at different storage volumes for all runs are given in Table 2.

Table 2: Modelled Storage Requirements

Intake site and reservoir	TP102 methodology		Rainfall-runoff model	
	Reliability (%)	Storage volume (m^3)	Reliability (%)	Storage volume (m^3)
Intake site E and Reservoir Q	35%	100,000	67%	100,000
	95%	515,000	95%	284,500
	97%	532,000	97%	301,000
	99%	580,000	99%	340,000
Intake site A + E and Reservoir Q	77%	100,000	90%	100,000
	95%	177,500	95%	137,000
	97%	190,800	97%	156,400
	99%	210,500	99%	172,000
Intake site C and Reservoir J	77%	100,000	91%	100,000
	95%	177,500	95%	132,000
	97%	190,600	97%	151,500
	99%	210,000	99%	169,000

5.1 Site E

When using only Site E as an irrigation supply with storage site Q (The Quarry), the model predicted that between 284,500-340,000 m³ of storage would provide between 95-99% reliability if the rainfall-runoff (WWLA) flow series is used. When the TP102 (PDP) flow series is used, the range increases to 515,000-580,000 m³ (see Figure 4).

For comparative purposes, a scenario with 100,000 m³ of storage was also run. This scenario predicted an average reliability of 35% using the TP102 flow series and 67% using the rainfall-runoff flow series.

These storage volume predictions are very high. This is due to the limited supply of water from site E which generates only a small amount of flow due to the relatively small upstream catchment area. For this reason, the river supply at site E is considered insufficient as an irrigation supply, even with the supplementary groundwater abstraction.

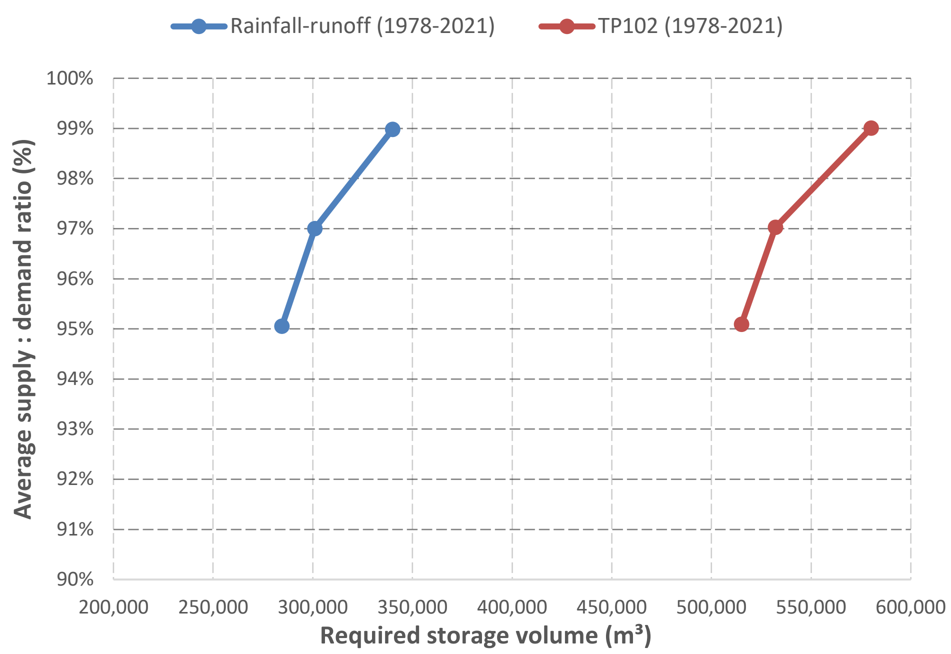

Figure 4: Site E Reliability Results

5.2 Site A + E

When site A was added to site E with storage site Q (The Quarry), the model predicted that between 137,000-172,000 m³ of storage would provide between 95-99% reliability if the rainfall-runoff (WWLA) flow series is used. When the TP102(PDP) flow series is used, the range increases to 177,500-210,500 m³ (see Figure 5).

For comparative purposes, a scenario with 100,000 m³ of storage was also run. This scenario predicted an average reliability of 77% using the TP102 flow series and 90% using the rainfall-runoff flow series.

The addition of site A drastically reduces predicted storage volumes as the irrigation supply can be met from the combined site A + E intake (70 L/s) when flows are available.

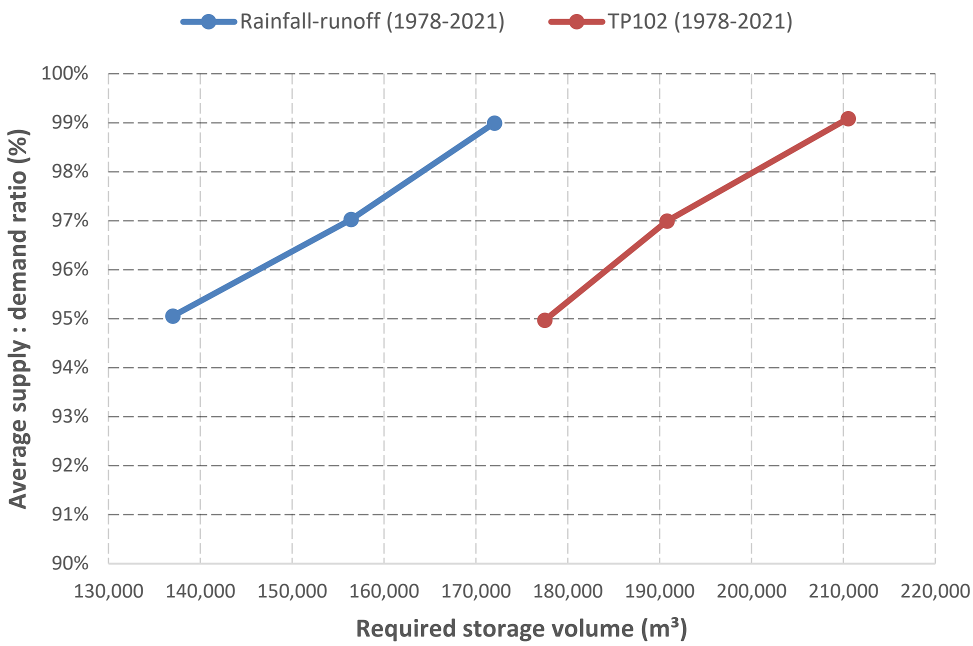

Figure 5: Site A + E Reliability Results

5.3 Site C

When using only Site C as an irrigation supply with storage site J, the model predicted that between 132,000-169,000 m³ of storage would provide between 95-99% reliability if the rainfall-runoff (WWLA) flow series is used. When the TP102 (PDP) flow series is used, the range increases to 177,500-210,000 m³ (see Figure 6).

For comparative purposes, a scenario with 100,000 m³ of storage was also run. This scenario predicted an average reliability of 77% using the TP102 flow series and 91% using the rainfall-runoff flow series.

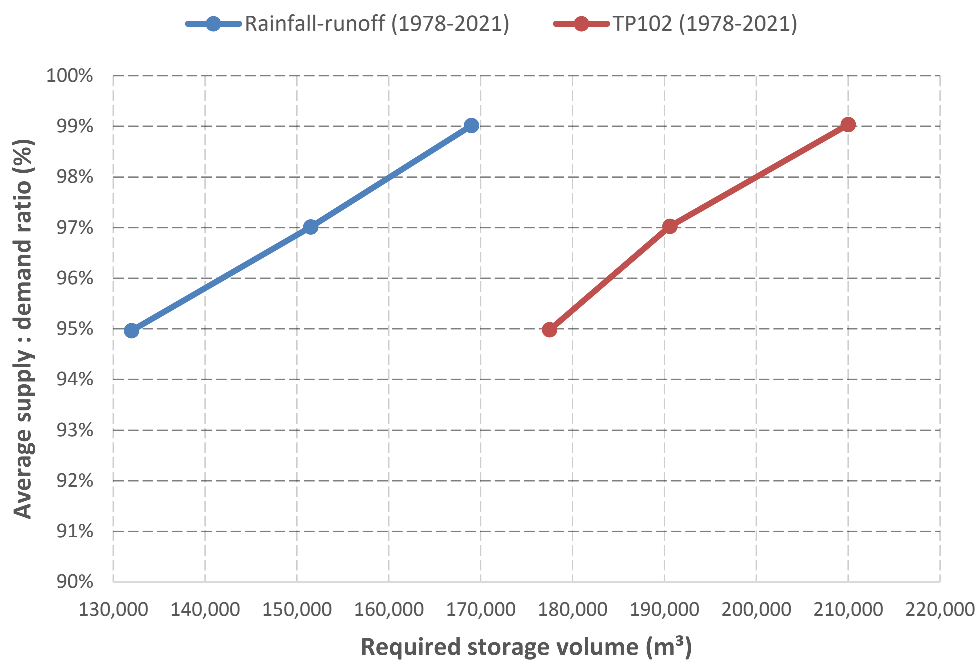

Figure 6: Site C Reliability Results

5.4 Detailed Reliability Results

To better illustrate the differences between the modelled levels of reliability, color-coded reliability breakdowns by month and season have been provided for the model scenarios involving site C. These results are presented in Appendix B. Green cells indicate high reliability (99% or higher), yellow cells indicate moderate to low reliability (90%-98%), while orange to red cells indicate low to very low reliability (below 90%).

For the 99% reliable scenario, there are only supply restrictions experienced in 1 out of the 41 complete seasons (2019-2020). These restrictions occur in late March (56.9% reliable) and April (5.9% reliable). Despite the potential severity of restriction in April, for much of the modelling period there is no demand for irrigation during this month (26 out of 41 seasons). Demand during April is only likely during drier years, and in this scenario, it is only in extreme dry years (such as 2019-2020) when this demand is not met.

For the 97% reliable scenario, there are only supply restrictions experienced in 2 out of the 41 complete seasons (2009-2010 and 2019-2020). As with the 99% scenario, severe restrictions occur during April in these years (4.2%-12.6% reliable), however in extreme dry years such as 2019-2020, supply is now largely unmet during March (4.7% reliable) and partial restrictions experienced in late February (95.4% reliable).

For the 95% reliable scenario, supply restrictions are experienced in 4 out of the 41 complete seasons (2009-2010, 2012-2013, 2013-2014, and 2019-2020). As with higher reliability scenarios, restrictions are severe in April during these years (3.7-79.4% reliable), however there are now also varying restrictions during March for 3 of these years (3.4-79.7% reliable). As with the 97% reliable scenario, during extreme dry years such as 2019-2020 there is a partial restriction during late February (68.1% reliable).

For the 91% reliable scenario, supply restrictions are experienced in 6 out of 41 complete seasons (1994-1995, 2009-2010, 2012-2013, 2013-2014, 2014-2015 and 2019-2020). The major difference between this scenario and the 95% reliable scenario is that restrictions are more severe and more frequent in March (3.2-78.6% reliable) and partial restrictions now also occur in February for 4 seasons (20.8-95.9% reliable).

6.0 Conclusion and Recommendation

This report has considered the available stream supply for irrigation at sites A, E and C (see Figure A1, Appendix A) and has modelled the required storage reservoir size for reservoir site Q (The Quarry) and reservoir site J to provide reliable irrigation for 49.5 ha of turf irrigation at the proposed golf course.

Given the uncertainties in water demand for the golf course, stream flows, and the volume of water available from streams and groundwater, it is recommended that the modelling will be updated once further information becomes available. This includes the following:

- Continuous flow data from the recently established flow recorder sites in the catchment;
- Available flow and volume of water from groundwater following further pump testing work (planned to be completed in July 2021);
- Finalising the golf course design including the irrigable area; and
- Determining the amount of left-over water from the core allocation currently allocated to one downstream user.

It is also recommended further work be undertaken to establish soil PAW values at the site and determine expected rooting depths for the varieties of turf grass to be grown at the proposed golf course.

7.0 References

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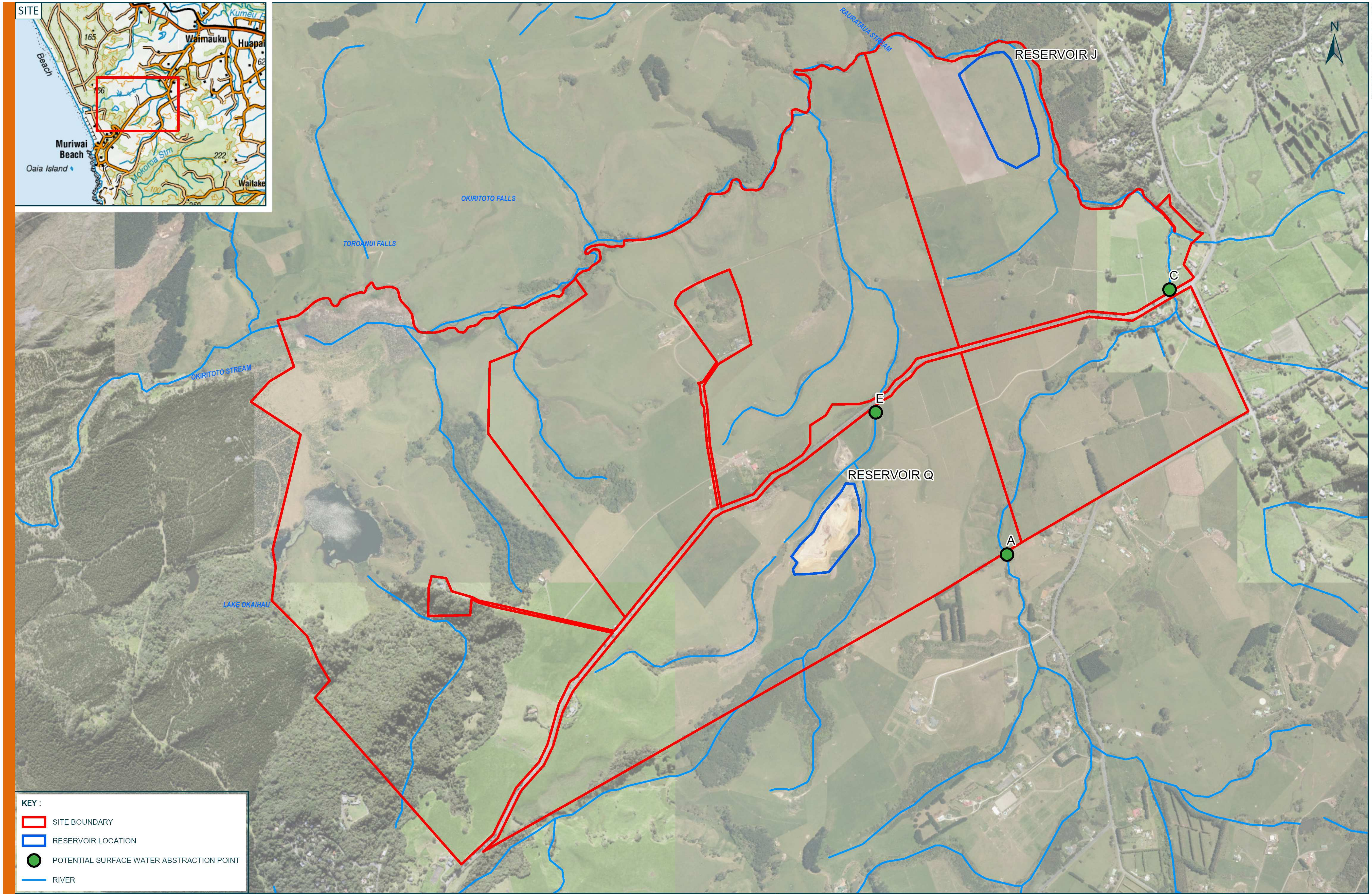
Appendix A
Maps



0 200 400
METRES

SCALE : 1:12,000 (A3)

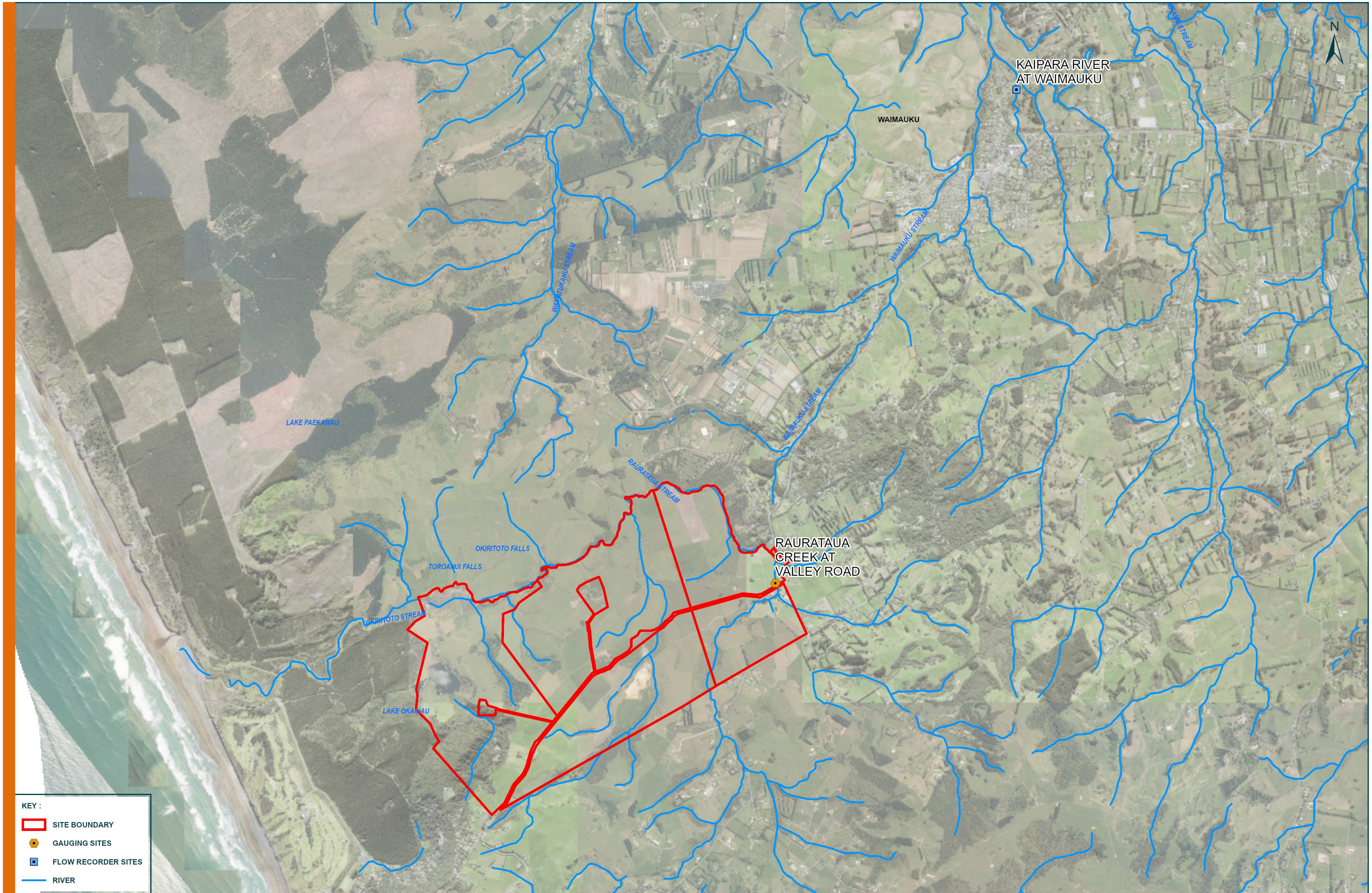
NO.	REVISION	DATE	BY
A	ISSUED FOR REVIEW	MAY 21	JS

SOURCE:
1. AERIAL IMAGERY (FLOWN 2016-2019) SOURCED FROM THE LINZ DATA SERVICE www.linz.govt.nz/about-linz/linz-data-service/help/using-linz-data/attributing-aerial-imagery-data AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. CADASTRAL/TOPOGRAPHICAL INFORMATION AND INSET DERIVED FROM LINZ DATA.

BEARS HOME COMPANY LIMITED

FIGURE A1: POTENTIAL SURFACE WATER ABSTRACTION SITES AND RESERVOIR LOCATIONS

MURIWAI DOWNS GOLF COURSE



A03582504.aprx - Fig2_PDP_A3L_Figure_2020

pdp

0 500 1000
METRES

SCALE : 1:30,000 (A3)

NO.	REVISION	DATE	BY
A	ISSUED FOR REVIEW	MAY 21	JS

SOURCE:
1. AERIAL IMAGERY (FLOWN 2016-2019) SOURCED FROM THE LINZ DATA SERVICE www.linz.govt.nz/about-linz/linz-data-service/help/using-linz-data/attributing-aerial-imagery-data AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. CADASTRAL/TOPOGRAPHICAL INFORMATION AND INSET DERIVED FROM LINZ DATA.

BEARS HOME COMPANY LIMITED

FIGURE A2: LOCATION OF GAUGING SITE AND FLOW RECORDER SITE USED FOR REGRESSION ANALYSIS

MURIWAI DOWNS GOLF COURSE

Appendix B

Site C Detailed Reliability Outputs

Site C: rainfall-runoff flows 99% reliable													
month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Annual**
1978-1979					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1979-1980						100.0%		100.0%					100.0%
1980-1981				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1981-1982						100.0%	100.0%	100.0%	100.0%				100.0%
1982-1983					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1983-1984					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1984-1985				100.0%		100.0%	100.0%	100.0%	100.0%				100.0%
1985-1986					100.0%		100.0%		100.0%	100.0%			100.0%
1986-1987					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1987-1988							100.0%	100.0%	100.0%	100.0%			100.0%
1988-1989					100.0%	100.0%		100.0%	100.0%	100.0%			100.0%
1989-1990					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1990-1991						100.0%	100.0%	100.0%					100.0%
1991-1992						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1992-1993					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1993-1994						100.0%	100.0%	100.0%	100.0%				100.0%
1994-1995					100.0%	100.0%	100.0%	100.0%					100.0%
1995-1996						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1996-1997					100.0%		100.0%	100.0%					100.0%
1997-1998					100.0%	100.0%	100.0%	100.0%					100.0%
1998-1999					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1999-2000						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2000-2001				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2001-2002			100.0%	100.0%			100.0%	100.0%	100.0%				100.0%
2002-2003					100.0%	100.0%	100.0%	100.0%					100.0%
2003-2004					100.0%	100.0%	100.0%		100.0%	100.0%			100.0%
2004-2005					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2005-2006					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2006-2007						100.0%	100.0%	100.0%	100.0%				100.0%
2007-2008					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2008-2009					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2009-2010					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2010-2011				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2011-2012					100.0%	100.0%	100.0%	100.0%		100.0%			100.0%
2012-2013					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2013-2014				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2014-2015						100.0%	100.0%	100.0%	100.0%				100.0%
2015-2016				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2016-2017						100.0%	100.0%	100.0%	100.0%				100.0%
2017-2018					100.0%	100.0%	100.0%		100.0%				100.0%
2018-2019				100.0%	100.0%		100.0%	100.0%	100.0%				100.0%
2019-2020					100.0%	100.0%	100.0%	100.0%	56.9%	5.9%			80.8%
2020-2021				100.0%	100.0%	100.0%	100.0%						100.0%
all-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	83.8%			99.1%
all-complete-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	83.8%			99.0%

Site C: rainfall-runoff flows 97% reliable													
month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Annual**
1978-1979					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1979-1980						100.0%		100.0%					100.0%
1980-1981				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1981-1982						100.0%	100.0%	100.0%	100.0%				100.0%
1982-1983					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1983-1984					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1984-1985				100.0%		100.0%	100.0%	100.0%	100.0%				100.0%
1985-1986					100.0%		100.0%		100.0%	100.0%			100.0%
1986-1987					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1987-1988							100.0%	100.0%	100.0%	100.0%			100.0%
1988-1989					100.0%	100.0%		100.0%	100.0%	100.0%			100.0%
1989-1990					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1990-1991						100.0%	100.0%	100.0%					100.0%
1991-1992						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1992-1993					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1993-1994						100.0%	100.0%	100.0%	100.0%				100.0%
1994-1995					100.0%	100.0%	100.0%	100.0%					100.0%
1995-1996						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1996-1997					100.0%		100.0%	100.0%					100.0%
1997-1998					100.0%	100.0%	100.0%	100.0%					100.0%
1998-1999					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1999-2000						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2000-2001				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2001-2002			100.0%	100.0%			100.0%	100.0%	100.0%				100.0%
2002-2003					100.0%	100.0%	100.0%	100.0%					100.0%
2003-2004					100.0%	100.0%	100.0%		100.0%	100.0%			100.0%
2004-2005					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2005-2006					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2006-2007						100.0%	100.0%	100.0%	100.0%				100.0%
2007-2008					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2008-2009					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2009-2010					100.0%	100.0%	100.0%	100.0%	100.0%	12.6%			82.7%
2010-2011				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2011-2012					100.0%	100.0%	100.0%	100.0%		100.0%			100.0%
2012-2013					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2013-2014				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2014-2015						100.0%	100.0%	100.0%	100.0%				100.0%
2015-2016				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2016-2017						100.0%	100.0%	100.0%	100.0%				100.0%
2017-2018					100.0%	100.0%	100.0%		100.0%				100.0%
2018-2019				100.0%	100.0%		100.0%	100.0%	100.0%				100.0%
2019-2020					100.0%	100.0%	100.0%	95.4%	4.7%	4.2%			63.7%
2020-2021				100.0%	100.0%	100.0%	100.0%						100.0%
all-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	99.8%	92.7%	67.7%			97.1%
all-complete-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	99.8%	92.5%	67.7%			97.0%

Site C: rainfall-runoff flows 95% reliable													
month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Annual**
1978-1979					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1979-1980						100.0%		100.0%					100.0%
1980-1981				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1981-1982						100.0%	100.0%	100.0%	100.0%				100.0%
1982-1983					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1983-1984					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1984-1985				100.0%		100.0%	100.0%	100.0%	100.0%				100.0%
1985-1986					100.0%		100.0%		100.0%	100.0%			100.0%
1986-1987					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1987-1988							100.0%	100.0%	100.0%	100.0%			100.0%
1988-1989					100.0%	100.0%		100.0%	100.0%	100.0%			100.0%
1989-1990					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1990-1991						100.0%	100.0%	100.0%					100.0%
1991-1992						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1992-1993					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1993-1994						100.0%	100.0%	100.0%	100.0%				100.0%
1994-1995					100.0%	100.0%	100.0%	100.0%					100.0%
1995-1996						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1996-1997					100.0%		100.0%	100.0%					100.0%
1997-1998					100.0%	100.0%	100.0%	100.0%					100.0%
1998-1999					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1999-2000						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2000-2001				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2001-2002			100.0%	100.0%			100.0%	100.0%	100.0%				100.0%
2002-2003					100.0%	100.0%	100.0%	100.0%					100.0%
2003-2004					100.0%	100.0%	100.0%		100.0%	100.0%			100.0%
2004-2005					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2005-2006					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2006-2007						100.0%	100.0%	100.0%	100.0%				100.0%
2007-2008					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2008-2009					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2009-2010					100.0%	100.0%	100.0%	100.0%	32.5%	7.5%			66.1%
2010-2011				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2011-2012					100.0%	100.0%	100.0%	100.0%		100.0%			100.0%
2012-2013					100.0%	100.0%	100.0%	100.0%	79.7%	31.0%			94.8%
2013-2014				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	79.4%			98.2%
2014-2015						100.0%	100.0%	100.0%	100.0%				100.0%
2015-2016				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2016-2017						100.0%	100.0%	100.0%	100.0%				100.0%
2017-2018					100.0%	100.0%	100.0%		100.0%				100.0%
2018-2019				100.0%	100.0%		100.0%	100.0%	100.0%				100.0%
2019-2020					100.0%	100.0%	100.0%	68.1%	3.4%	3.7%			53.8%
2020-2021				100.0%	100.0%	100.0%	100.0%						100.0%
all-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	84.6%	61.2%			95.2%
all-complete-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	98.5%	84.4%	61.2%			95.0%

Site C: rainfall-runoff flows 91% reliable													
month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Annual**
1978-1979					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1979-1980						100.0%		100.0%					100.0%
1980-1981				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1981-1982						100.0%	100.0%	100.0%	100.0%				100.0%
1982-1983					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1983-1984					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1984-1985				100.0%		100.0%	100.0%	100.0%	100.0%				100.0%
1985-1986					100.0%		100.0%		100.0%	100.0%			100.0%
1986-1987					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1987-1988							100.0%	100.0%	100.0%	100.0%			100.0%
1988-1989					100.0%	100.0%		100.0%	100.0%	100.0%			100.0%
1989-1990					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1990-1991						100.0%	100.0%	100.0%					100.0%
1991-1992						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1992-1993					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1993-1994						100.0%	100.0%	100.0%	100.0%				100.0%
1994-1995					100.0%	100.0%	100.0%	95.9%					99.3%
1995-1996						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
1996-1997					100.0%		100.0%	100.0%					100.0%
1997-1998					100.0%	100.0%	100.0%	100.0%					100.0%
1998-1999					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
1999-2000						100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2000-2001				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2001-2002			100.0%	100.0%			100.0%	100.0%	100.0%				100.0%
2002-2003					100.0%	100.0%	100.0%	100.0%					100.0%
2003-2004					100.0%	100.0%	100.0%		100.0%	100.0%			100.0%
2004-2005					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2005-2006					100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2006-2007						100.0%	100.0%	100.0%	100.0%				100.0%
2007-2008					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2008-2009					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			100.0%
2009-2010					100.0%	100.0%	100.0%	93.5%	3.5%	7.3%			54.4%
2010-2011				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2011-2012					100.0%	100.0%	100.0%	100.0%		100.0%			100.0%
2012-2013					100.0%	100.0%	100.0%	76.4%	14.0%	4.8%			63.2%
2013-2014				100.0%	100.0%	100.0%	100.0%	100.0%	14.5%	2.5%			72.9%
2014-2015						100.0%	100.0%	100.0%	78.6%				97.9%
2015-2016				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%				100.0%
2016-2017						100.0%	100.0%	100.0%	100.0%				100.0%
2017-2018					100.0%	100.0%	100.0%		100.0%				100.0%
2018-2019				100.0%	100.0%		100.0%	100.0%	100.0%				100.0%
2019-2020					100.0%	100.0%	100.0%	20.8%	3.2%	3.5%			44.7%
2020-2021				100.0%	100.0%	100.0%	100.0%						100.0%
all-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	95.0%	70.5%	51.2%			91.4%
all-complete-seasons			100.0%	100.0%	100.0%	100.0%	100.0%	95.0%	70.0%	51.2%			91.0%