Belmont Quarry

Hydrological analysis of proposed land exchange

Prepared by

Landscape Dynamics Ltd.

3 December 2025

Revision: 5.0

Revision Record

Revision	Date	Prepared By	Authorised By
5.0	3 December 2025	[redacted]	[redacted]

Basis of Report

This report has been prepared by Landscape Dynamics with all reasonable skill, care, and diligence, and taking account of the timescale and resources allocated to it by agreement with Winstone Aggregates (the client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

The report has been prepared on the instructions of our client in accordance with the agreed scope of work. If it is intended to support an application under the Fast-track Approvals Act 2024, it may be relied upon by the Expert Panel and relevant administering agencies for the purposes of assessing the application.

No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from Landscape Dynamics.

Landscape Dynamics disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

I confirm in my capacity as author of this report, that I have read and agree to abide by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses Practice Note 2023. A copy of my CV, setting out the necessary qualifications, is at Appendix 1.

Table of Contents

1.0 Background ... 1

1.1 Wider hydrological setting ... 2

2.0 Catchment Setting ... 3

2.1 Nature of streamflow ... 3

2.2 Waikoropupu Stream ... 4

2.3 Northern Gully ... 5

2.4 OBDA ... 7

2.5 Firth Block ... 9

2.6 Dry Creek ... 10

2.7 Southern Gully ... 11

3.0 Hydrological Processes ... 13

3.1 Hydrological data ... 15

3.2 Spatial analysis ... 15

4.0 Observations ... 17

4.1 Western tributary of 'Northern Gully' ... 17

4.2 Northern tributary of 'Northern Gully' ... 18

4.3 Sub-catchments OBDA-3 & OBDA-4 ... 18

4.4 Drainage calibration ... 23

5.0 Comparison ... 24

6.0 Conclusions ... 26

7.0 References ... 26

1.0 Background

Winstone Aggregates is seeking approval under the Fast-track Approvals Act 2024 for a land exchange as part of its Belmont Quarry Development. The exchange involves Crown-owned recreational reserve land, currently managed and controlled by Greater Wellington Regional Council as part of Belmont Regional Park, and privately owned land held by Winstone Aggregates. The exchange will enable the establishment of an Overburden Disposal Area (OBDA) which will secure the ongoing operation and expansion of Belmont Quarry.

The land exchange involves five distinct parcels (***Figure 1.1***):

- Crown-owned recreational reserve land, currently managed and controlled by Greater Wellington Regional Council as part of Belmont Regional Park (within which an OBDA will be developed with an appropriate buffer);
- Land surrounding the former Dry Creek Quarry (Dry Creek);
- The Firth Block, containing the lower reaches of two small unnamed streams draining the Wellington Fault scarp;
- The Northern Gully, containing that reach of Waikoropupu Stream between its headwaters and Belmont Quarry; and
- The Southern Gully, containing the middle reach of a small catchment southwest of the current Cottle Block OBDA.

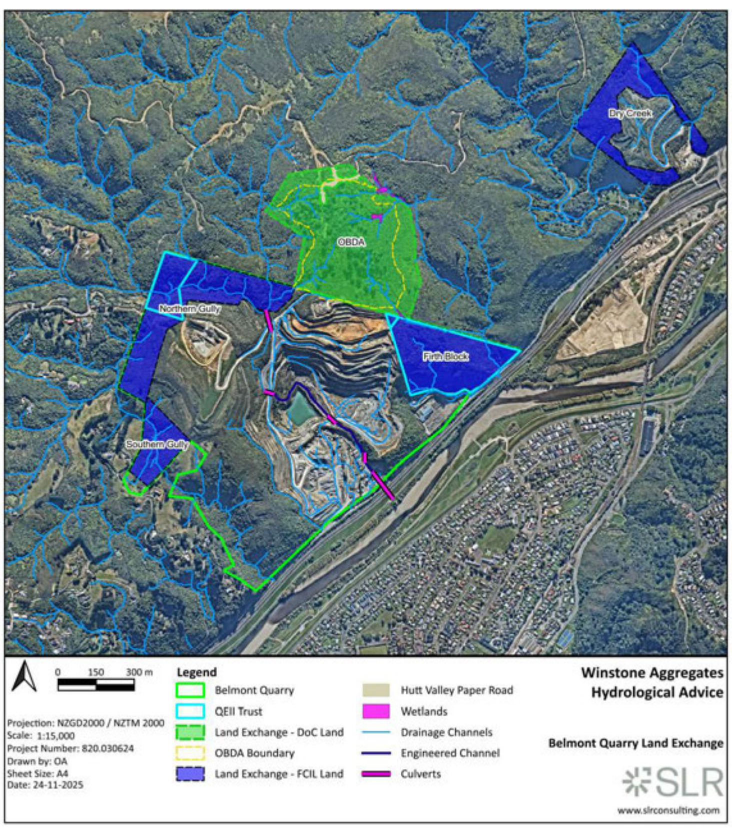

Figure 1.1: The five blocks considered for land exchange. ***Note: the land exchange area is larger than the proposed OBDA.***

This report considers the hydrological characteristics, values, and features of the five parcels of land being considered for exchange.

1.1 Wider hydrological setting

The parcels being considered for exchange all contain watercourses that drain either the uplifted block or the steep scarp to the west of the Wellington Fault. The two largest areas form portions of the Waikoropupu catchment; the proposed OBDA exchange area in the headwater gullies to the north, and the middle reach of Waikoropupu Stream (the Northern Gully) to the west of the quarry.

Prior to the establishment of the Belmont Quarry, the Waikoropupu catchment would have been typical of the other small streams draining the Western Hutt hills and the scarp of the Wellington Fault (***Figure 1.2***). The 1.7km² catchment would have had a dendritic drainage network and been largely covered with regenerating native bush and scrub, with areas of pasture towards the catchment divide. The area has now been quarried for over a century, and the landforms and associated watercourses/drainage network, have been modified by that activity.

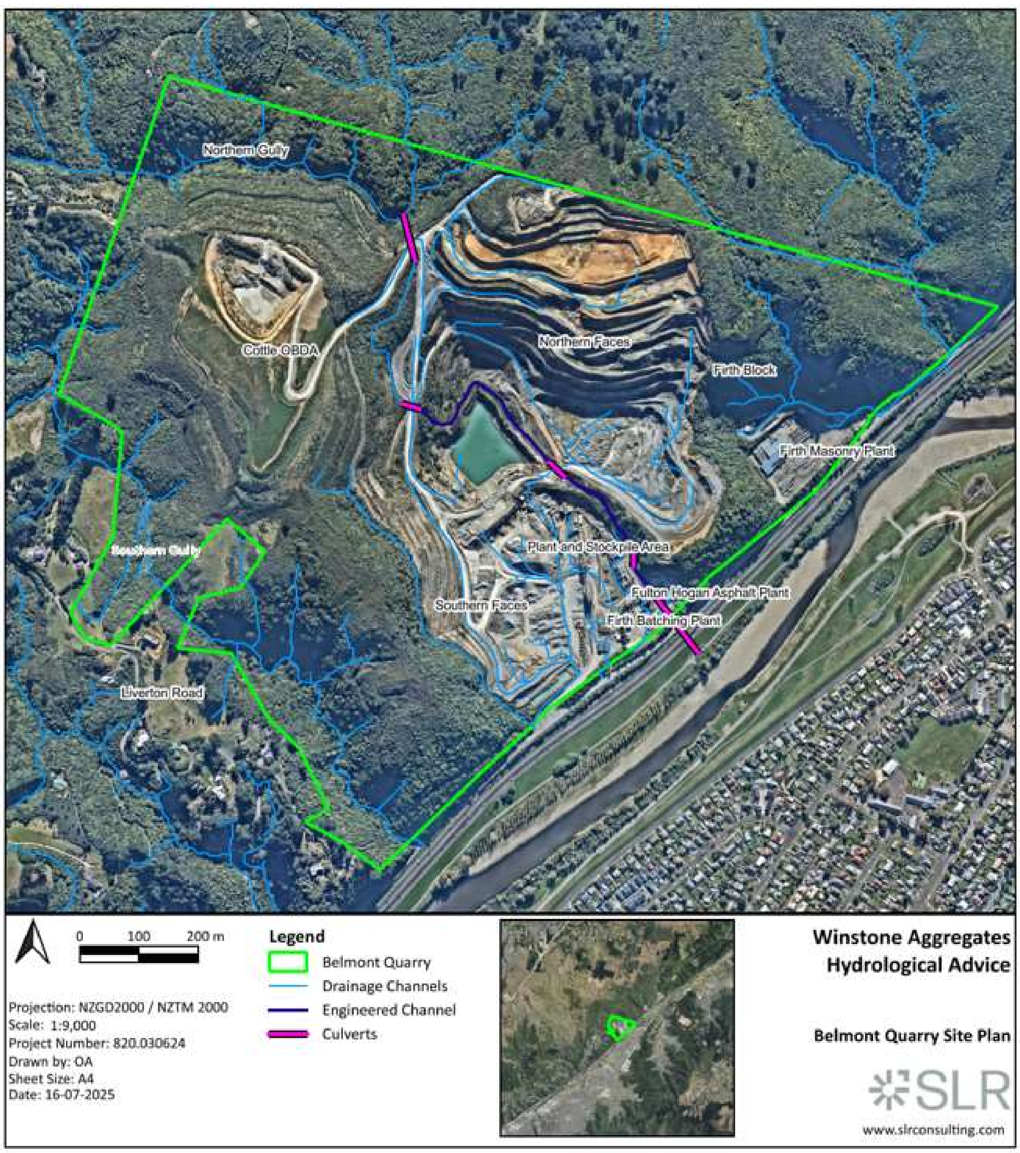

Figure 1.2: Belmont Quarry drainage and imagery.

Upstream of where a waterfall now descends onto the excavated benches above the large pond and towards the head of the quarry, shown by a purple line on ***Figure 1.2***, the drainage network remains typical of other gullies and streams in the area. The largely unaffected catchment upstream of the quarry is approximately 1.15km² or about 68% of the total Waikoropupu catchment. It should be noted therefore that quarrying activities have had no effect on the flow regime or stream channel network within more than two-thirds of the Waikoropupu catchment.

Waikoropupu Stream has steep incised headwater tributaries which exhibit a strong linkage and interconnection between slope and fluvial processes. The headwaters appear to be relatively stable currently; with few recent landslide scars being evident. Those landslide scars which are present, are in 'O'-order basins i.e., on the upper slopes and gully heads of small tributaries.

2.0 Catchment Setting

2.1 Nature of streamflow

Belmont Quarry, and the various areas proposed for the land exchange, are located on the uplifted block immediately west of the Wellington Fault. The relatively flat slopes on the ridges contrast with the steeply incised small watercourses, and numerous headwater gullies, eroded into the uplifted block. The small catchments, particularly in the headwater gullies, mean that surface flow is highly variable, both in space and over time. While the lower reaches of the larger streams have perennial flow, the continuity of surface flow decreases moving upslope, becoming first intermittent and then largely ephemeral (***Figure 2.1***). It should be noted, however, that the boundaries between these different 'theoretical' flow regimes vary over time. Therefore, providing a robust definition of the exact nature of the flow regime at a particular location can be problematic.

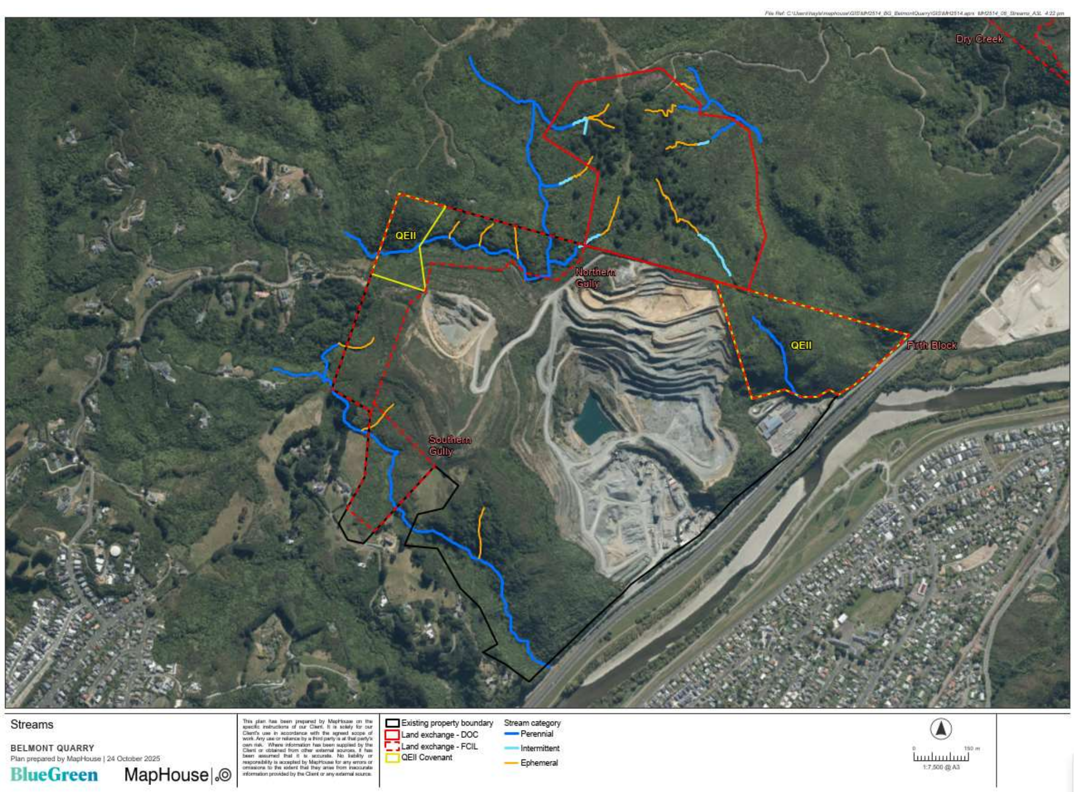

Figure 2.1: Characterisation of the likely flow regimes of larger watercourses in the vicinity of Belmont Quarry.

Excess precipitation can move as either surface or subsurface flow depending on antecedent conditions, the properties of the regolith, catchment size, and the intensity and duration of rainfall. A key hydrological characteristic of the watercourses in the exchange areas is therefore whether there is continuous surface flow. Hydrologically, the more significant watercourses are those with perennial flow. The hydrological values of watercourses with intermittent or ephemeral flow will vary with conditions as discussed above.

2.2 Waikoropupu Stream

As mentioned, Waikoropupu Stream, prior to the development of Belmont Quarry, would have been typical of other small streams draining the Western Hutt hills and the scarp of the Wellington Fault.

A high-resolution DTM that provides the elevation of each 1m cell allows the topographic relationship between the various cells to be analysed. From this, the potential overland flow paths (e.g., potential streams, watercourses and other drainage lines) can be inferred (***Figure 2.2***).

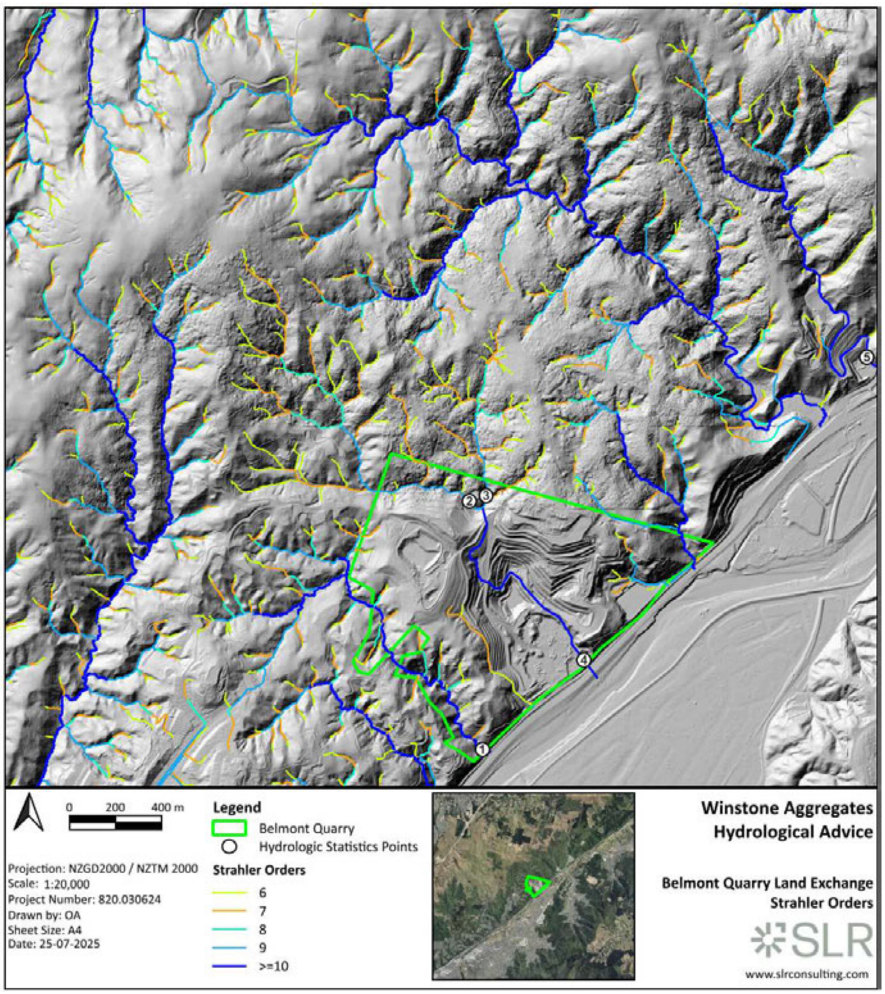

Figure 2.2: Waikoropupu catchment and inferred surface drainage.

The potential overland flow paths i.e., watercourses, derived from analysis of the DTM are a function solely of the topography. There is no consideration of any rainfall-runoff relationship, and it is assumed that the ground surface is both bare of vegetation and impermeable. Consequently, the actual rainfall-runoff processes operating within the catchment have been simplified greatly.

It is assumed that any runoff flows from cells at higher elevation into cells at lower elevation. Flow accumulates downslope as more cells receive flow from upslope until some threshold defined for the commencement of surface flow i.e., streamflow, is reached.

The threshold for assuming when surface flow might become apparent i.e., the potential flow lines shown on ***Figure 2.2***, is determined by the Strahler stream order (i.e., a measure of the number of connected drainage lines upstream). Under the Strahler classification, an order two stream starts below the confluence of two first order streams, and a third order stream below the confluence of two second order streams etc. Consequently, the higher the Strahler number, the greater the number of upstream tributaries, and potentially the larger and more stable the flow regime.

It should be noted, however, that the Strahler system was developed initially for actual stream networks and not the assumed flow when analysing DTMs. In DTMs, the digital 'streams' commence much nearer the interfluve or catchment divide than shown on paper maps. Therefore, the Strahler stream orders derived from a DTM are higher than would be found in the field. For example, for streams draining the Wellington Fault, it appears that a 'stream' with a Strahler order ten from the DTM is necessary for it to be shown on LINZ topographic maps. For comparison, the small tributary streams shown on a LINZ map would have a Strahler order one, if determined from the map.

The potential drainage lines shown on the various images in this report commence at a Strahler stream order six, with the Strahler order then increasing downstream. Subsequent inspection in the field during various site visits showed that the hydrological modelling was realistic in terms of drainage lines, although in the headwater gullies the assumption of overland flow from the DTM is conservative i.e., surface flow is shown higher up the slope than observed. This, and its implications, are discussed in more detail later in this report. Even within the footprint of the quarry, (subject to extensive earthworks and landscape change), the potential drainage lines are still consistent with what is observed in the field.

As discussed above, more than two-thirds of the Waikoropupu catchment has been largely unaffected by activities associated with Belmont Quarry (***Figure 2.2***). The culvert under the access track to the current Cottles' OBDA, and the high and steep waterfall within the quarry, buffer the largely unmodified upper catchment (i.e., the Northern Gully) from the lower reaches of Waikoropupu Stream that pass through, and then under, some quarry infrastructure.

The geology of the Waikoropupu catchment consists of relatively thin regolith[1], formed from both *in situ* and colluvially-derived weathered bedrock, overlying generally impermeable greywacke bedrock. This geology and stratigraphy do not provide the conditions necessary for the formation of aquifers or any significant groundwater resource. Any groundwater is likely to only exist within the regolith in the heads of gullies, and other concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within the Waikoropupu catchment, or any of the areas being considered for exchange.

2.3 Northern Gully

The Northern Gully is the largest parcel of land (~36%) that will be swapped by Winstones as part of the proposed land exchange (***Figure 2.3***). This area comprises largely the mid-reach of the main

[1] Regolith is the unconsolidated material that overlies the bedrock.

tributary of the Waikoropupu catchment (that drains from the west) and the lower reach of the secondary tributary (that drains from the north). These two larger tributaries discharge most of the runoff from the largely unaffected upper catchment of Waikoropupu Stream. The exchange area is 12.62ha, although the upstream catchment contributing flow adds a further 71.3ha.

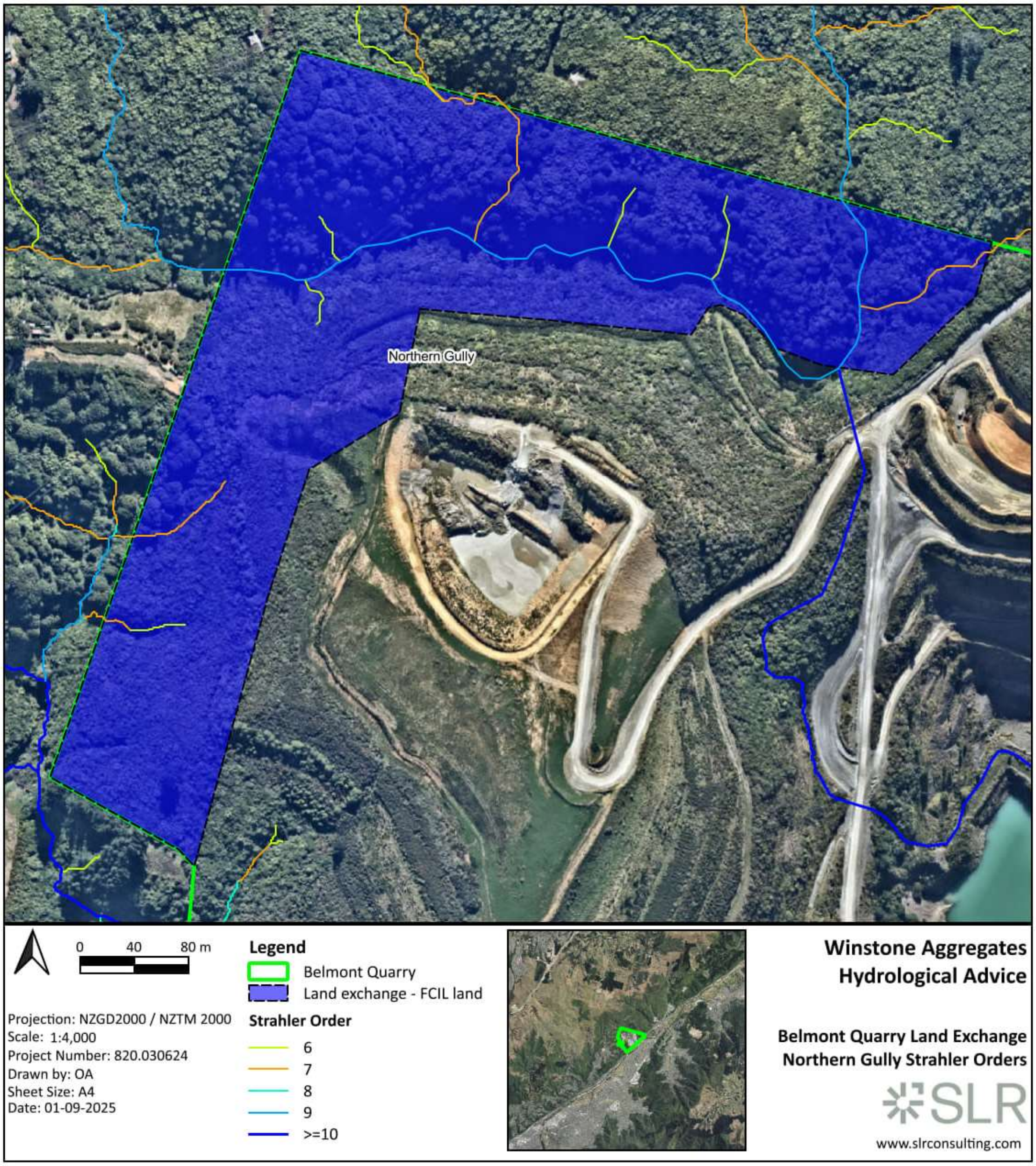

Figure 2.3: The 'Northern Gully' exchange area and inferred drainage network.

The various streams and tributaries in the Northern Gully have a combined length of 1191m, with the longest stream in the exchange area being 463m. Approximately 70% of the streams have the Strahler order of at least seven, and there are 599m (50%) of streams with a Strahler order of at least nine. This analysis indicates that the Northern Gully is comprised mainly of larger streams with higher and more stable flow regimes.

For the reasons discussed above relating to the geology of the Waikoropupu catchment, conditions are unlikely to host any aquifers or significant groundwater resource. Any groundwater is likely to only exist within the heads of gullies, and other concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within this exchange area. There are also unlikely to be any wetlands, and none have been mapped during various ecological and vegetation surveys.

Because of difficulties with access and its physical characteristics, the Northern Gully is unlikely to have any current water-based recreational use.

2.4 OBDA

The proposed 'OBDA' will be approximately 17.3ha and lie within the 23.24ha exchange area located on the interfluve (catchment divide) between four small headwater gullies (***Figure 2.4***). Those gullies that drain to the west, have relatively low Strahler stream orders indicating small drainage lines which are unlikely to support perennial flow. These gullies discharge into the upper reaches of the second tributary of Waikoropupu Stream discussed above. The gullies that drain to the east, discharge into streams that drain a small catchment eroded into the fault scarp to north of Belmont Quarry and Waikoropupu Stream. This stream discharges into the Hutt River. The lower reaches of this stream have relatively high Strahler orders because of the large number of small gullies that form the upper catchment. The exchange of land for the proposed OBDA, being a land transaction, has no potential to affect the flow regime and characteristics of Waikoropupu Stream, or the smaller stream to the north.

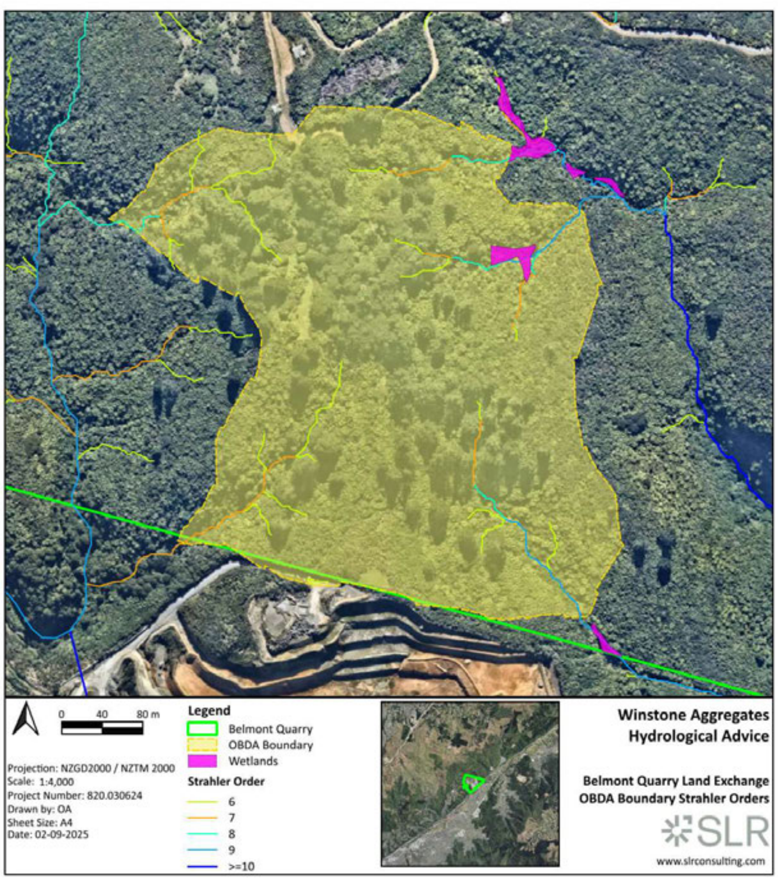

Figure 2.4: The 'OBDA' exchange area, inferred drainage network, and mapped wetlands.

The potential overland flow paths within the proposed OBDA exchange area are exaggerated in ***Figure 2.4*** because of the threshold of surface flow adopted, and the assumptions regarding the generation of surface flow when analysing the DTM. Flow in the upper reaches of these potential drainage lines is subsurface, with water flowing on the concave bedrock interface rather than on the ground surface. Surface flow in the headwaters of these gullies under current conditions is likely only following either intense or prolonged rainfall. This is discussed in more detail later in this report.

A better indication of the presence of perennial streams in the OBDA exchange area is provided by LINZ's topographical map. This shows no streams in this area (***Figure 2.5)***. Consequently, there is likely to be only limited surface flow in the proposed OBDA. The existing rainfall-runoff relationships, and patterns and characteristics of drainage, will be retained during any land exchange.

Figure 2.5: Topographic map showing perennial watercourses. Note the generally rolling topography of the proposed OBDA (indicated) and the lack of any streams shown in this area.

The various gullies and tributaries in the OBDA exchange area have a combined length of 1855m, with the longest drainage line in the exchange area being 265m. Approximately 48% of the gullies have the Strahler order less than seven. This indicates damp gully heads, rather than perennial watercourses. While there are 223m of watercourse with a Strahler order of at least nine, these are located just inside the boundary of the OBDA. This analysis indicates that the OBDA exchange area is comprised mainly of smaller streams and damp gully heads, with only short lengths of streams likely to have perennial flow.

For the reasons discussed above relating to the geology of the Waikoropupu catchment and the Wellington Fault scarp, conditions are unlikely to host any aquifers or a significant groundwater resource. Any saturated ground is likely to only exist within the heads of gullies, and other concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within this exchange area.

Vegetation surveys have identified a small wetland at the confluence of two gullies above the small stream that drains the eastern side of the OBDA exchange area. Given the location of the wetland, and its morphological characteristics, it was likely formed by impeded drainage caused by a landslide blocking the original flow path. The Wellington Fault scarp and Western Hutt hills were affected by thousands of landslides during intense rainfall on 20 December 1976. This wetland may have formed after that event.

2.5 Firth Block

The ‘Firth Block’ is the second largest parcel of land (~28%) that will be swapped by Winstones as part of the proposed land exchange. This area comprises the mid-reaches of one tributary and the lower reaches of a larger tributary of the stream immediately north of the Waikoropupu catchment (***Figure 2.6***). The addition of the second reach will provide a direct hydraulic connection between the Hutt River and streams within Belmont Regional Park. While the exchange area is only 9.6ha, a further 41.1ha contributes flow from upstream, enhancing and maintaining a perennial flow regime.

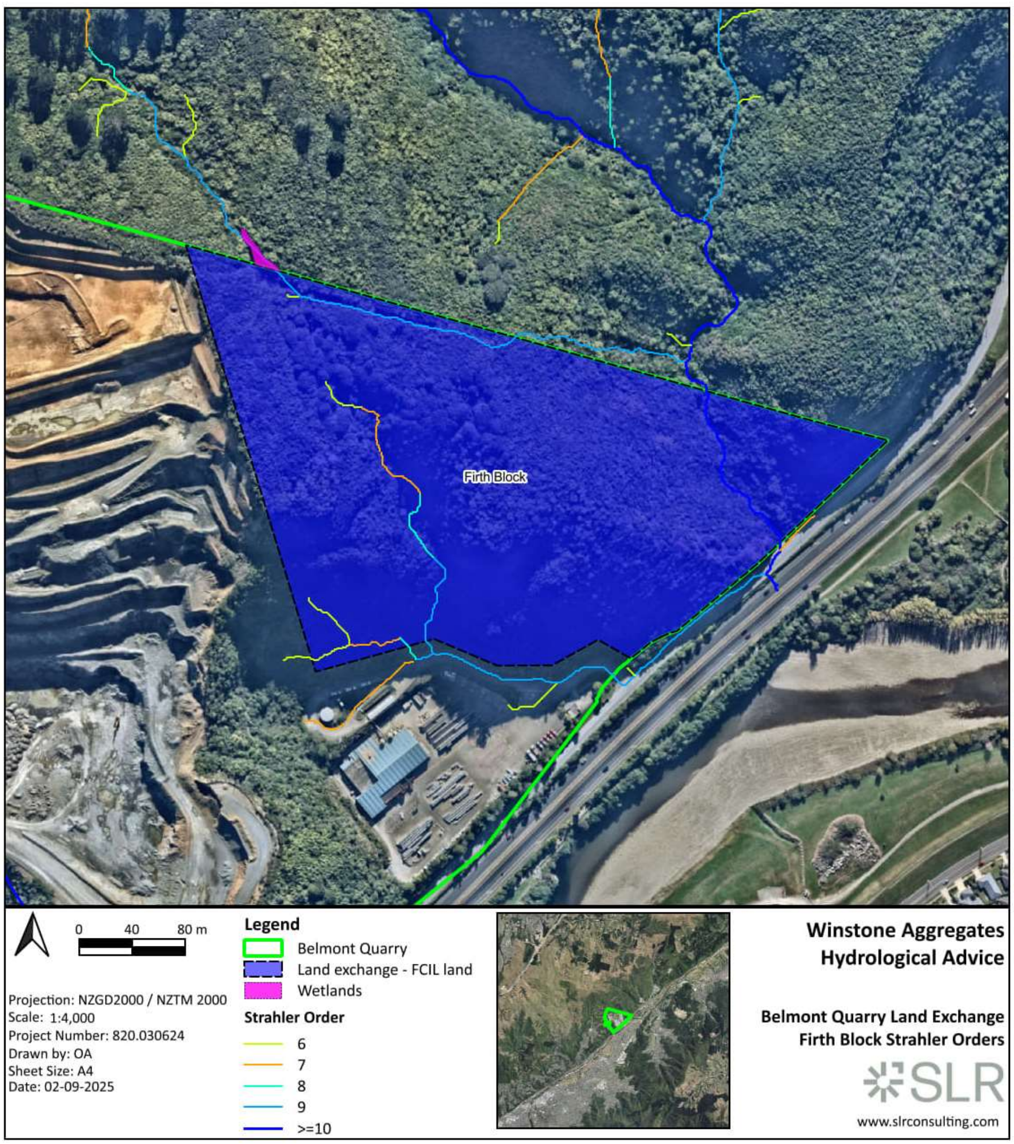

Figure 2.6: The 'Firth Block' exchange area, inferred drainage network, and mapped wetlands.

The Firth Block provides a diversity of watercourses ranging from small damp gully heads through to a larger stream (Strahler order ten) with likely perennial flow. There is a small 'pond' that follows the general alignment of the tributary on the boundary between the Firth Block and Belmont Regional Park. This 'pond' is surrounded by a small wetland. As described above, it is likely that this pond was also caused by a landslide blocking the original channel and, because of the small catchment upstream, flows have so far been unable to erode a new channel through the landslide deposit.

The various gullies and tributaries in the Firth Block have a combined length of 715m, with the longest potential watercourse in the exchange area being 256m. It is significant that 57% of the watercourses within the Firth Block have Strahler order of at least nine. This indicates that these watercourses are relatively large and may have perennial flow. As mentioned, these larger streams with more stable flow regimes provide a continuous hydraulic connection to the small watercourses with variable flow regimes within Belmont Regional Park.

For the reasons discussed previously, the geology of the Firth Block is unlikely to host any aquifers or a significant groundwater resource. Any saturated ground is likely to only exist within the heads of gullies, and other concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within this exchange area.

2.6 Dry Creek

The 'Dry Creek' exchange area is located approximately 1800m further up the Hutt Valley than Belmont Quarry (***Figure 1.1***). Despite the separation, the geology and environmental and hydrological processes at both locations are the same. Much of the discussion relating to the Waikoropupu catchment can therefore also be applied to the Dry Creek catchment, but on a smaller scale. At 7.9ha, the Dry Creek exchange area is the second smallest of all land parcels in the proposed exchange. It makes up only about 23% of the land that will be swapped by Winstones as part of the proposed land exchange. The catchment upstream of the exchange area is also small, adding only 4.1ha. This, however, means that the exchange area is largely 'self-contained' and includes most of the area up to the interfluve or catchment divide.

The area to be exchanged comprises the upper catchment and gully heads that surround the now closed Dry Creek Quarry (***Figure 2.7***). As such, these watercourses were largely unaffected by activities associated with historic quarrying.

The various streams and tributaries in Dry Creek have a combined length of 507m, with the longest stream in the exchange area being 255m. Approximately 92% of the streams have the Strahler order of at least seven, and there are 440m (87%) of streams with a Strahler order of at least nine. This is because of the larger tributary that flows through the northern portion of the area. This stream continues through the SE portion of the exchange area and provides a hydraulic connection (although highly modified) to the Hutt River. The area of the catchment that has been excluded from the exchange is the historic quarry; however, this has a highly modified and largely artificial drainage network.

For the reasons discussed above relating to the geology of the Waikoropupu catchment, conditions in Dry Creek are unlikely to host any aquifers or a significant groundwater resource. Any groundwater is likely to only exist within the heads of gullies, and other concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within this exchange area. There are also unlikely to be any wetlands, and none have been mapped during various ecological and vegetation surveys.

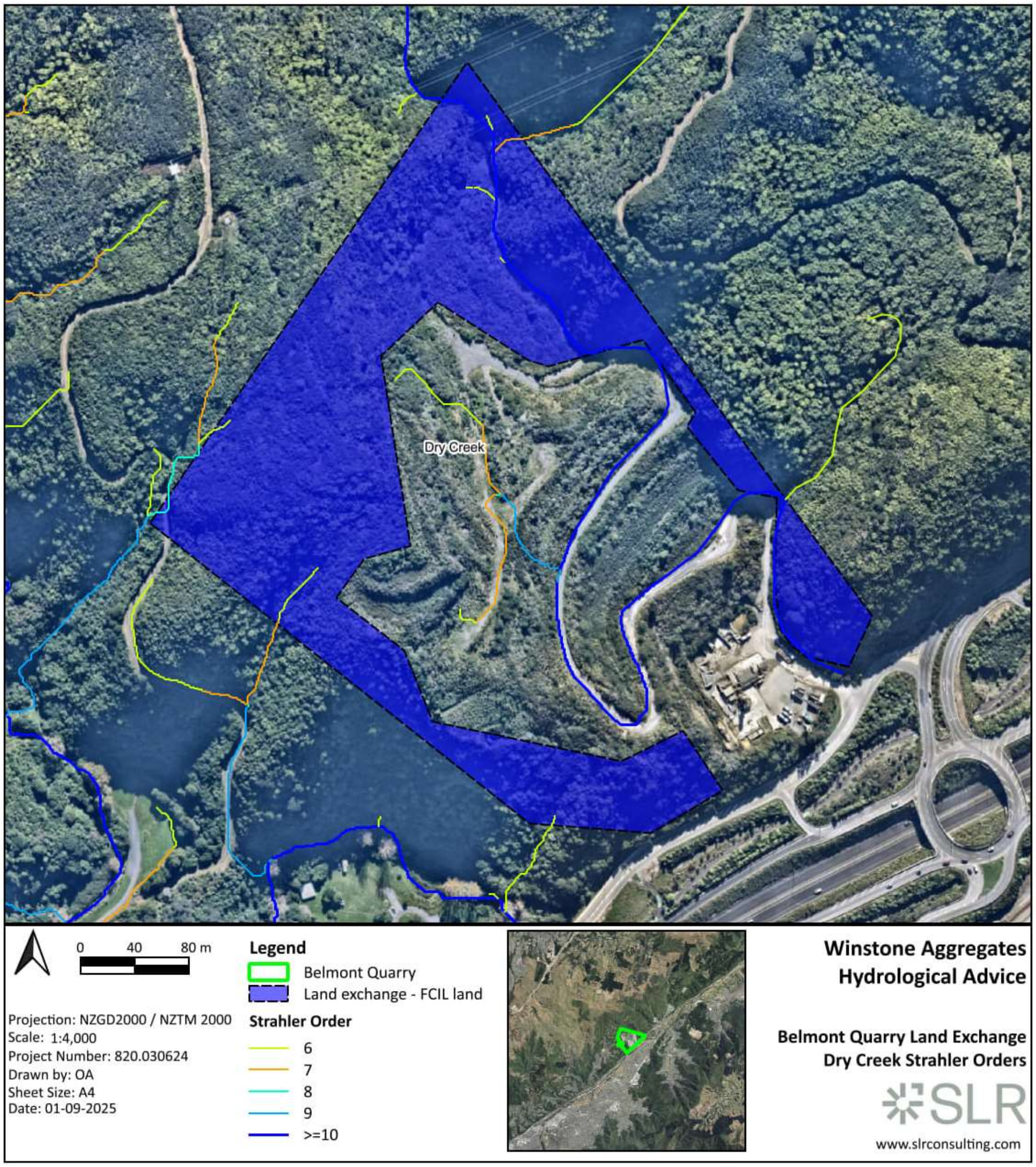

Figure 2.7: The 'Dry Creek' exchange area and inferred drainage network.

2.7 Southern Gully

The Southern Gully is in a small catchment that drains the upper section of Kaitangata Road. The stream flows between Liverton Road and Belmont Quarry before discharging into the Hutt River, about 600m downstream of the Waikoropupu confluence.

The Southern Gully land parcel has an area of 3.9ha (***Figure 2.8***). It largely encompasses the open, wider, valley floor of the mid-reach of the catchment. However, it also includes the lower slopes on both sides of the valley, a small north-facing gully that leads up to Liverton Road, and a few small gullies to the southwest of the existing Cottle Block OBDA.

The wider valley floor in the proposed exchange area has a relatively flat gradient and lies between the steeper headwater gullies and tributaries below Kaitangata Road, and the steep gorged section where the stream flows down the fault scarp in a series of waterfalls to its confluence with the Hutt River. The reduced gradient and wider valley lead to impeded drainage and hydrological conditions conducive to the formation of wetlands, several of which have been mapped during an ecological survey. These characteristics make the Southern Gully a unique part of the proposed land exchange from a hydrological perspective.

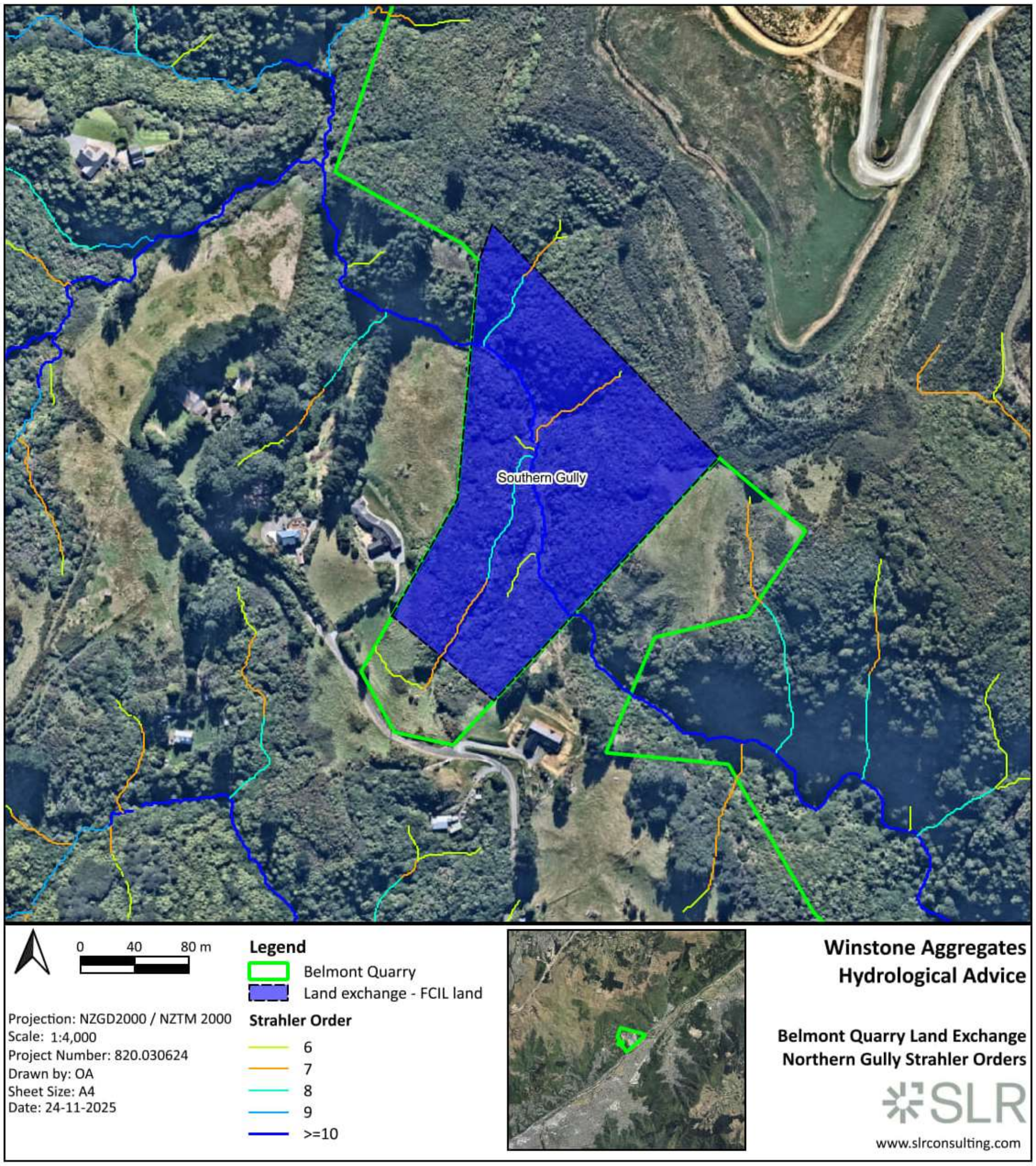

Figure 2.8: The 'Southern Gully' exchange area and inferred drainage network.

Since this catchment is immediately south of Waikoropupu Stream, and both catchments share an interfluve, the geology and environmental and hydrological processes are the same. Much of the discussion relating to the Waikoropupu catchment can therefore also be applied to this catchment, but on a smaller scale.

At 3.9ha, the Southern Gully is the smallest of all land parcels in the proposed exchange. It makes up only about 12% of the land that will be swapped by Winstones as part of the proposed land exchange. The catchment upstream of the exchange area, however, is relatively large, adding an additional 60.9ha. This upstream catchment means that the exchange area contains a watercourse with hydrological characteristics and a flow regime typical of a much larger catchment. Despite its relatively small size, the stream through the Southern Gully is likely to have a perennial flow regime.

The various streams and tributaries in the Southern Gully have a combined length of 616m, with the longest stream in the exchange area being 235m. Approximately 91% of the streams have the Strahler order of at least seven, and there are 235m (38%) of streams with a Strahler order of at least nine. This is because of the larger watercourse that flows through the centre of the area. The lower reaches of the stream are largely unmodified, and, despite its waterfalls, provide a hydraulic connection to the Hutt River.

For the reasons discussed above relating to the geology of the Waikoropupu catchment, conditions in the Southern Gully are unlikely to host any aquifers or a significant groundwater resource. Any groundwater is likely to exist only within the regolith overlying bedrock, and in concave depressions, following either intense or prolonged rainfall. Consequently, there is no groundwater resource or any bores within this exchange area.

3.0 Hydrological Processes

The characteristics of any watercourses and their flow regimes within the five areas included in the land exchange proposal are directly related to the passage of water from the point that rainfall lands on the ground, to its runoff into rivers and streams (***Figure 3.1***).

Because of their proximity and similar elevation, relative relief, and orientation to prevailing westerly conditions, all five areas are likely to experience the same rainfall patterns and characteristics. The similar geology, slope form, and general vegetation cover also mean that the same rainfall-runoff relationships are likely to exist in all five areas. Any variation in the flow regimes is likely to be largely related to the size of the upstream catchment, and the distance of the gully or stream from the interfluve.

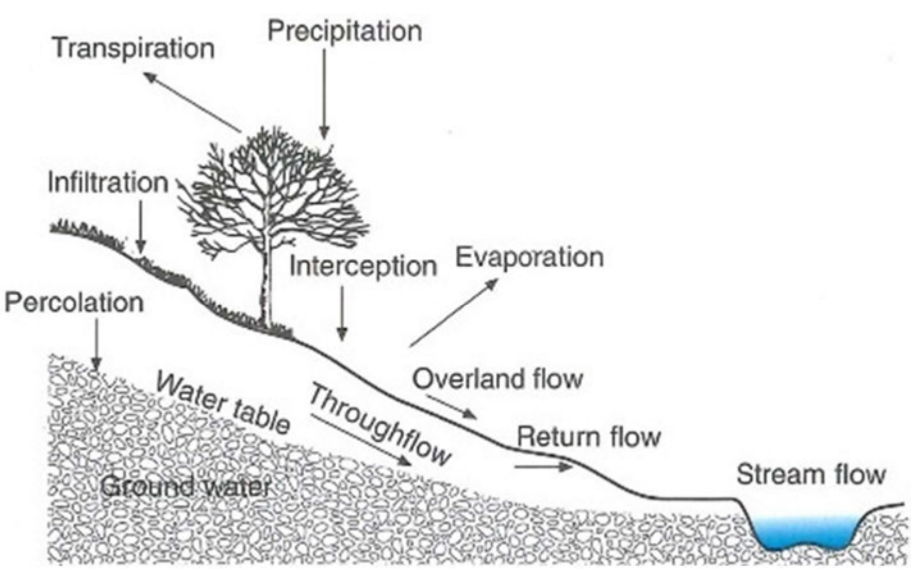

Figure 3.1: Various pathways and storages within a hillslope (McConchie, 2001).

Since many of the slopes in the five exchange areas are short, steep, and planar, there is only a rudimentary channel network. Under 'natural' conditions, and with good vegetation cover, there is unlikely to be any surface runoff from most of the areas during most rainfall events. Surface runoff will only commence once the regolith overlying the bedrock becomes saturated. This is most likely to occur in concave depressions such as gullies. The position at which surface flow commences depends on the upstream catchment area (as summarised by the Strahler order), antecedent moisture conditions, and the intensity and duration of rainfall. As a result, the origin of surface flow is likely to migrate up and down the headwater gullies depending on these conditions. During winter, and following either intense or prolonged rainfall, surface runoff will commence higher up the slope than at the end of autumn or after a prolonged dry spell.

Given the relatively impermeable nature of the bedrock underlying all five areas, there is unlikely to be any significant groundwater resource or aquifers. Consequently, there are no bores or consents for groundwater abstraction within any of the areas. The only groundwater that may exist occurs when the regolith overlying the bedrock becomes saturated. Even this groundwater, however, is transient and maintains baseflow in the streams rather than providing a groundwater resource.

The total volume and timing of runoff, and ultimately the characteristics of any flow in the gullies and streams in the five exchange areas, therefore, includes three mechanisms (**Figure 3.2**):

- Overland flow (water flowing across the land surface, which as explained is negligible under current conditions);
- Throughflow (water flowing through the soil or unsaturated zone); and
- Groundwater flow (water flowing through the groundwater or saturated zone).

The relative importance of each of these mechanisms to runoff generation and streamflow depends on the catchment and rainfall characteristics (i.e., duration, intensity, and depth). As described above, these are similar across all five areas. Consequently, the principal control on any differences in the runoff regimes of the different parcels is catchment area.

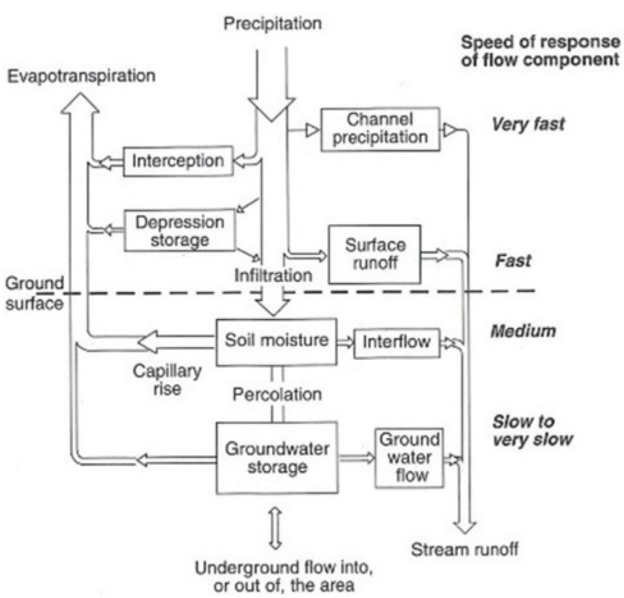

Figure 3.2: Processes by which moisture moves across and through a slope and generates runoff (McConchie, 2001).

3.1 Hydrological data

There are few hydrometric data available for the Waikoropupu catchment, or any of the small streams draining the Western Hutt hills and the Wellington Fault scarp, and no instrumental flow records. This acts as a significant constraint on any hydrological analysis. The only data available are generalised flow parameters (***Table 3.1***) derived from hydrological modelling (NIWA, 2018). Experience has shown that these data, since they are derived from the spatial interpolation of flow records from larger catchments, generally draining mountains and hill country, are conservative i.e., high, for small catchments draining lowland areas such as the Belmont hills. Consequently, the flow regimes of the various gullies and streams have had to be inferred from the catchment characteristics and hydrological principles.

Table 3.1: Hydrological statistics (NIWA, 2018).

Location*	Catchment area	Median flow (L/s)	Mean flow (L/s)	MALF (L/s)
1	84.6	9.5	18.2	2.5
2	78.0	9.9	18.7	2.6
3	27.9	3.4	6.1	0.8
4	153.9	19.5	34.7	5.1
5	89.2	13.7	24.4	3.9

Note: * These locations are shown on Figure 4.9.

3.2 Spatial analysis

Because of the lack of hydrological data, the high resolution DTM was used to derive potential drainage lines and overland flow paths within each of the five exchange areas. A Strahler stream order six was chosen to indicate where sufficient runoff may accumulate to result in overland flow. This threshold appeared to provide a balance between an appropriate level of detail for the potential drainage network and unnecessary noise.

Analyses identified and quantified the drainage lines within each area, the relative sizes of these drainage lines using the Strahler order, and the catchment areas upstream of where the drainage lines exit the various exchange areas (***Figure 3.3***).

The upstream catchment areas, longest drainage line lengths within each catchment, and longest drainage line lengths within each land exchange block, are presented in ***Table 3.2***. It should be noted that these metrics are derived solely from analysis of the DTM. As discussed later in this report, following a detailed site visit, it was apparent that the digital analysis over-estimated the length of surface flow. Any uncertainty, however, is consistent across all land parcels. If the lengths of the various streams shown in ***Figure 2.3*** through ***Figure 2.4***, ***Figure 2.7*** through ***Figure 2.8***, and ***Figure 3.3*** were reduced to be consistent with what was observed during the field visit, the benefits to the Department of Conservation of the proposed land exchange from a hydrological perspective would be even greater than shown in ***Table 3.2***.

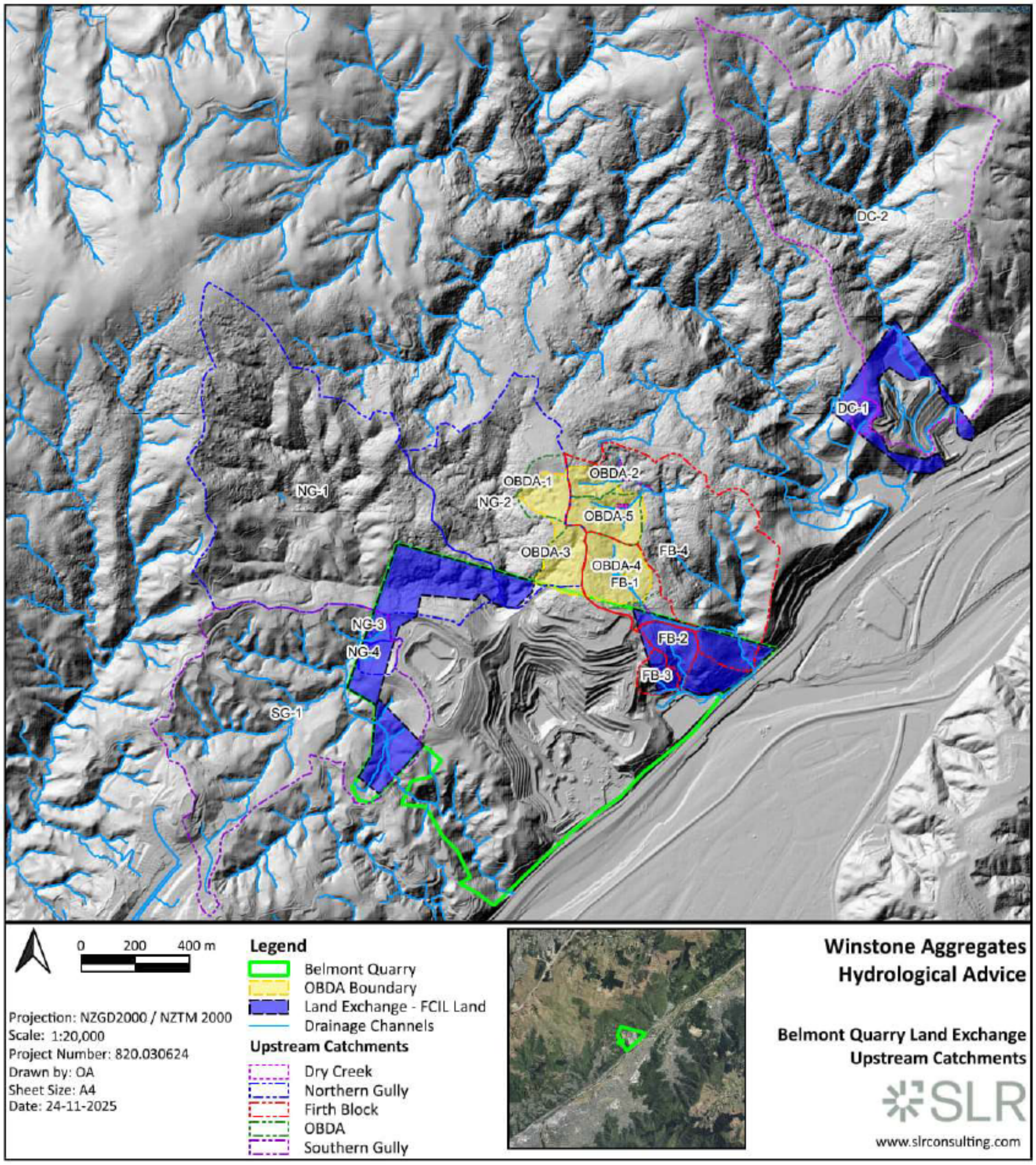

Figure 3.3:* *Map of the potential land exchange areas showing drainage lines and upstream catchments. ***Note the watercourses through the quarry are not shown.***

Table 3.2:* *Various drainage metrics for the areas being proposed as part of the proposed land exchange.

Land exchange area	Catchment ID	Catchment area (ha)	Longest stream length in catchment (m)	Total stream length in catchment (m)
OBDA	OBDA-1	4.6	186	496
	OBDA-2	2.9	165	171
	OBDA-3	3.9	265	444
	OBDA-4	6.9	264	411
	OBDA-5	4.9	208	371

Land exchange area	Catchment ID	Catchment area (ha)	Longest stream length in catchment (m)	Total stream length in catchment (m)
Dry Creek	DC-1	0.9	53	53
	DC-2	89.2	2280	7535
Firth Block	FB-1	7.8	513	684
	FB-2	2.7	256	259
	FB-3	1.8	96	160
	FB-4	43.3	1180	3775
Northern Gully	NG-1	78.6	1765	8553
	NG-2	32.5	904	4465
	NG-3	0.6	84	84
	NG-4	1.6	63	63
Southern Gully	SG-1	60.9	1465	3895

4.0 Observations

Detailed site visits to the Belmont Quarry and its environs were undertaken on the 24 June and 23 July 2025. During these visits, the two main tributaries of Waikoropupu Stream upstream of the culvert through which the stream passes under the road to the Cottle OBDA were investigated. Two of the headwater gullies within the proposed exchange area for the OBDA were also traversed downslope until surface flow was observed.

Three factors need to be considered when considering these observations:

- The two site visits were undertaken during 'winter' and while there was no rain on the actual day, antecedent conditions were wet. It is therefore likely that the assessment of runoff and overland flow conditions was conservative i.e., greater flow and flow commencing further upslope than 'normal';
- Despite the above, the commencement of surface flow was significantly further downslope than indicated by the digital analysis and the assumption of surface flow starting at Strahler order six; and
- Despite the presence of overland flow, there was no defined channel or bed where surface flow commenced. This supports the argument that the flow conditions observed were wetter than normal and the estimation of the start of overland flow from the DTM was conservative.

The hydrological characteristics of various sites visited are described below.

4.1 Western tributary of 'Northern Gully'

The western tributary of Waikoropupu Stream provides the principal flow in the 'Northern Gully'. It has a catchment area of about 78.6ha, and the main stem of the stream is about 1.8km long. Flow at the time of the site visit was approximately 20L/s (***Figure 4.1***). Hydrological statistics from NIWA (2018) provide a median flow of 9.9L/s, a mean flow of 18.7L/s, and a mean annual low flow (MALF) of only 2.6L/s. The flow observed during the site visit was therefore greater than average and likely reflected the generally wet antecedent conditions.

Upstream of the 'pond' that forms occasionally at the culvert, the stream has a gravel bed and flows through regenerating bush and scrub (***Figure 4.2***). This tributary has perennial flow. The flow regime and catchment characteristics of this major tributary of Waikoropupu Stream would be transferred to the Department of Conservation as part of the land exchange.

From a hydrological perspective, this tributary offers a significantly greater, better, and more natural flow regime than the gully heads within the proposed OBDA.

4.2 Northern tributary of 'Northern Gully'

The northern tributary of Waikoropupu Stream provides most of the remaining flow in the 'Northern Gully'. It has a catchment area of about 32.5ha and the main stem of the stream is about 0.98km long. Flow at the time of the site visit was only about 5L/s (***Figure 4.3***). Hydrological statistics from NIWA (2018) provide a median flow of 3.4L/s, a mean flow of 6.1L/s, and a MALF of only 0.8L/s. The flow observed during the site visit was therefore about average and likely reflected the discharge from slow subsurface drainage because of the generally wet antecedent conditions.

Upstream of the 'pond' that forms occasionally at the culvert, the northern tributary has a gravel bed and flows through regenerating bush and scrub (***Figure 4.4***). While this tributary may have perennial flow, this is uncertain given the lack of available data. Irrespective, there will be long periods of very low flow, and flow may not be continuous down the entire channel. Despite this, from a hydrological perspective, this tributary still offers a significantly greater, better, and a more natural flow regime than the gully heads within the OBDA; two of which discharge any flow into this tributary.

4.3 Sub-catchments OBDA-3 & OBDA-4

Only sub-catchments OBDA-3&4 were traversed during the site visit. These are small topographic depressions that have eroded into the scarp of the Wellington Fault. OBDA-3 drains east from the interfluves with sub-catchment OBDA-1 to the north and OBDA-4 to the east. OBDA-4 drains west from the interfluves with sub-catchment OBDA-5 to the north and OBDA-3 to the west. (***Figure 3.3***).

The gullies that form these sub-catchments are depressions eroded into the bedrock that are infilled with colluvium from the surrounding slopes, primarily during the last glacial (Vaughan, 1989). Precipitation infiltrates the ground surface and percolates through the colluvium until it intercepts the bedrock interface. Water then flows parallel to the bedrock surface until it accumulates sufficient volume that it saturates the entire regolith, and runoff starts to flow on the ground surface. The position where surface flow commences depends on both antecedent conditions and the intensity and duration of rainfall.

Figure 4.1: ***Principal (western) headwater tributary of Waikoropupu Stream at its confluence with the other tributary in the Northern Gully.***

Figure 4.2: ***Catchment of the principal (western) headwater tributary of Waikoropupu Stream forming part of the Northern Gully.***

Figure 4.3: ***Lesser (northern) headwater tributary of Waikoropupu Stream at its confluence with the other tributary in the Northern Gully. Note that the very small stream is below the branches in the centre of the photograph.***

Figure 4.4 : ***Catchment of the lesser (northern) headwater tributary of Waikoropupu Stream forming part of the Northern Gully.***

The upper reaches of these gullies therefore tend to have moist valley floors (***Figure 4.5*** & ***Figure 4.6***) rather than having any surface flow or defined channel (***Figure 4.7***). As mentioned, during the site visit, surface flow commenced significantly further down the two gullies inspected than inferred from analysis of the DTM (***Figure 4.8***).

Figure 4.5: Commencement of surface flow during winter in sub-catchment OBDA-4. There is no defined channel or stream bed until further down the gully.

Figure 4.6: Commencement of surface flow during winter in sub-catchment OBDA-3. There is no defined channel or stream bed until further down the gully.

***Figure 4.7:* Any form of channel and stream bed is present only further down the gully in OBDA-4.**

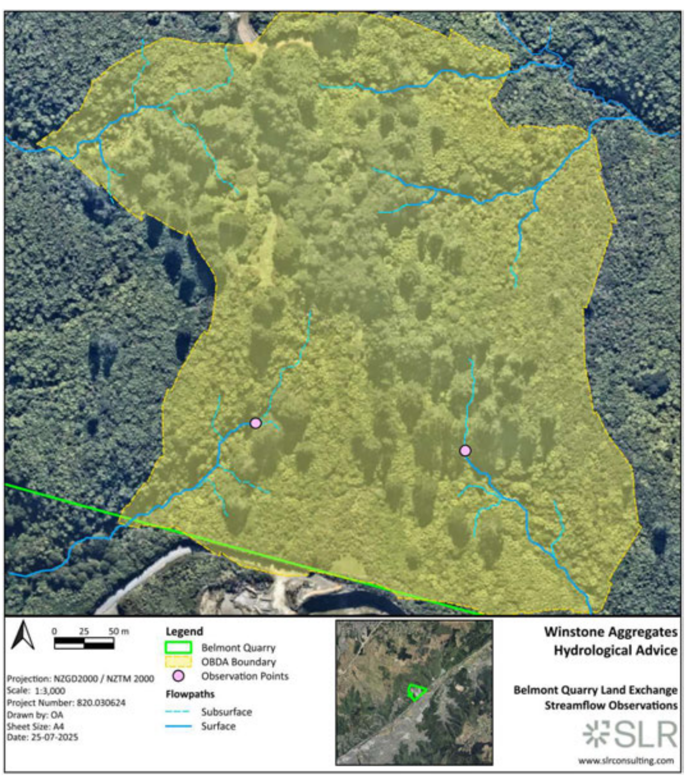

***Figure 4.8:* Boundary between subsurface and surface flow based on field observations.**

It should be noted therefore, that the data shown on ***Figure 3.3*** and in ***Table 3.2*** with respect to stream lengths will be conservative. The actual stream lengths in the various gullies and sub-catchments draining the proposed land exchange for the OBDA are likely to be significantly shorter than indicated by the digital analysis.

4.4 Drainage calibration

As discussed, during a site visit, the locations where surface flow commenced in sub-catchments OBDA-3&4 were identified (***Figure 4.8***). The drainage lines inferred from analysis of the DTM were therefore investigated in more detail to determine at what Strahler stream order surface flow commenced. Although there is only limited information, it appears that surface flow commences when the Strahler stream order was at least seven, and not six as assumed initially. It is likely that only subsurface flow occurs within the regolith and colluvium at Strahler stream order six.

The Strahler stream orders for the drainage lines derived from the DTM of the wider area are presented in ***Figure 4.9***. At a Strahler order of nine or greater more significant flows are expected, especially during and immediately following rainfall events. Streams of this order are also expected to have perennial flow and are shown in the NZ River Maps database (NIWA, 2018). Various hydrological statistics for these streams were extracted from the database at the locations numbered 1-5 in ***Figure 4.9*** and these metrics were presented in ***Table 3.1***.

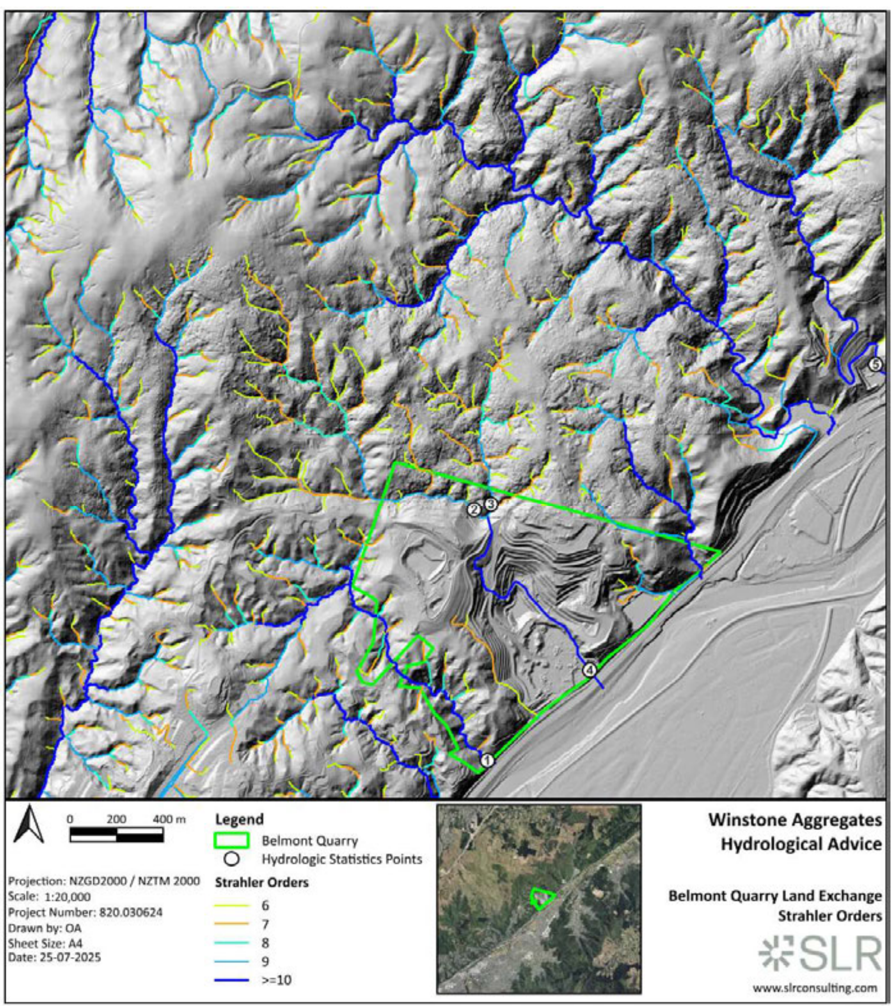

Figure 4.9: Strahler stream order of the various drainage lines.

5.0 Comparison

A range of hydrometric indices derived from detailed analysis of a high resolution DTM were obtained for the five areas being considered for an exchange of land between Winstones and the Department of Conservation (***Table 5.1***).

Table 5.1: Summary of stream channel metrics for the different potential exchange areas.

Land exchange parcel	Area (ha)	Longest stream in exchange area (m)	Stream length less than Strahler order 7	Stream length Strahler orders 7&8	Stream length greater than Strahler order 9	Total stream length in exchange area (m)	Upstream contributing catchment area (ha)
OBDA	23.24	265	899	723	223	1,845	89.2
Dry Creek	7.9	255	43	24	440	507	4.1
Firth Block	9.6	256	116	191	408	715	41.1
Northern Gully	12.62	463	234	358	599	1191	71.3
Southern Gully	3.9	235	56	325	235	616	60.9

The proposed OBDA exchange area lies on the interfluve (catchment divide) between four small headwater gullies, two of which form very small tributaries to Waikoropupu Stream. These gullies are not likely to support a perennial flow regime. Surface flow in these gullies likely occurs only in the lower reaches and is likely to be intermittent. Flow will only occur after intense or prolonged rainfall.

The proposed land exchange will see these four small headwater gullies, with low Strahler stream orders, exchanged for:

- Two catchments with perennial flow and higher Strahler stream orders e.g., Dry Creek and the south branch of the Firth Block;
- The mid reach of the principal tributary in the Northern Gully which has a very high Strahler stream order. This reach of Waikoropupu Stream has a perennial flow regime;
- The lower reaches of the northern stream that drains the Firth Block; and
- The mid reach, with perennial flow, and associated gullies (Southern Gully) of the unnamed stream to the south of Belmont Quarry and Waikoropupu Stream.

When comparing the hydrology of the various exchange areas it is important to see the reaches within each area in context. The gully heads are all very small sub-catchments, with low Strahler stream orders. Even when combined, these make up an extremely small proportion of both the area and flow of the Waikoropupu catchment.

The streams in Dry Creek, and the south branch of the Firth Block, are entire larger catchments, with higher Strahler order. Both these streams have perennial flow.

The Northern Gully exchange area includes the mid-reaches of Waikoropupu Stream. However, this reach has a significant upstream catchment, a higher Strahler order, perennial flow, a more dynamic flow regime, and likely offers a wider range of instream services.

The lower reaches of the Firth Block also have relatively high Strahler stream orders, provide a hydraulic connection to the upper reaches to support potential fish passage, and likely provide a wider range of instream services.

The Southern Gully exchange area includes the mid-reaches of the unnamed stream immediately south of Belmont Quarry. However, this reach has a significant upstream catchment, a higher Strahler order, perennial flow, a more dynamic flow regime, and likely offers a wider range of instream services.

The exchange therefore offers protection of, and potential access to, streams of significantly higher Strahler order, with perennial flow regimes, and likely providing a wider range of instream services. The streams being exchanged to the Department of Conservation have significantly greater total lengths of channel and longer main stems. The exchange will also provide potential access to a greater total length of stream channels. These channels are larger and offer a greater range of hydrological characteristics (***Table 5.1***).

It is important to remember that the land exchange is a package and needs to be considered in its entirety rather than as discrete parcels. Consequently, the hydrological metrics within the OBDA are compared to the combined metrics for the four Winstone blocks in ***Table 5.2***.

Table 5.2: Comparison of stream channel metrics for land exchange.

Land exchange parcel	Area (ha)	Longest stream in exchange area (m)	Stream length less than Strahler order 7	Stream length Strahler orders 7&8	Stream length greater than Strahler order 9	Total stream length in exchange area (m)	Upstream contributing catchment area (ha)
OBDA parcel	23.24	265	899	723	223	1,855	89.2
Winstone parcels	34.1	463	449	898	1,682	3,029	177.4

When considered as a package the proposed land exchange will provide the Department of Conservation with:

- A net increase of 10.86ha of land;
- Significantly longer streams i.e., 463m compared to 265m;
- Although there will be a reduction in the number of gully heads and ephemeral flow paths, there will be a significant increase in both the length and number of larger streams with higher and more resilient flow regimes i.e., 1,682m compared to 223m;
- A significant increase in the total length of streams and watercourses;
- A significant increase in the areas of upstream catchments contributing flow. This will ensure more stable and resilient flows in the larger streams which form part of the exchange; and
- The land exchange will provide hydraulic connections to several upstream catchments.

Because of the relatively impermeable nature of the bedrock underlying all four areas, there is no significant groundwater resource or aquifers in any of the exchange areas. Consequently, there are no bores or consents for groundwater abstraction within any of the areas. The only groundwater that exists, occurs when the regolith overlying the bedrock becomes saturated from rainfall. Even this groundwater, however, is transient and maintains baseflow in the streams rather than providing a groundwater resource.

From a hydrological perspective therefore, the proposed land exchange offers a range of attributes and advantages to the Department of Conservation. The exchange will protect and provide access to a greater range of larger watercourses than exists at present. It will also offer potential protection of the mid and lower reaches of some streams. This will enhance hydraulic connectivity of watercourses within the public domain.

6.0 Conclusions

The proposed exchange offers protection of, and potential access to, streams of significantly higher Strahler order, with perennial flow regimes, and likely providing a wider range of instream services. These streams have both a significantly greater total length of channel and longer main stems. The exchange will also provide potential access to a greater total length of stream channel, which are larger, and offer a greater range of hydrological characteristics.

There are no adverse hydrological effects of the exchange, and no parties impacted from a hydrological perspective by the proposed change in ownership.

From a hydrological perspective, the proposed land exchange offers a range of advantages to the Department of Conservation. The exchange will protect and provide access to a greater range of larger watercourses than exists at present. It will also offer potential protection of the mid and lower reaches of some streams. This will enhance hydraulic connectivity of watercourses within the public domain.

7.0 References

McConchie, J.A. 2001: *Water transport processes.* (in) Introduction to the physical environment - a New Zealand perspective. Edited by A. Sturman and R. Spronken-Smith, Oxford University Press p175-205.

NIWA, 2018: New Zealand Rivers Flood Statistics. The NIWA “Regional Method” online application. Henderson & Collins (V2.0)

Vaughan, E.E. 1989: The character and occurrence of colluvium-filled bedrock depressions in the Wellington Region. Unpublished MSc thesis in Physical Geography, Victoria University of Wellington. 221.

Appendix 1

Short CV of [redacted]

CURRICULUM VITAE

[redacted]

TECHNICAL DIRECTOR

Hydrology & Geomorphology

QUALIFICATIONS

BSc (Hons)	1978	Bachelor of Science (Honours), Victoria University of Wellington
PhD	1986	Doctor of Philosophy, Victoria University of Wellington
Commissioner	2011-	Resource Management Hearings' Commissioner

EXPERTISE

- Rainfall analysis
- Frequency analysis and design flood estimation
- Stormwater modelling, and management
- Surface water hydrology & flooding
- Climate change impacts
- Natural hazards
- Fluvial processes and change
- Preparation of technical reports
- Preparation and delivery of expert evidence
- Science comunication

[redacted] has over 40 years' experience investigating and modelling hydrological systems including stormwater, surface water, and groundwater and their interactions with human activities.

[redacted] has skills in rainfall analysis, rainfall-runoff modelling, stream-flow generation and variability, hydrometric and frequency analyses, PMP/PMF estimation, flood routing, flood risk and flood hazard analysis, and erosion and sediment transport. He has strengths in quantifying the impact of land use and climate change on environmental processes, water resources, landscape dynamics, and lifelines. [redacted] has applied his expertise internationally having worked in Australia, Hong Kong, China, Cambodia, India, the United States and Antarctica.

[redacted] has quantified the effects of natural hazards, particularly flooding and slope instability, including Cyclone Alison in the Ruahine Range (1975), the Hutt Valley rainstorm (1976), extensive landsliding in Wairarapa (1978), Cyclone Bola (1988), Waikato floods (1998), the Manawatū floods (2004), and the Kaikōura Earthquake (2016).

He has been involved in major infrastructure projects including Hamilton North Bypass, Western Link Road, Kopu Bridge, Tauranga Eastern Link Road, Basin Bridge Project, Transmission Gully, Peka Peka to Ōtaki Expressway, Petone-Grenada Link Road, the realignments of SH3 at both Mt Messenger and Awakino Gorge, Te Ahu a Turanga: Manawatū Tararua Highway (the replacement of SH3 through the Manawatū Gorge), and the Ōtaki to north of Levin Highway.

[redacted] provided expert technical evidence and support to the Environment Court relating to their enquiries into the Peka Peka to Ōtaki Expressway, Te Ahu a Turanga: Manawatū Tararua Highway, and the Ōtaki to north of Levin Highway.

He provided independent expert evidence on behalf of Gisborne District Council in relation to several Environment Court enforcement order applications relating to commercial forests in Tairāwhiti. These include the Council's enforcement order applications for Kanuka Forest, West Ho Forest, Wakaroa Forest, Te Marunga Forest, and most recently Samnic Forest.

He assisted Taupō District Council assess the flood risk posed by Lake Taupō and its major tributaries and then incorporate this information into their District Plan. This

	included appearing as their technical flood hazard expert at hearings and before the Environment Court. [redacted] developed design rainfalls for Tauranga City Council to inform infrastructure planning and future development. This included acting as their technical expert during Environment Court mediation which resolved all outstanding matters. [redacted] has considerable local experience having worked on various projects throughout the Hutt basin, Wellington City, Wairarapa, and on the Kāpiti Coast. As a result of this experience, Jack has an in-depth understanding of climate, hydrology, flooding, and sediment transport processes and issues across the Wellington Region. Through these projects, [redacted] has developed an excellent working relationship with Ngāti Raukawa ki te Tonga, Rangitāne o Manawatū, Rangitāne ki Tāmaki nui-ā-Rua, Kahungunu ki Wairarapa Tāmaki nui-ā-Rua and the Te Āpiti Ahu Whenua Trust. After over 20 years at Victoria University, leaving as an Associate Professor, [redacted] academic background, combined with practical experience, make him an effective communicator at public meetings, and expert witness at consent hearings and the Environment Court. He is also a Resource Management Hearings' Commissioner, an Independent Professional Advisor to Waka Kotahi on climate change and stormwater, and an Independent Natural Hazards' Expert for MBIE (Determinations).