North-western water supply: storage requirements

Assessment of storage required and site selection assessment

Prepared for Watercare Services Ltd
Prepared by Beca Limited

22 May 2019

make everyday better.

Creative people together transforming our world

Contents

Appendices

Figures

Tables

Revision History

Revision Nº	Prepared By	Description	Date
1	**Scott Pearson / Jon Reed**	Draft for comment	**10/05/2019**
2	**Scott Pearson / Jon Reed**	Final draft	**17/05/2019**
3	**Scott Pearson / Jon Reed**	For resource consent	**22/05/2019**

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Scott Pearson / Jon Reed**	S Pearson Jon Reed	**22/05/2019**
Reviewed by	**John Wardle**	J Wardle	**22/05/2019**
Approved by	**Jon Reed**	Jon Reed	**22/05/2019**
on behalf of	**Beca Limited**		

© Beca 2019 (unless Beca has expressly agreed otherwise with the Client in writing).
This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Executive Summary

Water storage within the north-western water supply area

The Huia Water Treatment Plant is the third largest water treatment plant in Auckland and is due to be replaced. As part of this work, Watercare also plans to construct additional water storage capacity to meet its operational requirements. The reasons for water storage include:

- To equalise pumping and treatment rates
- To optimise transmission pipe sizes
- Resilience, in the event of a shutdown of part of the network
- To reduce pressure fluctuations
- To provide sufficient water for firefighting

Assessment of the total storage required

The first part of this report investigates and establishes the total storage required across the north-western water supply area. This is based on storage within Watercare's network being required for three reasons:

- Resilience, to provide a volume equal to the average day of the peak month demand
- Operational lag storage, to enable the Huia WTP to 'ramp up' from average to peak capacity
- Buffer storage, to enable the Huia WTP to operate at a fixed rate with the diurnal variation in demand provided from storage

The north-western water supply is divided into four areas which enables (for each area) the total storage required now and in the future to be established. The analysis shows that although there is sufficient storage across the whole of the supply area, there is currently a deficit of about 25,000 m^3 in Area 1 (closest to the Huia WTP). This deficit in Area 1 is expected to grow to 50,000 m^3 by 2065. Further analysis demonstrates that if the first 25,000 m^3 of storage is completed as part of the construction of the replacement Huia WTP, the second 25,000 m^3 would be required by the late 2020s. This provides an opportunity for the reservoirs to be constructed at either the same, or separate, locations.

Once 50,000 m^3 of additional storage is provided in Area 1, this analysis also shows that Area 2 (between Waikumete Reservoir and Upper Harbour Highway) has a storage deficit. This is expected to commence in the early 2030s and grows to 25,000 m^3 by the 2060s.

Assessment of where this storage should be located

Watercare prepared an original site layout which included 50,000 m^3 of storage at the Woodlands Park Rd site. Watercare then decided to re-evaluate the proposed location of the reservoirs to further test alternative sites and layouts. This was driven by a combination of consultation and the Watercare Board's directive to avoid wherever possible significant trees and significant ecological effects. As part of this process, the following principles for reviewing potential sites for storage were established:

- Volume
- Elevation
- Location
- Resilience
- Complexity
- Sustainability

To investigate different location options for the required reservoir storage, analysis was carried out to identify potential sites within 2km of the designated NH2 watermain route which fitted the required elevation criteria (which is critical to enable a gravity fed system).

This resulted in a narrow band of locations, which were investigated to establish a total of 11 potential options. Coarse screening of these was carried out against Watercare's principles, which identified a shortlist of six sites, although not all of these have space available for a full 50,000 m^3 of storage.

Based on the analysis of when this storage is required, it was confirmed that the total 50,000 m^3 storage could be provided by a combination of two reservoirs, each of approximately 25,000 m^3. This enabled five different reservoir combinations to be established, which meet the first two criteria, of volume and elevation.

A qualitative assessment of the potential advantages and disadvantages of these five reservoir combinations was carried out, with reference to the original layout (50,000 m^3 storage at Woodlands Park Rd). This enabled the relative advantages and disadvantages of each combination of options to be compared. This resulted in the shortlist being reduced to two combinations, being:

- Combination 1 - 50,000 m^3 at Woodlands Park Rd
- Combination 2 - 25,000 m^3 at Woodlands Park Rd, followed by a further 25,000 m^3 at the existing Huia WTP site (once the existing site has been decommissioned)

A quantitative assessment of these sustainability and complexity criteria was carried out. This shows that Combination 1 is less complex to operate as it has two reservoirs at a single site, at the same elevation. However, Combination 2 offers social and environmental benefits, particularly as it retains the existing prominent knoll, together with the 17 Kauri trees at the Woodlands Park Rd site. It is therefore recommended that Watercare proceed with:

- 25,000 m^3 of storage at Woodlands Park Rd constructed in conjunction with the replacement Huia WTP, and
- 25,000 m^3 of storage at the existing Huia WTP site by the late 2020s.

1 Introduction

Watercare Services Limited (Watercare) is responsible for the treatment and supply of potable water and for the collection, treatment and disposal of wastewater to around 1.4 million people in Auckland. Watercare is a Council Controlled Organisation (CCO), wholly owned by the Auckland Council.

Watercare operates five dams within the Waitākere Ranges, including the Upper and Lower Huia Dams and the Upper and Lower Nihotupu Dams. Water from these Western Water Supply dams is treated at the Huia and Waitākere Water Treatment Plants before being distributed via the water transmission network, primarily to west and north Auckland. The Huia Water Treatment Plant (Huia WTP) is the third largest water treatment plant in Auckland and is a crucial component of Auckland's water supply network, treating approximately 20% of Auckland's water.

The Huia WTP was constructed in 1929 and is now nearing the end of its operational life (90 years old). Watercare therefore proposes to construct a new WTP to replace the aging Huia WTP. As part of this project Watercare also determined to increase treated water storage within the north-western water supply area.

This report has been prepared to determine the volume of storage required and assess options for the location of this storage. It accompanies the regional resource consent application and the outline plan of works in relation to the proposed construction and operation of the WTP and reservoirs.

1.1 Project description

To support the replacement WTP work, Watercare engaged Beca Limited (Beca) to investigate and assess the water reservoir storage requirements for its north-western supply area. Watercare recognised that current storage was not sufficient for operational requirements. Construction of the replacement WTP provides an opportunity to identify and deliver adequate treated water storage for its north-western supply area.

Watercare prepared an original site layout which included 50,000 m^3 of storage at the Woodlands Park Rd site. Watercare decided to re-evaluate the proposed location of the reservoirs to further test alternative sites and layouts. This was driven by a combination of consultation and the Watercare Board's directive to avoid wherever possible significant trees and significant ecological effects.

1.2 Our approach to this study

This work identifies the volume and location of treated water storage to satisfy demand and security of supply requirements within the north-west supply area. At a high level, the steps taken comprise:

- A review of national international and international practice in relation to the provision of treated water reservoir storage requirements;
- An assessment of the total storage required, based on Watercare's current and future needs;
- Development of a suite of Watercare's principles and operational requirements, to guide the location of storage in the north-western supply area;
- A desk top study to identify potential locations where this reservoir storage could be located; and
- Screening and more in-depth analysis to identify the preferred location for strategic storage.

This report builds on earlier options assessment work, particularly the site selection report named "CH2M Beca site selection report." written in May 2019.

2 The storage required for water supply

2.1 The Watercare metropolitan water supply network

Watercare's metropolitan network supplies more than 400,000 m^3/day (on average) to approximately 1.4 million consumers across the Auckland region. Water is supplied from five water treatment plants with the following capacities:

- Ardmore WTP: 350,000 m^3/d
- Waikato WTP: 150,000 m^3/d
- Huia WTP: 126,000 m^3/d
- Waitakere WTP: 25,000 m^3/d
- Onehunga WTP: 23,000 m^3/d

The water treatment plant capacities shown above are a theoretical maximum. In reality it is normal for the available capacity to be lower than those shown, due to both hydrological constraints and planned / unplanned outages.

Watercare operates a bulk water transmission system to supply Auckland's metropolitan water supply system. The bulk water network is shown as Figure 1. This enables Watercare to operate an integrated distribution system, which provides redundancy in the event that a WTP or watermain is out of service for any reason.

Watercare's network is generally gravity fed but supplies to higher areas are maintained by pumping water to higher elevations throughout the system that cannot be supplied by gravity. Treated water is supplied from the bulk water network to local distribution networks through 198 Bulk Supply Points (BSPs). As part of the network Watercare maintains 67 service reservoirs throughout the Auckland Region with a total storage capacity of 839,000 m^3.

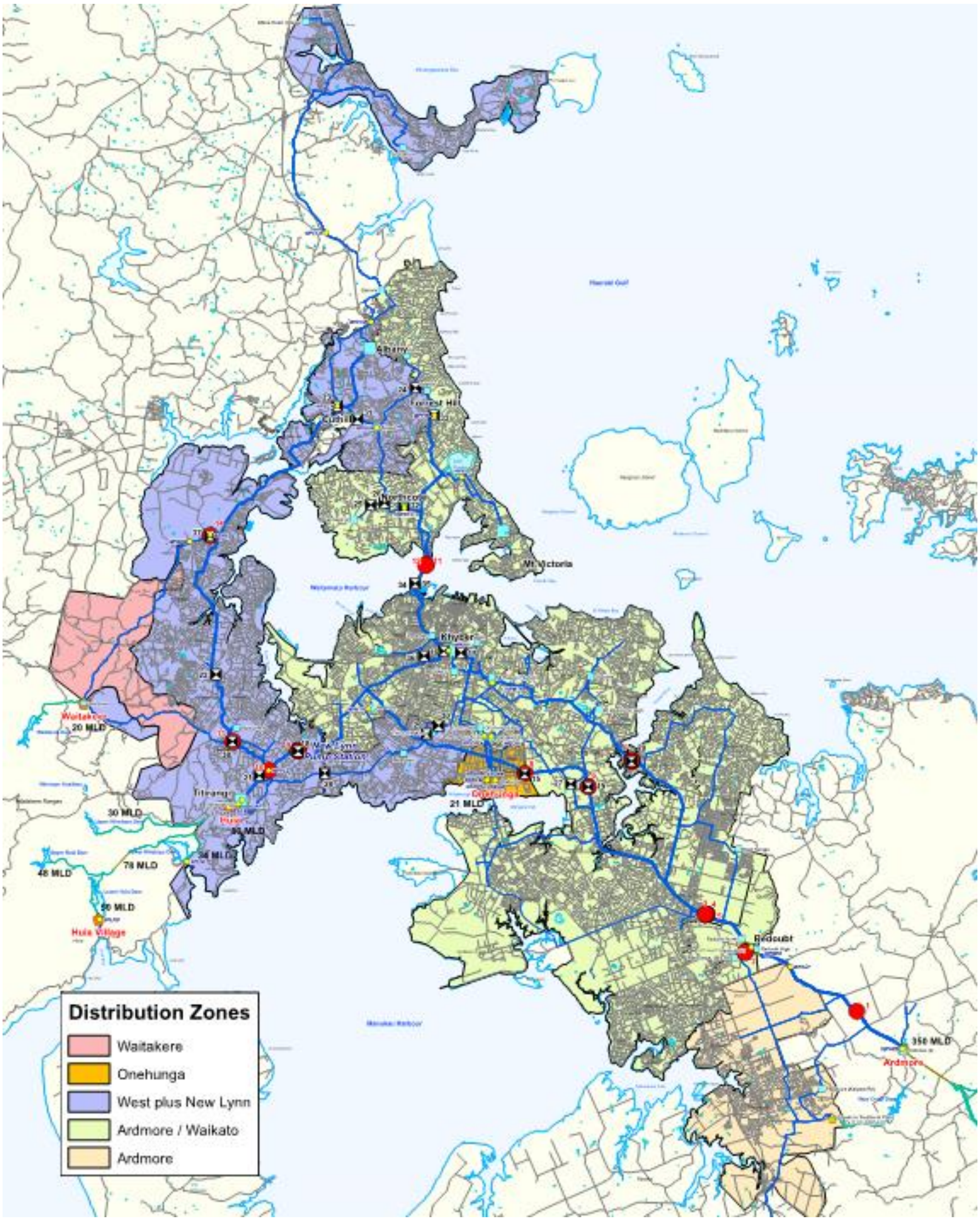


Figure 1: Watercare supply network (Source: Watercare)

2.2 The North-western Water Supply

Water from the five water supply dams in the Waitakere Ranges is treated at the Huia and Waitakere WTPs before supplying the north-western water supply network. This is shown in the purple shaded area in Figure 1 above (West plus New Lynn). The New Lynn Pump Station is in place to provide additional water from the southern sources (Ardmore and Waikato WTPs) during high demand periods, or when there is a planned or unplanned outage at the Huia WTP.

The majority of the water is conveyed using the North Harbour 1 transmission main (NH1). Currently, water from the Huia WTP gravitates to the Titirangi reservoirs and from there by gravity to the NH1 pipeline (Figure 2). Under normal conditions, water can reach the Albany reservoirs under gravity. During periods of high demand, water pressure is boosted by the Triangle Road pump station.

The NH1 demand can be supplied from the southern sources via the wider transmission network. This water from the southern sources is pumped into the NH1 system from the New Lynn pump station (also shown in Figure 2). Usually this would only be operated when demand in the north-western water supply area exceeds the capacity of the Huia WTP.

The transmission network does not have enough capacity to meet the forecast growth in demand and Watercare is in the process of constructing a second high-capacity transmission main to supply these communities. The designation of this main follows a different route and is called the North Harbour 2 transmission main (NH2).

Based on the existing reservoir locations, the North Western Water Supply system has been separated into the following four areas (Table 1 and Figure 2). This shows that there is over 135,000 m^3 of current storage within the supply area, with a further 30,000 m^3 planned within Area 3.

Watercare has also advised that:

- The Titirangi 1 reservoir capacity (5,000 m^3) will be decommissioned and should not be included in the future required volume assessment
- Nihotupu Reservoir can only supply local customers downstream, so any surplus storage from this reservoir is not available to the remainder of the network and is not considered in the overall assessment.

Table 1: North western water supply areas

Area	Areas supplied	Reservoirs and capacities	Total storage
One	▪ Titirangi ▪ New Lynn ▪ Hillsborough ▪ Oratia ▪ Mt Roskill	**Existing Reservoirs:** ▪ Titirangi 1 (5,000 m^3) ▪ Titirangi 2 (16,700 m^3) ▪ Nihotupu 1 and 2 (3,400 m^3)	**Current storage:** ▪ 25,100 m^3
Two	▪ Henderson ▪ Te Atatu ▪ Waitakere ▪ Massey ▪ Westgate	**Existing Reservoirs:** ▪ Waikumete (22,200 m^3) ▪ Waitakere (9,800 m^3)	**Current storage:** ▪ 32,000 m^3
Three	▪ Hobsonville ▪ Greenhithe ▪ Glenfield ▪ Sunnynook ▪ Rosedale ▪ North Harbour	**Existing Reservoirs:** ▪ Cuthill (28,300 m^3) ▪ Sunset West (4,600 m^3) **Future Reservoirs:** ▪ Schnapper Rock (20,000 m^3) ▪ Hobsonville (10,000 m^3)	**Current storage:** ▪ 32,900 m^3 **Future storage:** ▪ 30,000 m^3
Four	▪ Albany ▪ Whangaparoa	**Existing Reservoirs:** ▪ Albany (20,000 m^3) ▪ Glenvar (7,700 m^3) ▪ Maire Rd (10,000 m^3) ▪ Scott Rd (7,500 m^3)	**Current storage:** ▪ 45,200 m^3

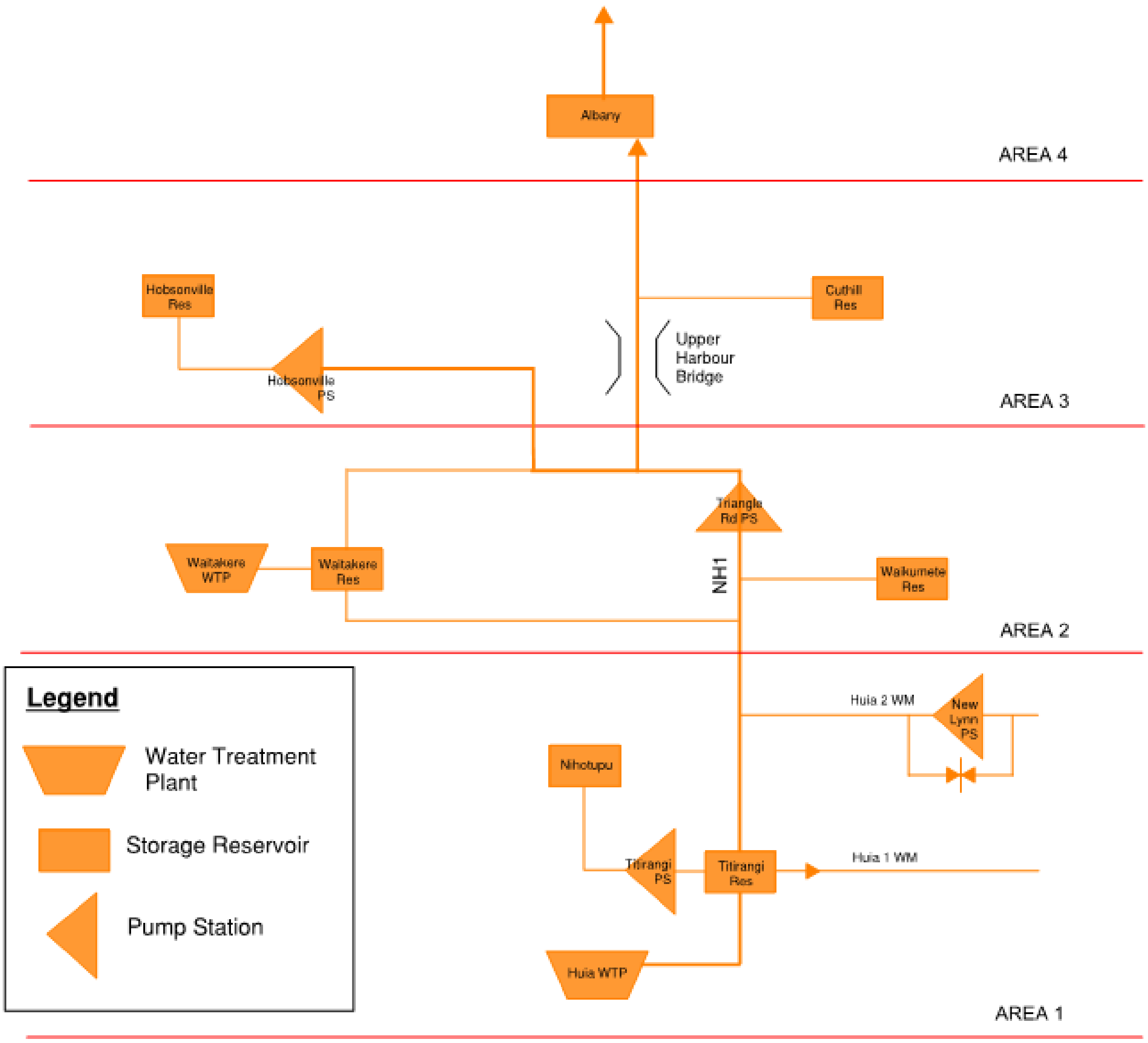


Figure 2: Current north western water supply area transmission schematic (simplified)

2.3 Reasons for water storage

Water storage provides resilience and reliability to a water supply system to meet consumer driven demand variation, manage disruptive events and facilitate economic system operation. The American Water Association (AWWA) Water Distribution Systems Handbook states "*Water distribution storage is provided to ensure reliability of supply, maintain pressure, equalise pumping and treatment rates, reduce the size of transmission lines, and improve operational flexibility and efficiency*".

The following are the key reasons for water storage:

- **Equalise pumping and treatment rates:** Storage can allow for water treatment plants and pumping stations to operate uniformly at average day demands, without the need to provide additional capacity respond to the diurnal peaks. Uniform treatment rates provide stable process stream flows, efficient and effective operation of the plant and lower risk of adverse drinking water quality.

- **Optimise transmission pipe sizes / maximise transmission pipe capacities**: provides capacity to "buffer" normal diurnal demand variation, reducing the capacity requirement of transfer mains due to average rather than peak flows being transferred from the WTPs. Strategically located storage therefore supports efficient operation of the system and enables trunk pipeline sizes to be optimised.
- **Resilience:** In the event of a failure, or if a shutdown of significant treatment or transmission infrastructure is required for maintenance activities, storage is required to be drawn down to supplement the limited capacity available through any alternative piped supply/source available. These outages may be of a significant duration where reservoir storage cannot be relied on entirely, and thus alternative piped supplies are also required. Significant lag times are often necessary to reconfigure alternative surplus in such circumstances placing further demands on storage.
- **Reduces pressure fluctuations:** Reservoir storage provides a stable pressure to the downstream distribution network.
- **Firefighting:** The New Zealand Fire Service Firefighting Water Supplies Code of Practice (SNZ PAS 4509:2003) details water needed to meet fire demands including the total volume of water required for each Fire Water Classification.

These reasons for reservoir storage are shown diagrammatically as Figure 3. This shows the different types of storage, including the dead storage water at the lowest part of the reservoir which cannot be used effectively.

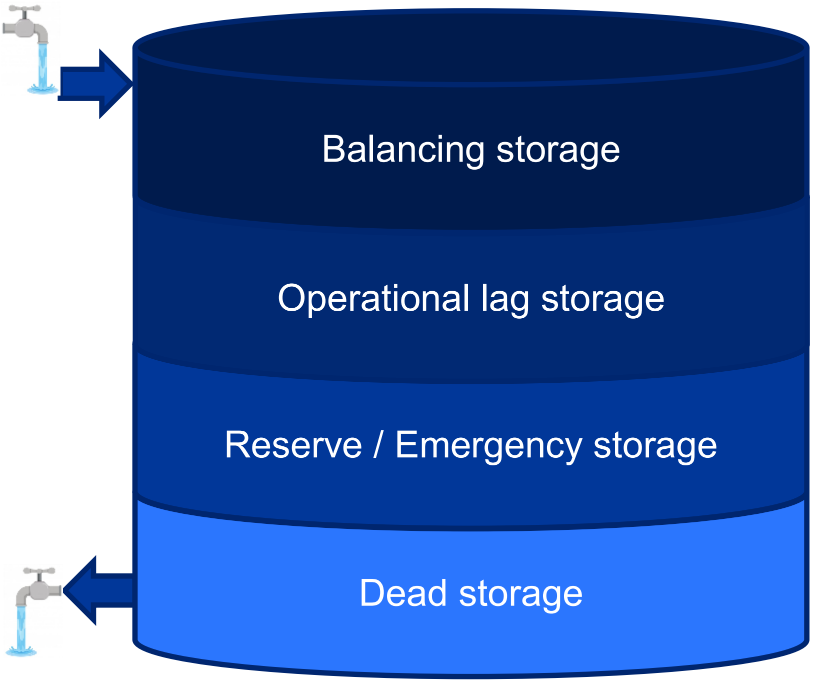


Figure 3: Diagrammatic representation of the reasons for reservoir storage

Water storage is best provided both:

- Local to a water treatment plant to allow for efficient and effective operation of the water treatment plant, and to provide emergency storage to as much of the network as possible for outage events at the WTP
- Local to its supply area customers to provide emergency storage for local outages within the water supply network

Watercare adopt two key criteria for reservoir storage:

- To meet an Aa grading (previously this required 24 hours of storage at average demand)
- To meet their Statement of Corporate Intent objective to have less than 10 complaints per 1000 connections on an annual basis, of low pressure or low flow at the customer connection.

To minimise customer complaints, assurance of continuity of supply is required. Watercare must manage supply risks to their customers at their water treatment plants, from unplanned transmission or network outages such as plant and pipe failures, and during significant maintenance activities.

Watercare operates a large water supply system with numerous potentially critical points which pose a significant risk in the event of an unplanned supply interruption, or if a shutdown is required for maintenance activities. A maximum time to repair (MTTR) for watermain breaks can be in excess of three days, so reservoir storage is required to be drawn down during to supplement the limited capacity available through alternative piped supplies available in such events.

Ideally, any single point of supply failure in the supply network should be provided with storage that enables continuous supply to customers to be maintained during adjustments to the networks or enable a reasonable time for the failure to be restored.

3 Storage required

This section describes and compares Watercare's approach to reservoir storage against national and international standards and practices, and then determines the required timing, volume and location of reservoir storage for the North Western Water Supply.

3.1 Summary of the approach to water storage in New Zealand and overseas

Currently there is no legislation or guidelines in place in New Zealand for the provision of network storage. Advice was sought from Water NZ's technical staff, who noted that there is little in the way of standards. A 'rule of thumb' of 24 hours at average demand is often used as a starting point for calculating required reservoir storage.

Appendix A shows a summary of the different approaches that are applied by other Councils in New Zealand together with overseas water utilities. These approaches vary based on risk profile, nature and configuration of the sources and the extent of the water supply network.

3.2 Watercare's proposed approach

3.2.1 Reservoir storage principles

Based on existing international best practice, operational knowledge and Watercare's risk profile, the following volume principles were defined by Watercare in relation to reservoir storage:

V1 The useable volume of storage should provide for a minimum of 24 hours peak month average day demand.

V2 The total volume of storage within the North Western Supply Area should buffer diurnal water demand fluctuations to enable the WTP to operate uniformly at the daily demand. This storage is required between the Huia Replacement WTP and the first customer Bulk Supply Point (BSP).

V3 Storage is required to balance any operating lag during flow increases from the Huia Replacement WTP when required from minimum to maximum output (80,000 m^3/d to 140,000 m^3/d). This storage is required between the Huia Replacement WTP and the first BSP.

3.2.2 The relative difference in the approach used

A relative assessment of the adopted storage volumes of national and international water suppliers, based on an average demand of 100,000 m^3/d, is provided in Figure 4. This suggests that Watercare's proposed approach results in a required storage volume that aligns closely with many other water suppliers.

The analysis suggests that Queenstown and Sydney Water would both design less storage, with Watercare's approach aligning closely to that of Hamilton City, Bristol Water and the Melbourne retailers. Higher storage volumes are proposed by the Melbourne retailers (high risk), Wellington Water and Tauranga City.

The different approaches correspond to the different risk profiles, networks and nature of the water sources within each water utility. Watercare has adopted an approach that reflects the nature of their integrated network, but recognises the essential role that reservoirs have to play in maintaining public health.

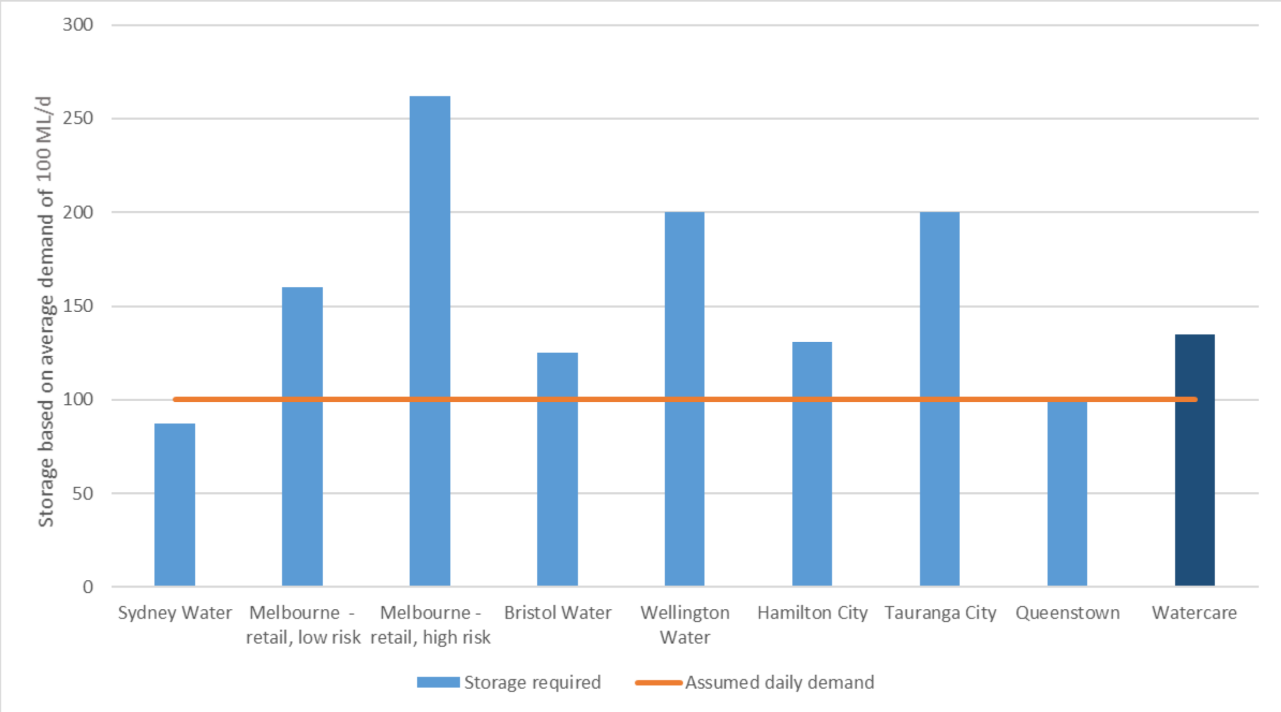


Figure 4: Relative assessment of storage volumes

3.3 Current and future demand

Current demand from the Huia WTP to the NH1 transmission main is approximately 65,000 m^3/d on average, increasing to 105,000 m^3/d during the summer peak period.

Watercare provided a NH2 Long Term Operational Philosophy and Resilience Assessment to determine the required capacity of the proposed NH2 watermain and the future demand that would be met from the proposed Huia WTP. The outputs of this study include a diurnal profile of the expected demand across the North Western Water Supply zone and estimates of the future demand for water. The Assessment also reviewed a number of different outage scenarios to assess the infrastructure constraints and how the proposed Huia WTP and reservoirs could be used to overcome these.

The current and future peak day demands are shown in Table 2. This suggests that the current connected population of approximately 480,000 people is expected to grow by almost 300,000 people over the period to 2065.

Table 2: North western water supply area demand and population data

	2018	2065
Peak Day Demand (m^3/d)[1]	104,160	207,900
Connected population[2]	297,000	599,000

1 Provided Watercare's Transmission model
2 From Watercare GIS output of North Western Water Supply Area

3.4 Storage volume required for the North Western Water Supply

This section shows how the required storage volume is calculated, based on the three Principles of transmission network storage, buffer storage and operational lag storage.

3.4.1 Transmission Network Storage

The total transmission network storage component is required to meet the peak month, average day demand. This storage volume is calculated using a peak day factor of 1.3 and a peak month factor of 1.15 relative to average day demand. The total storage volumes are provided in theTable 3 below and are shown distributed down into the geographical areas identified in Figure 2 as Figure 5. This allows us to determine the transmission network storage required to compare with current storage within each area over time.

Table 3: Average day, estimated growth in population and average day peak month demand

Year	Estimated Population	Average day peak month demand (m^3/day)
2018	297,000	92,140
2023	349,000	108,139
2028	390,000	120,951
2033	425,000	132,017
2038	456,000	141,527
2043	485,000	150,460
2048	511,000	158,548
2053	535,000	165,981
2058	561,000	173,915
2063	586,000	181,850
2068	612,000	189,786

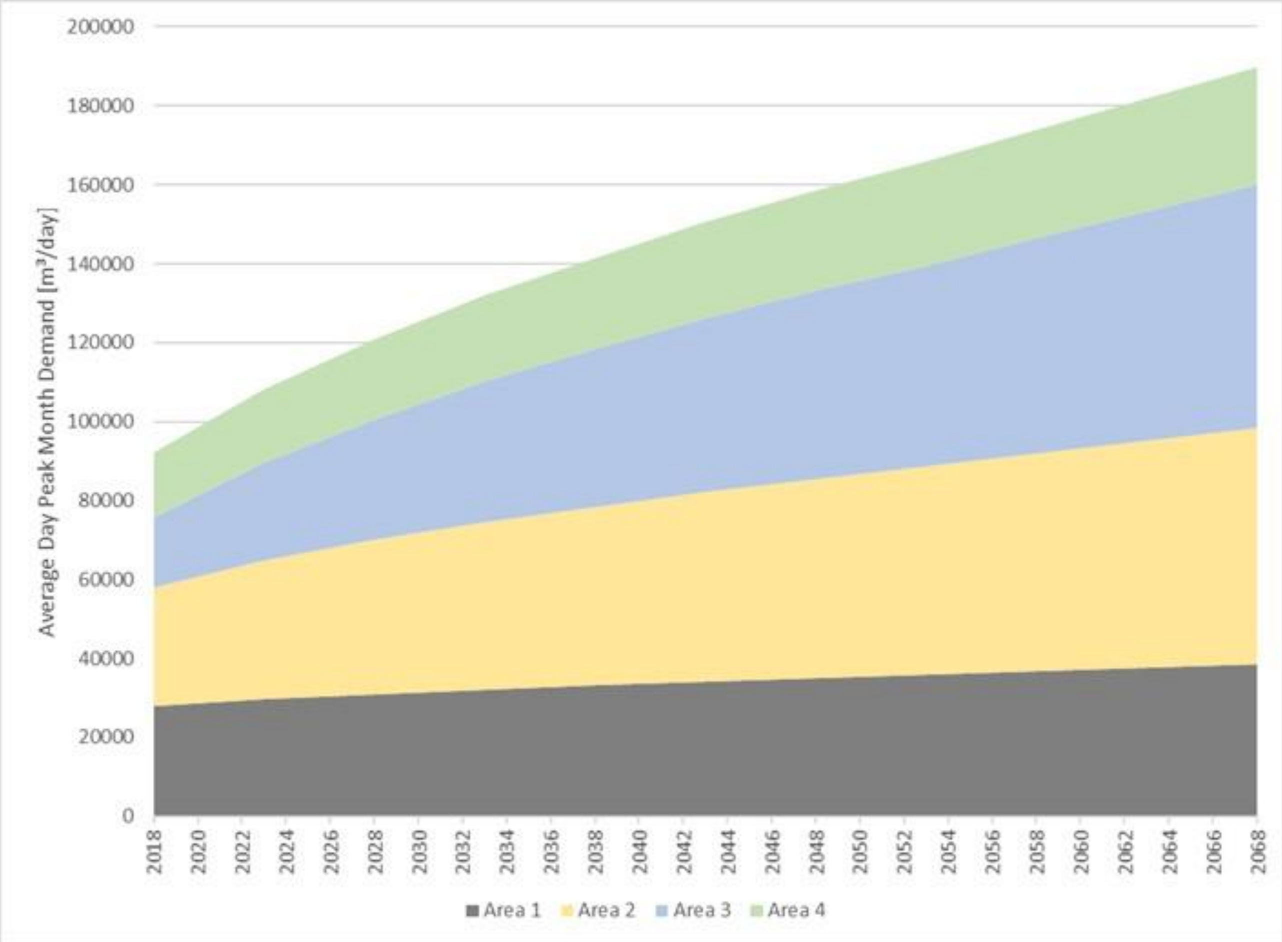


Figure 5: Transmission network storage component by area over time

3.4.2 Buffer Storage

The 2065 peak day flow profile for the proposed Huia Replacement WTP Reservoir was provided from the Watercare transmission model, with a total daily flow of 80,000 m³/day. The WRC[1] guide for balance tank storage is used to calculate reservoir volume required to maintain the diurnal flow profile with a constant inflow through the following steps:

- Plot the cumulative inflow over a 24-hour period
- Join the start and endpoint of the cumulative flow to provide an average flow
- Draw parallel lines to the average rate of flow, touching the cumulative plot above and below
- Determine the buffer capacity by the vertical distance between the upper and lower parallel lines.

The resulting buffer volumes for the current and future demand profiles are provided in Table 4. Figure 6 and Figure 7 also show the resulting plots for an inflow of 80,000 m³/day (current) and 140,000 m³/day (future), assuming the same scaled up diurnal flow pattern.

[1] WRC, Application Guide to Waterworks Sludge Treatment and Disposal, 1997, section 5.3.2

Table 4: Calculated buffer volumes

	Current	Future
Flow through reservoir(s)	80,000 m³/day	140,000 m³/day
Required buffer volume	14,000 m³	24,000 m³

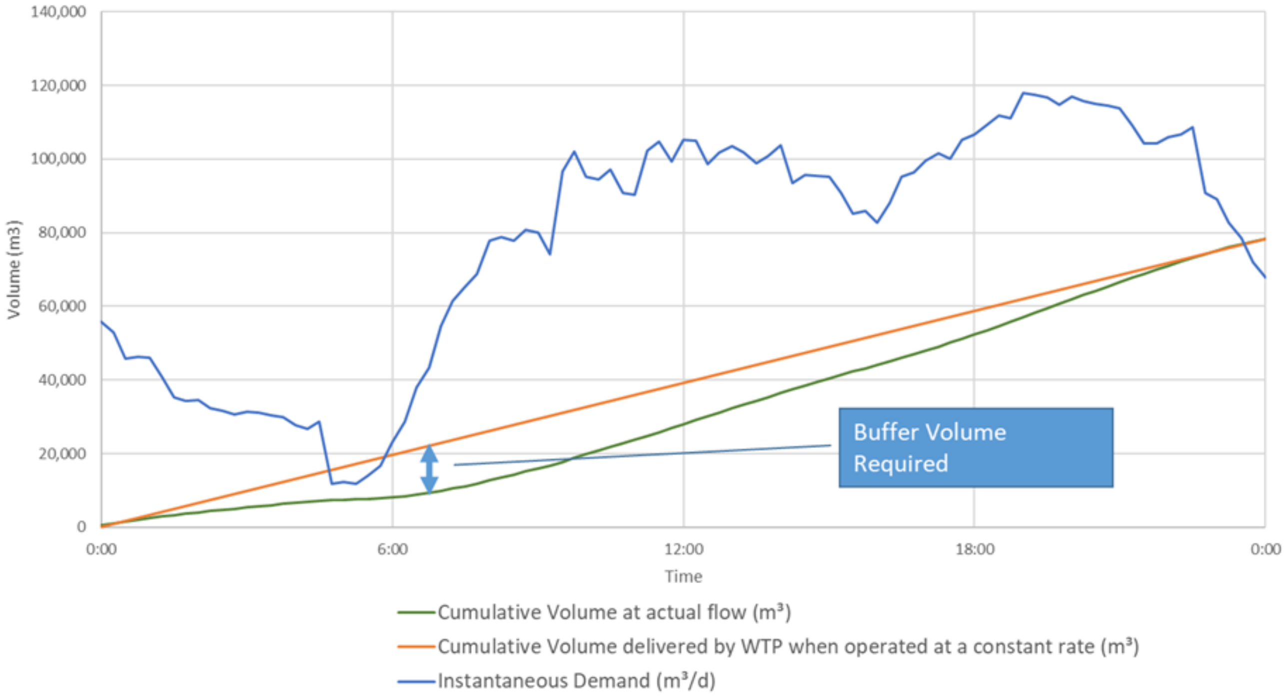


Figure 6: Buffer volume at 80,000 m³/day flow

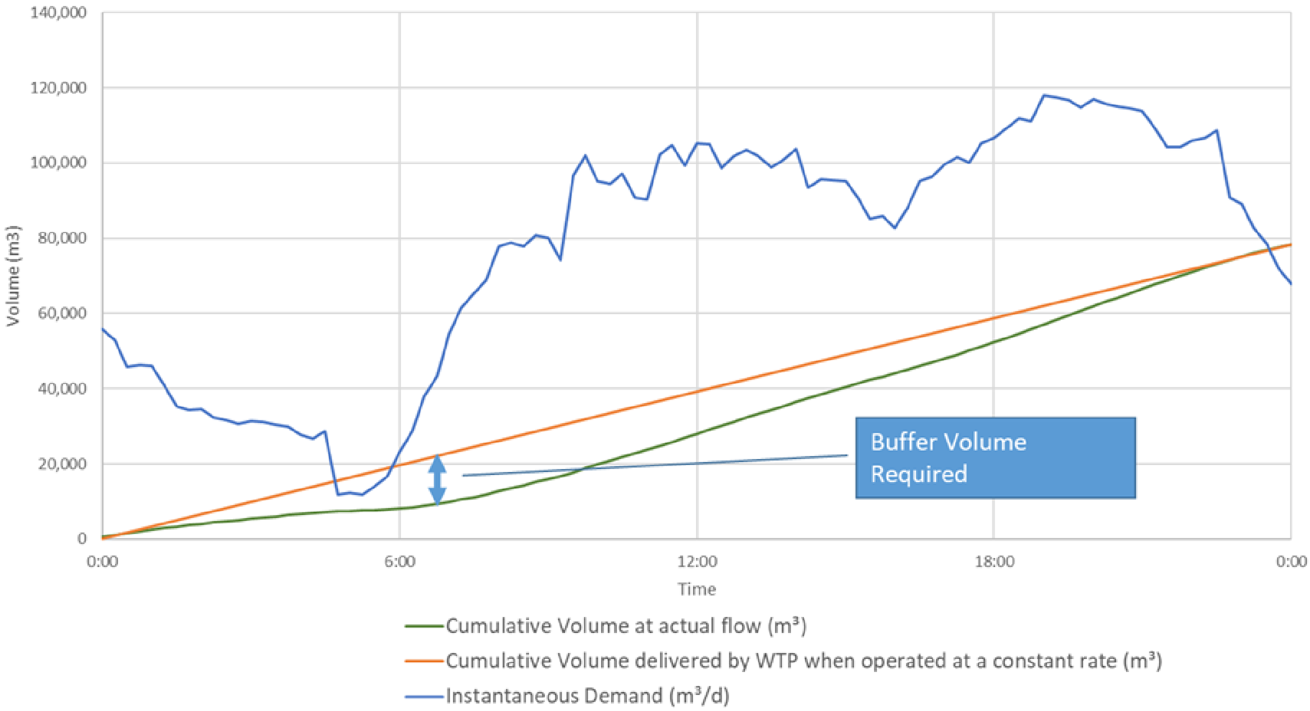


Figure 7: Buffer volume at 140,000 m³/day flow

3.4.3 Operational Lag Storage

This storage balances any operating lag to respond to increased demand during incremental flow increases from the Huia Replacement WTP when required from average to maximum output. This calculation assumes the same maximum incremental increase in treatment plant rate of flow for the current and future scenarios as it is based on increasing from a 'low flow' of 80,000 m^3/day to a peak flow of 140,000 m^3/day. Table 5 shows the output of this assessment which shows that 7,500 m^3 of storage is required.

Table 5: Calculation for operational lag storage

Parameter	Value	Basis
Average flow	80,000 m^3/day	Approximate drought level of service source yield
Maximum flow	140,000 m^3/day	Huia Replacement WTP peak capacity
Huia Replacement WTP ramp up rate	10,000 m^3/day/hour	Typical ramp up rate of Watercare's WTPs
Total flow increase	60,000 m^3/day	Calculated
Time to increase flow to meet increased demand	6 hours	Calculated
Volume required	7,500 m^3	Calculated

3.5 Water storage required for the North Western Water Supply

3.5.1 Current requirement for storage

The total current storage required within the north-western water supply area is approximately 114,000 m^3, as shown in Table 6. Currently there is approximately 135,000 m^3 of storage available within the North Western Water Supply area, which is 20,000 m^3 more storage in total than required. This is based on the requirements developed in section 3.4 with the current population and demand patterns.

Table 6: Current year storage required

Storage parameter	Storage required (m^3)
Transmission network storage	92,140
Buffer storage	14,000
Operational lag storage	7,500
Total storage required	**113,640**

However, the location of the storage available to the local network is also an essential component of this analysis. Storage can only usually support demand downstream of a reservoir (flow reversal creates water quality risks and is avoided where possible).

A similar analysis using the demands by sub-areas in the north western water supply identified in Figure 2 was carried out. This analysis is presented graphically as Figure 8.

This shows:

- The schematic of the north-western water supply
- The total storage available (thick blue bar)
- The total storage volume required by sub-area (blue arrows)

This shows how the total storage required increases as more customers are supplied in each zone, together with the allowance for operational lag and buffer storage in Area 1. Whilst the storage in Area 4 provides excess storage for that area, its geographical location does not meet distribution criteria, particularly in Area 1. This analysis therefore demonstrates that there is a deficit in the storage volumes available to the first three areas. Only Area 4 has a current surplus of storage.

The current deficit in the current year in Area 1 is approximately 25,000 m^3. With a further 25,000 m^3 in this Area, the deficit is removed in the current year. This is shown graphically as Figure 9.

This analysis demonstrates that there is a current deficit of about 25,000 m^3 in the current year in Area 1. Whilst the overall storage requirement is achieved, the current geographical location does not meet distribution criteria, particularly in Area 1, closest to the WTP.

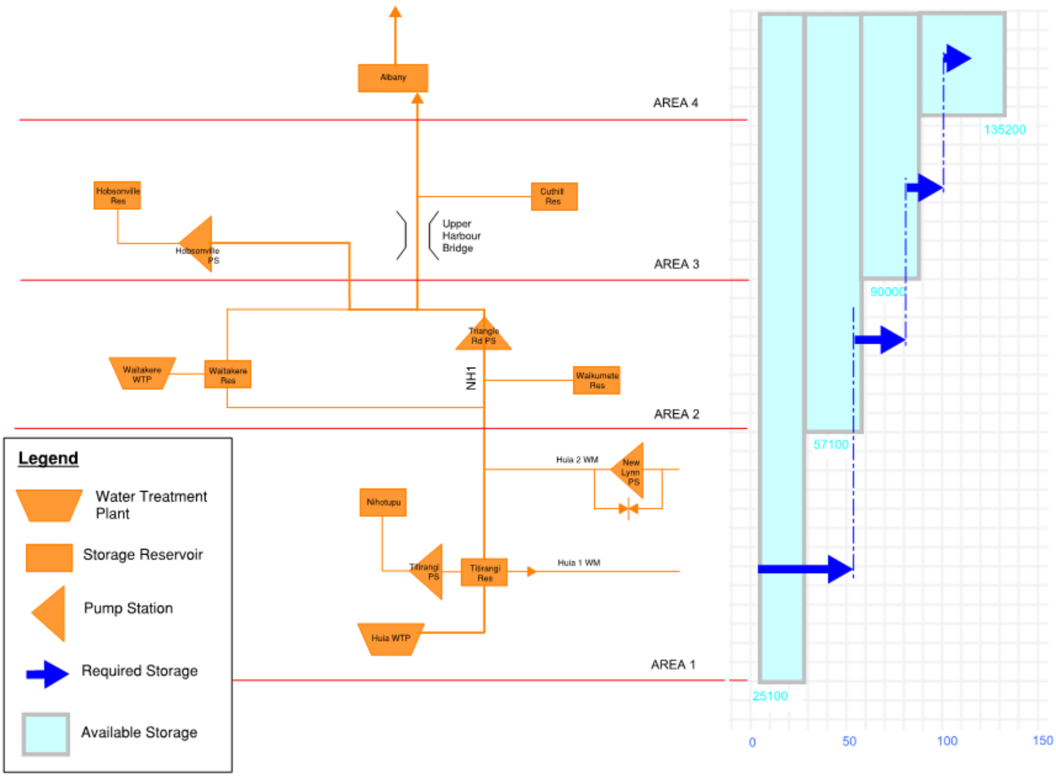


Figure 8: Available and required storage by area – current

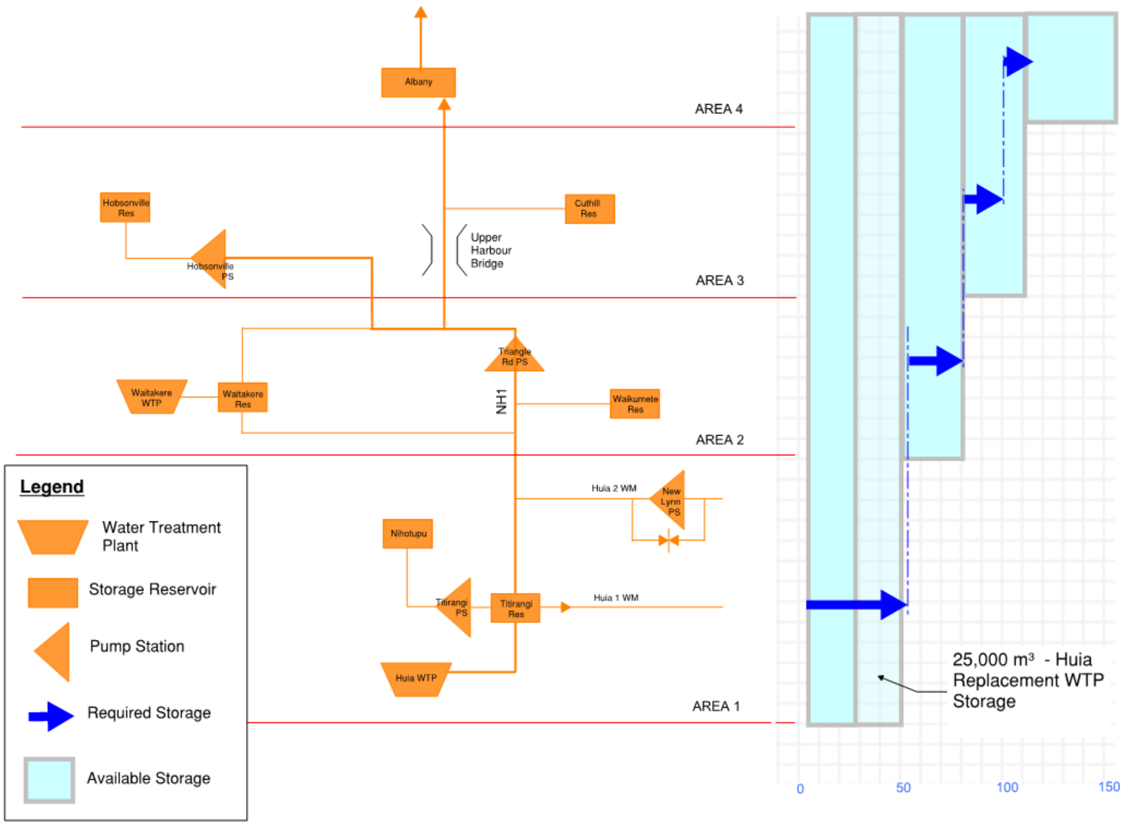


Figure 9: Available and required storage by area - current including 25,000 m^3 of new storage within Area 1

3.5.2 Future requirement for storage

By 2065 there is an increased requirement for storage due to the growth in demand. The operational lag component stays the same, but the buffer storage increases as the Huia WTP is supporting higher demand and therefore the diurnal variation is greater.

The total future storage required within the North Western Water Supply area is approximately 220,000 m^3, as shown in Table 7. The future storage within the area is expected to be:

- 135,000 m^3 (existing)
- Less 5,000 m^3 when Titirangi no. 1 is taken out of service
- Plus 30,000 m^3 additional storage planned at Hobsonville and Schnapper Rock (Area 3)

This gives a future total across the area of approximately 160,000 m^3. This is 60,000 m^3 less storage in total than required for the North Western Supply Area.

Table 7: 2065 storage required

Storage parameter	Total storage required (m^3)	Comment
Transmission network storage	189,000	Distributed according to demand at BSPs
Buffer storage	24,000	Required close to the WTP
Operational lag storage	7,500	Required close to WTP
Total storage required	**220,500**	

Similar analysis to the base year, using the forecast demands by sub-areas of the North Western Water Supply identified in Figure 2, was carried out. This analysis is presented graphically as Figure 10.

This analysis shows that the predicted future deficit within Area 1 is approximately 50,000 m^3 (if there are no additional reservoir developments). If 50,000 m^3 of storage is provided in Area 1, this provides sufficient storage (in Area 1) until 2065. This is shown graphically as Figure 11.

Figure 11 also indicates that the growth in demand in Area 2 will lead to an increased requirement for storage here. This could either be provided within Area 1 or Area 2. The deficit in storage in Area 2 by 2065 is expected to be in the order of 25,000 m^3.

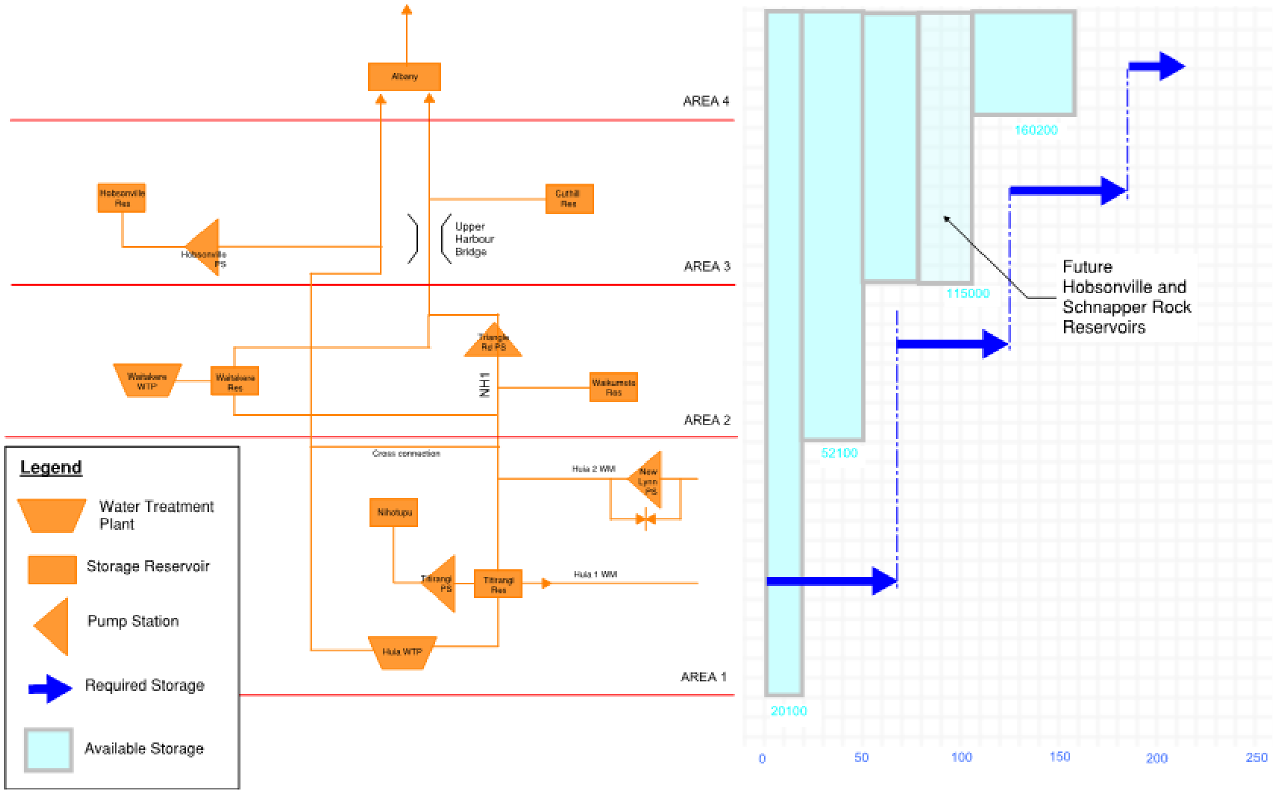


Figure 10: Available and required storage – 2065, excluding Huia Replacement WTP storage

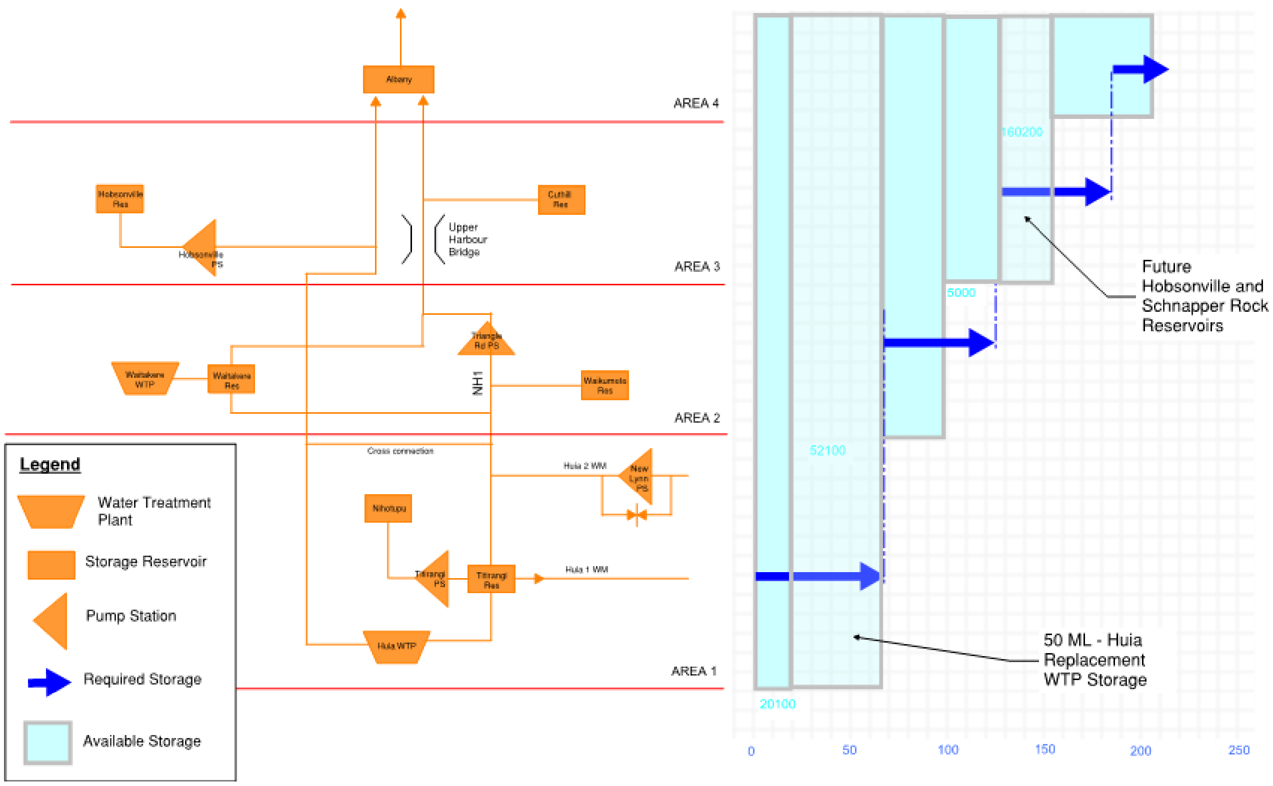


Figure 11: Available and required storage - 2065, including 50,000 m^3 Huia Replacement WTP storage

3.5.3 Timing of storage required

The analysis above demonstrates the additional storage required both now and until 2065. A review of when the additional storage required to determine when construction of the storage should occur.

The total volumes required for buffer storage, operational lag and transmission storage by area are depicted by the shaded areas in Figure 12. The lines on the graph show the available cumulative storage from Areas 1 to 4 inclusive, including any proposed changes to reservoir storage (removal of Titirangi no 1 and the addition of 30,000 m^3 of storage at Hobsonville and Schnapper Rock). As detailed in section 3.5.1, this diagram shows that there is a current storage deficit of approximately 25,000 m^3 in Area 1, even though the total storage meets Watercare's overall requirements.

The required storage increases over time and shows the total current deficit of approximately 60,000 m^3 required to meet 2065 demand. Figure 13 repeats the same information, but with the proposed additional storage of 50,000 m^3 as part of the Huia replacement WTP project. This shows that the deficit in Area 1 remains even when the first 25,000 m^3 of storage has been constructed, although this is much reduced compared with the current level of deficit.

This is shown more clearly by Figure 14, where the red arrow shows the deficit in storage within Area 1 until the second 25,000 m^3 of storage has been constructed (shown in the late 2020s).

Figure 13 also shows that once the proposed 50,000 m^3 of storage has been constructed (late 2020s), there is adequate storage provided within the whole of the north-western water supply. As the population grows, there is also a deficit in Area 2. This deficit first appears in the 2030s and increases to approximately 25,000 m^3 by the late 2060s.

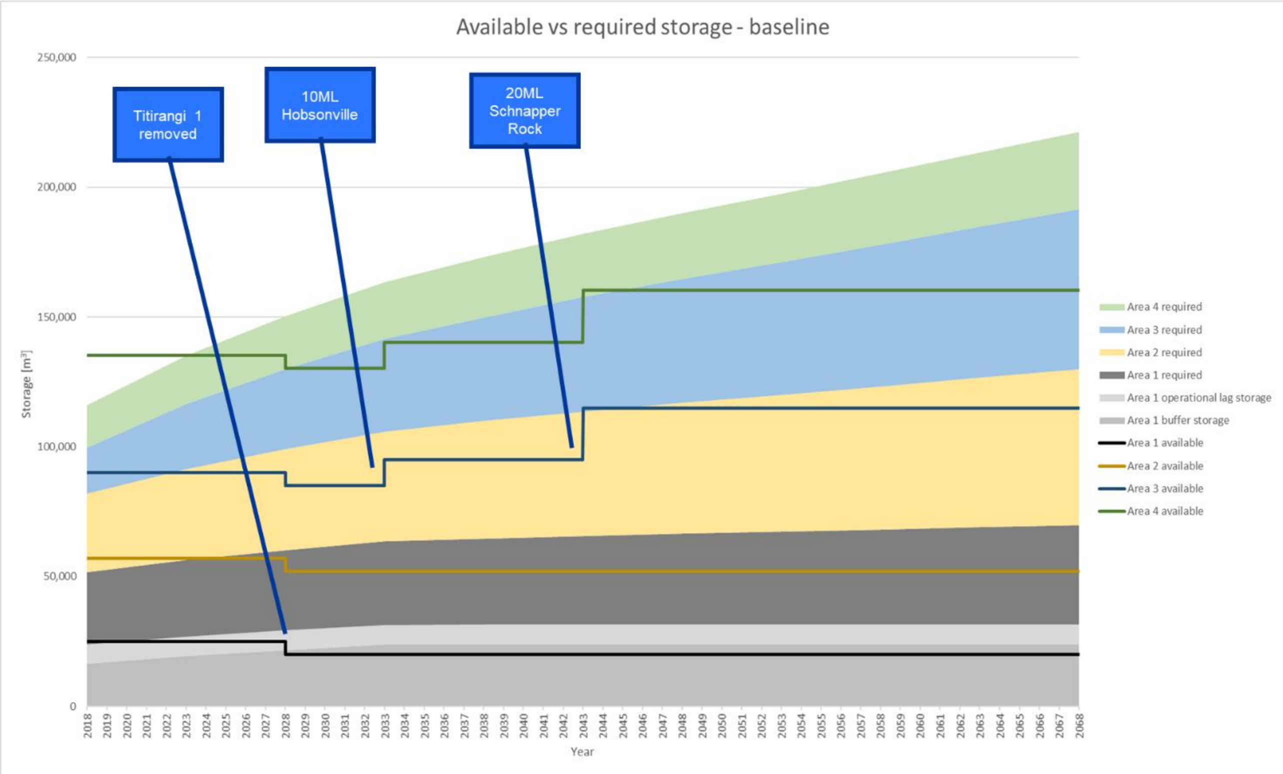


Figure 12: Current and planned total storage and available storage volumes (excluding any proposed Huia Replacement WTP storage)

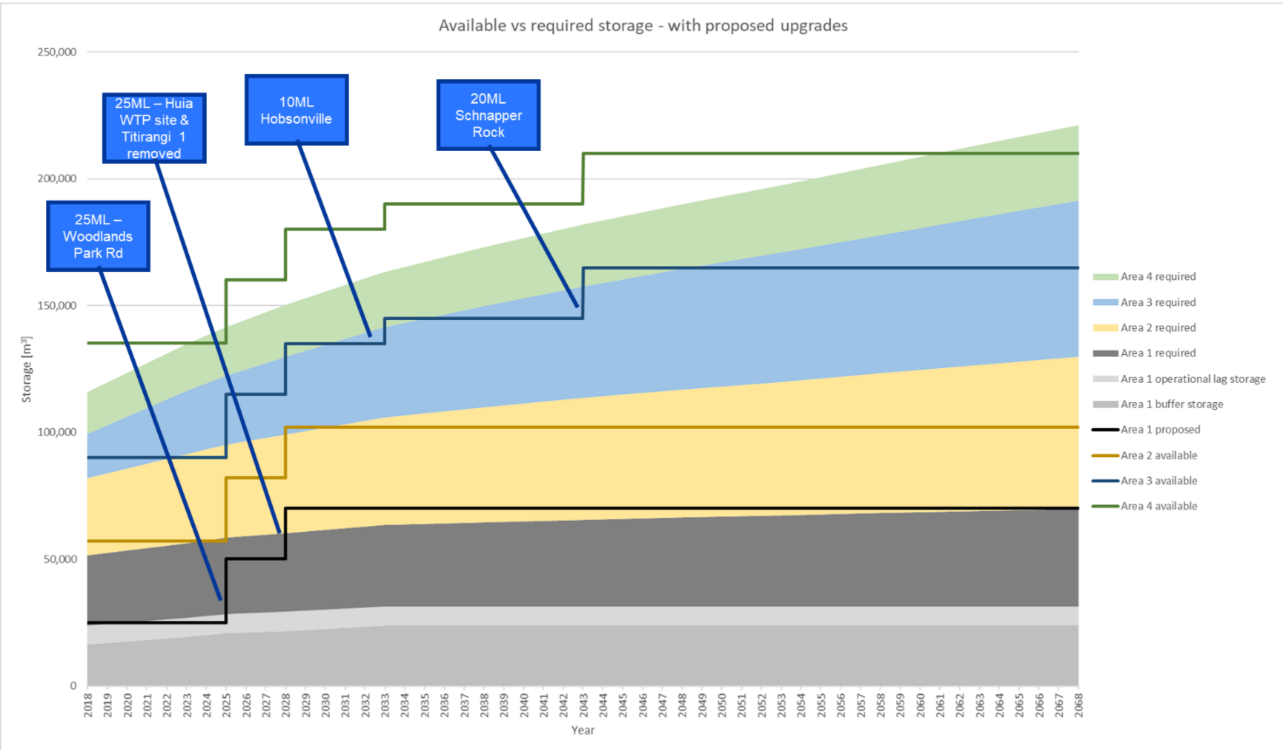


Figure 13: Proposed total storage and available storage volumes (including the proposed storage as part of the Huia Replacement WTP)

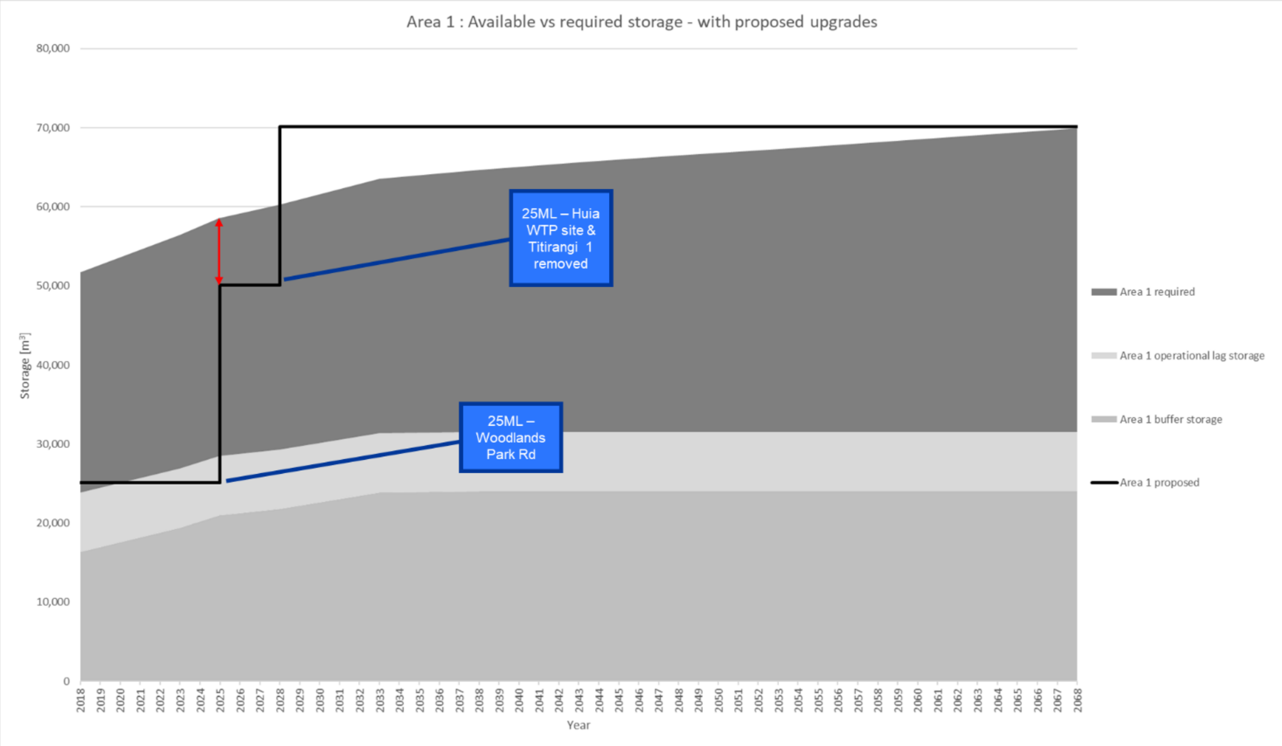


Figure 14: Proposed total storage and available storage volumes - Area 1 only

3.5.4 Summary

This analysis demonstrates that for the North Western Water Supply area:

- There is currently enough total storage to meet the requirements for the whole of the north western water supply area
- The storage is located downstream of where it is required
- The current storage deficit in Area 1 (near the Huia WTP) is approximately 25,000 m^3
- The future total deficit in storage, accounting for planned changes in the reservoir storage, is approximately 60,000 m^3
- The future storage deficit in Area 1 (near the Huia WTP) totals approximately 50,000 m^3
- 25,000 m^3 of additional storage is therefore required now and a further 25,000 m^3 by the late 2020s
- Given with the addition of 50,000 m^3 of storage in Area 1, Area 2 is also expected to be in deficit starting by the 2030s then growing to a total deficit of approximately 25,000 m^3 by the late 2060s

4 Approach to the assessment of potential sites for storage

4.1 Approach to the options assessment

Section 3 of this report established that the storage deficit in Area 1 (near the Huia WTP) totals approximately 50,000 m^3. Watercare's original approach was to provide 50,000 m^3 at the Woodlands Park Road site, following a comprehensive site selection process. Watercare decided to re-evaluate the proposed location of the reservoirs to further test alternative sites and layouts, now the location of the replacement Huia WTP was fixed. This was driven by a combination of consultation and the Watercare Board's directive to avoid wherever possible significant trees and significant ecological effects. The following sections of the report investigate a number of different options for providing this storage.

The process followed to identify potential sites is as follows:

- The development of Watercare's key principles and operational requirements, followed by
- A screening process to identify and assess potential sites that meet these criteria

The process acts as a 'funnel' with increasing levels of detail applied as the number of sites is reduced. The relative benefits of two sites are then examined in detail to identify a preferred option. The flow chart (Figure 15) shows the process that was taken to identify a preferred option.

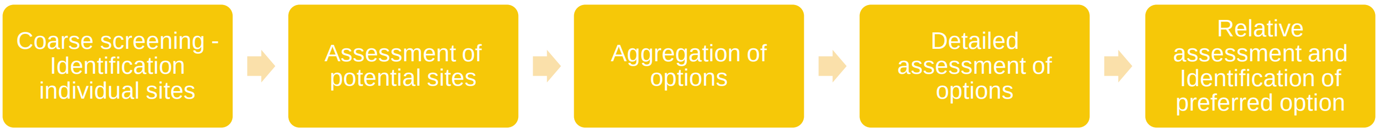


Figure 15: Flowchart showing the screening and options assessment process

4.2 Key principles and operational requirements

As determined in Section 3.4, storage is required in Area 1, local to the proposed Huia Replacement WTP. A series of site principles was developed to inform the initial site identification and overall evaluation of sites, particularly in terms of their technical feasibility (elevation, size, location) and connection to the existing water supply network. These principles were developed from the site selection principles for the Huia Replacement WTP[2], modified to account for the Replacement Huia WTP being situated at the Manuka Rd site. This section provides the key principles and operational requirements for a reservoir in this location.

The principles are set out below:

4.2.1 Elevation

An elevation band is required with:

- **A Bottom Water Level (BWL) at or above 107 m RL, not lower than the existing Titirangi Reservoir.** A gravity supply from the treated water reservoir into the transmission system is required. The BWL of the Titirangi Reservoirs is approximately 107 m. This level currently supplies the transmission system under gravity. This limit will maintain conditions for the current operation of the transmission system and allow for the integration of planned future upgrades.

[2] *Huia WTP Site Selection Site Principles report prepared by CH2M Beca Ltd, Dec. 2015.*

Note that a BWL of 107m will not provide for resilience in the future event of a North Harbour 2 Watermain failure downstream of the proposed West Coast road cross connection, and additional pumping may be required.

- **A top water level (TWL) at or above 115 m RL, and no higher than a top water level of 128 m RL.** A top water level at or above 115 m RL not lower that the existing Titirangi Reservoir, and no higher than a top water level of 128 m RL to allow a gravity supply from the proposed Huia Replacement WTP.

4.2.2 Location

A reservoir site must satisfy the following location principles:

- **Storage is required between the proposed Huia Replacement WTP and the first customer or BSP:** Watercare's standard practice is to not allow for any customer connections from their transmission mains, reducing operational constraints for any shutdowns or maintenance activities upstream of the reservoir. Minimising this distance will maximise potential for future growth to connect as close as possible to the bulk supply and reduce any possibility of future connections between the WTP and its reservoir.
- **Storage must be located upstream of the proposed cross connection between the North Harbour 1 and 2 Watermains.** The proposed cross connection between the North Harbour 1 and 2 Watermains is in place to allow for the flows to be hydraulically balanced between these watermains during normal operation. Installation of a reservoir downstream of this connection would mean that the Huia Replacement WTP flow would need to vary to meet diurnal demands of any customers upstream of the reservoir increasing the risk of pipelines becoming partially full. A partially full pipe provides a significant risk of higher turbidity and contamination from the ingress of air or stormwater when the pipe is drained down.
- **The site characteristics must be suitable for the construction and operation of a reservoir, pipework and valve chamber(s) to be constructed.** The site must not be susceptible to known hazards such as seismic and flood risks, including consideration of the potential effects of climate change.
- **The proposed reservoir site must be able to maintain the normal function of the transmission system.** A 2km distance from the proposed North Harbour 2 Watermain is considered the feasible limit for situating a new reservoir. Hydraulics losses occur as pipework distance increases. Allowing for a 2km distance (up to 4km of interconnecting pipelines) is considered to be the maximum head loss that could be accommodated.

4.2.3 Resilience

A reservoir site must satisfy the following resilience principles:

- **Storage is required to meet peak month average day demand during a single outage within the water supply system.** Watercare has adopted a principle to meet the peak month average day demand through the water supply system, with reservoir storage to meet any shortfall in supply on a short-term basis. This volume is included in the 50,000 m^3 total storage required.
- **Storage is required to provide resilience during long term unplanned outages.** Restrictions (either formal or informal) may be required to minimise risks due to long term unplanned outages, should they occur. Two critical resilience scenarios for the north-western supply area have been identified which guide how much and where reservoir storage should be provided. These are:
  - Failure of the Huia Replacement WTP where demand would be met by a combination of supply from the southern sources and storage
  - A break of the NH2 transmission main. Additional pressure than can be provided by gravity from the existing storage at Titirangi is required to convey high volumes of water through the north Harbour 1

Watermain, with a TWL from the Proposed Huia Replacement WTP of 128 m RL required to meet average day demand[3].

4.2.4 Complexity

A reservoir site shall consider the following complexity principles:

- **Storage is required to supply both the North Harbour 1 and 2 watermains under gravity.** A supply to both the NH1 and NH2 watermains from the reservoir storage gives the benefit of the storage to both watermains and downstream supplies.
- **Storage is required to provide the required buffer function, resilience storage and operational lag storage to all downstream customers** (as described in section 2.3)**.** Installation of storage which cannot supply directly into the Titirangi Reservoirs under normal operation is not considered to provide these functions to the customers connected from the Titirangi Reservoirs.
- **The total storage should be provided with not more than two additional reservoirs.** More than two reservoirs would create significant complexity and additional effects. A total of 25,000 m^3 is required now and is logical to be provided as a single reservoir. The remaining 25,000 m^3 should be provided in a single reservoir due to scale, efficiencies (duplication of infrastructure), maintenance burden, land area and the additional construction effects.

4.2.5 Sustainability

A reservoir site shall consider the following sustainability principles:

- **Minimise Environmental, Ecological and Social effects.** In alignment with Watercare's sustainability principles to the wider community and environment
- **Carbon.** Carbon required throughout the lifecycle of a reservoir site shall be considered.
- **Climate change.** The effects of climate change need to be considered in selecting a site for a reservoir.

[3] GHD Resilience presentation, 8 November 2018 at Watercare offices

5 Options assessment

5.1 Coarse screening against principles

The initial identification of potential sites involved using GIS tools to identify potentially suitable locations that aligned with the principles. The principles applied in this initial GIS screening approach focused on 'technical feasibility'. These key technical requirements were then overlaid to identify suitable sites on the basis of alignment to each of these principles:

- Elevation of between 107 and 125 mRL (section 4.2.1)
- Located within Area 1, and with the storage upstream of the first BSP and West Coast Road cross connection
- Located within 2km of the proposed NH2 pipeline route and relative to the Huia Replacement WTP location on Manuka Road.

This analysis resulted in the identification of eleven sites that meet these principles. The location of these sites is included as Figure 16. High level analysis of the sites was carried out to identify the potential storage volume that could be accommodated at each site and a high-level review of each of the options against the principles set out in section 4. This is included as Appendix B of this report.

An overall summary of this analysis is shown as Table 8. The sites that have been disregarded are shown in red and the main reason for removing them at this stage is included in the same table. After high-level review and analysis, six reservoir sites remained under consideration.

Table 8: Summary of potential reservoir sites

Reservoir site	Location	Reason for disregarding	Estimated capacity (m^3)
1	Proposed Huia Replacement WTP	The current site layout does not allow space for construction of a reservoir[4].	20,000
2	Existing Huia WTP		25,000
3	Woodlands Park Road		50,000
4	81-85 Shetland Street	Removal of a number of properties required, very steep slope, less than 20,000 m^3 of storage likely to be available.	17,000
5	184 & 186 Shaw Road	Difficult site access and significant construction complexities (within floodplain and undulating terrain).	22,000
6	131 Shaw Road		22,000
7	105-107 Carter Road		50,000
8	97 Carter Road		23,000
9	112 Carter Rd	Close to existing properties, limited capacity.	18,000
10	85-87 Carter Road	Inadequate storage volume of 11,000 m^3.	11,000
11	11 Glengarry Road		25,000

4 *Huia Replacement Water Treatment Plant Consenting Phase Site Layout Development Report, GHD, May 2019*

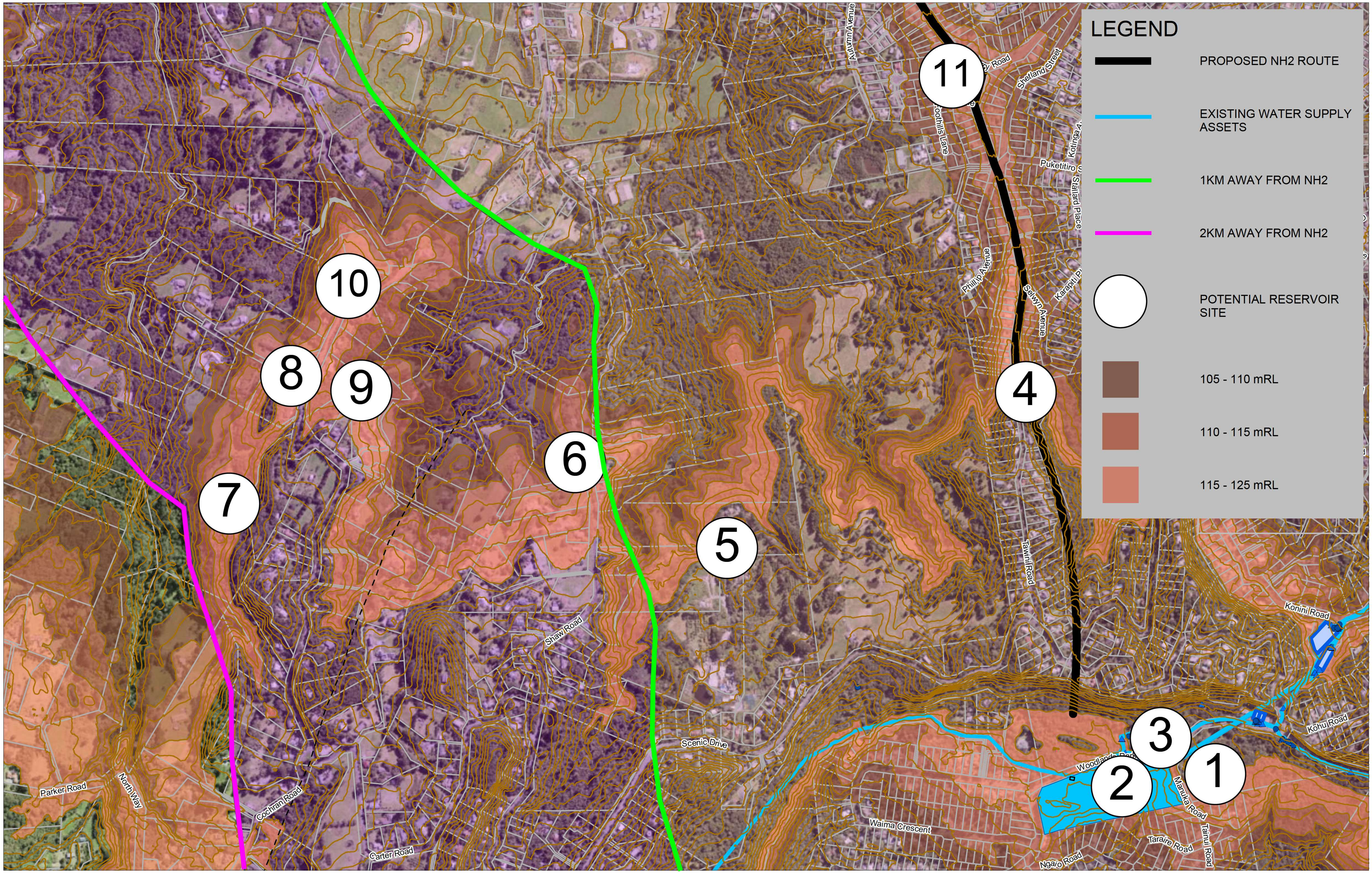


FIGURE 16: PLAN SHOWING THE LOCATION OF POTENTIAL RESERVOIR SITES

5.2 Aggregation of options

Two approaches could be taken to providing the required storage, either at one single location or a combination of locations. The desktop review of potential reservoir sites has identified six potential locations, although only two appear to have the potential total required capacity of 50,000 m^3.

Based on the volumetric assessment (section 3.5) and Watercare's expected commissioning requirements, a volume of storage of approximately 25,000 m^3 is required to meet the principles, and commission and operate the Huia WTP. A further 25,000 m^3 is required by the late 2020s. Therefore, not all the storage is required immediately on completion of the proposed Huia WTP.

Practically, this raises the opportunity to provide the required storage using a combination of two reservoirs, potentially at two different sites. The desktop review shortlisted six potential reservoir sites based on elevation and proximity to watermains, from which five combinations of sites were identified to provide the storage volume required. The five combinations are:

- Combination 1 – 50,000 m^3 at Woodlands Park Road
- Combination 2 – 25,000 m^3 at Woodlands Park Road, with a further 25,000 m^3 at the existing WTP site
- Combination 3 – 50,000 m^3 at 105 Carter Road
- Combination 4 - 25,000 m^3 at Woodlands Park Road, with a further 22,000 m^3 at 131 Shaw Road
- Combination 5 - 25,000 m^3 at Woodlands Park Road, with a further 25,000 m^3 at 11 Glengarry Road

Combination 4 has been selected as a surrogate site for a combination of 25,000 m^3 at the Woodlands Park Rd site then any viable storage options further to the west (sites 7,8 and 11). All combinations provide a gravity supply under normal operating conditions. These aggregated options are each described below, followed by an assessment against the principles in section 4.2.

5.2.1 Combination 1: 50,000m³ at Woodlands Park Road

A schematic of this option is shown as Figure 17. For this option:

- 50,000 m³ would be provided at Woodlands Park Rd, opposite the proposed Huia WTP site
- It is likely that all the storage would be constructed at the same time as the proposed Huia WTP
- The NH2 watermain would follow the designated route from this reservoir site
- In the future, a pump station could be constructed at the existing Titirangi reservoirs (if required) to enable the transfer of treated water to the Woodlands Park site.

This option would result in a technical solution that would best meet Watercare's storage, elevation and resilience requirements.

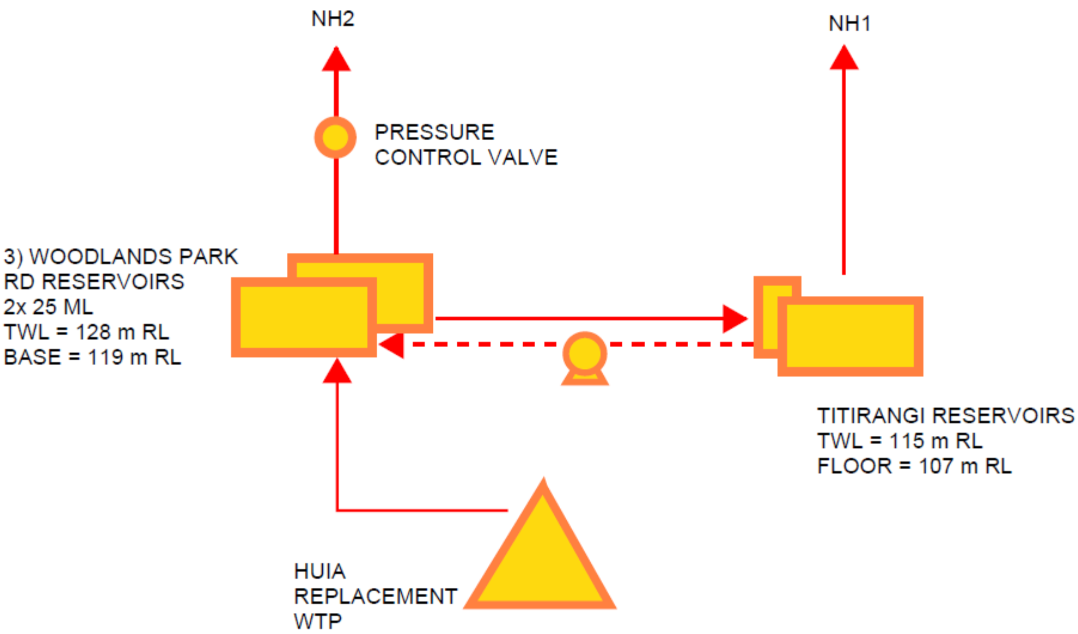


Figure 17: Combination 1 - 50,000 m³ at Woodlands Park Road

5.2.2 Combination 2: 25,000 m^3 at Woodlands Park Road, with a further 25,000 m^3 at the existing WTP site

A schematic of this option is shown as Figure 18. For this option:

- Approximately 25,000 m^3 of storage would be provided at the Woodlands Park Rd site, opposite the proposed Huia WTP and would be in place prior to commissioning.
- This would be located to enable the majority of the identified kauri trees located on a prominent knoll to be retained
- The NH2 watermain would follow the designated route from this site (with an invert of approximately 115 mRL).
- Once the existing Huia WTP is decommissioned, a 25,000 m^3 reservoir with a TWL of approximately 125 mRL would be constructed, giving a total storage of 50,000 m^3 which would be able to supply both North Harbour 1 and 2 watermains by gravity.
- In the future, a pump station could be constructed at the existing Titirangi reservoirs (if required) to enable the transfer of treated water to the Woodlands Park site (via the existing Huia WTP reservoir).

This option would result in a technical solution that meets Watercare's storage, elevation and resilience requirements. The investment in reservoir infrastructure would be staged.

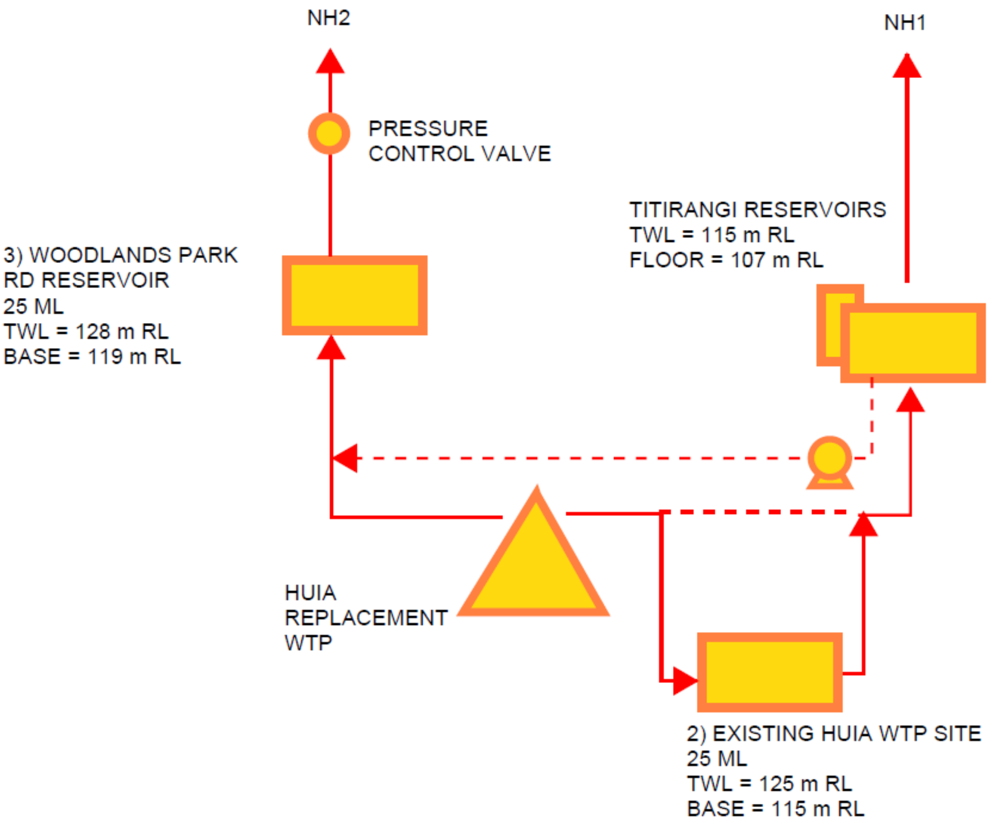


Figure 18: Combination 2 – 25,000 m^3 at both Woodlands Park Road and the existing Huia WTP

5.2.3 Combination 3: 50,000 m^3 at 105 Carter Rd

A schematic of this option is shown as Figure 19. For this option:

- All required storage would be provided at a single site (in two reservoirs)
- The TWL of the reservoirs is less than the required 128mRL for resilience, therefore there would be a potential requirement for a booster pump station within the transmission system to meet all resilience requirements
- An alternative route alignment would be required for NH2, requiring redesign and designation of the new (longer) route

This option would result in a slightly more complex arrangement with the 50,000 m^3 storage at Carter Rd likely requiring reconfiguration or pumping within the network to provide the required storage to Titirangi, and with the potential for pumping to meet resilience scenarios. The route of the NH2 would be approximately 2.5km further than the currently designated route. Otherwise, this would provide a technical solution that would meet Watercare's storage, elevation and resilience requirements.

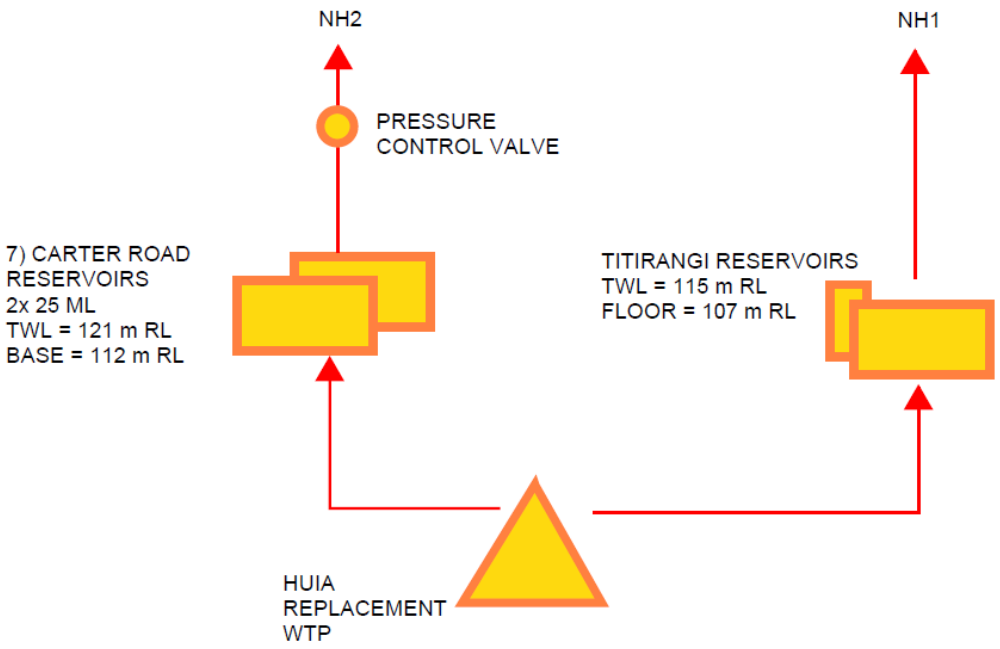


Figure 19: Combination 3 – 50,000m^3 at 105 Carter Rd

5.2.4 Combination 4: 25,000 m3 at Woodlands Park Rd, with a further 22,000 m3 at 131 Shaw Rd

A schematic of this option is shown as Figure 20. For this option:

- 25,000 m³ would be provided at the Woodlands Park Rd site, opposite the proposed Huia WTP. This would be in place to commission the proposed WTP
- The NH2 watermain would follow a longer route from this site, requiring redesign and a new designation
- A bypass would be provided around the proposed Shaw Rd reservoir, to enable the Huia WTP to supply at a grade of 128mRL during a resilience scenario when this is required.
- A pressure control valve is likely required to match the NH1 hydraulic grade during bypass of the Shaw Rd Reservoir.

This option would result in a slightly more complex arrangement with reservoirs at two different sites. The NH2 watermain would be approximately 1.5km longer than the shortest route. Otherwise, this would provide a technical solution that would meet Watercare’s storage, elevation and resilience requirements.

The Shaw Rd site was selected as the closest site with a suitable volume. Identified sites further from the proposed Huia Replacement WTP are considered to be more complex than the Shaw Rd site without any technical or economic benefit. This combination can be considered as the most likely combination where 25,000 m³ is provided at Woodlands Park Rd with a further 25,000 m³ to the west of the proposed Huia Replacement WTP.

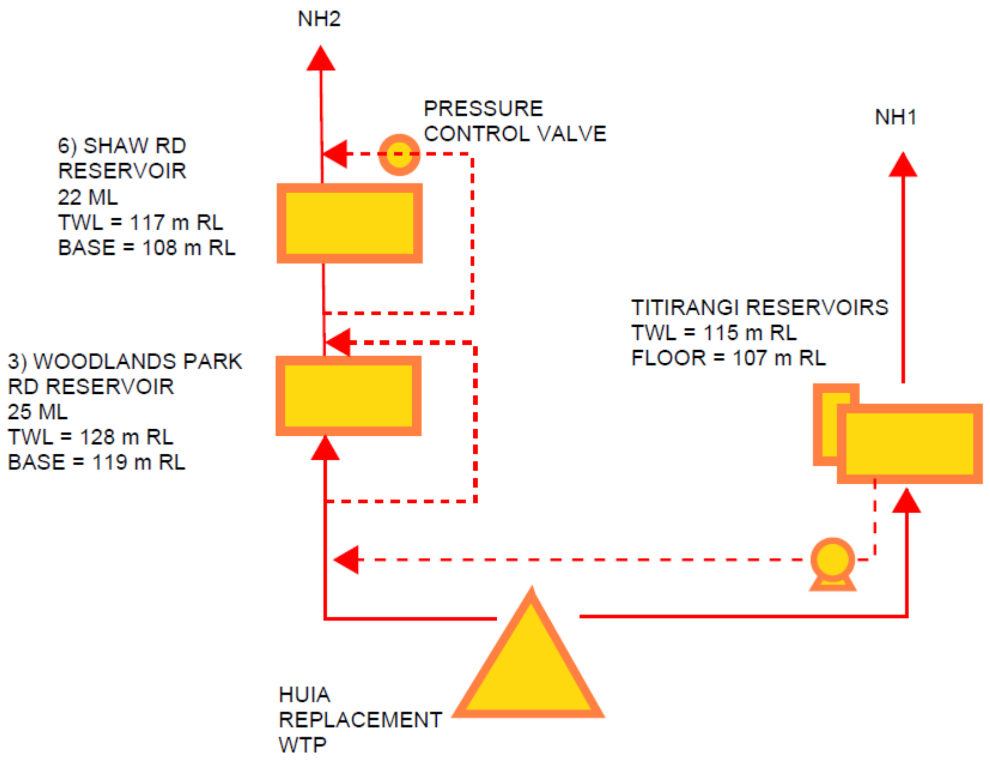


Figure 20: Combination 4 – 25,000 m^3 at Woodlands Park Road and 22,000 m^3 at 131 Shaw Rd

5.2.5 Combination 5: 25,000 m^3 at Woodlands Park Rd, with a further 25,000 m^3 at 11 Glengarry Road

A schematic of this option is shown as Figure 21. For this option:

- 25,000 m3 would be provided at the Woodlands Park Rd site, opposite the proposed Huia WTP. This would be in place to commission the proposed WTP.
- A bypass would be provided around the proposed Glengarry Road reservoir, to enable the Huia WTP to supply at a grade of 128mRL during a resilience scenario when this is required.
- A pressure control valve is likely required to match the NH1 hydraulic grade during bypass of the Phillip Ave reservoir.

This option would result in a slightly more complex arrangement with reservoirs at two different sites. Otherwise, this provides a technical solution that would meet Watercare's storage, elevation and resilience requirements.

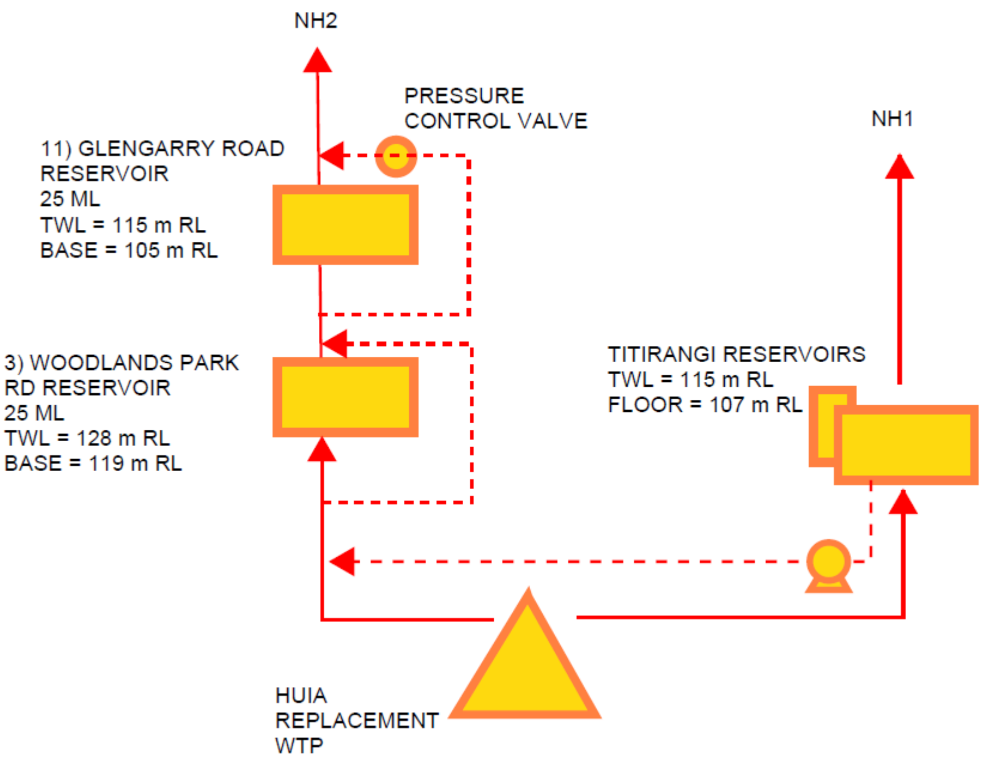


Figure 21: Combination 5 – 25,000m^3 at Woodlands Park Rd and 25,000m^3 at Glengarry Road

5.3 Assessment and analysis of aggregated options

5.3.1 Assessment process

The five combinations of options described above were assessed relative to each other, shown as Table 9. Each of the combinations of options is able to provide the total required storage (50,000 m^3). This comparison was carried out for each of the principles, being:

- Volume
- Elevation
- Location
- Resilience
- Sustainability
- Complexity

These are compared relative to a baseline option of 50,000 m^3 storage at the Woodlands Park Rd site (Combination 1), with inputs from Watercare stakeholders and consultants. Combination 1 reflects the current concept and was selected as the baseline on this basis. No quantitative analysis was used to prepare this analysis, rather the expertise of a group of people was used to assess the relative advantages and disadvantages of the combinations of reservoir options.

5.3.2 Results of the qualitative assessment

This assessment process shows that Combinations 1 and 2 are expected to provide a solution that is more closely aligned to Watercare's Principles than Combinations 3, 4 and 5. All combinations can provide adequate storage at an elevation that would enable normal operation without pumping, however Combinations 3, 4 and 5 are not taken forward for the following reasons:

- Combination 3 (50,000 m^3 at Carter Rd) – the additional cost and complexity due to a longer tunnel and pipeline route, effects on two communities and risks to the construction programme (as the pipeline route and reservoir site would require land acquisition and designation) were considered to outweigh the potential benefit of reduced vegetation clearance at the proposed Woodlands Park Rd site
- Combination 4 (25,000 m^3 at Woodlands Park Rd, followed by 25,000 m^3 at Shaw Rd) – similar negative issues to combination 3 were identified, again outweighing the potential benefit of reduced vegetation clearance at the proposed Woodlands Park Rd site
- Combination 5 (25,000 m^3 at Woodlands Park Rd, followed by 25,000 m^3 at Glengarry Rd) – where the negative issues around the effect on the local community at Glenvar Rd, removal of multiple houses and long-term visual effects were considered to outweigh the potential benefit of reduced vegetation clearance at the proposed Woodlands Park Rd site.

Table 9: Assessment of combined options relative to 50,000m^3 storage at Woodlands Park Rd

Principle	Combination 1: 50,000 m^3 at Woodlands Park Rd	Combination 2: 25,000 m^3 at Woodlands Park Rd then 25,000 m^3 at the existing Huia WTP site	Combination 3: 50,000 m^3 at Carter Rd	Combination 4: 25,000 m^3 at Woodlands Park Rd then 25,000 m^3 at Shaw Rd	Combination 5: 25,000 m^3 at Woodlands Park Rd then 25,000 m^3 at 11 Glengarry Road
Volume	↔ Baseline – 50,000 m^3 storage	↔ 50,000 m^3 storage	↔ 50,000 m^3 storage	↔ 50,000 m^3 storage	↔ 50,000 m^3 storage
Elevation	↔ Baseline – meets normal operation	↔ Meets normal operation	↔ Meets normal operation	↔ Meets normal operation	↔ Meets normal operation
Location	↔ Baseline – storage close to proposed Huia WTP and before first BSP	↔ Close to proposed Huia WTP Existing WTP site is also designated	↓ ▪ Significant distance with additional tunnelling and pipework required ▪ Site not designated.	↓ ▪ Significant distance with additional tunnelling and pipework required ▪ Site not designated.	↓ ▪ Site not designated.
Resilience	↔ Baseline – Top water level of 128mRL	↓↔ Reduced storage available during one resilience scenario	↓↔ Boost pumping required for some resilience scenarios	↓↔ Reduced storage available during one resilience scenario	↓↔ Reduced storage available during one resilience scenario
Sustainability	↔ Baseline	↑ **Social:** Extended construction period **Environmental:** The single reservoir at the Woodlands Park site can be engineered to avoid many of the high value trees. **Carbon:** ▪ Reduced earthworks expected ▪ No difference in operational energy inputs are expected	↔ **Social:** Effects on two communities. Reservoirs may have a visual impact **Environmental:** Effect of construction at Carter Rd estimated as less than at Woodlands Park Rd **Carbon:** Increase in carbon during construction from longer pipeline route	↔ **Social:** affects two communities. Reservoir may dominate the landscape. **Environmental:** The single reservoir at the Woodlands Park site can be engineered to avoid many of the high value trees. **Carbon:** Increase in carbon during construction from longer pipeline route	↓ **Social:** affects two communities. Glengarry Rd reservoir situated in residential area and will displace multiple households and may dominate the landscape. **Environmental:** The single reservoir at the Woodlands Park site can be engineered to avoid many of the high value trees. **Carbon:** ▪ Reduced earthworks expected ▪ No difference in operational energy inputs are expected
Complexity	↔ Baseline	↓↔ **Operation:** Slightly more complex due to different sites and top water levels **Construction:** ▪ Some additional pipelines required ▪ Less excavation required	↓↓ **Operation:** Supply to the Titirangi area requires back feed from NH2 to NH1 cross connection **Construction:** Significant risk to programme with site requiring land acquisition and site designation prior to construction	↓↓ **Operation:** Slightly more complex due to different sites and top water levels **Construction:** Significant risk to programme with site requiring land acquisition and site designation prior to construction	↓↓ **Operation:** Slightly more complex due to different sites and top water levels **Construction:** Significant risk to programme with site requiring land acquisition and site designation prior to construction

5.4 Detailed assessment of the two shortlisted options

The results of this qualitative assessment are that Combinations 1 and 2 are preferred, as they align most closely to Watercare's principles. A quantitative assessment of the potential impacts of these options was carried out to investigate and compare them, which is summarised as Table 10. This only considers the sustainability and complexity principles identified in Table 9, as there are no differences considered for the other principles. This analysis has been carried out with reference to a number of separate reports which are included as part of the wider Assessment of Environmental Effects.

The analysis suggests that:

- From a social perspective, Combination 2 is preferred. There are advantages of Combination 1, with less vehicle movements and the work would be carried out over a shorter time period. Contrary to this are the important permanent visual effects, where for Combination 2 the knoll shaped landform with the stand of native Kauri trees at the entrance to the Woodlands Park Rd site (Reservoir 1) would be retained. This is an important landscape feature and combined with the fact that the majority of Reservoir 1 will be buried, will minimise the visual effects.
- From an environmental / ecological perspective, Combination 2 is preferred. This avoids the removal of 19 notable native trees, of which 17 are Kauri trees on the Reservoir 1 site. Neither combination results in the removal of land classed as Ecological High Value Class 1, but Combination 2 results in 2,000 m^2 more land lost that is Ecological High Value Class 2 (at the existing Huia WTP site). The layout of Reservoir 2 still avoids the highest value vegetation in this area. Using excavation as a proxy for embedded carbon, Combination 2 would be preferred as this requires less excavation.
- From a complexity perspective, there are advantages of Combination 1 as it would be simpler to operate. There are no clear advantages or disadvantages of either combination when construction is considered.

5.5 Summary of the options assessment

This options assessment demonstrates that, although there is an increased complexity of operation with two reservoirs on adjacent sites at different elevations, there are clear social, environmental and ecological benefits associated with this approach. The preferred option is therefore Combination 2, comprising:

- 25,000 m^3 of storage at Woodlands Park Rd constructed in conjunction with the replacement Huia WTP, and
- 25,000 m^3 of storage at the existing Huia WTP site by the late 2020s.

A report setting out the basis of design and development of the reservoir site layout has also been prepared.

Table 10: Summary of the quantitative assessment comparing reservoir options

Criteria		Combination 1: 50,000 m³ at Woodlands Park Road	Combination 2: 25,000 m³ at Woodlands Park Road and 25,000 m³ at the existing Huia WTP site	Comparison of options
Sustainability criteria				
Social	Duration of construction period, based on the Indicative Construction Methodology Report and Programme	Duration of construction period estimated as between 5 and 6 years, <u>excluding</u> decommissioning of the existing Huia WTP.	Total duration of construction period estimated as between 7 and 8 years, <u>including</u> decommissioning of the existing Huia WTP.	Combination 1 has some slight advantages compared to Combination 2, as the construction period is approximately 1 year or potentially 10% to 15% shorter.
	Traffic movements, based on the Indicative Construction Methodology Report and Programme	▪ 32 months of HCV movements ▪ Average of 15 movements per day, with a maximum of 54 truck movements per day ▪ Total vehicle movements estimated as 14,000 to 15,000	▪ 48 months of HCV movements, with 21 months for Reservoir 1 and 24 months for Reservoir 2 ▪ Average of 21 movements per day (Reservoir 1) and 9 movements per day (Reservoir 2) ▪ Total vehicle movements estimated as 17,000 to 18,000	Combination 1 has advantages compared to Combination 2, as the total vehicle movements are potentially 20% lower.
	Visual effects (permanent) based on	The advantages of this approach are: ▪ A 10m wide physical separation of the reservoirs and the Woodlands Park Rd will be provided ▪ Placement against the highly vegetated escarpment provides containment of views and allows visual merging of the vegetation clearance The disadvantages are: ▪ The western elevation of the reservoir will be visible up to 7m in height from Woodlands Park Rd ▪ The knoll shape landform would be mostly removed ▪ Increased separation from the toe of the escarpment would be preferable	Reservoir 1 advantages: ▪ Due to the reduced footprint, the entire structure will be buried ▪ Wider separation between the escarpment is achieved ▪ The knoll shape landform would be mostly retained ▪ Placement against the highly vegetated escarpment provides containment of views and allows visual merging of the vegetation clearance Reservoir 1 disadvantages: ▪ Vegetation clearance along the south eastern boundary of the reservoir during construction, to be mitigated by replanting. Reservoir 2 advantages ▪ The site already accommodates existing WTP structures ▪ Vegetation to be removed, except two Totora trees, is relatively young and is not regarded as having high landscape value ▪ The northern elevation will be 20m from the footpath ▪ The northern elevation will not exceed the height of existing structures ▪ Screening can be provided following decommissioning of the existing Huia WTP	The main disadvantages of Combination 1 (removal of the knoll shape landform) are largely removed by Combination 2. The other main effect of Combination 2 is the construction of a second reservoir, however this replaces existing water supply structures in this location. There is therefore an advantage for Combination 2 compared to Combination 1.
Environmental / ecological	Area of high value ecological area lost (m²)	High value ecological area (ecological area classes 1 and 2) impacted as follows: ▪ Reservoir 1 site Class 1: 0 m² ▪ Reservoir 1 site Class 2: 2,200 m²	High value ecological area (ecological area classes 1 and 2) impacted as follows: ▪ Reservoir 1 site Class 1: 0 m² ▪ Reservoir 1 site Class 2: 1,700 m² ▪ Reservoir 2 site Class 1: 0 m² ▪ Reservoir 2 site Class 2: 2,600 m² Therefore, a total of 0 m² Class 1 and 4,300 m² Class 2 will be lost.	Neither Combination 1 or 2 results in a loss of Class 1 ecological areas. A larger area of Class 2 land is lost (approximately 2,000 m² more) with Combination 2. There is therefore an advantage for Combination 1 compared to Combination 2.
	Effect on surveyed notable native trees (number and species of trees expected to be lost)	▪ 17 x Kauri trees ▪ 10 x Kahikatea trees ▪ 1 x Totara tree ▪ 4 x Rimu trees ▪ 1 x Titoki tree ▪ 1 x Rewarewa tree A total of 34 notable native trees will be impacted.	Reservoir 1 ▪ 0 x Kauri trees ▪ 9 x Kahikatea trees ▪ 2 x Totara trees ▪ 2 x Rewarewa trees Reservoir 2 ▪ 0 x Kauri trees ▪ 0 x Kahikatea trees ▪ 2 x Totara trees ▪ 0 x Rewarewa trees A total of 15 notable native trees will be impacted.	With Combination 2, 19 less notable native trees will be impacted. Importantly, the design allows for the 17 Kauri trees on the Reservoir 1 site to be protected. This is a clear advantage for Combination 2.

Criteria		Combination 1: 50,000 m³ at Woodlands Park Road	Combination 2: 25,000 m³ at Woodlands Park Road and 25,000 m³ at the existing Huia WTP site	Comparison of options
	Embedded carbon	▪ Excavation volume for Combination 1 of approximately 65,000 m³ and 2,000 m³ of imported fill.	▪ Excavation volume for Reservoir 1 of 44,000 m³ and 400 m³ of imported fill. ▪ Excavation volume for Reservoir 2 of 6,000 m³ and 10,000 m³ of imported fill	Excavation is a major contributor to embedded carbon. Combination 2 shows a lower volume of excavation (50,000 m³) but more fill (10,400 m³). Using this simple approach to embedded carbon, there are advantages of using Combination 2.
Complexity criteria				
Complexity of operation	Flexibility, operability and resilience	The reservoirs have the same water levels and could be configured to operate in parallel or series operation. The Top Water Level of 128m RL enables network resilience scenarios to be achieved.	The reservoirs are located at different elevations, with Reservoir 1 being 3m higher than Reservoir 2. Operation in series or parallel is possible, however additional control valves is required to allow for this. With the reservoirs located across two sites, additional pipework is required to transfer water from each reservoir to both the Titirangi Aqueduct (NH1) and NH2.	Both reservoir configurations allow normal operation in either parallel or series. Combination 1 is less complex with shorter pipework and does not require additional control valves to balance the hydraulic grade. Combination 1 also provides a greater volume of water at a higher elevation, meaning that flows can be maximised under certain resilience scenarios. Combination 1 therefore offers operational advantages compared to Combination 2.
Complexity of construction		A construction methodology has been developed to enable construction of the reservoir within the site constraints. The reservoirs (excluding pipework and chambers) is estimated as 50% of the proposed site construction footprint area. A benefit of this option is that it will be undertaken over a shorter timeframe, but the work will be more intensive.	A construction methodology has been developed to enable construction of the reservoir within the site constraints. The reservoirs (excluding pipework and chambers) is estimated as 36% of the proposed site construction footprint area. The construction of one above ground reservoir will be less risky and less technically challenging.	Construction of Combination 1 includes more excavation than Combination 2, but the work is over a shorter timescale. Combination 2 includes construction of a second site (although the decommissioning work here would require work at this site). The difference between the two is therefore considered to be neutral.

6 Conclusions

In relation to the volume of reservoir storage in the north-western water supply area:

- There is currently a deficit in storage in the area closest to the Huia WTP (Area 1) of approximately 25,000 m^3
- This deficit in Area 1 is expected to increase to about 50,000 m^3 by 2065
- Therefore 25,000 m^3 of additional storage is required now, and a further 25,000 m^3 by the late 2020s
- If population growth occurs as expected, there will also be a deficit in Area 2 in the 2030s increasing to 25,000 m^3 by 2065

In relation to the location of reservoir storage within Area 1:

- The preferred approach is Combination 2, i.e. one 25,000 m^3 reservoir at Woodlands Park Rd and a second 25,000 m^3 reservoir at the existing Huia WTP site
- The additional operational complexity to Watercare from two reservoirs at different elevations is offset by the social and environmental benefits of retaining part of the existing landscape features including the prominent knoll and the 17 Kauri trees at the Woodlands Park Rd site. Reservoir 1 is also largely buried on this site further reducing any visual effects.

A

Appendix A – Water utility approaches to reservoir storage

New Zealand legislation and guidelines

Currently there is no legislation or guidelines in place in New Zealand for the provision of network storage. Advice was sought from Water NZ's technical staff, who noted that there is little in the way of standards. A 'rule of thumb' of 24 hours at average demand is often used as a starting point for calculating required reservoir storage.

The storage requirements adopted by other New Zealand councils are summarised below.

Hamilton City Council

Hamilton City Council's approach to reservoir storage includes:

- The Water Supply Masterplan's approach allows for a total storage balance across the network equivalent to the peak day
- This provides the ability for operations to have full control of reservoir turnover and provides for 50% turnover once per day while maintaining a minimum volume equivalent to the maximum fire class required in the zone and 4 hours peak day storage in line with the WTP requirements
- A current 24-hour day is 90,000 m^3 but increases with the growth forecast
- The maximum fire allowance is based upon an FW6 classification (2,160 m^3 per event)
- 4 hours peak day storage volume is based upon the specific zone demand relating to that reservoir

Queenstown Lakes District Council

Queenstown Lakes District Council adopts an approach where the minimum available reservoir storage across each network should be the greater of:

- 24 hours of average day storage
- 12 hours of peak day storage
- 6 hours of average day storage plus the greatest firefighting storage requirement for the network as defined by SNZ PAS 4509:2008.

Wellington Water

The Regional Standard for Water Services is to set reservoir storage requirements to the maximum of either:

- 700 L/person plus firefighting storage requirements where existing demand is unknown (e.g., new development area) or 2 x Average Day Demand (ADD*) plus firefighting storage requirements when existing demand is available

OR

- Peak day demand (PDD*) plus 20% for operational storage plus firefighting storage requirements as outlined in SNZ PAS 4509

OR

- Storage for seismic resilience – required storage to provide minimum levels of service after a significant earthquake based on:
  - **Days 1 to 7 – Emergency State -** People and businesses will be self-sufficient, relying on their own stored water supplies, their communities, and Civil Defence centres.
  - **Days 8 to 30 – Survival & Stability -** Residents collect up to 20 litres per person per day from Distribution Points while Critical Customers begin to receive water to their boundary.

- **From Day 30 – Restoration & Recovery -** the region moves toward restoration of normal service through provision of reliable reticulated supplies.

Tauranga City Council

The level of service that Tauranga City Council (TCC) has adopted for water storage is 48 hours at Annual Average Daily Demand, (as referenced in TCC's Water Supply Asset Management Plan 2005). This has been carried forward in the current AMP and is formally documented as a target in the AMP appendices. The two technical levels of service with respect to storage are included in the AMP as shown in Table 11).

Table 11: TCC Storage

Performance Indicator	Data Source	Process	Target	Result
Cubic metres of water stored in reservoirs/household	Water NZ Performance Review (WSA7)	Based on average of reservoir levels at 1 am each day (81.9%) so does not reflect the average for the 24-hour period.	1.6 m^3/ household	1.187
Annual average storage per reservoir	Water Supply AMP	To be developed	2 days	1.8[1]

1 Across the city at 80% full

The reservoir storage is not uniformly spread across the city so the indices need to be used with understanding of the demands on the individual supply zones serviced by the reservoirs. The information on levels of reservoir storage includes the treated water storage at the treatment plants.

International legislation and guidelines

American Water Works Association (AWWA) design guidelines

The AWWA recommended design guidelines specify Operational Storage (OS), Equalising Storage (ES) and Fire Suppression Storage (FSS), where OS is between 25% and 30% of the expected Maximum Daily Demand (MDD). ES volume is estimated based on the time taken to resume normal operating conditions following an emergency. Typically, this is calculated by multiplying the MDD by the anticipated emergency downtime.

Guidance from AWWA Water Distribution Systems Handbook

"Water distribution storage is provided to ensure reliability of supply, maintain pressure, equalise pumping and treatment rates, reduce the size of transmission lines, and improve operational flexibility and efficiency"

"tanks should be designed to satisfy the aesthetic considerations of stakeholders to the extent possible without sacrificing the purpose of the tank and the efficiency of the system's operation"

Water Services Association of Australia (WSAA)

WSAA water supply code calls for storage capacity of 8-24 hours consumption at peak day demand for service reservoirs, and no net depletion of operating capacity over the design period.

Sydney Water

Sydney Water reservoir capacity is sized based on providing 2/3 of the zone's Maximum Daily Demand (MDD). This sizing is based on 1/3 of MDD being available for operational storage and 1/3 of MDD being set aside for reserve storage.

Melbourne Water (Bulk Supply)

Melbourne has a similar water supply network to Auckland prior to the amalgamation of councils with a bulk distributor and then local network operators.

Melbourne Water has its own design standard for service reservoir capacity – a 5 stage risk-based approach is now taken rather than using the previous target storage of 8 hours of peak demand.

Service reservoirs are currently sized considering the following storage components with the total storage capacity provided being the sum of these individual storage components (as illustrated by Figure 22):

- *A Balancing Storage Component* to balance out the variation of demands over a peak demand day
- A *Storage Component for Operating Lag*, to account for operating requirements
- A *Reserve Storage* to provide sufficient storage for contingencies such as power outages and inlet supply failures
- A *Dead Storage* to ensure an adequate pressure and to prevent air entrainment in the outlet

The likelihood and consequences of a supply failure depend on a range of factors including asset age, alternative means of providing supplies, likelihood and duration of power outages, the impact of a failure on the supply network and a number of other asset factors.

The process to carry out the risk assessment and calculate the storage required is as follows:

- **Stage 1 - Risk Assessment:** Identify the risk factors which would contribute to a critical supply interruption and assign a score to each risk factor to quantify its likelihood/prominence. A risk score is derived for each critical supply interruption.
- **Stage 2 - Select Design Demand Condition and Duration of Inlet Supply Interruption. Determine Approximate Size of Reserve Storage –** Based on the risk score from Stage 1:
  - Determine the design demand condition to be adopted based on the risk level/design demand condition table.
  - Estimate the duration of the critical supply interruption in consultation with operations personnel.
  - Estimate approximate reserve storage volume required for critical supply interruption using design demand condition and duration.
- **Stage 3 - Assess reserve storage capacity by extended period hydraulic simulations -** Simulate system operation for the critical supply interruption in Stage 2. The purpose of the simulation is to accurately estimate the reserve storage capacity requirement, accounting for the status of the reservoir level at the commencement of the supply interruption and the contribution from alternative supplies. The reserve storage capacity required should satisfy the minimum requirement specified below and be assessed against the capacity required for cleaning of the inlet pipeline. A detailed assessment of the requirement for and duration of pipeline cleaning should be carried out if it becomes critical in the sizing of the reserve storage capacity
- **Stage 4 - Economic Assessment** - Assess the cost of reserve storage capacity against the cost of providing an alternative/backup supply or other means of reducing the risk.

- **Stage 5 - Develop plans for maintenance and contingencies -** Maintenance and contingency plans are required to address any potential capacity shortfalls in the event of a supply interruption. Contingency plans and are to be developed in consultation with retail businesses.

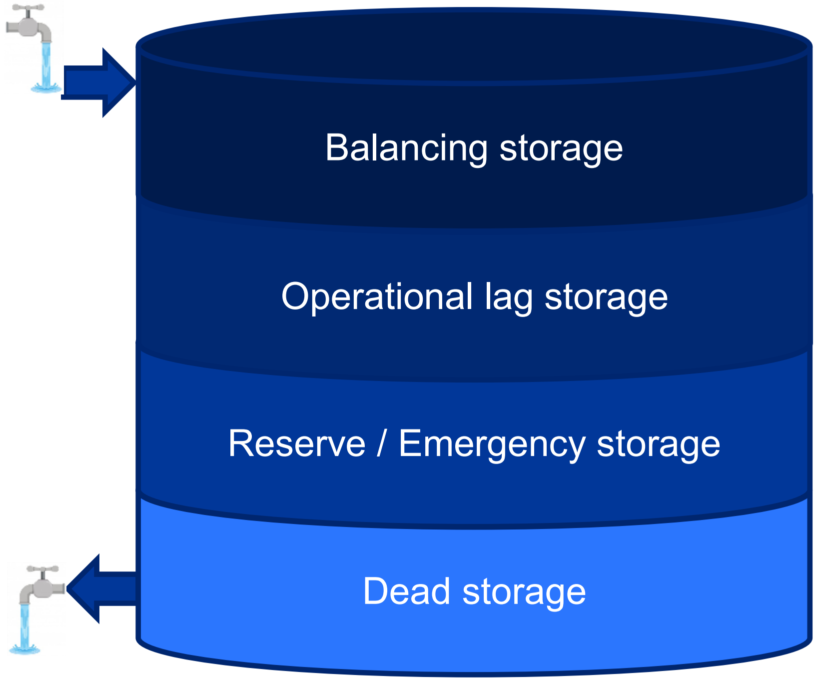


Figure 22: Schematic Representation of Storage Components

Melbourne Water (Retail Supply)

The Melbourne retailers (Yarra Valley, City West Water and South East Water) apply a risk-based approach, for example:

- Low risk – 2 day winter demands
- High risk – 2 day average summer day demands.
- Generally 10-20% for balancing, 50-60% of peak day demands for security and 10% dead storage.

Bristol Water (United Kingdom)

Bristol Water currently design for effectively 24 hours Average day peak week demand, typically with 12 hours emergency + 12 hours operational storage.

Wessex Water (United Kingdom)

The Wessex Water standard for reservoir storage is equivalent to:

- 15 hours storage for distribution demand (i.e. reservoir outlet supplying distribution demand)
- and/ or 6 hours storage for transfer from one reservoir to another

This is based on the average of the previous three year's demands. Where there may be deviations in the standard would include the following reasons:

- Robustness of supply to a reservoir (e.g. if it can it be supplied from 2 or more ways/ sources etc, a lower level of storage may be accepted)
- Significant variations in seasonal demand (e.g. in a location with a large tourist demand, the maximum summer demand may be used)

- Variation in the reservoir depth (significant reservoir depth variation might require more storage)
- Any major customers supplied from the reservoir
- An assessment of potential future development growth in the area (or reduction)

Thames Water (United Kingdom)

Below is an extract from the Thames Water design standard for service reservoirs.

“Reservoir capacity is provided on the basis of the following three parameters:

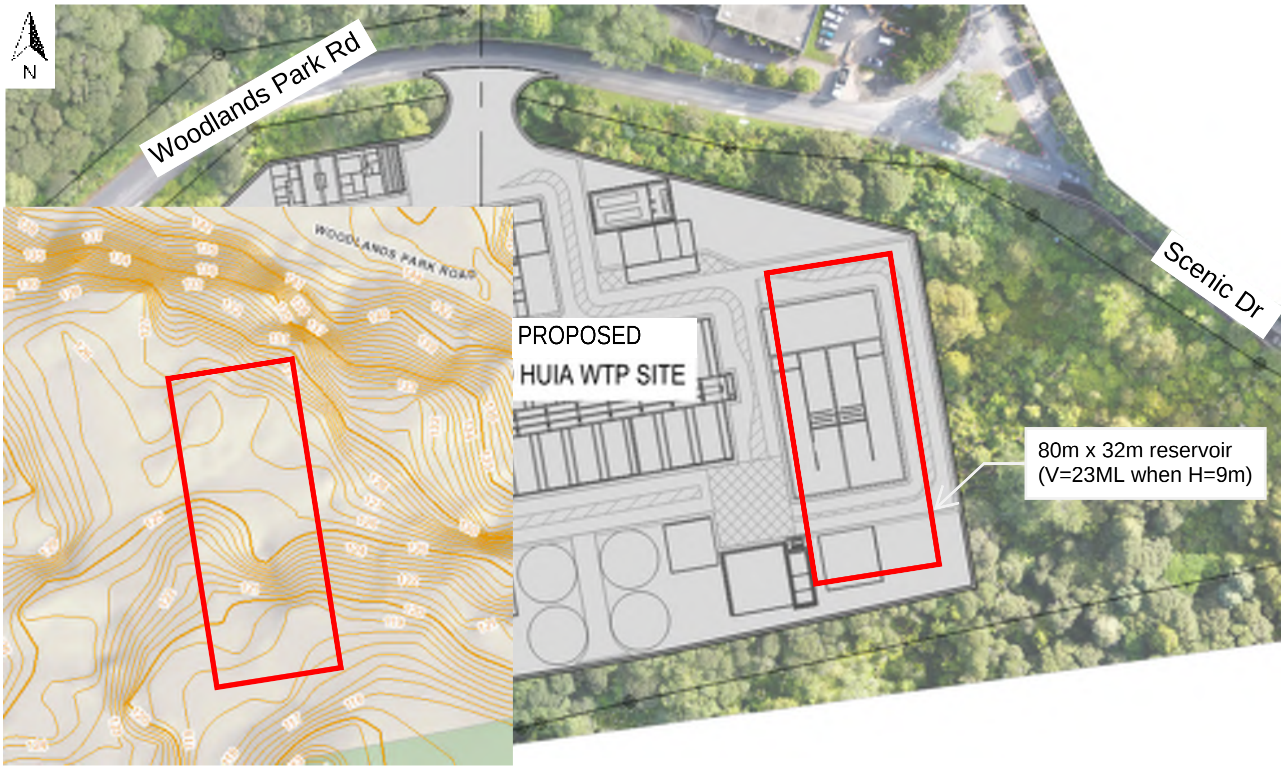
- **Demand balance:** To meet peak daily demand and balance daily fluctuation in demand, having regard to the level of reliable supply to the particular zone (This capacity is to cover the requirements for trunk mains failure unless that capacity requirement is greater). Zones where the reliable supply to the reservoir is either more or less than "normal" (supply equal to the average day over a peak week, projected to a suitable planning horizon) would require a corresponding reduction or increase in calculated reservoir capacity. In particular cases, where source and trunk main capacity can be provided economically to meet peak requirements, service reservoir capacity for flow balancing would not be required, subject to satisfactory control of pressure fluctuations.
- **Trunk mains failure:** In some zones, the flow balancing capacity would be exceeded by trunk main failure requirements. Capacity to cover trunk mains failure would be based upon the time for restoration of supply, determined by a combination of operational experience, response times to mains failure included in the target levels of service and the circumstances in each zone, in particular, taking into account alternative means of supply and the opportunity for interconnection between zones. The maximum capacity to be provided to cover for trunk mains failure would be 36 hours or 1.5 times the average daily demand, the maximum provision only being used in the most unfavourable circumstances.
- **Special circumstances:** In special cases, consideration would be given to providing additional reservoir capacity for tariff exploitation or cost-effective use of a restricted site.”

B

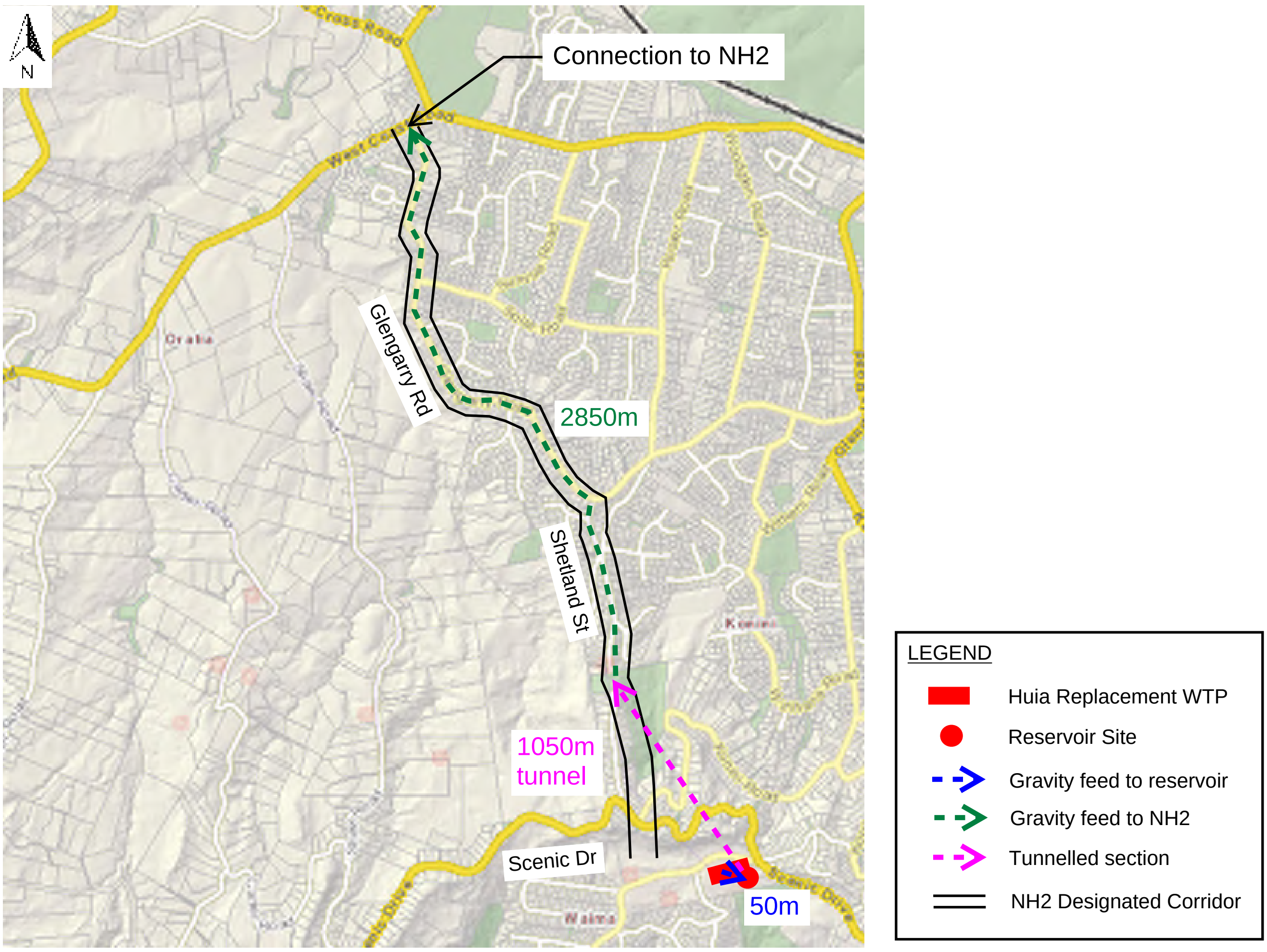
Appendix B – Reservoir location coarse screening

Huia Replacement WTP Storage Analysis		
Site:	1	
Location:	Proposed Huia Replacement WTP site	
Elevation:	Reservoir base level 119mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:10. Cut of up to 10m required. Retaining wall around eastern half of reservoir likely required. Site located within Huia Replacement WTP site and therefore to fit reservoir on site, the proposed WTP layout would need modification. Within minor overland flow path however with Huia Replacement WTP construction, the overland flow path will likely be diverted away from site. Pipelines: WTP to Reservoir: 50m gravity pipeline Reservoir to NH2: 3900m, including 1050m gravity tunnel between Reservoir and Shetland Street. WTP to NH2: Total length = 3950m (50m > shortest route)	
Volume:	V=23ML when height is 9m. Constrained by proposed WTP infrastructure.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Open space - Conservation Zone. Significant Ecological Area. Waitakere Ranges Heritage Area. Stormwater Management Control Area. Social: No houses are directly impacted. Area is within a significant ecological area however as the Huia Replacement WTP is already proposed on this site, including the reservoir should not create any additional ecological issues.	
Resilience:	Top water level = 128mRL. Meets all resilience scenarios from GHD study.	
Comments:	Watercare have advised this site is not feasible	

Reservoir Site 1

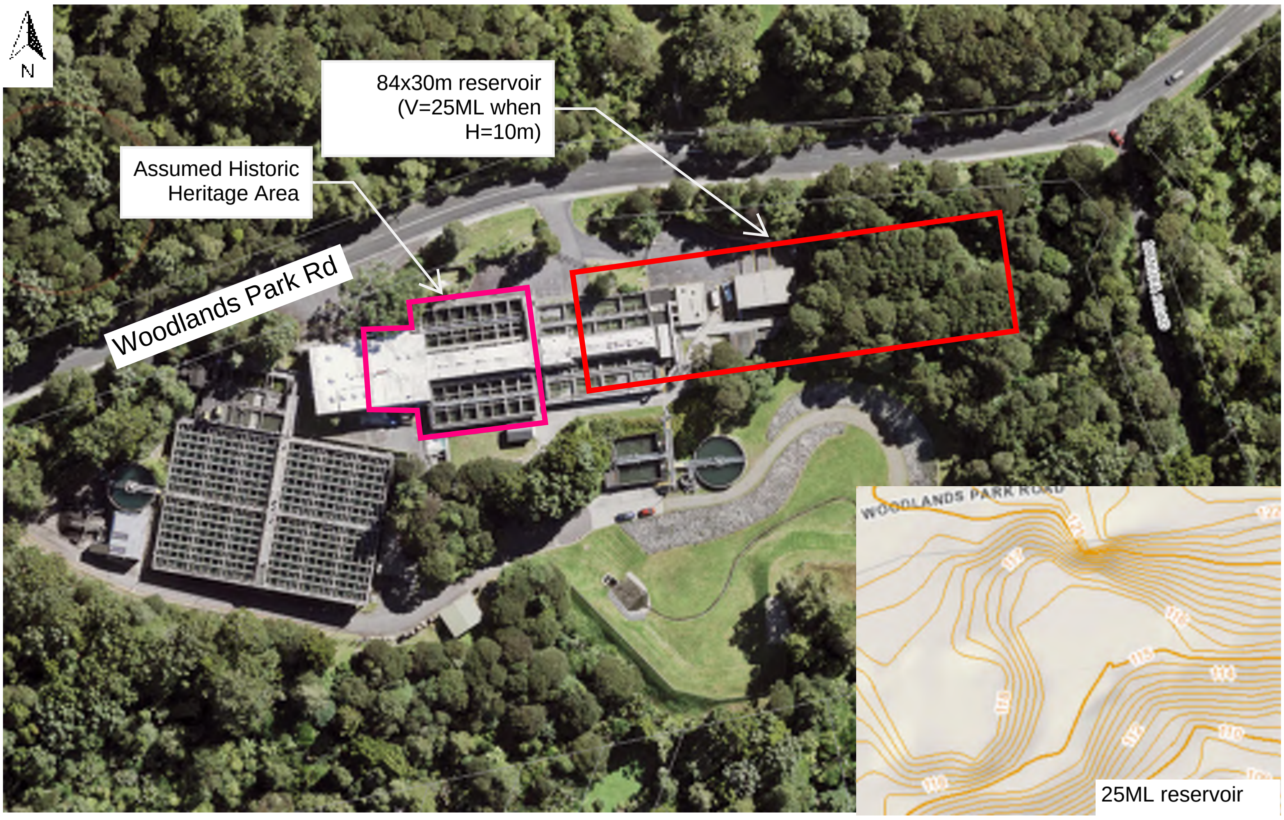


Pipeline Routes

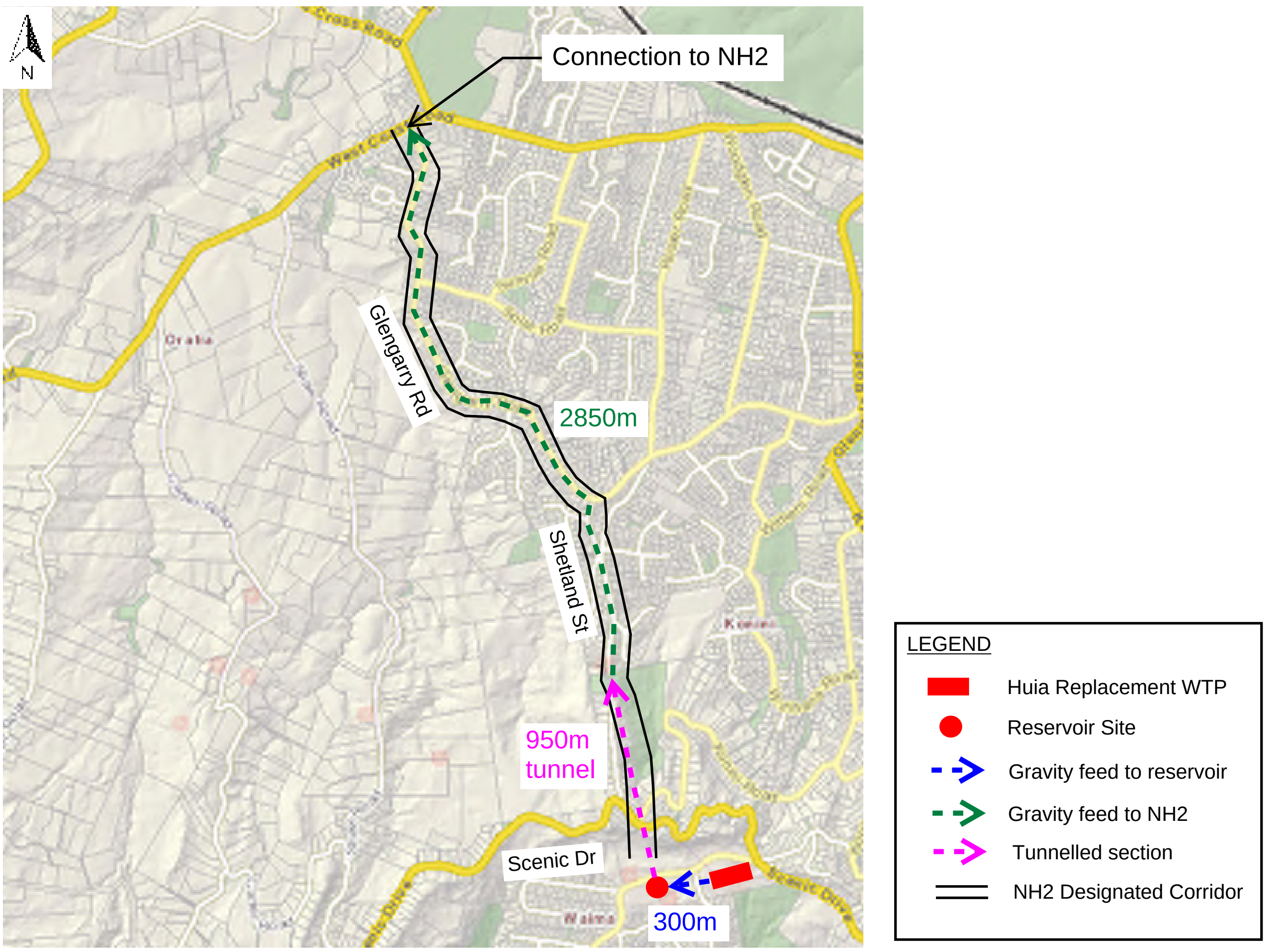


Huia Replacement WTP Storage Analysis		
Site:	2	
Location:	Existing Huia WTP site off Woodlands Park Rd	
Elevation:	Reservoir base level 115mRL	
Complexity:	Reservoir/Access: Two potential sites have been identified at the existing Huia WTP site. One is located where the existing clarifiers are and the other (smaller reservoir) is at the north east corner. Less than 5m cut and fill required. Both sites are located at a suitable base level of approximately 115mRL and access is readily available from nearby Woodlands Park Rd. No known flood risks at reservoir sites. Pipelines: WTP to Reservoir: 300m gravity pipeline Reservoir to NH2: 3800m, including 950m gravity tunnel between Reservoir and Shetland Street. WTP to NH2: Total length = 4100m (200m > shortest route)	
Volume:	V=26ML with one 20ML and one 6ML reservoir - each with height of 9m. Constrained by existing Huia WTP being within Historic Heritage Area under the Unitary Plan.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Open space - Conservation Zone. Historic Heritage Area. Stormwater Management Control Area. Social: This site contains areas of Historic Heritage zoning. Further collaboration with Auckland Council would be necessary to ensure the proposed reservoir locations do not detract from the heritage elements on the site. No houses are directly impacted.	
Resilience:	Top water level = 124mRL	
Comments:	Storage not available at this site until existing Huia WTP is decommissioned. Therefore another reservoir site would be needed prior to use of this site.	

Reservoir Site 2



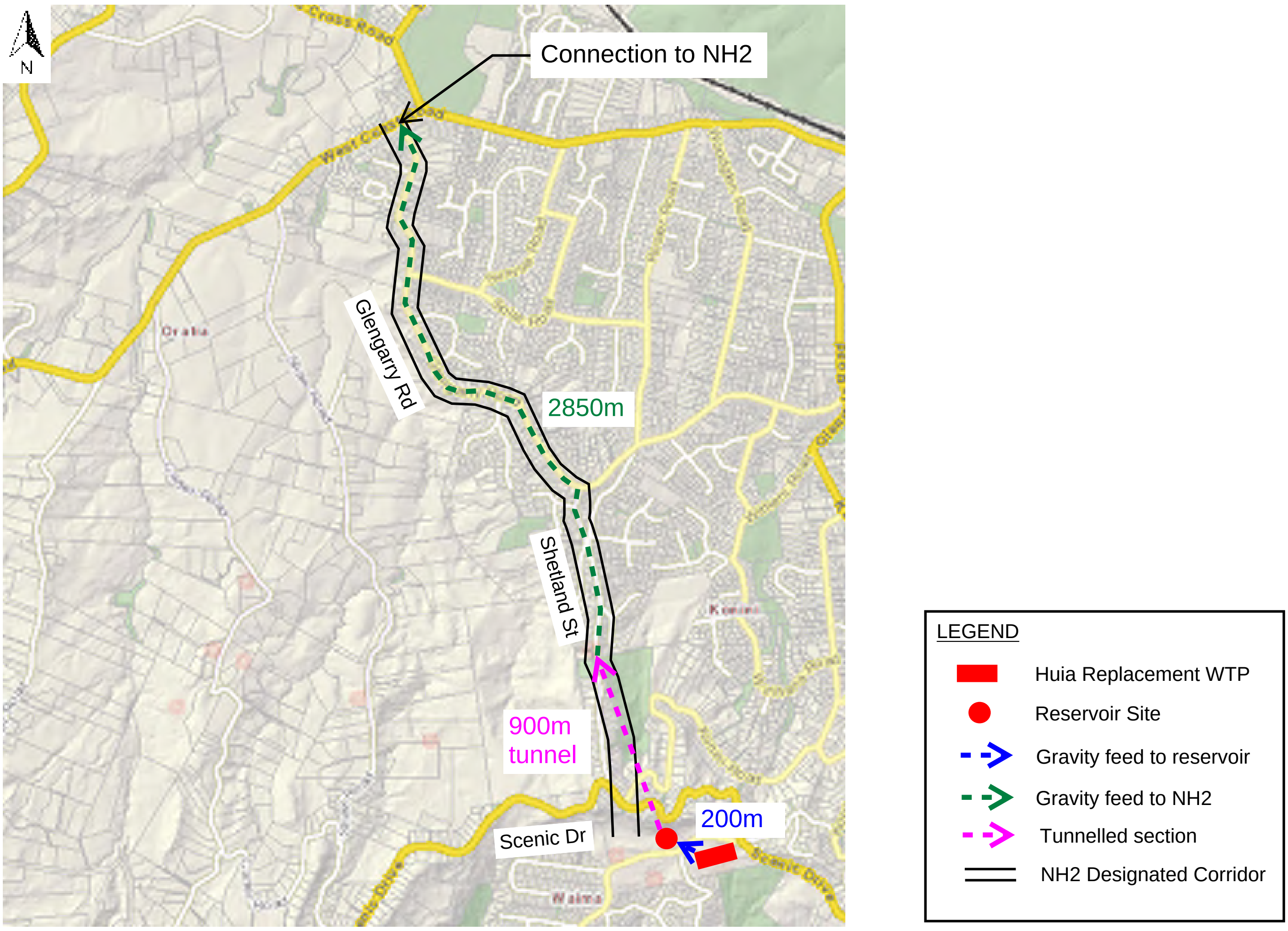
Pipeline Routes



Huia Replacement WTP Storage Analysis		
Site:	3	
Location:	Woodlands Park Rd Site	
Elevation:	Reservoir base level 119mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:7. Significant cut of up to 15m and retaining walls required. Site located within heavily forested area across the road from Huia Replacement WTP site. Although forested, reservoir is 10m from Woodlands Park Road so access road not a constraint. Reservoir partly within flood plain and flood prone area. Pipelines: WTP to Reservoir: 200m gravity pipeline Reservoir to NH2: 3800m, including 950m gravity tunnel between Reservoir and Shetland Street. WTP to NH2: Total length = 4000m (100m > shortest route)	
Volume:	V=50 ML with two reservoir tanks side by side - each with height of 9m.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Open space - Conservation Zone. Significant Ecological Area. Waitakere Ranges Heritage Area. Stormwater Management Control Area. Social: This site is a forested site within a significant ecological area. No houses are directly impacted.	
Resilience:	Top water level = 128mRL. Meets all resilience scenarios from GHD study.	
Comments:		

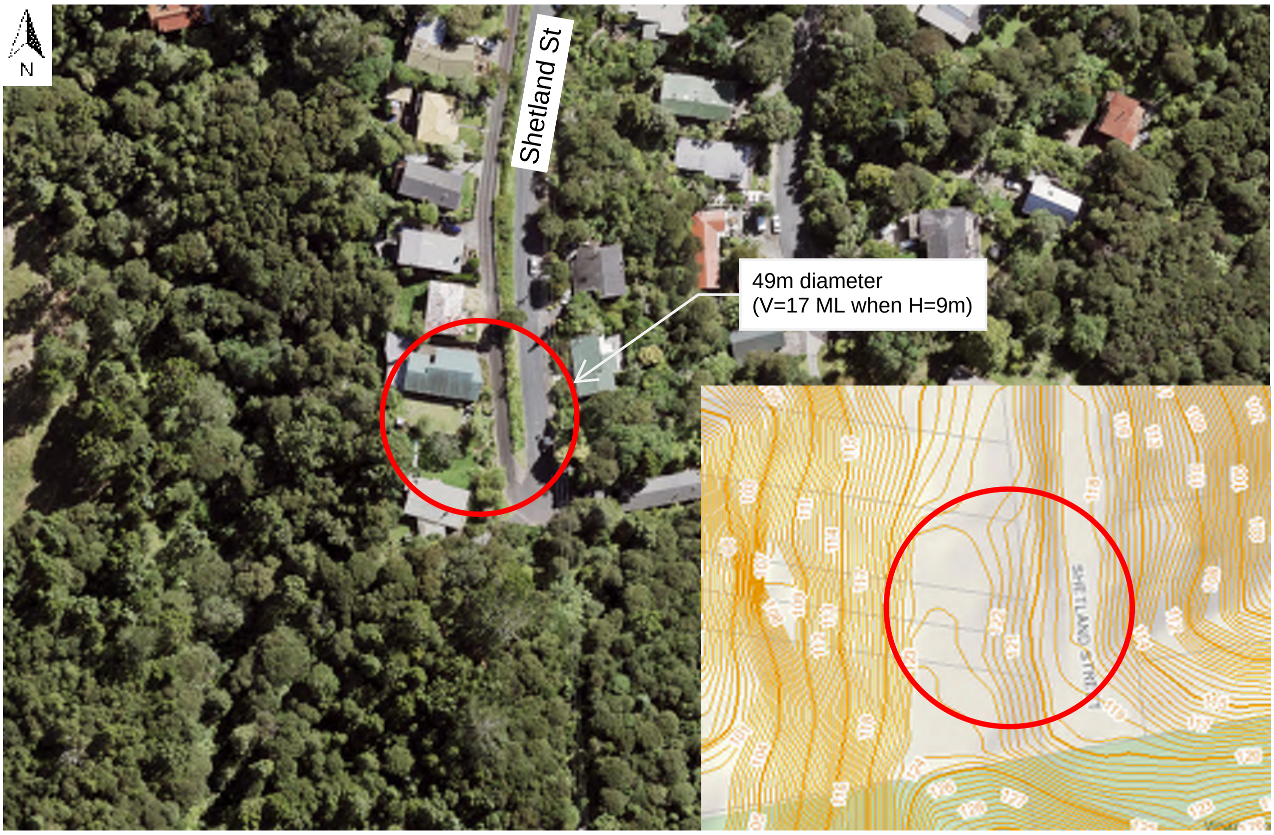
Reservoir Site 3

Pipeline Routes

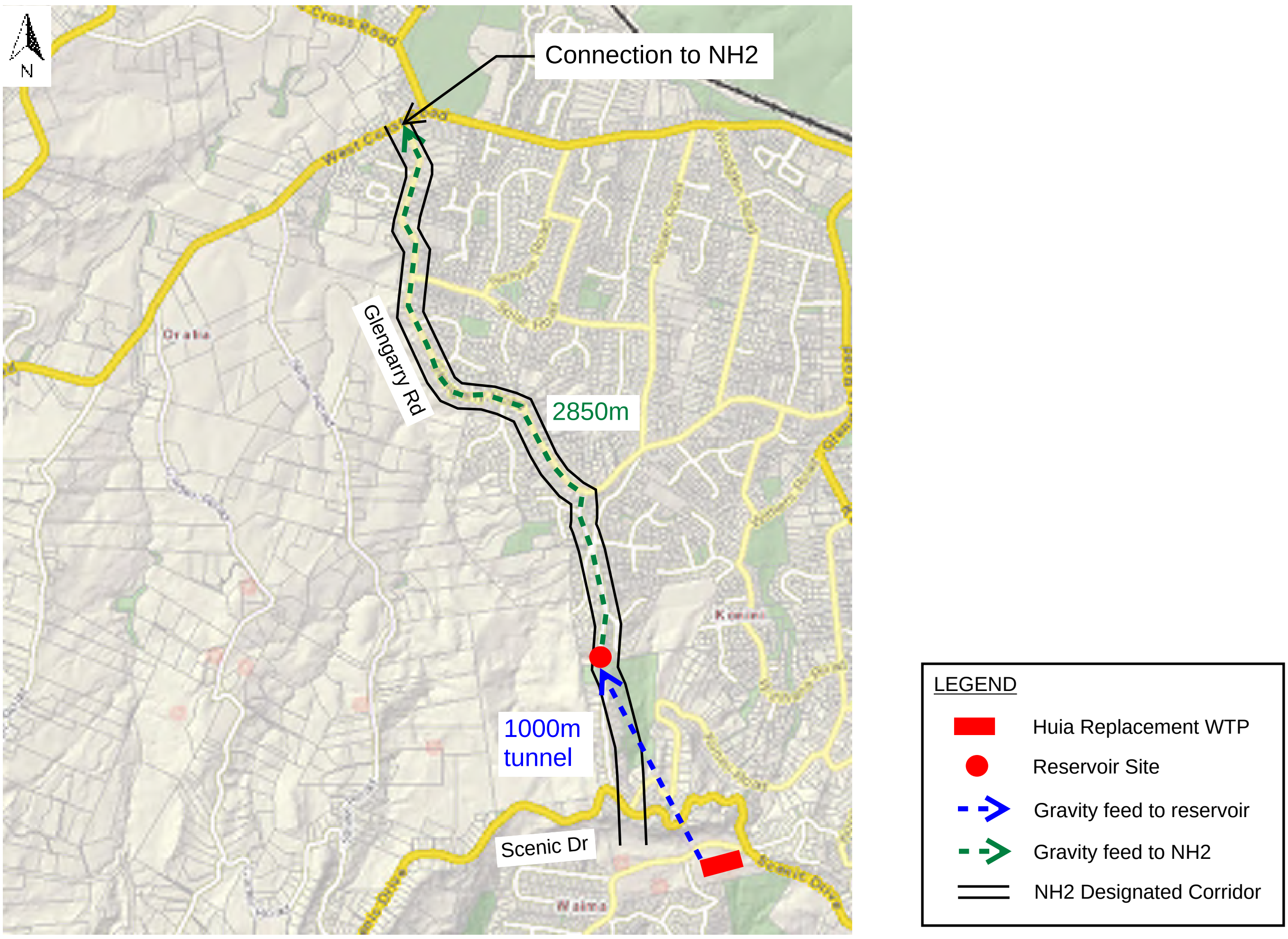


Huia Replacement WTP Storage Analysis		
Site:	4	
Location:	81-85 Shetland Steet	
Elevation:	Reservoir base level 119mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:6, mostly positioned on Shetland Rd itself. Cut and fill of up to 5m required. Site includes building over approximately five existing houses. Located at Shetland Rd cul-de-sac. This location is also the proposed tunnel exit from the WTP which makes this a good strategic location for a reservoir. No known flood risks at reservoir site. Pipelines: WTP to Reservoir: 1050m gravity tunnel Reservoir to NH2: 2850m along Shetland St, Phillip Ave, and Glengarry Rd. WTP to NH2: Total length = 3900m (shortest route)	
Volume:	V=17 ML when height is 9m. Constrained by steep slopes which fall away to the east and west, and additional existing housing which would require removal to accommodate a larger reservoir.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Residential - Single House Zone. Partly within Significant Ecological Area. Ridgeline Protection Area. Social: Building a reservoir on this site would require removal of approximately five existing houses.	
Resilience:	Top water level = 128mRL. Meets all resilience scenarios from GHD study.	
Comments:	This site becomes more viable if temporary works for tunnelling already require removal of four or five houses at Shetland Street cul-de-sac. Additional storage of approximately 30ML required at another site.	

Reservoir Site 4



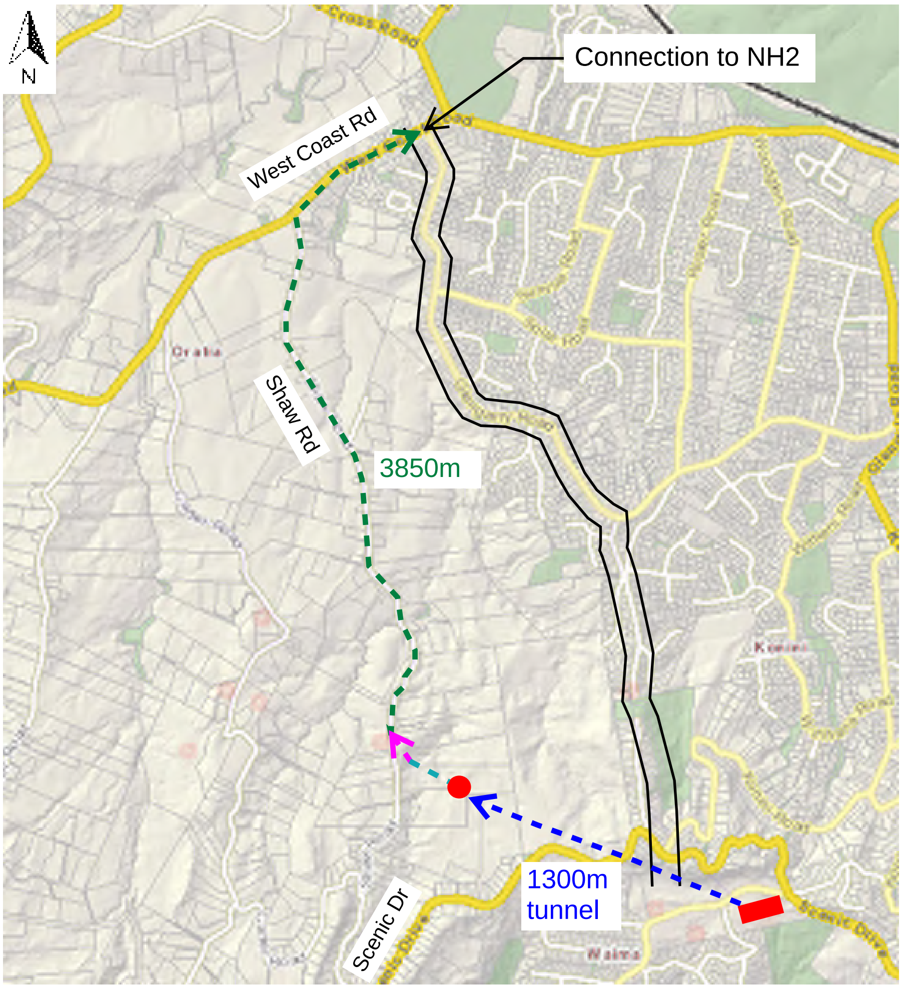
Pipeline Routes



Huia Replacement WTP Storage Analysis		
Site:	5	
Location:	184 & 186 Shaw Road	
Elevation:	Reservoir base level 115mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:5 and with gullies/undulating terrain to the west. Significant cut and fill required of between 5 and 10m. Retaining walls likely required. Access to site difficult. Current access is along 500m gravel driveway from Scenic Drive in the south. Work necessary to make this access suitable for heavy vehicles. Shaw Rd is 250m to east of site, however undulating terrain would make an access road for heavy vehicles challenging but possible. Reservoir within flood plain and significant overland flow path. Pipelines: WTP to Reservoir: 1300m gravity tunnel Reservoir to NH2: 3850m along Shaw Rd and West Coast Rd, including 750m of tunnelled pipe between Reservoir and Shaw Rd. Alternative tunnelled and aerial route exists between Reservoir and Shaw Rd which would reduce length by 450m. WTP to NH2: Total length = 5150m (1250m > shortest route)	
Volume:	V=22 ML when height is 9m. Constrained by steepening slopes of gully to north and west of reservoir.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Significant Ecological Area. Waitakere Ranges Heritage Area. Social: Reservoir site itself doesn't impact any houses directly. Construction of access road/s would likely impact multiple properties. Site is also within significant ecological area.	
Resilience:	Top water level = 124mRL	
Comments:		

Reservoir Site 5

Pipeline Routes



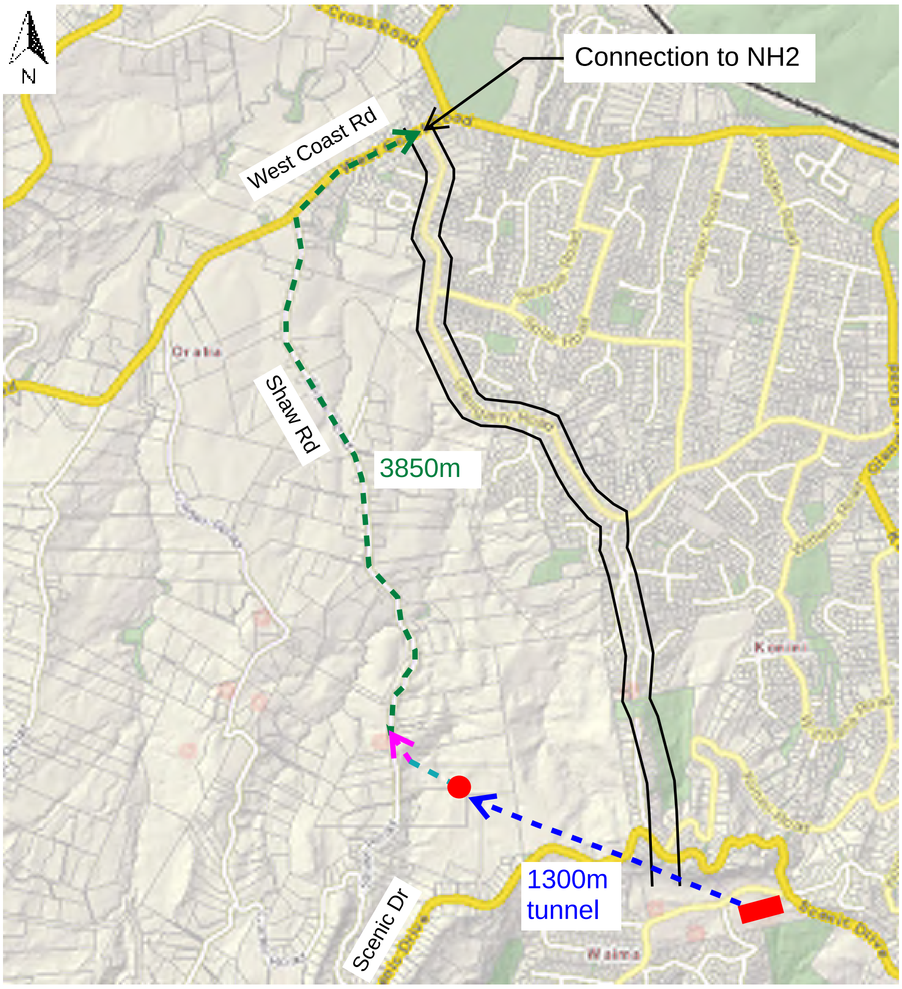
LEGEND

Huia Replacement WTP
Reservoir Site
Gravity feed to reservoir
Gravity feed to NH2
Tunnelled section
Aerial section
NH2 Designated Corridor

Huia Replacement WTP Storage Analysis		
Site:	6	
Location:	131 Shaw Road	
Elevation:	Reservoir base level 108mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:10. Cut and fill of up to 5m required. Retaining walls likely required. Site is clear of trees and vegetation, however an existing shed is present which would need removal. Good site access available from adjacent Shaw Road however note that Shaw Rd is narrow at this location. Potential opposition from neighbours due to the reservoir's prominance which may dominant the landscape. No known flood risks at reservoir site. Pipelines: WTP to Reservoir: 2300m gravity tunnel Alternative 1700m tunnelled and aerial route exists, with aerial pipeline length being 250m towards western length of pipeline. Reservoir to NH2: 3100m along Shaw Rd and West Coast Rd. WTP to NH2: Total length = 5400m (1500m > shortest route)	
Volume:	V=22 ML when height is 9m. Constrained by steepening slopes to north and west of reservoir, and road/driveway to east and south.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Significant Ecological Area. Waitakere Ranges Heritage Area. Social: No houses are directly impacted however given the reservoirs position adjacent Shaw Rd there may be opposition from property owners. Existing shed on site would need removal. Site is also within significant ecological area.	
Resilience:	Top water level = 117mRL	
Comments:	The site could potentially avoid impact to both trees and properties. Visual impact to neighbouring properties could be greatly reduced with screening.	

Reservoir Site 5

Pipeline Routes



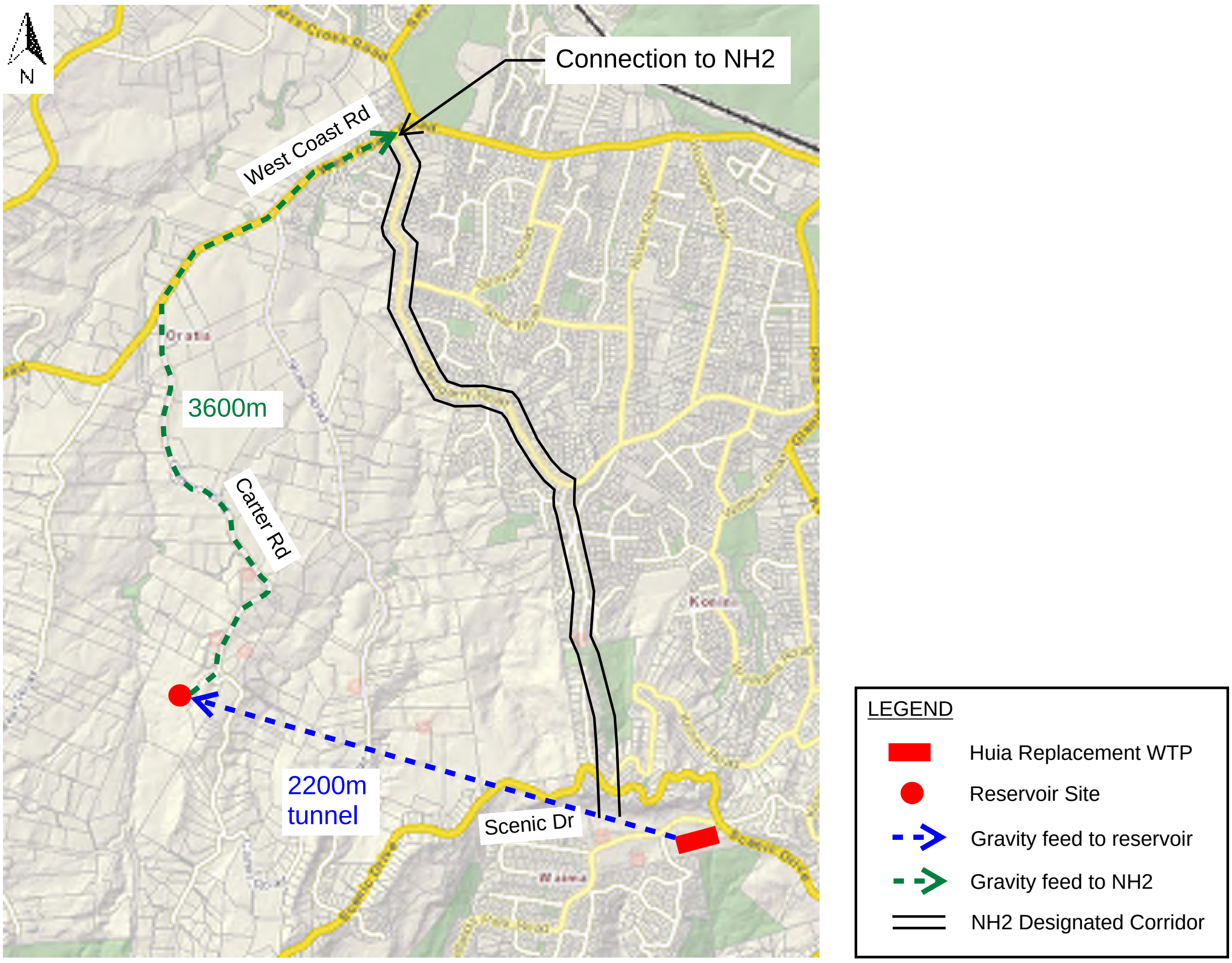
LEGEND

- Huia Replacement WTP
- Reservoir Site
- Gravity feed to reservoir
- Gravity feed to NH2
- Tunnelled section
- Aerial section
- NH2 Designated Corridor

Huia Replacement WTP Storage Analysis		
Site:	7	
Location:	105-107 Carter Road	
Elevation:	28ML reservoir base level 114mRL. 22ML reservoir base level 110mRL.	
Complexity:	Reservoir/Access: Located on average slope of 1:10. Cut and fill of up to 5m required and retaining walls likely required. Site is partly clear of trees and vegetation, however significant vegetation clearing required for access road. Potentially difficult site access due to undulating terrain, dense vegetation, and limited available road frontage along Carter Rd for driveway. Access road length of approx 200m required. Advantage of the site is the large area of available land and the hidden nature of the site. Reservoir/s within minor overland flow path. Pipelines: WTP to Reservoir: 2750m gravity tunnel Reservoir to NH2: 3600m along Carter Rd and West Coast Rd including 200m between reservoir site and Carter Rd. WTP to NH2: Total length = 6350m (2450m > shortest route)	
Volume:	V=50 ML with one 28 ML reservoir and one 22 ML reservoir - each with height of 9m. Additional storage available at site if required.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Significant Ecological Area along access road and partly at reservoirs. Waitakere Ranges Heritage Area. Social: No houses are directly impacted and due to reservoirs location away from the road there should be few property owner who have objections to the reservoir location. The site is only partly within the significant ecological area.	
Resilience:	28ML reservoir top water level = 123mRL. 22ML reservoir top water level = 119mRL.	
Comments:		

Reservoir Site 7

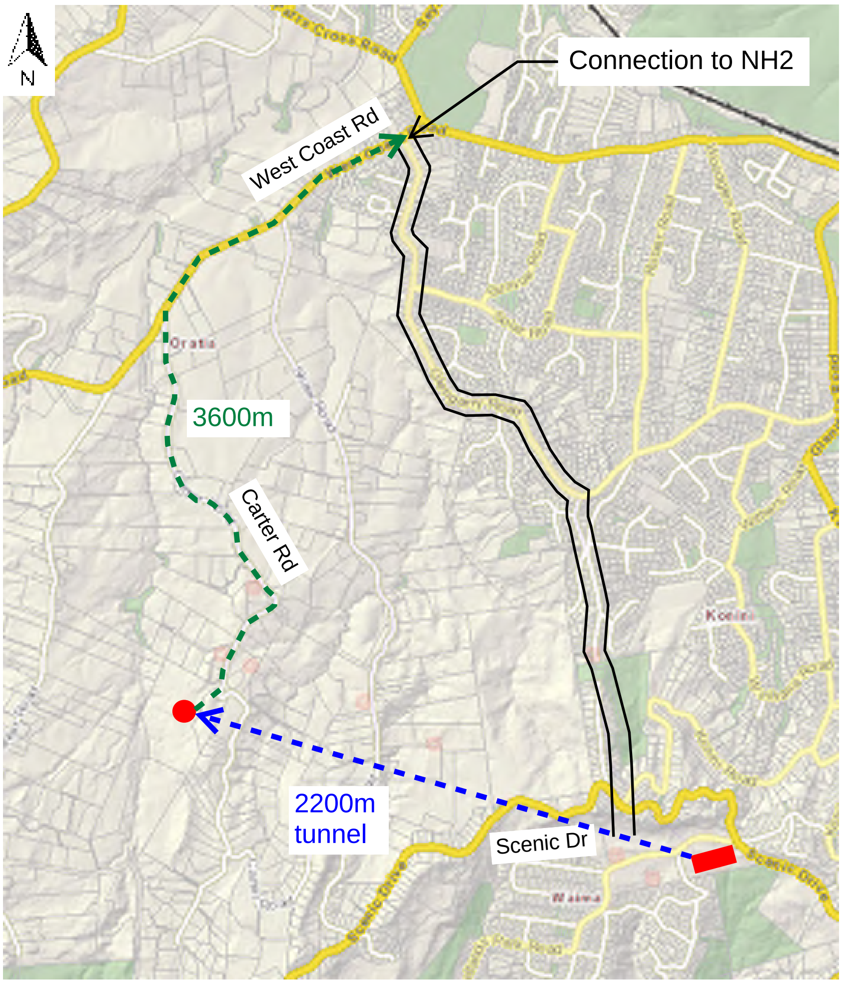
Pipeline Routes



Huia Replacement WTP Storage Analysis		
Site:	8	
Location:	97 Carter Road	
Elevation:	Reservoir base level 119mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:8. Some cut and fill up to 5m required to level site and retaining walls likely. Site is heavily vegetated and would require clearing. Short access road of less than 30m required. Site slopes steeply down towards the north west. Reservoir within minor overland flow path. Pipelines: WTP to Reservoir: 3000m tunnel route Reservoir to NH2: 3250m along Carter Rd and West Coast Rd. WTP to NH2: Total length = 6250m (2350m > shortest route)	
Volume:	V=23 ML when height is 9m. Constrained by proximity to property boundaries and crest of land to west of reservoir which would require significant cut of 10m if built on.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Waitakere Ranges Heritage Area. Social: No houses are directly impacted however given the reservoirs position adjacent Carter Rd there may be opposition from property owners.	
Resilience:	Top water level = 128mRL. Meets all resilience scenarios from GHD study.	
Comments:		

Reservoir Site 7

Pipeline Routes



LEGEND

Huia Replacement WTP

Reservoir Site

Gravity feed to reservoir

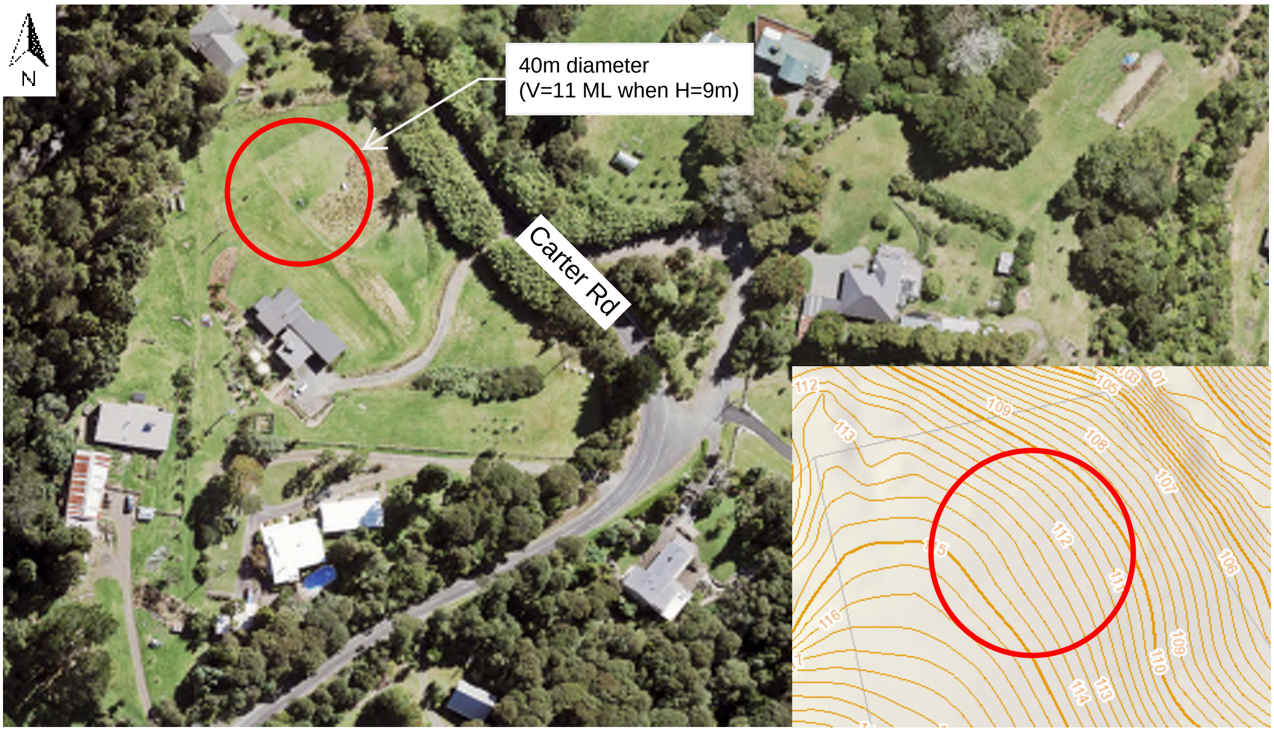
Gravity feed to NH2

NH2 Designated Corridor

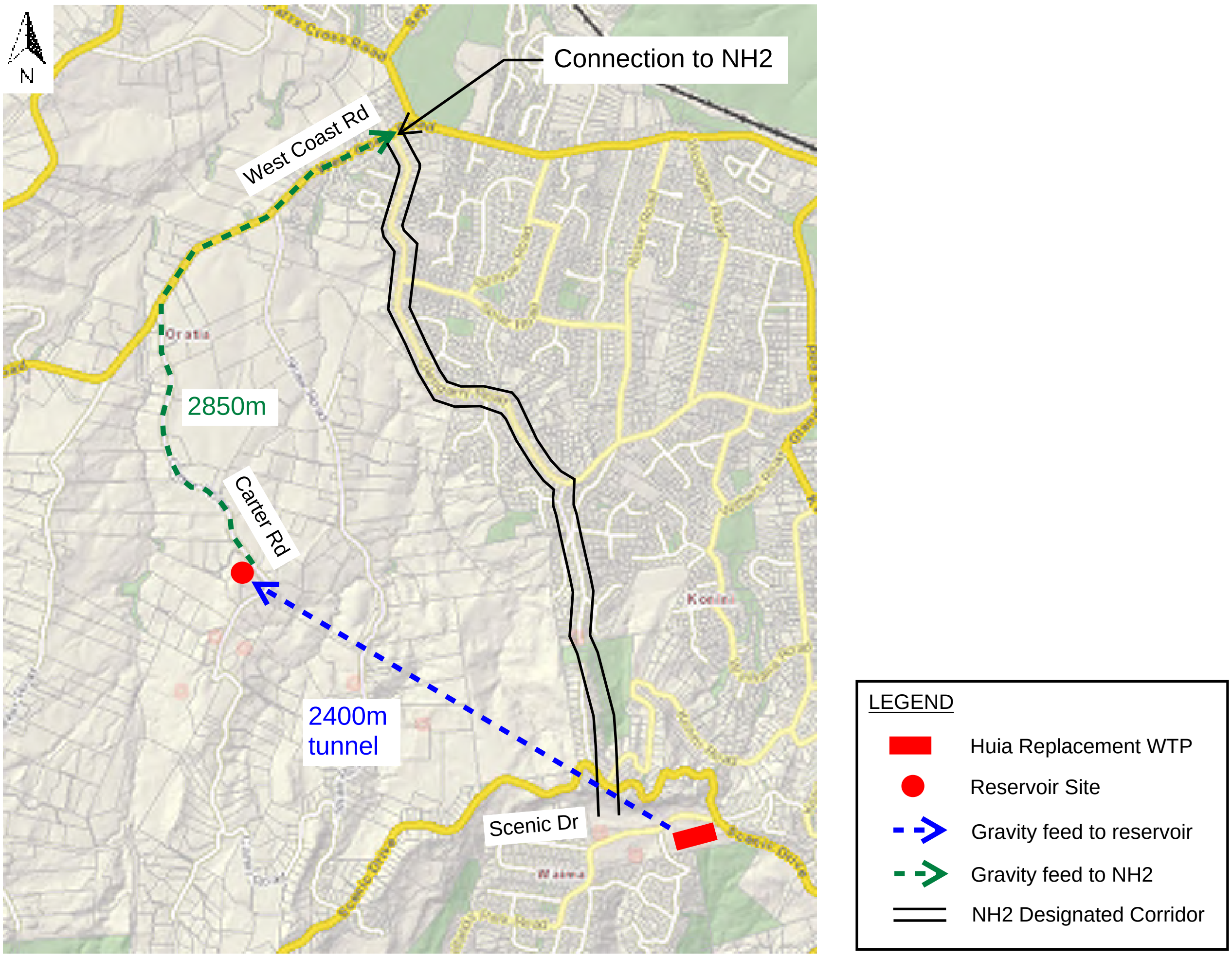
Huia Replacement WTP Storage Analysis		
Site:	9	
Location:	112 Carter Road	
Elevation:	Reservoir base level 119mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:7. Cut and fill required between 5 and 10m to level site and retaining walls likely. Site is completely clear of vegetation. Access road required and potentially difficult. Site is 250m from Carter Road down an existing shared driveway, or 100m from Carter Road through dense vegetation to the south west of the reservoir. Close proximity to existing housing may be an issue. No known flood risks at reservoir site. Pipelines: WTP to Reservoir: 3000m gravity tunnel Reservoir to NH2: 3450m along Carter Rd and West Coast Rd, including 200m between reservoir site and Carter Rd. WTP to NH2: Total length = 6450m (2550m > shortest route)	
Volume:	V=18 ML when height is 9m. Reservoir volume could be increased slightly by extending reservoir to the west.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Waitakere Ranges Heritage Area. Social: No houses are directly impacted however there are houses in close proximity to the reservoir site.	
Resilience:	Top water level = 128mRL. Meets all resilience scenarios from GHD study.	
Comments:		

Huia Replacement WTP Storage Analysis		
Site:	10	
Location:	85-87 Carter Road	
Elevation:	Reservoir base level 113mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:6. Cut and fill of up to 5m required to level site and retaining walls likely. Site is clear of vegetation, however vegetation clearing necessary for short access driveway. Close proximity to two existing houses in particular may be an issue. No known flood risks at reservoir site. Pipelines: WTP to Reservoir: 3300m gravity tunnel Reservoir to NH2: 2850m along Carter Rd and West Coast Rd. WTP to NH2: Total length = 6150m (2250m > shortest route)	
Volume:	V=11 ML when height is 9m. Constrained by proximity to property boundaries and adjacent housing.	
Sustainability:	Environmental: As per Unitary Plan overlays, the reservoir is within the following zones/areas: Rural - Waitakere Foothills Zone. Waitakere Ranges Heritage Area. Social: No houses are directly impacted however there are houses in close proximity to the reservoir site.	
Resilience:	Top water level = 122mRL	
Comments:		

Reservoir Site 10



Pipeline Routes



Huia Replacement WTP Storage Analysis		
Site:	11	
Location:	11 Glengarry Rd	
Elevation:	Reservoir base level 105 mRL	
Complexity:	Reservoir/Access: Located on average slope of 1:10. Cut and fill of up to 5m required to level site and retaining walls likely. Site is clear of vegetation, however 10 existing houses would require removal. No known flood risks at reservoir site. Pipelines -Sits on the proposed NH2 pipeline route, so minimal increase in pipework compared to options 1,2 and 3. Pipeline length of 3900m, including 950m gravity tunnel between WTPand Shetland Street. Reservoir elevation and location makes a cros conneciton to the Titirangi Reservoirs difficult.	
Volume:	V=25 ML when height is 9m.	
Sustainability:	Environmental: Minor, within a residential area Social: Requires removal of 10 houses.	
Resilience:	Top water level = 114 mRL	
Comments:	This site is further detailed in the NH2 Storage - Alternative Site Suitability memorandum (GHD, Septemebr 2018). The site has a significant social impact with the removal of 10 houses in a highly residential area.	

Reservoir Site 11