AQUALINC RESEARCH LIMITED

Upper Manuherikia Valley distribution

Prepared for the Manuherikia Catchment Water Strategy Group

Report C12119/5

October 2012

CENTRAL OTAGO DISTRICT COUNCIL

Ministry for Primary Industries
Manatū Ahu Matua

Otago Regional Council

AQUALINC RESEARCH LIMITED

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EXECUTIVE SUMMARY

Studies to date have shown that the Manuherikia Valley is not water short on an annual basis. Raising Falls Dam is a realistic proposal that would provide sufficient water to meet the potential irrigation demand.

Compared with other irrigated areas in New Zealand, most irrigated farms in the Upper Manuherikia Valley are low input–output systems. Investment to maximise productivity per unit of water lags well behind the vast majority of irrigation in New Zealand. The biggest impact of deemed permits expiring is likely to be on-farm. ORC have indicated much of the existing wild flood irrigation will need to convert to efficient spray irrigation. This will require major on-farm investment; in the order of $3,000 - $5,000 per hectare, necessitating a shift to higher input-output systems.

With higher input-output systems, the provision of high or very high irrigation supply reliability becomes increasingly important.

We estimate there is currently 4.0 m^3/s of reliable water available in the Upper Manuherikia Valley. Distribution losses (in the order of 20%) means only about 3.2 m^3/s of this water is available on-farm. In most areas about 4.3 mm per day is necessary for full production. This means only about 6,500 ha can be fully irrigated with current distribution infrastructure. In addition to this reliable water, there is a significant amount of water that is generally only available in spring and early summer, that is used for partial irrigation. We estimate an additional 4,000 – 6,000 ha in the Upper Manuherikia Valley may be partially irrigated with unreliable water.

The Falls Dam Company have indicated Falls Dam needs to be modified; to address the risk the dam may not be able to pass a Probable Maximum Flood. As part of these works, the dam would also be raised 5 to 6 m to provide high supply reliability. We have assumed raising Falls Dam 5 to 6 m will be part of the "Do minimum" option. Under this "Do Minimum" option it is likely that there would be no or little new irrigation in the Upper Manuherikia Valley, because the increase in storage will largely be required to counter the impacts of improved on-farm irrigation efficiency, and because higher reliability is required under spray irrigation. Furthermore, existing distribution cannot accommodate any significant additional capacity [necessary to expand the irrigated area], without significant capital expenditure.

A total of 25,000 ha of irrigable land in the Upper Manuherikia Valley could be serviced with reliable irrigation water if a new high race was constructed. Of this 25,000 ha, the actual area that could be supplied will depend on how high Falls Dam is raised, and how far the High Race extends. We considered four development scenarios as summarised below. Scenario 1 is the "do minimum" option.

Development scenarios

Scenario	High Race termination point	Falls Dam height	Area fully irrigated (ha)	
			From High Race	Upper Valley Total
1	No High Race	+5m	0	6,500
2	Hamilton Road	+15m	5,500	12,000
3	Muddy Creek	+23m	11,500	18,000
4	Matakanui Station	+27m	14,500	21,000

Long term, the degree of pumping largely determines the cost of operating an irrigation scheme. While inflation eventually minimises capital expenditure costs, pumping costs continue indefinitely; increasing at a rate greater than inflation. 80% of the supply area can be supplied under gravity. 20% of the supply area is located above the race, and farmers would need to pump direct from the race. We envisage that pumping would be an individual irrigator responsibility rather than an irrigation scheme responsibility. Because no scheme pumping is necessary, annual operation charges, excluding debt servicing, should be minimal ($30-$50/ha).

Secondary distribution below the High Race could largely be PVC pipes. Piped secondary distribution has a number of advantages over open races, including negligible distribution losses; a continuous on-demand supply; and in some cases a pressurised supply. The extensive network of existing races, used at present to distribute largely unreliable water, is another option for secondary distribution.

We expect "do minimum" distribution upgrades necessary to obtain resource consents will cost existing irrigators $500-1,000 per hectare. Given development Scenarios 2-4, we expect distribution costs for new reliable irrigation to be in the range of $2,000 - $3,000/ha. This includes the construction cost of providing unpressurised water to farm boundaries, but excludes land purchase costs. By 'new' irrigation we mean land that currently does not have access to reliable water; some of this land will however have access to unreliable spring water. Cost estimates are summarised below.

Capital cost of Upper Valley distribution upgrades

Scenario	Total	Cost		Cost/ha(2)	
		Total	Marginal(1)	Existing	New
1	6,500	$4.4M	$0.0	$675	$0
2	12,000	$18.2M	$13.8	$675	$2,517
3	18,000	$30.1M	$25.7	$675	$2,235
4	21,000	$41.1M	$36.7	$675	$2,533

(1) Total cost minus "do minimum cost" (Scenario 1)
(2) Estimated accuracy ±30%. Exclude land purchase costs, legal fees, and GST.

The above costs indicate the per hectare distribution costs are relatively independent of the High Race termination point. All Scenarios we considered assume 80-85% uptake of the irrigable area. Distribution costs for new irrigators will be higher if uptake is lower than 80%. For development scenarios 2 to 4, 60-70% of the costs are associated with constructing the High Race. The remaining 30-40% of cost is associated with secondary distribution and upgrades to existing races. Secondary distribution construction could largely be staged, if required. Whether there are opportunities to stage the development of the High Race and upgrades to existing races will depend on where the initial farmer uptake interest lies.

In addition to distribution upgrade costs, Upper Valley irrigators will need to contribute to Falls Dam upgrade costs.

1 Introduction

The Manuherikia Catchment Water Strategy Group (MCWSG) was set up to develop and oversee the implementation of a water strategy for the catchment. The MCWSG has proposed that a project be undertaken in three sections to:

(i) Define the potential irrigation demand in the Manuherikia River catchment (land),
(ii) Provide an initial assessment of the water availability for meeting this demand (hydrology), and
(iii) Options to close the gap between supply and demand (options).

The project has been broken into two parts, Part A (Sections (i), (ii) and (iii a)) and Part B (Section (iii b)). Part A provides the initial big-picture information to understand the overall water resources in the catchment. Part B looks in more detail at specific options to progress water resources development. The MCWSG envisages that the project will provide information to help the community make informed decisions, leading to a comprehensive Manuherikia Catchment water strategy. Figure 1 provides an overview of the study.

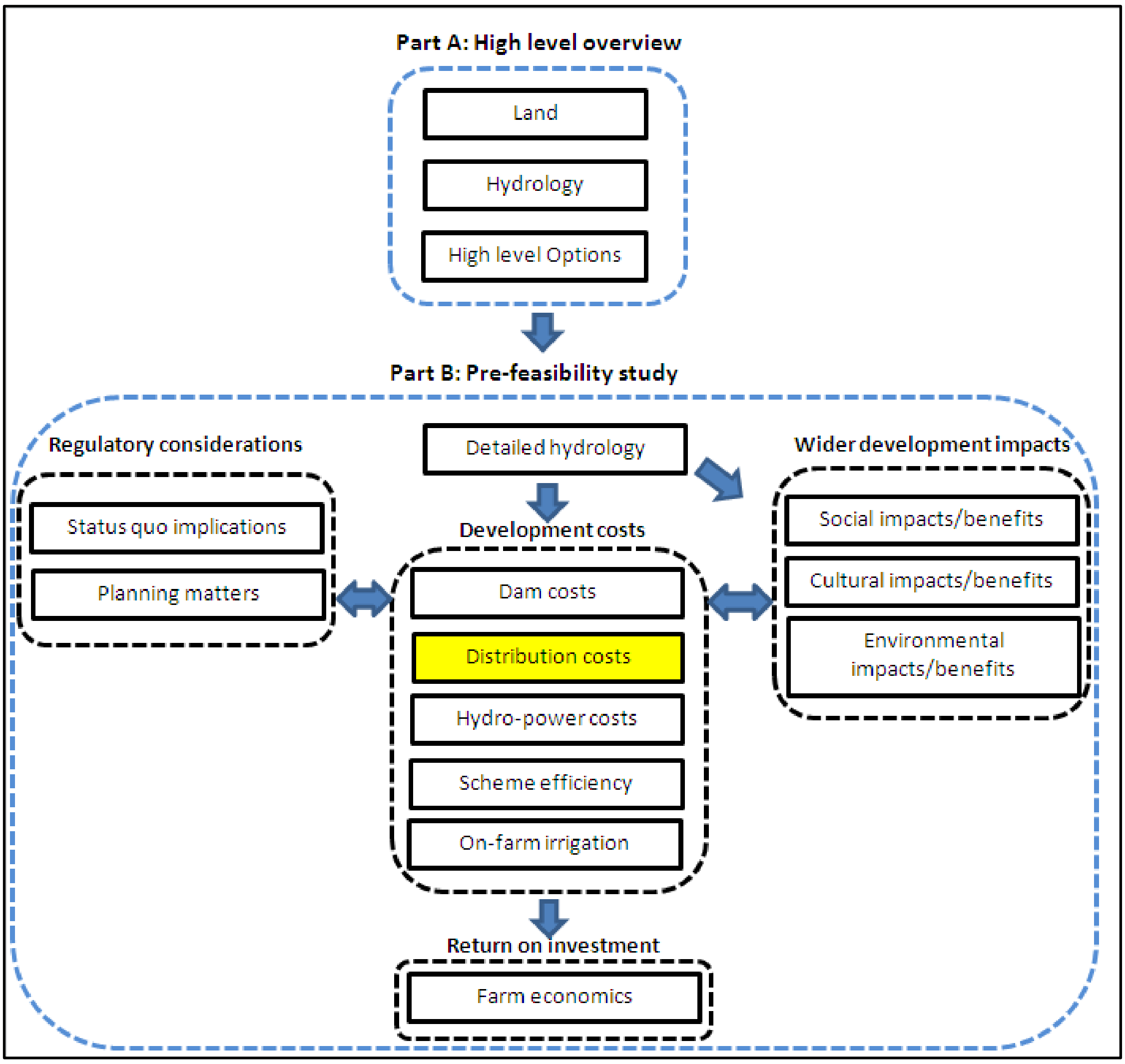

Figure 1: Manuherikia Catchment Study overview

This report covers distribution options and costs in the Upper Manuherikia Valley. Most of the command area falls within the existing Omakau Irrigation Scheme, although it also includes areas such as the Downs, Blackstone Irrigation Scheme, Blacks Flat, and the flats around Coal Pit Road. We have considered both the "do minimum" costs associated with meeting likely regulatory requirements and replacing aging critical infrastructure; and costs associated with large scale irrigation development. A separate report addresses Lower Manuherikia Valley distribution options.

This report builds on the High Level Options report, where a new Omakau high race was identified as an option for servicing the bulk of the irrigable land in the Upper Manuherikia Valley.

This report should be read in conjunction with the Land, Hydrology and Falls Dam reports.

Design and costings are at a pre-feasibility level. Total costs are expected to be accurate to ±30%. Cost uncertainly may be higher for individual items.

This study has been made possible by the generosity of the following who have contributed by way of direct funding or by in-kind contributions. MCWSG are grateful for this support and wish to thank the following:

- Ministry of Primary Industries with funding via the Irrigation Acceleration Fund
- The Otago Regional Council (ORC)
- The Central Otago District Council (CODC)
- The Manuherikia Community

2 Regulatory requirements

Compared with other irrigated areas in New Zealand, most irrigated farms in the Manuherikia Valley are low input–output systems. Investment in water infrastructure, to maximise productivity per unit of water, lags well behind the vast majority of irrigation elsewhere in New Zealand.

No-one knows for sure exactly what conditions irrigators and irrigation schemes may be subject to, when deemed water permits are replaced with RMA consents. However, it is inevitable that major changes will be required to bring practices in line with other irrigated areas in New Zealand. National water quality requirements will likely have the greatest impact; these requirements will only become more, not less, stringent as 2021 approaches.

2.1 A shift to spray irrigation

We expect the biggest changes will be on-farm, rather than off-farm. ORC have indicated water quality requirements, together with water use efficiency requirements, will likely mean that existing wild flood irrigation supplied from a reliable water source will need to convert to efficient spray irrigation. This will require major on-farm investment; in the order of $3,000 - $5,000 per hectare. While improvement in irrigation practices should mean significant production improvements, the necessary investment will inevitably mean a major shift from the existing low input-output systems to more intense agriculture.

Where unreliable water sources are used for flood irrigation ORC has indicated these areas will probably not need to convert to spray irrigation. Converting unreliable water from surface to spray irrigation is probably not economically viable.

We envisage that consent conditions would allow for a transition period, where systems such as wild-flooding are phased out. We don't expect changes would need to be fully implemented before RMA consents are granted. Retaining the best performing contour irrigation on steeper slopes may also be acceptable, provided runoff is captured and reused and drainage is not excessive.

A major shift from surface to spray irrigation will have a significant impact on irrigation schemes. Ideally, irrigation schemes should modify their distribution systems to make it as easy as possible for irrigators to convert from surface to spray irrigation. Instead of providing high flows on a roster supply, the schemes will need to provide low flow on-demand to spray irrigators. To add to the challenges, not everyone will convert to spray systems at the same time. Schemes need to be able to accommodate a transition period, which could be 5 to 10 years, when there is a mix of surface systems (which will still require a roster supply) and spray systems.

There is some opportunity to provide some areas with a fully or partially pressurised pipe supply. On-going pumping costs are the major expense for operating spray systems. Providing a fully pressurised supply is potentially worth an additional $2,000 per hectare to irrigators in energy and pump maintenance savings alone. We recommend schemes price the level of service provided into the rate charged to irrigators, rather than trying to provide all irrigators with identical service. For example, irrigators who are provided with a fully pressurised supply may be charged $150 [or an equivalent capital contribution] more than irrigators who need their own on-farm pumping system. These additional charges should as a minimum cover the scheme's marginal cost of providing a pressurised supply. Where irrigators are provided with partial pressure, their additional charge should reflect the on-farm cost savings compared with being provided no pressure.

2.2 Other requirements

Other consent requirements are likely to include flow recorders on all intakes and possibly fish screens or physiological fish deterrents on the Manuherikia and Dunstan Creek intakes.

Current allocation rates in the Upper Manuherikia Valley are generally below the rate required to achieve full production under efficient spray irrigation. We envisage most existing allocation rates will not be at risk through the consenting process.

As part of the consenting process, an assessment of environmental effects will be required. Water quality requirements may require the schemes implement a farm plan or nutrient management system and/or undertake some on-going monitoring. These costs should be relatively small compared with other scheme upgrade costs.

3 Design approach

Irrigation schemes are inherently difficult to get off the ground. Almost every scheme that has been built in New Zealand was considered expensive and initially struggled to get full uptake. However, once constructed, these schemes have transformed the region around them, providing greater resilience and land use options not only for those with water, but also for the surrounding dryland farms. Our design approach has been to promote ideas that we expect will have the greatest chance of getting off the ground. Ideally irrigation development should:

- Be affordable;
- Be environmentally acceptable;
- Have high reliability;
- Minimise pumping;
- Accommodate a transition period from surface to spray irrigation;
- Minimise disruption of farms; and
- Make maximum reuse of existing races;

Affordability is a key design consideration. Major costs include raising Falls Dam and the cost of constructing new distribution. We have focused on options where off-farm Present Value costs for new irrigation are likely to be less than $5,000 per hectare for an unpressurised supply.

We have broadly considered possible environmental requirements in our design approach and pricing. Milestone 8, due at the end of October, will give further consideration of environmental impacts and environmental design considerations

Irrigation in New Zealand has seen a major shift in the last 20 years from being viewed as drought insurance to an integral part of the farming system. Greater importance and economic value is now placed on supply reliability. In our Falls Dam storage requirements, we have allowed for either high or very high reliability.

Long term, the degree of pumping largely determines the cost of operating an irrigation scheme. While inflation eventually minimises capital expenditure costs, pumping costs continue indefinitely; increasing at a rate greater than inflation. Our design approach has been to assume the vast majority of land irrigated will be gravity supply. For the few areas where a gravity supply cannot be delivered, we have assumed pumping pressures would be limited to 40 m plus the pressure necessary to operate spray systems.

The upgrade of surface irrigation systems to more efficient spray systems is unlikely to occur all at one time. Irrigation schemes need to be able to accommodate a transition period, where there is a mix of both surface and spray systems. Delivery systems need to be able to provide both an on-demand low flow for spray irrigators, and a high flow roster delivery for existing surface irrigation.

Farm systems are set up around the existing race infrastructure. Maximising the reuse of these races should minimise farm layout disruption.

4 Existing irrigation

Most of the reliable water in the Upper Manuherikia Valley is sourced from the Manuherikia River main stem. Current allocation is about 2.6 m^3/s (Table 1). Most of this water is supplemented from Falls Dam, and in general is about 90% reliable during the irrigation season. We estimate all other water sources provide about 1.3 m^3/s of 90% reliable water (Table 2). Including Manuherikia main stem water, we estimate there is a total of about 3.9 m^3/s of 90% reliable water taken in the Upper Manuherikia Valley. Distribution losses (estimated to currently be in the order of 20%) means only about 3.1 m^3/s of water is available on-farm. In most areas, about 4.3 mm per day (0.5 l/s/ha) is necessary for full production under spray irrigation. This means only about 6,300 ha can be fully irrigated with current storage and distribution infrastructure. If distribution losses were reduced to 10%, potentially 7,000 ha could be fully irrigated.

In addition to this reliable water, there is a significant amount of water that is generally only available in spring and early summer, that is used for partial irrigation. We estimate an additional 4,000 – 6,000 ha in the Upper Manuherikia Valley may be partially irrigated with unreliable water; corresponding to the equivalent of about 2,000 ha of full irrigation.

Table 1: Manuherikia River main stem takes

Take	Supply area	Flow (l/s)
Blackstone Main Race	Blackstone Hill	330
Thurlow	Blackstone Hill	28
Omakau Main Race	Omakau Irrigation Scheme	1,981
Larkhall	Blacks Flat	222
Leask	Blacks Flat	56
Total		**2,617**

Table 2: Sources of reliable water other than the Manuherikia River main stem

Water source	Low flow (l/s)		Minimum Flow[2] (l/s)	Available flow	
	90% reliable	98% reliable		90% reliable	98% reliable
Dunstan Creek at Cambrians[1]	920	535	250	670	285
Lauder Creek at Cattle Yards[1]	235	145	20	215	125
Thomsons Creek at Division Weir[1]	180	100	20	160	80
All other sources[3]	250	140	0	250	140
Total	**1,585**	**920**		**1,295**	**630**

(1) Low flow from 1 October to 31 March. From Aqualinc 2012d. Flows at the Downs and Omakau Dunstan Creek intake were assumed to be 1.38×flow at the Dunstan Gorge. The 1.38 multiplier was based on the ratio of the mean annual natural flow at the Gorge and Cambrians, estimated using the NIWA Water Resource Explorer runoff model.

(2) Aqualinc 2012b.

(3) Rough estimate.

5 Potential supply areas

A total of 25,000 ha of irrigable land in the Upper Manuherikia Valley could be serviced with reliable irrigation water if the new high Omakau race was constructed. This area excludes land slopes greater than 15° and crown land associated with roads and river margins. Of this 25,000 ha, the actual area that could be supplied will depend on how high Falls Dam is raised and how far the race extends. If Falls Dam was raised the full 27 m, and the race extends to Matakanui Station, about 21,000 ha could be fully irrigated. Supply areas are illustrated in Figure 2 and Table 3.

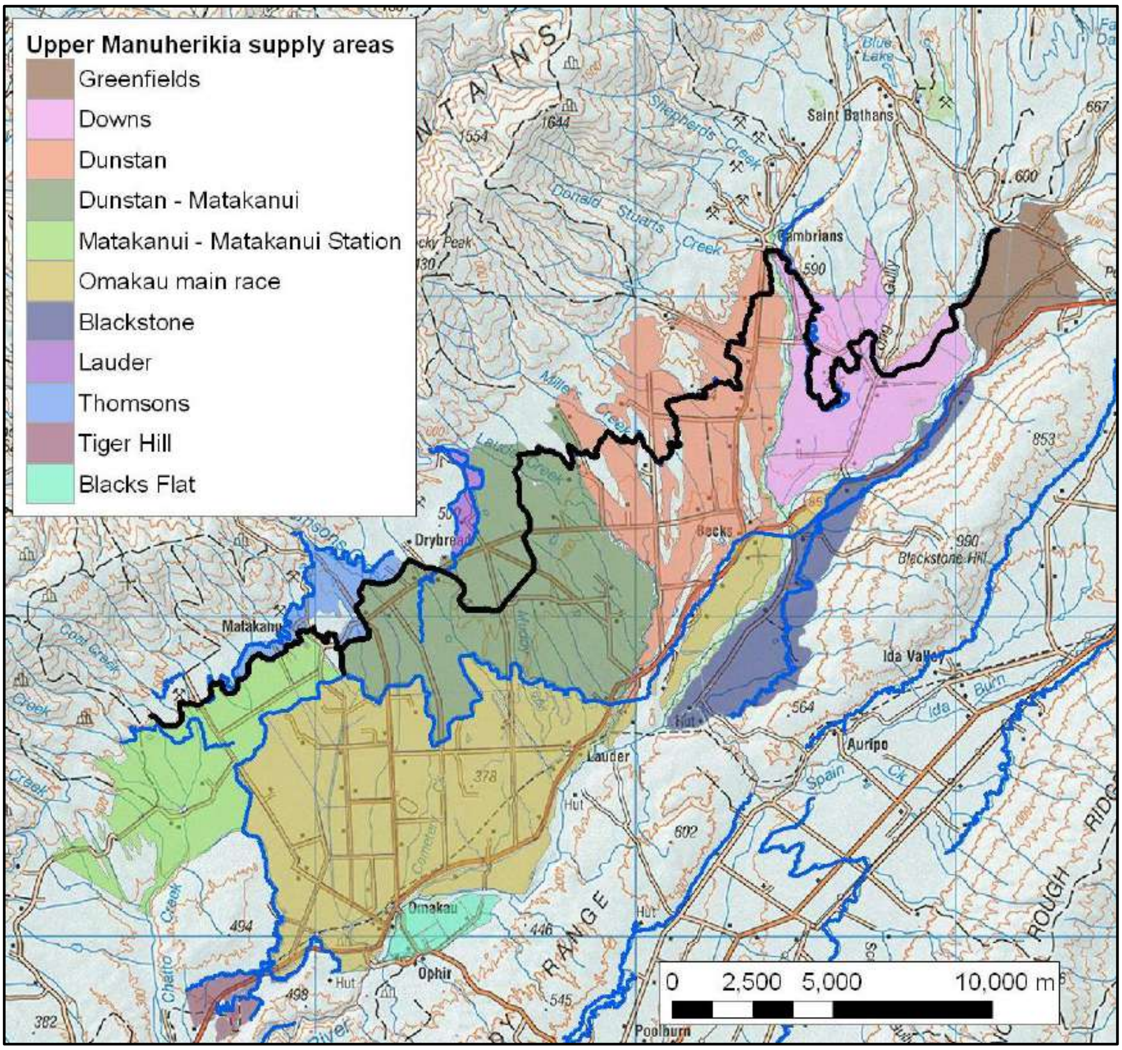

Figure 2: Upper Manuherikia Valley supply areas

Table 3: Upper Manuherikia Valley supply areas

Scheme	Irrigable land (ha)	Primary supply source
Greenfields	1,010	New High Race
Downs	2,510	New High Race
Dunstan	3,590	New High Race
Dunstan - Matakanui	4,920	New High Race
Matakanui - Matakanui Station	2,520	New High Race
Omakau Main Race	7,310	Omakau Main Race
Blackstone	1,660	Blackstone Main Race
Lauder	180	Lauder Creek
Thomsons	580	Thomsons Creek
Tiger Hill	340	Tiger Hill pumped supply
Blacks Flat	380	Existing races
Total	**25,000**	

About 90% of the irrigable land is flat to undulating, with only 10% rolling country (Figure 3). Flat to undulating land is particularly suitable for spray irrigation and is less prone to runoff issues than rolling land.

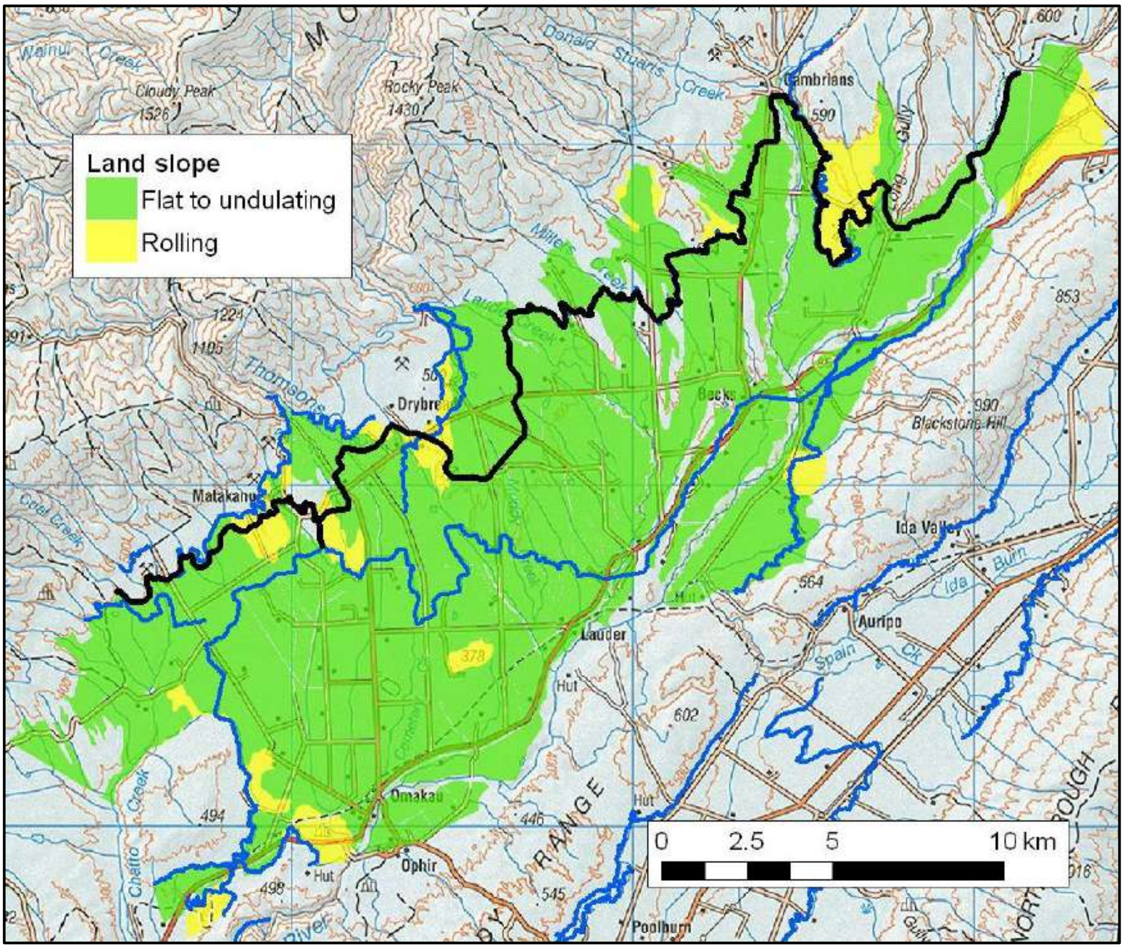

Figure 3: Supply areas by land slope

Almost half of the supply area has very shallow soils (Figure 4 and Table 4). These shallow soils are particularly susceptible to moisture stress and dry out rapidly. With short return spray systems, these soils should show a very good response to irrigation. Production improvements from converting from surface irrigation to efficient spray irrigation will be most pronounced on these very shallow soils.

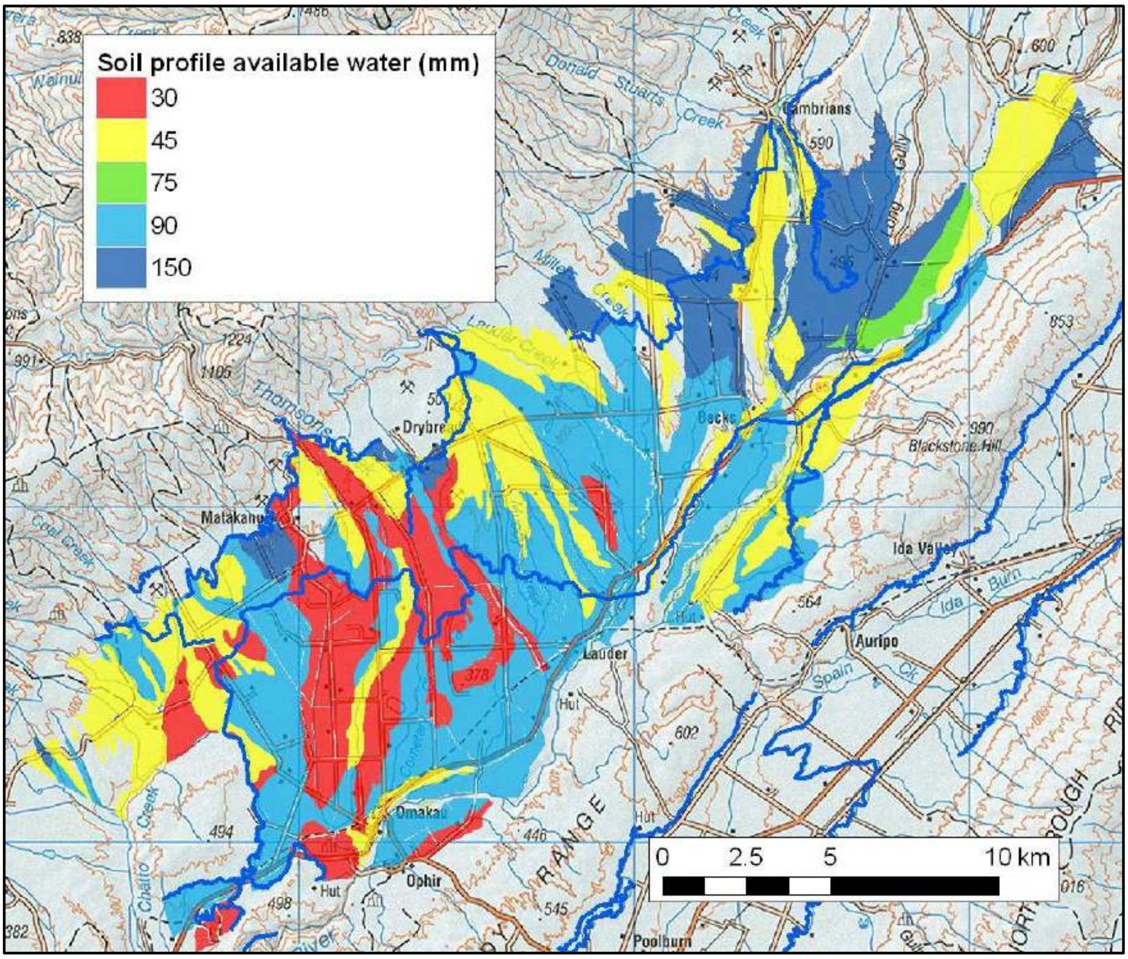

Figure 4: Supply area by soil profile available water (Source: Landcare 2000)

Table 4: Supply area by soil profile available water

Soil type	Soil PAW	% of supply area
Very shallow	30-45mm	44%
Moderately deep	90mm	40%
Deep	150mm	16%

The majority of soils are reasonably well draining, minimising the risk of runoff under spray irrigation (Figure 5). A few areas; parts of the Downs and Greenfield areas in particular, have a combination of both rolling land and imperfect soil drainage. Particular care is required on this land to avoid run-off under spray irrigation.

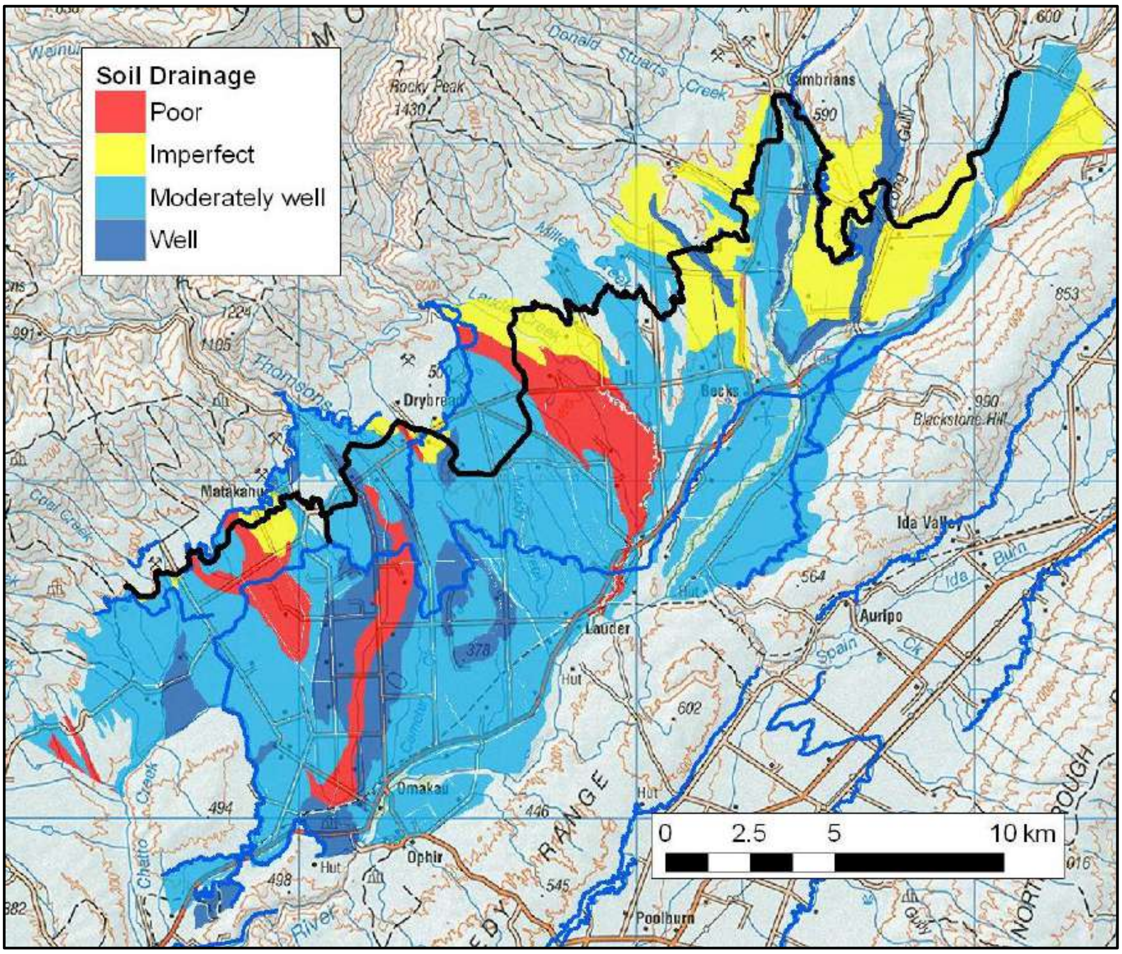

Figure 5: Supply area by soil drainage (Source: Landcare 2000)

Mean annual rainfall in the command area is predominately 500 to 600 mm (Figure 6). Rainfall is higher further up the Valley. Higher rainfall means irrigation demand will be lower in the Greenfields, Downs, and Dunstan supply areas.

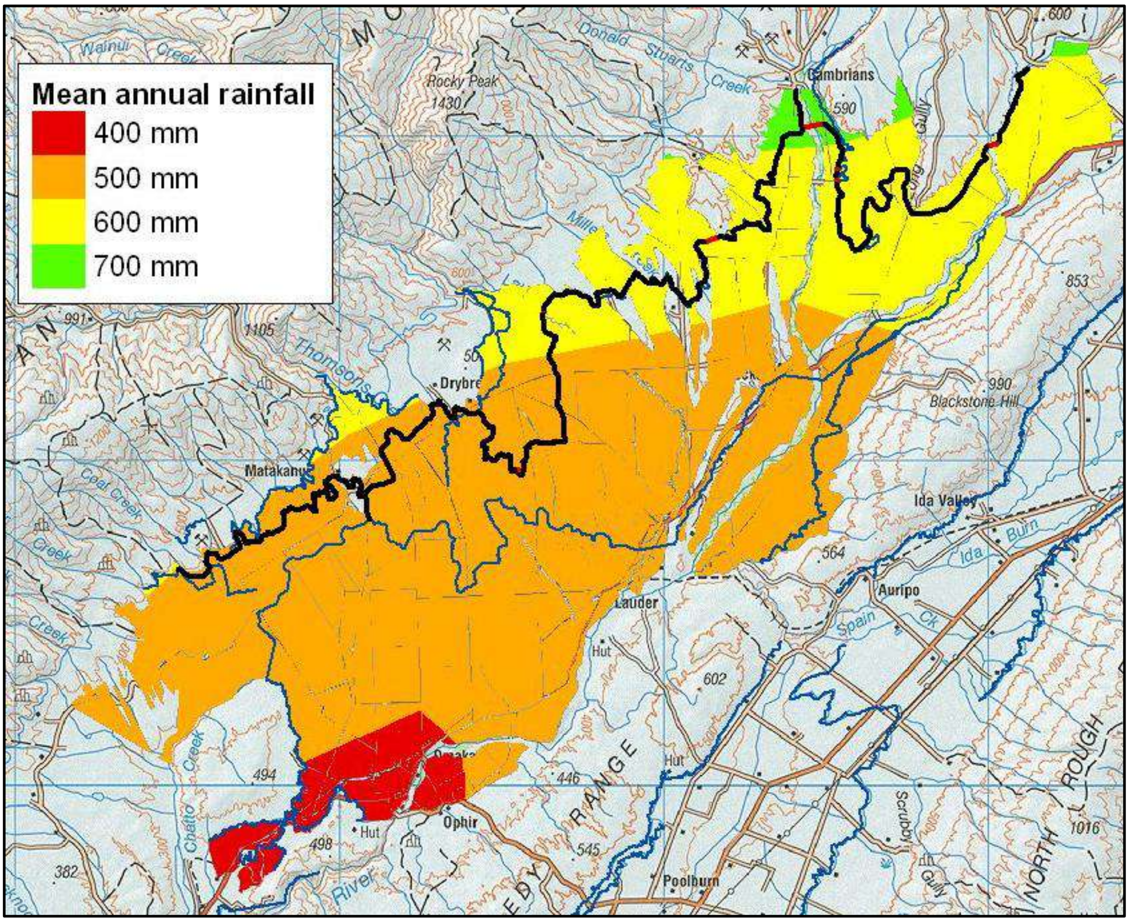

Figure 6: Supply area by rainfall zone

80% of the supply area can be supplied under gravity. For the remaining 20% of the supply area, land elevation ranges from 0 – 40 m above the supply race (Figure 7). We envisage that in almost all situations pumping would be an individual irrigator responsibility rather than an irrigation scheme responsibility. Most farms that need to pump above the race either have direct access to the race, or are located a short distance from the race.

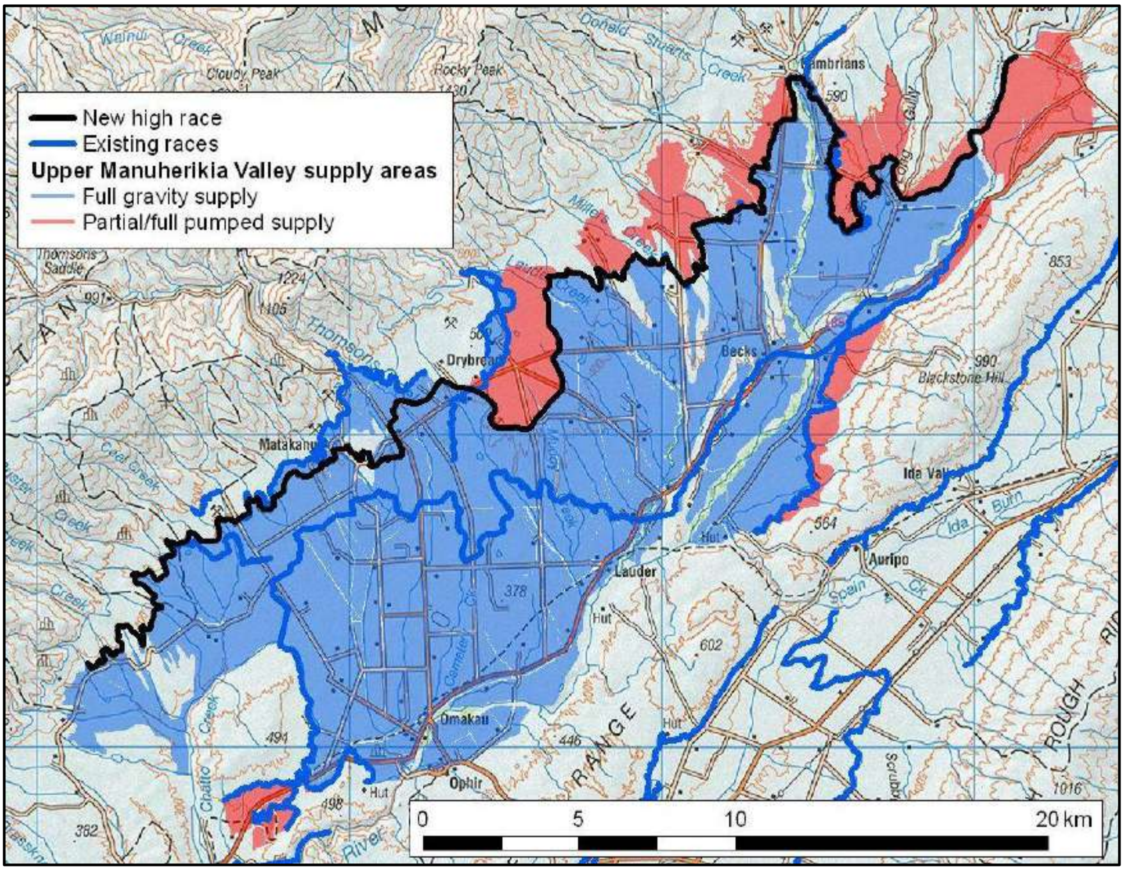

Figure 7: Gravity and pumped supply areas

Further details of supply areas are provided in Appendices A to D.

6 High Race

6.1 Overview

In the High Level Options report (Aqualinc 2012c), a new Omakau High Race was identified as an option for servicing the bulk of the irrigable land in the Upper Manuherikia Valley.

A high race, together with a 60 m high dam at Falls, was originally proposed in the early 1900's as a means of servicing the entire Upper and Lower Manuherikia Valley. This proposal was again explored as part of the Manuherikia Valley Scheme investigations in the 1970's and 1980's.

Our proposed intake is approximately at the same location as proposed by the Ministry of Works and Development (MWD) in the 1980's (MWD 1984). However, we have assumed the race grade would be steeper; consequently the alignment is lower than MWD's proposal. The advantage of this lower alignment is the race in general passes through flatter country that is more amendable to race construction, and because the Dunstan Main Race alignment can be reused. MWD's higher race alignment has its own advantages, including a slightly greater command area, and the ability to supply a greater area with pressurized water.

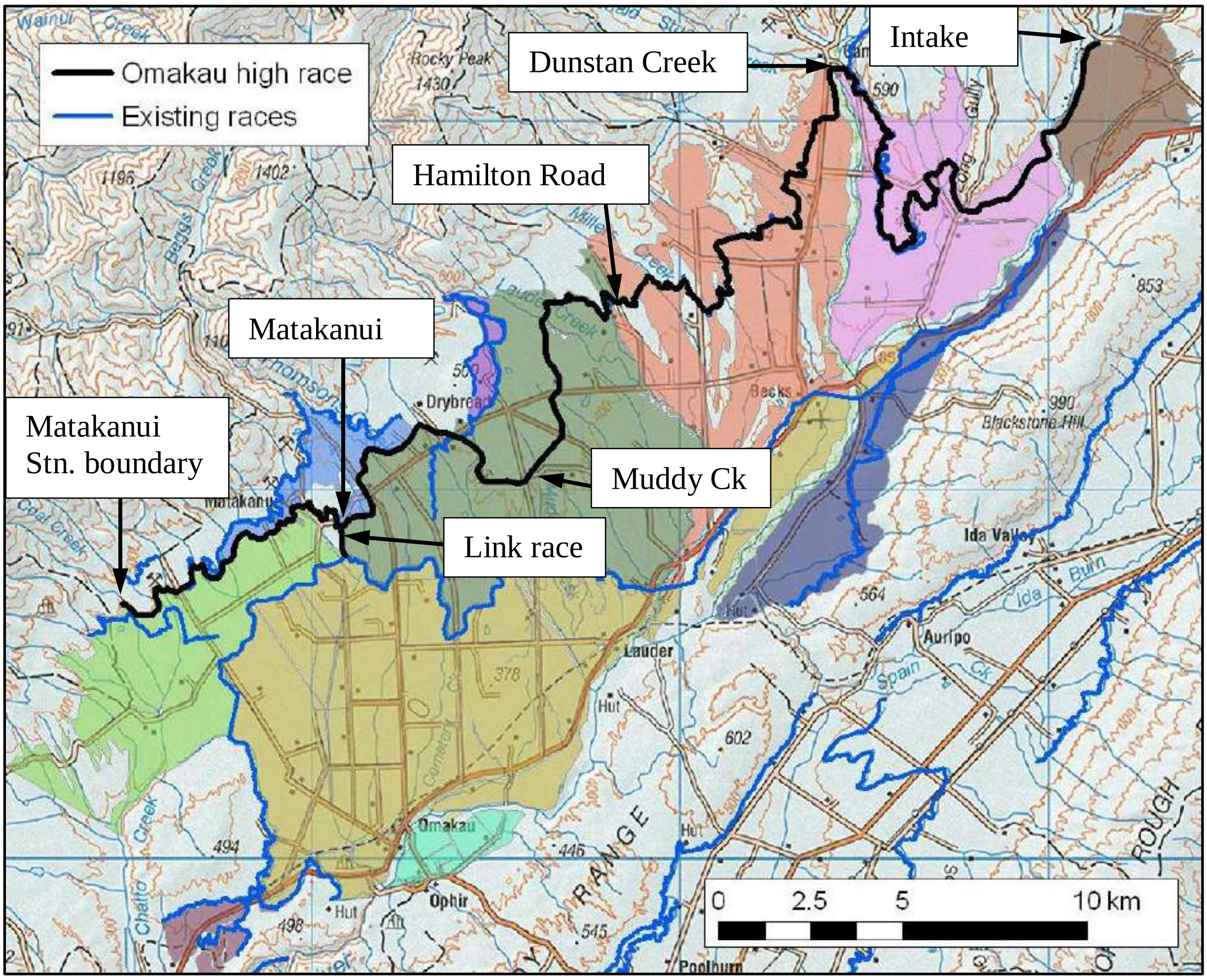

Figure 8: Omakau High Race

We envisage the High Race would supplement the Omakau Main Race, allowing the Main Race to service a larger area. Currently the Main Race only has sufficient water to supply 40% of the command area[1]. Muddy Creek, or a short link race at Matakanui are two possible supply points.

Our design has the High Race being at least 40% shorter than originally proposed by MWD, terminating at or before the boundary of Matakanui station. The original MWD proposal had the new high race extending as far as Golden Road. The proposal would have seen parts of Manuherikia Irrigation Scheme (MIS) Main Race abandoned. A key disadvantage of this option is the environmental benefits of the Manuherikia Irrigation Scheme conveyance flow are largely lost. The proposal would also make the catchment hydrologically very top heavy, with a lot of water being taken out at the top of the catchment, negating current water re-use benefits where MIS is largely supplied from irrigation drainage water. There is also considerable cost saving in a shorter race, since race construction becomes more difficult beyond Matakanui.

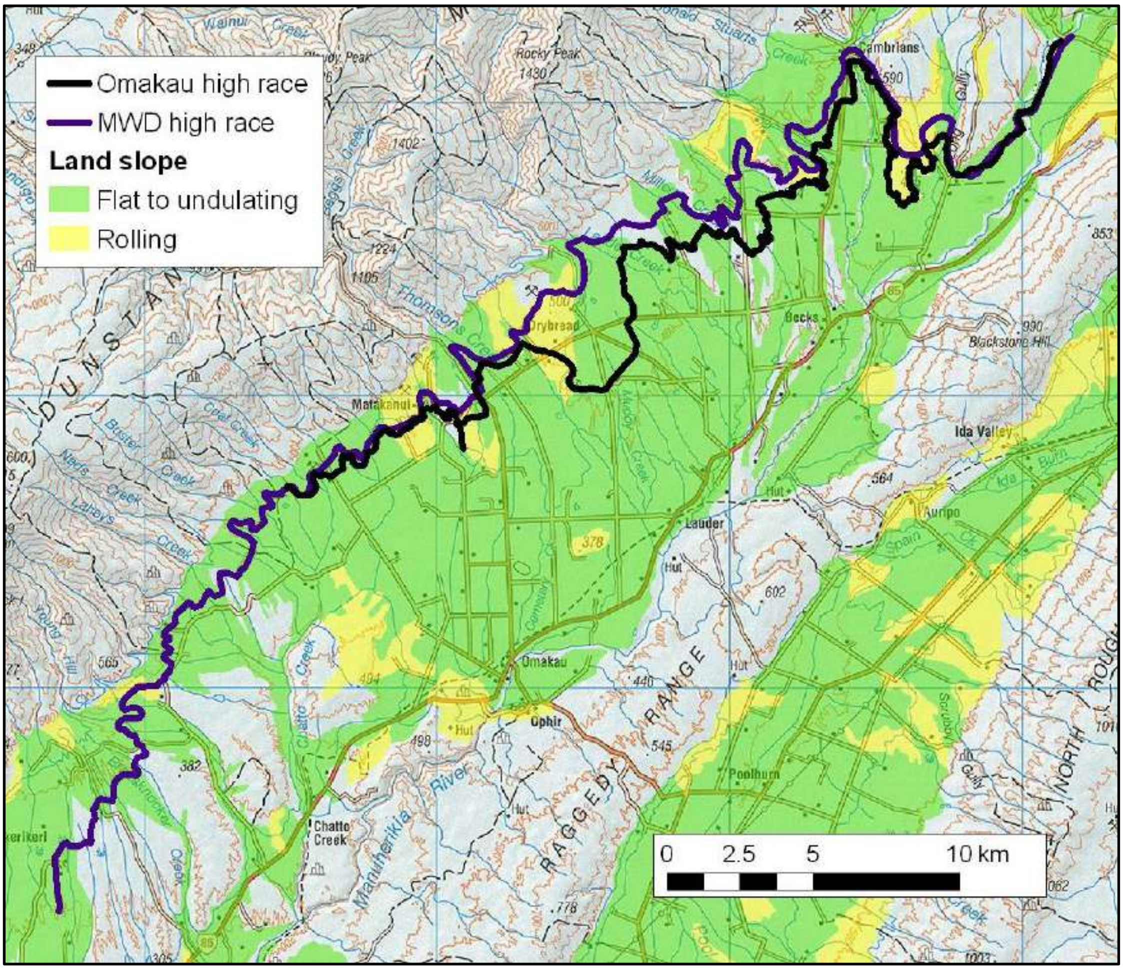

Figure 9: Comparison between proposed Omakau High Race and MWD High Race.

The high race is illustrated in further detail in Appendix E.

[1] Omakau main current on-farm allocation is 55 heads or 1,557 l/s. This is sufficient to irrigate 3,100 ha at 4.3 mm per day. The total command area below the race, including the Tiger Hill area, is 7,650 ha.

6.2 Design variants

There are a range of design options for the high race concept. Perhaps the most important decision is at what point to terminate the race. Possible termination points are illustrated in Table 5 and Figure 10.

Table 5: Possible High Race termination points

Termination point	Race length (km)		Command area (ha)	
	Additional	Total	Additional	Total
Dunstan Creek	17.5	17.5	3,500	3,500
Hamilton Road	15.1	32.6	3,500	7,000
Muddy Creek[(1)]	8.5	41.1	7,000	14,000
Matakanui[(2)]	14.3	55.4	1,500	15,500
Matakanui Station Boundary	12.5	67.9	2,000	17,500

(1) Omakau Main Race would be supplemented from the High Race using Muddy Creek for conveyance. Includes 4,000 ha unirrigated land that could potentially be supplied from Omakau Main Race (1,000 ha of which is above the Main Race where pumping would be necessary)

(2) Assumes link race is used to supplement Omakau Main Race.

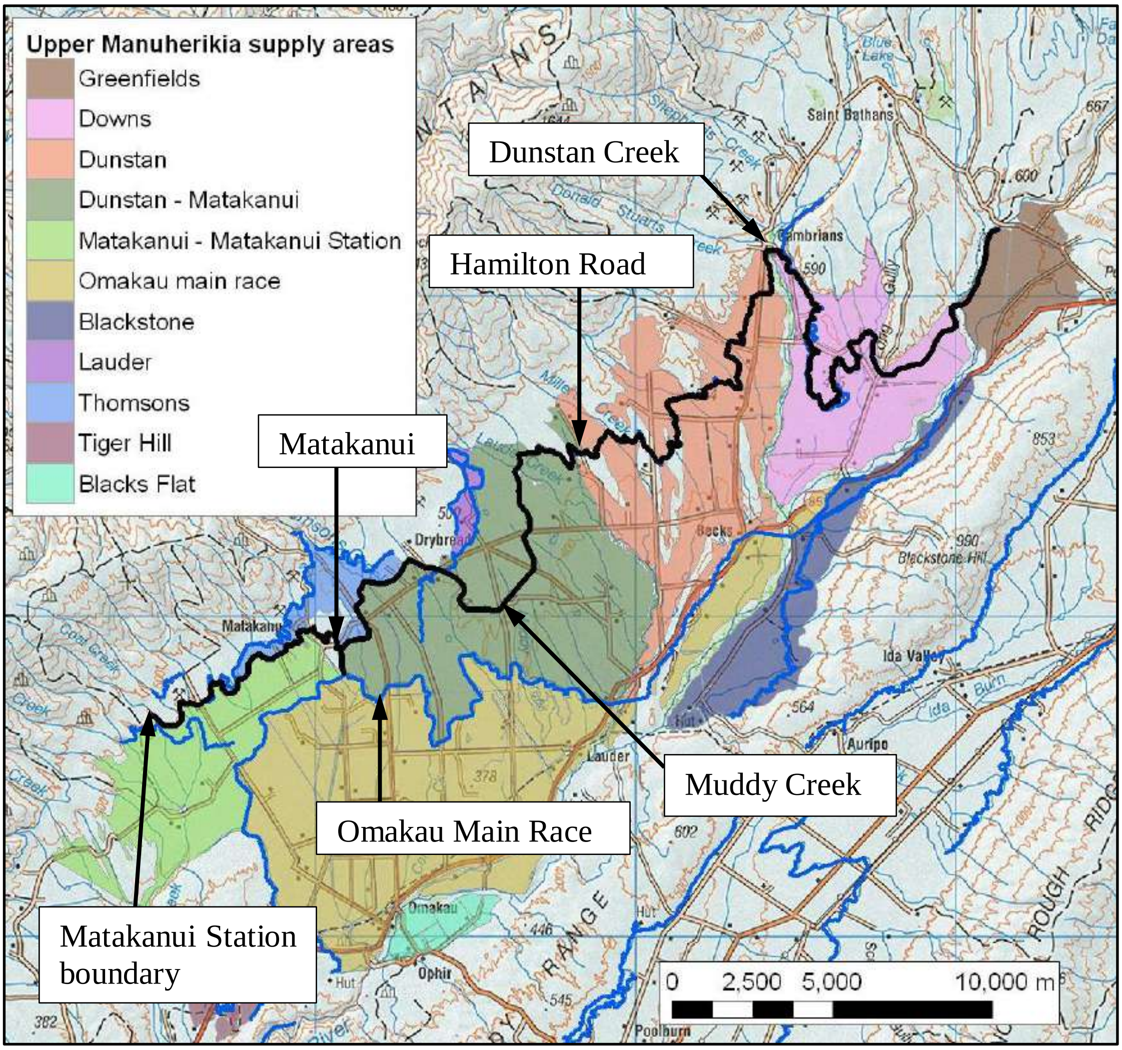

Figure 10: Possible High Race termination points

Terminating the High Race at Dunstan Creek would allow the Downs and Greenfield areas to be fully irrigated. The existing Dunstan Creek race could still supplement the Dunstan Race, without the race needing to be enlarged. This would allow the Dunstan Race full 20 head allocation to be supplied with very high reliability. Currently, during dry periods Dunstan Race is restricted to 5 to 6 heads.

Muddy Creek is the optimal point to terminate the High Race in terms of maximising the command area while minimising the High Race length. Beyond this point the additional command area brought in with each kilometre of race reduces from about 340 ha/km to 130 ha/km. Another reason for terminating the race at this point is beyond Muddy Creek the topography is generally less favourable for race construction, with more frequent gullies.

The next logical point to terminate the race would be at Matakanui. At this point the high race is at the closest distance to the Omakau Main Race, and a short 800 m link race would supplement the Omakau Main Race. Compared with the Muddy Creek option, an additional 14 km of race through relatively challenging country is required. Additional costs are partially off-set by reduced Omakau Main Race capacity upgrade costs.

The last location we would recommend as a possible termination point is the boundary of Matakanui Station. The reason for terminating at this point is there is land owner interest, and 800 – 1,000 ha of irrigable land on the property that could be supplied.

The second major decision that needs to be made with the high race is the elevation of the race. We have chosen a steeper race grade than originally proposed by MWD, with an average gradient of 1.2 m fall per kilometre. The steeper grade was primarily selected to allow the Dunstan Race alignment to be reused; it also allows for smaller siphons and culverts. However there are disadvantages of our alignment relative to the MWD alignment. One disadvantage of a steeper race means the race does not sit as high up the Valley, reducing the area that can be supplied with pressurised water if pipes are used for secondary distribution. The largest fall occurs in the section where the Dunstan Race is enlarged, where the grade averages 2.2 m per kilometre, or 1 in 450. This grade is at the high end of the recommended range for larger races [large races generally require less fall than small races], and may require erosion protection material to be imported, adding to construction costs. If a lesser race grade was chosen, the section from Dunstan Creek to Hamilton Road would be the obvious section to change. In the full feasibility investigations, we recommend the MWD higher race alignment be considered as a possible design alternative.

The decision on the race elevation will depend on the point where the high race is terminated. Generally, if the high race is shorter, it will tend to favour a lower alignment, with a higher alignment being favoured if it is longer.

There is some flexibility in the exact race alignment, and it should be relatively easy to avoid any buildings or structures.

6.3 Scenarios

Development scenarios for the Upper Valley range from a “do minimum” option, where the irrigated area remains at present levels, through to full development where 21,000 ha is fully irrigated. We have chosen four scenarios to broadly represent the wide spectrum of options. These are described in Table 6. Total irrigated areas for each of these scenarios are given in Table 7.

Table 6: Development scenarios

Scenario	High Race termination point	Falls Dam height	Area fully irrigated (ha)	
			From High Race	Upper Valley Total
1	No High Race	+5m	0	6,500
2a	No High Race	+14m	0	11,000
2	Hamilton Road	+15m	5,500	12,000
3	Muddy Creek	+23m	11,500	18,000
4	Matakanui Station	+27m	14,500	21,000

Table 7: Total Upper Valley irrigated area for each scenario

Scenario	Irrigated area (ha)		
	Full irrigation	Partial irrigation	Total irrigation
1	6,500	4,500	11,000
2	12,000	2,000	14,000
3	18,000	1,500	19,500
4	21,000	1,000	22,000

Scenario 1 is the “do minimum” option. This option does not include any new races. For this option we assumed that Falls Dam would be raised 5 to 6 m, to address flood risk and reliability concerns. We have assumed that the irrigated area would not be increased; rather water would be used to improve reliability. Without upgrading race capacity, it is not possible to supply more than about 6,500 ha with reliable water. We envisage the 4,000 to 5,000 hectares of partial irrigation using unreliable water, primarily sourced from the Dunstan Range, would continue.

Scenario 2a does not include a new high race. An expanded irrigated area would primarily come from a major upgrade of the Omakau Main Race, increasing the race capacity to 3.5 m^3 at the intake, with the race supplying a total of 6,850 ha. This would require complete replacement of the Manuherikia and Lauder siphons, in addition to replacing all culverts, modifying the intake, enlarging the race, and possibly enlarging the three tunnels. The Blackstone Irrigation race would also be upgraded to increase the capacity to about 720 l/s, increasing the area supplied to 1,300 ha. We also envisage an additional 300 ha being supplied directly from the Manuherikia River via a private take, either in the Greenfields or Downs supply areas. Scenario 2a has not been costed. This option may warrant further consideration during feasibility investigations.

For Scenarios 2 to 4 we envisage some of the areas that are currently partially irrigated from Dunstan Range water will remain, while some of these areas will be provided with a reliable water supply, either from the High Race, or via a water swap. A water swap would involve Dunstan Range reliable water [e.g. Lauder Creek, Thomsons Creek] being focused on land nearest the range, while areas below the High Race that currently receive reliable Dunstan Range water would be supplied from the High Race.

Any unreliable water infrastructure could largely remain as it is at present. Farmers who bought into supply from the High Race would transfer their unreliable water right to the scheme. This water would be captured and used in the high race when it was available, thereby reducing reliance on Falls Dam water in the spring time.

There may be some isolated cases where existing allocation rates exceed the water required for efficient spray irrigation. A possible example of this is the 222 l/s of mining rights from the Manuherikia River water allocated to Larkhall on Blacks Flat. This is likely to be significantly more than is necessary for efficient spray irrigation; allocation could therefore be adjusted accordingly.

All options assume an 80-85% uptake [of the irrigable area] for full irrigation supply, in areas where reliable water can be supplied.

6.4 Design details

Design details, including supply areas and race and siphon capacities, for Scenarios 1 to 4 are given in the tables below. Design flow rates exclude unreliable water, which we envisage would continue to be supplied using existing infrastructure.

6.4.1 Scenario 1 (Do minimum)

Table 8: Supply areas and flow rates – Scenario 1.

Sub-zone	Design supply area (ha)	Design supply rate (l/s)
Supplied from Falls Dam		
Omakau Main Race	3,350	1,980*
Blackstone Irrigation Scheme	600	330*
Blacks Flat	300	170*
Thurlow private Manuherikia take	50	28
Total	**4,300**	**2,508**
Areas not supplied from Falls Dam		
Dunstan Creek (90% reliable water)	1,150	720
Lauder Creek (90% reliable water)	400	235*
Thomsons Creek (90% reliable water)	300	180*
Other minor Dunstan Range tributaries above Ophir (90% reliable water)	300	200
Thurlow private Pool Burn take.	50	27
Total	**2,200**	**642**
Total Upper Manuherikia Valley	**6,500**	**3,870**
*Includes distribution losses of 10-20%.		

6.4.2 Scenario 2a (11,000 ha fully irrigated)

Table 9: Supply areas and flow rates – Scenario 2a.

Sub-zone	Design supply area (ha)	Design supply rate (l/s)
Supplied from Falls Dam		
Omakau Main Race	6,850	3,500
Blackstone Irrigation Scheme	1,300	720*
Blacks Flat	300	170*
Greenfields or Downs direct from Manuherikia	300	150
Thurlow private Manuherikia take	50	28
Total	**8,800**	**4,568**
Areas not supplied from Falls Dam		
Dunstan Creek (90% reliable water)	1,150	720
Lauder Creek (90% reliable water)	400	235*
Thomsons Creek (90% reliable water)	300	180*
Other minor Dunstan Range tributaries above Ophir (90% reliable water)	300	200
Thurlow private Pool Burn take.	50	27
Total	**2,200**	**642**
Total Upper Manuherikia Valley	**11,000**	**5,210**
*Includes distribution losses of 10-15%.		

6.4.3 Scenario 2 (12,000 ha fully irrigated)

Table 10: Supply areas and flow rates – Scenario 2

Sub-zone	Design supply area (ha)	Design supply rate (l/s)
Omakau High Race		
Greenfields	500	250
Downs	2,000	1,000
Dunstan	3,000	1,500
Total	**5,500**	**2,750**
Other sources supplied from Falls Dam		
Omakau Main Race	3,500	1,980*
Greenfields high race intake	300	150
Blackstone Irrigation Scheme	1,300	720*
Blacks Flat	300	170*
Thurlow private Manuherikia take	50	28
Total	**5,450**	**3,048**
Areas not supplied from Falls Dam		
Lauder Creek (90% reliable water)	400	235*
Thomsons Creek (90% reliable water)	300	180*
Other minor Dunstan Range tributaries above Ophir (90% reliable water)	300	200
Thurlow private Pool Burn take.	50	27
Total	**1,050**	**642**
Total supplied from Falls Dam	**10,950**	**5,798**
Total Upper Manuherikia Valley	**12,000**	**6,440**
*Includes distribution losses of 10-15%.		

Table 11: High Race capacities – Scenario 2

Race section	Race length (km)	Race capacity (m^3/s)	
		Start	End
Intake to Manuherikia siphon	2.8	2.5	2.3
Manuherikia siphon to Dunstan siphon	14.6	2.3	1.3
Dunstan siphon to Hamilton Road	15.1	1.5	0
Total	**32.5**		

6.4.4 Scenario 3 (18,000 ha fully irrigated)

Table 12: Supply areas and flow rates – Scenario 3

Sub-zone	Design supply area (ha)	Design supply rate (l/s)
Omakau High Race		
Greenfields	500	250
Downs	2,000	1,000
Dunstan	3,000	1,500
Hamilton Road – Muddy Creek	2,500	1,250
Omakau Main Race via Muddy Creek	3,500	1,750
Total	**11,500**	**5,750**
Other sources supplied from Falls Dam		
Omakau Main Race	3,500	1,980*
Greenfields high race intake	300	150
Blackstone Irrigation Scheme	1,300	720*
Blacks Flat	300	170*
Thurlow private Manuherikia take	50	28
Total	**5,450**	**3,048**
Areas not supplied from Falls Dam		
Lauder Creek (90% reliable water)	400	235*
Thomsons Creek (90% reliable water)	300	180*
Other minor Dunstan Range tributaries above Ophir (90% reliable water)	300	200
Thurlow private Pool Burn take.	50	27
Total	**1,050**	**642**
Total supplied from Falls Dam	**16,950**	**8,798**
Total Upper Manuherikia Valley	**18,000**	**9,440**
*Includes distribution losses of 10-15%.		

Table 13: High Race capacities – Scenario 3

Race section	Race length (km)	Race capacity (m^3/s)	
		Start	End
Intake to Manuherikia siphon	2.8	5.5	5.3
Manuherikia siphon to Dunstan siphon	14.6	5.3	4.3
Dunstan siphon to Hamilton Road	15.1	4.5	3.0
Hamilton Road to Muddy Creek	8.5	3.0	1.8
Total	**41.1**		

6.4.5 Scenario 4 (21,000 ha fully irrigated)

Table 14: Design supply areas and rates – Scenario 4.

Sub-zone	Design supply area (ha)	Design supply rate (l/s)
Omakau High Race		
Greenfields	500	250
Downs	2,000	1,000
Dunstan	3,000	1,500
Hamilton Road - Matakanui	4,000	2,000
Matakanui - Matakanui Station	2,000	1,000
Link race to Omakau Main Race	3,000	1,500
Total	**14,500**	**7,250**
Other sources supplied from Falls Dam		
Omakau Main Race	3,500	1,980*
Greenfields high race intake	300	150
Blackstone Irrigation Scheme	1,300	720*
Blacks Flat	300	170*
Thurlow private Manuherikia take	50	28
Total	**5,450**	**3,048**
Areas not supplied from Falls Dam		
Lauder Creek (90% reliable water)	400	235*
Thomsons Creek (90% reliable water)	300	180*
Other minor Dunstan Range tributaries above Ophir (90% reliable water)	300	200
Thurlow private Pool Burn take.	50	27
Total	**1,050**	**642**
Total supplied from Falls Dam	**19,950**	**10,298**
Total Upper Manuherikia Valley	**21,000**	**10,940**
*Includes distribution losses of 10-15%.		

Table 15: High Race capacities – "Falls + 27m"

Race section	Race length (km)	Race capacity (m^3/s)	
		Start	End
Intake to Manuherikia siphon	2.8	7.0	6.8
Manuherikia siphon to Dunstan siphon	14.6	6.8	5.8
Dunstan siphon to Hamilton Road	15.1	6.0	4.5
Hamilton Road to Matakanui	22.1	4.5	2.5
Link race to Omakau Main Race	0.8	1.5	1.5
Matakanui - Matakanui Station	12.5	1.0	0.5
Total	**67.9**		

7 High Race structures

Brief descriptions of the various components of the High Race are provided below. Any designs are at a concept level at best, and are intended only to provide indicative ideas of possible solutions. Further details are provided in Appendix E.

7.1 Intake

We envisage the High Race intake would be at an elevation of about 467 to 470 m amsl, at or just downstream of Loop Road Bridge (see Figure 13). A 2-3 m high rock weir, similar to the Manuherikia Irrigation Scheme intake, may be a possible intake structure. A rock weir could be designed in such a way as to provide fish passage past the weir. Bed stability is a major factor when considering intake design. Photographs taken in 1976 and 2006 suggest that immediately downstream of the Bridge, the bed appears to be relatively stable.

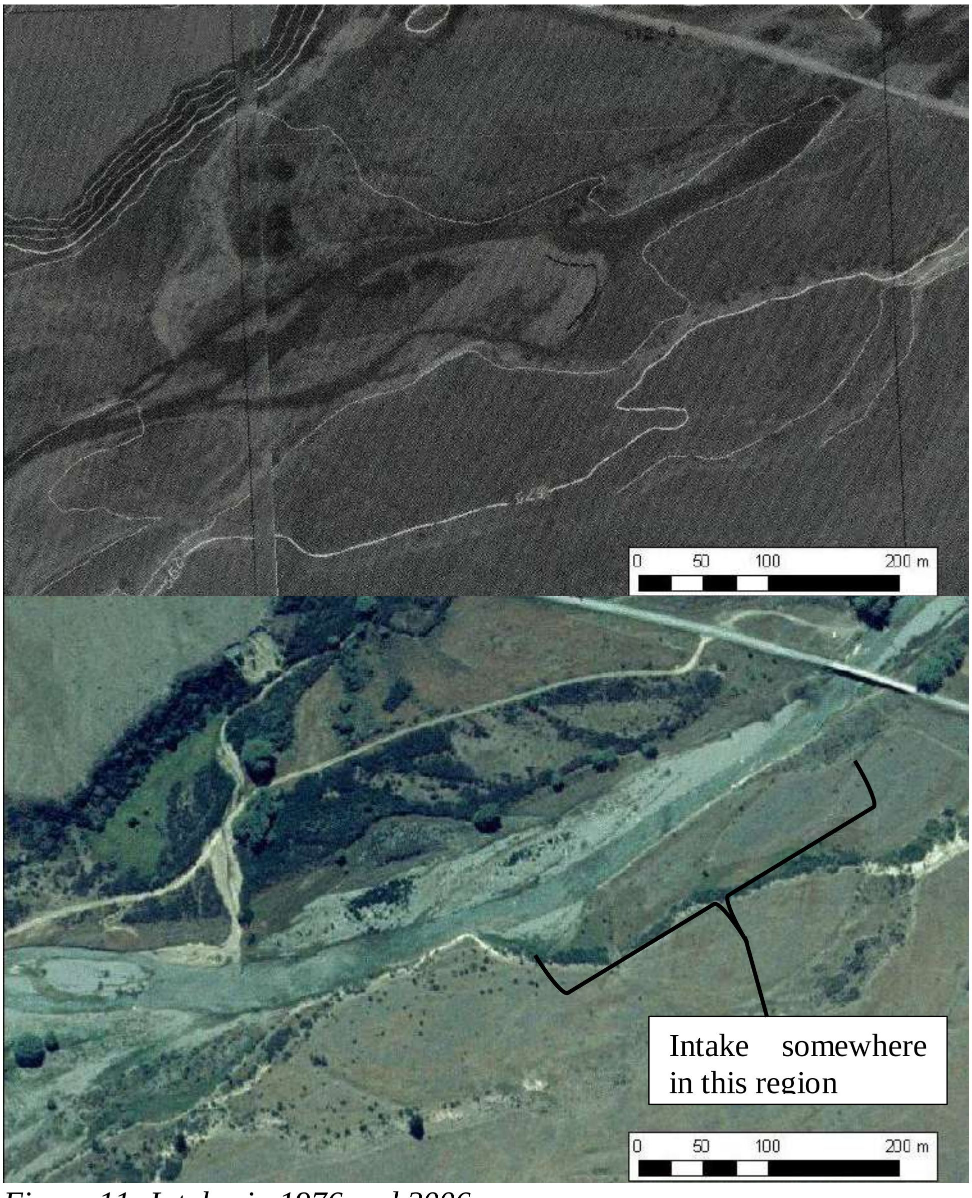

Figure 11: Intake, in 1976 and 2006.

Fish and Game have indicated it may not be necessary to exclude fish from the race, since races can provide valuable spawning areas in Central Otago. This would require further investigation. If the decision is made to exclude fish from the intake possible options include gallery intakes (e.g. similar to the RDR intake on Ashburton South Branch), stainless steel screens, or physiological deterrents such as bubble screens.

The Manuherikia River at this point has cut down into the surrounding outwash plains and sits 15-20 m below the plains. Below the intake, a contour race would be benched into the terrace face (see Figure 14 and Figure 15). The terrace faces appear to be predominately alluvial deposits, with some remnant sandstone formations (refer geological maps in Appendix E). The sandstone could make race construction more difficult in places. For example, the last 500 m of the contour race, the terrace face is quite steep despite the river channel being hard up against the base of the terrace, indicating relatively hard material. Through this section, the race would probably need to be cut down into this sandstone to a depth of up to 8 m (see Figure 16). A higher intake point (i.e. 470 m amsl) and a reduced race grade would minimise sandstone excavation requirements.

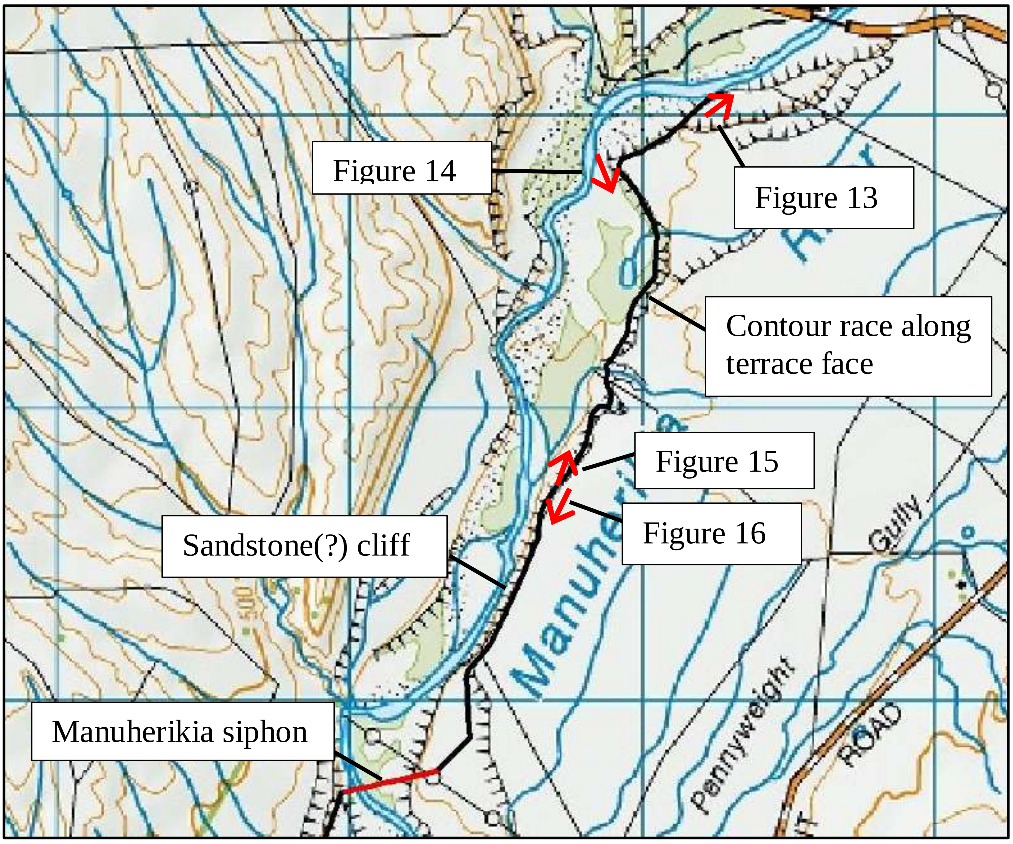

Figure 12: High Race intake

Figure 13: Looking upstream at possible High Race intake site

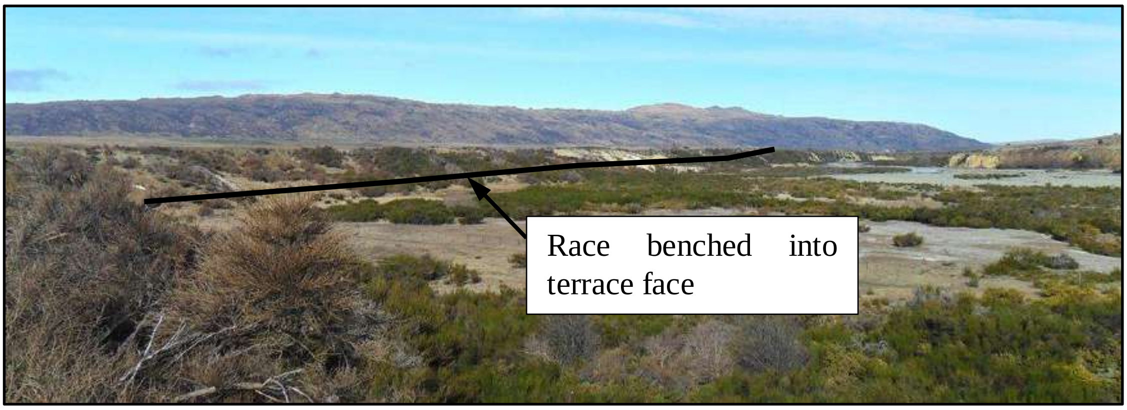

Figure 14: Contour race along terrace face (looking downstream)

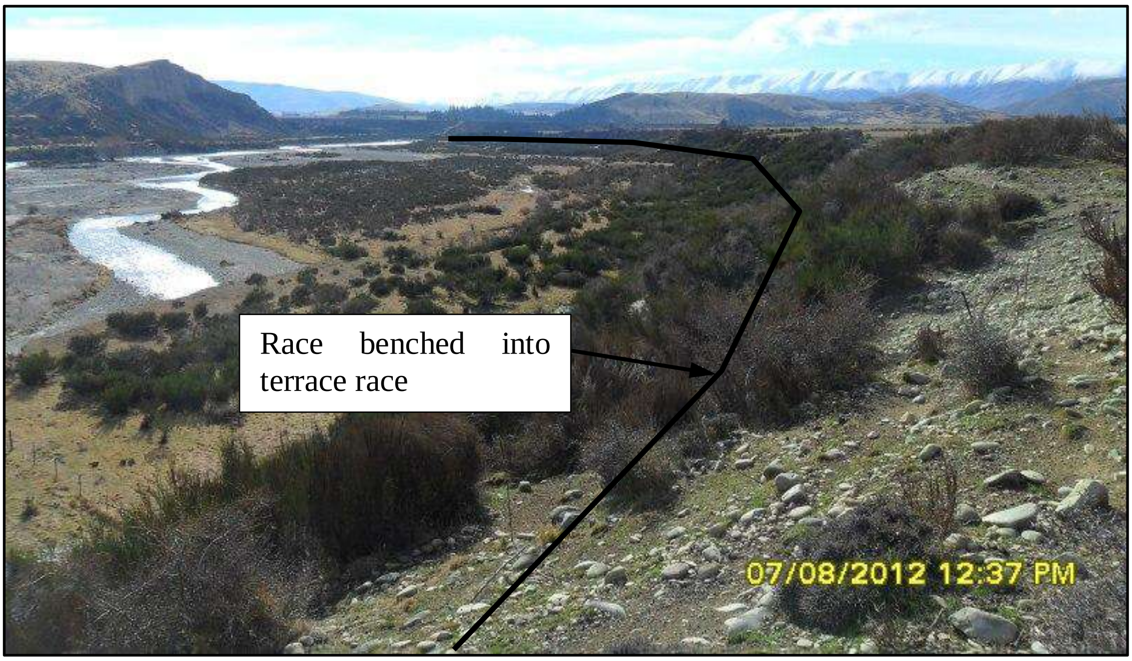

Figure 15: Contour race along terrace face (looking upstream)

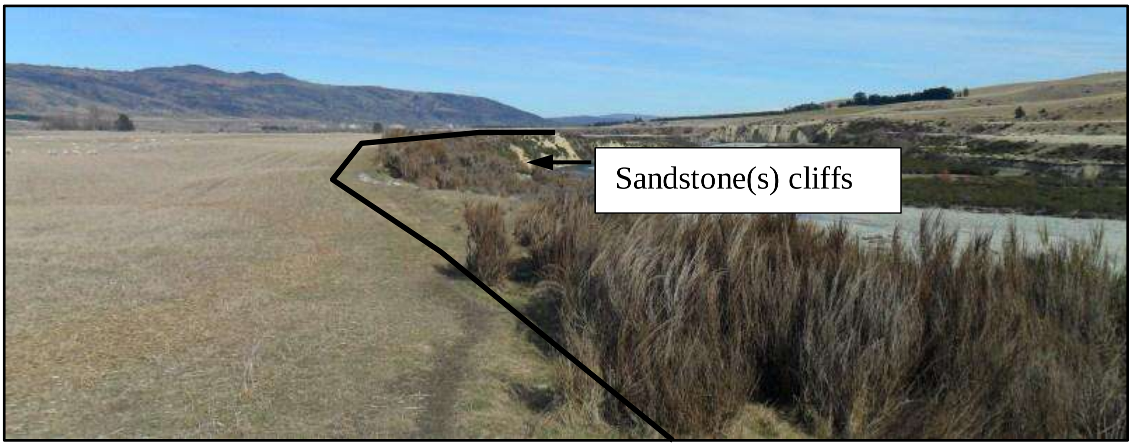

Figure 16: Possible excavation through sandstone

7.2 Races

We envisage the only new race of significance would be the High Race. The size of the High Race depends on the development scenario. For Scenario 4 – full development, at the start of the High Race the capacity would be 7.0 m^3/s or 247 heads, telescoping down to about 0.5 m^3/s or 18 heads by the time the race reaches the boundary of Matakanui Station. While this race is large by Central Otago standards, it is a medium sized race by Canterbury and North Otago standards, where some irrigation races are as large as 30 m^3/s (1,060 heads). Figure 17 and Figure 18 illustrate what a 6 m^3/s race looks like.

In race capacity design, we have assumed all new distribution would be designed to have less than 5% leakage. We have also made an allowance for leak reduction in existing races. In engineering costings we have allowed for parts of the High Race and existing races to be lined with a buried plastic or geotextile liner. Such liners are becoming increasingly common in Canterbury, as an economical method of minimising leakage. The method appears to be particularly effective where races pass through porous ground. In Canterbury, these liners are increasingly being used on existing races to minimise leakage.

Minimising distribution losses becomes increasingly important for the larger development Scenarios 3 and 4. This is because race lengths are quite long and because of the benefits of keeping as much water as possible in the Manuherikia River below the High Race and Omakau Main Race intakes.

The high race would require vehicle access on at least one side, along the entire length of the race. Fencing has not been allowed for in engineering costs.

Figure 17: Example of a 6 m^3/s race when full

Figure 18: Example of a 6 m^3/s race when empty


Figure 19: Example of a buried plastic race liner used in Canterbury

7.3 Siphons

Siphons can be a major expense with medium to large sized races. Indicative pipe lengths and sizes for each of the scenarios are given in Table 16. The Becks and Dunstan siphon lengths will depend on how much effort is made with race earthworks. The more earthworks used to extend the race, the shorter the length of siphon required. The Manuherikia siphon is illustrated in Figure 20.

Table 16: Major siphon lengths and sizes

Name	Length	Indicative capacity (cu = m^3/s) & Pipe ID		
		Scenario 2	Scenario 3	Scenario 4
Manuherikia	350m	2.3cu/1.0m	5.3cu/1.5m	6.8cu/1.7m
Dunstan	160 – 700m	1.3cu/0.8m	4.3cu/1.4m	5.8cu/1.6m
Becks	50 – 500m	0.7cu/0.6m	3.7cu/1.3m	5.2cu/1.5m
Lauder	75m	N/A	3.0/1.2m	4.5cu/1.4m
Thomson	75m	N/A	N/A	2.5cu/1.1m

Figure 20: Manuherikia siphon (looking east)

7.4 Farm and road crossings

Farm track and road crossings should generally involve "off the self" concrete box, pipe culvert products or precast concrete panels. Box culverts will generally be more suitable for higher flow races. Figure 21 illustrates a box culvert road crossing on a large (460 heads) race. Figure 22 illustrates a box culvert farm track crossing on a mid-size (210 heads) race. For smaller races concrete pipe culverts (e.g. Figure 23) or precast panels tend to be more common solutions.

We have made an initial estimate of the number of farm tracks. The exact number of farm crossings for each property will require land owner negotiations.

Figure 21: Example of a box culvert road crossing over a 13 m^3/s race

Figure 22: Example of a box culvert farm track over a 6 m^3/s race

Figure 23: Example of a pipe culvert farm track over a 1.8 m^3/s race

7.5 Farm turnouts

We envisage most farm turnouts will be either pipe or pump off-takes in the race, since most of the secondary distribution will be pipes rather than open races. Some examples of pipe and pump intakes are given below. Several other solutions, such as galleries for pipe off-takes are also available.

Figure 24: Example of a pipe supply from a race

Figure 25: Example of pumping from a race

Figure 26: Example of pumping from a race with a screen on a pontoon.

8 Secondary distribution

We envisage secondary distribution below the Omakau High Race would largely be 200 to 450 diameter PVC or PE pipe. PVC or PE pipe, supplied from a headrace offers a number of advantages including:

- Negligible distribution losses;
- Continuous supply; and
- Partial [and in some cases full] pressure supply.

The size of pipes required depends on the flow rate and the amount of allowable head loss in the pipe. In most situations, head loss allowances will range from 2 to 10 m per kilometre. Table 17 provides an indication of pipe sizes given different flow rates and supply areas. We envisage the maximum pipe size necessary would be 450 mm, as PVC or PE pipes are readily available up to this size. Supply and installation of these smaller diameter pipes is straight forward, reducing costs.

Table 17: PVC pipe capacity

Pipe NB[1] (mm)	Capacity (l/s)		Area supplied at 4.5mm/d capacity	
	10 m/km headloss	2 m/km headloss	10 m/km headloss	2 m/km headloss
200	58 l/s	24 l/s	110 ha	45 ha
225	76 l/s	32 l/s	145 ha	60 ha
250	102 l/s	43 l/s	200 ha	80 ha
300	139 l/s	58 l/s	270 ha	110 ha
375	261 l/s	110 l/s	500 ha	210 ha
450	470 l/s	197 l/s	900 ha	650 ha
(1) Nominal bore. Roughly equal to the internal diameter (ID)				

Piping costs depend on the length of pipe, the flow rate, and the amount of fall between the headrace and the point of supply. Indicative PVC pipe prices are given in Table 18. The biggest factor in piping costs is the length of pipe: the shorter the distance from the headrace to the point of supply, the lower the cost. A key advantage of pipes over races is generally the shortest route can be used, since pipes do not need to follow the land contour, and because pipes are below the ground, the disruption to land once installed, is minimal. The cost of piping increases as pipe head losses decrease. The advantage of minimising pipe head loss is that it maximises the pressure that can be delivered on-farm. On a $ per l/s basis, piping costs decrease as pipe sizes increase. This is because doubling the pipe diameter increases the pipe carrying capacity six-fold, while costs only increase three-fold. Practically this means a preference for fewer, larger pipes where possible.

Table 19 gives indicative secondary distribution piping costs. By way of example, a 270 ha farm, located 1 km below the high race, would require a 300 mm ID pipe given head-losses of 10 m/km. This pipe would cost about $100,000, which equates to $370 per hectare. If the same farm were located 2 km from the high race, secondary piping costs would be $740/ha. Secondary distribution costs will be lower in areas where most farms are adjacent to the high race, such as the Greenfields and Downs supply areas.

Typical land slope grades below the high race range from 7-20 m fall per kilometre. Larger pipes minimise pipe headloss, thereby delivering more pressure on farm. There is a trade-off between the capital expenditure of larger pipe and the amount of pressure delivered, which reduces on-farm pumping costs. Our secondary distribution price estimates are likely to be more indicative of smaller pipes delivering minimal pressure at the farm boundary. Upgrading these pipes to deliver a pressurised supply would be an additional expense.

We recommend schemes price the level of service provided into the rate charged to irrigators, rather than trying to provide all irrigators with identical service. For example, irrigators who are provided with a fully pressurised supply may be charged $150 [or an equivalent capital contribution] more than irrigators who need their own on-farm pumping system. These additional charges should as a minimum cover the scheme's marginal cost of providing a pressurised supply. Where irrigators are provided with partial pressure, their additional charge should reflect the on-farm cost savings compared with being provided with no pressure.

Table 18: Indicative piping costs for PN6 PVC with large pipe orders (5km+)

Pipe size		Pipe costs				Capacity cost	
mm		*$/m*				*$/m per l/s*	
NB	ID	Pipe	Fittings (1)	Install.	Total	10 m/km headloss	2 m/km headloss
200	213	$35.1	$3.5	$13	**$52**	$0.90	$2.14
225	237	$43.1	$4.3	$14	**$62**	$0.81	$1.93
250	265	$53.9	$5.4	$15	**$74**	$0.73	$1.73
300	298	$68.7	$6.9	$20	**$96**	$0.69	$1.64
375	379	$110.7	$11.1	$22	**$144**	$0.55	$1.31
450	473	$173.4	$17.3	$24	**$215**	$0.46	$1.09
(1) Assumed to be 10% of pipe costs							

Table 19: Indicative secondary piped distribution costs

Scheme	Supply area (ha)	Supply rate (l/s)	Average dist.(1)	Cost at $1.0/m per l/s
Greenfields	800	400	0 m	$0
Downs	2,000	1,000	100 m	$0.1M
Dunstan	3,000	1,500	1,000 m	$1.5M
Hamilton Road - Matakanui	4,000	2,000	1,000 m	$2.0M
Matakanui - Matakanui Station	2,000	1,000	500 m	$0.5M
Total				**$4.1M**
(1) Average distance from the high race to farm boundaries. For farms bordering the high race, no secondary distribution is required and secondary distribution costs are nil.				

While we expect in most situations piped supplies will be the most suitable for spray irrigation, we envisage some existing races may be used for High Race secondary distribution. The use of secondary races may require some on-farm storage, to accommodate the roster system. Both pipes and the reuse of existing races should be considered during feasibility investigations.

For existing command areas, such as the Omakau Main Race and Blackstone Irrigation Scheme, we have not made any allowance for additional secondary distribution; the assumption being in most cases existing secondary races will continue to be used for conveyance.

Our design assumes schemes provide water to farm boundaries, with on-farm distribution costs the responsibility of individual irrigators.

9 Upgrades to existing races

We envisage some upgrades to existing schemes will be necessary under both the "do minimum" and development scenarios. Under all scenarios, we have made an allowance for automatic gates on the main intakes and races. Automatic gates are generally necessary to ensure compliance with flow rate and minimum flow consent conditions. We have not, however, allowed for buffer storage ponds, instead assuming that existing and new on-farm storage ponds will be used to provide for the on-demand supply spray irrigators need.

We have included an allowance for lining particularly leaky race sections. Race length estimates are broad estimates based only on the size of each scheme. Actual lengths of race that may be worth lining may therefore vary from our estimates.

For the Omakau Main Race we have included an allowance to replace the first 1.1 km of the Lauder siphon, since this is currently scheduled for replacement. We have allowed a further $350,000 for the replacement of other minor structures, where necessary in critical locations. No allowance has been made to replace other major structures such as the Manuherikia siphon.

We have not included an allowance for fish screens. Fish and Game has recommended that the necessity of fish screens be considered on a case by case basis. In some situations there may be an advantage in allowing fish to have access to races, since races can provide very good spawning environments due to the stable flows. The provision of fish screens and/or fish passage is likely to add relatively minor additional cost, compared with other capital works costs.

For development scenarios 2 to 4 we have included an allowance to increase the race capacity of Blackstone Irrigation main race to 720 l/s, allowing the scheme to supply a total of 1,300 ha. We expect it to be relatively straight forward to increase the race capacity, with most of the cost associated with replacing culverts.

For development scenarios 3 and 4 we have included an allowance to increase the race capacity of Omakau Main Race, to accommodate an additional 1.5 to 1.8 m^3/s from the High Race. Cost estimates were very broad; with no specific consideration of what siphons may require upgrading, and the number of culverts that would require replacement. More detailed consideration would be required as part of feasibility investigations.

10 Engineering costings

Scenarios 1 to 4 have been costed to a pre-feasibility level, using rates from other recent irrigation proposals, and an Irrigation NZ publication on irrigation scheme pipe and open race costs (Ritso 2007). Costings are primarily based on broad desktop assessments with little consideration of site specific factors. Race costs are highly dependent on ground conditions and may vary from predictions accordingly. We recommend as part of feasibility investigations that a contractor(s) with earthworks and irrigation scheme experience be engaged to help refine cost estimates.

Costs for new infrastructure are estimated to be accurate to ±30%. Cost estimates are a mean estimate, given an average to favourable construction environment and a well-run tender process. Costs also assume the bulk of the work is tendered as part of a single contract, thereby reducing the price by the scale of construction. Costings are summarised in Table 20. Full costings are provided in Appendix F

Cost uncertainty is greater for upgrades to existing infrastructure. Costs are also less certain for Scenario 1 (“do minimum”), since it is currently unclear exactly what upgrade works may be necessary to get resource consents granted.

Costs exclude land purchase costs, legal fees, and GST.

Table 20: Upper Manuherikia Valley distribution cost summary

	Irrigated area			Cost		Cost/ha	
Scenario	Existing	New	Total	Total	Marginal	Existing	New
1	6,500	0	6,500	$4.4M	$0.0	$675	$0
2	6,500	5,500	12,000	$18.2M	$13.8	$675	$2,517
3	6,500	11,500	18,000	$30.1M	$25.7	$675	$2,235
4	6,500	14,500	21,000	$41.1M	$36.7	$675	$2,533

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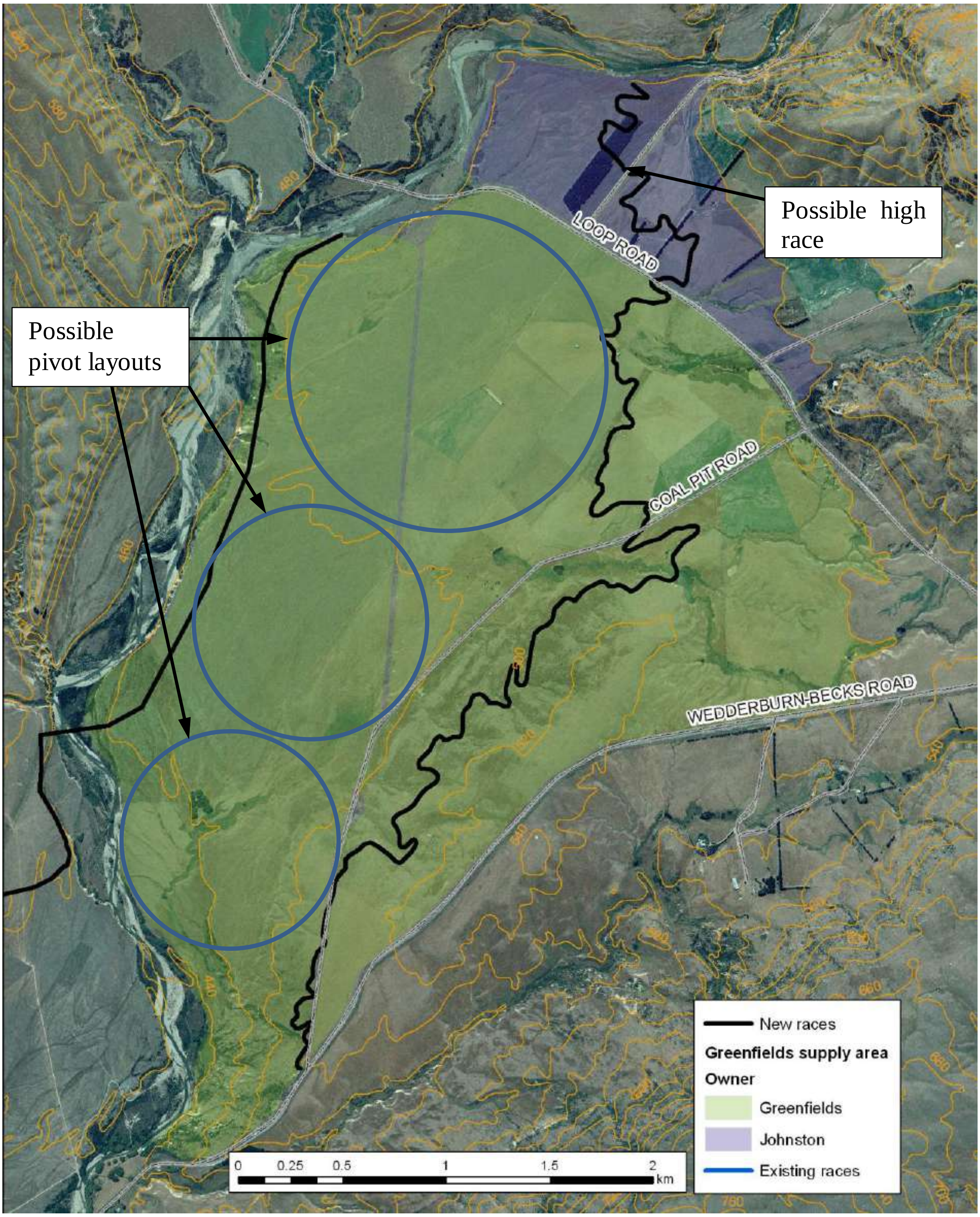
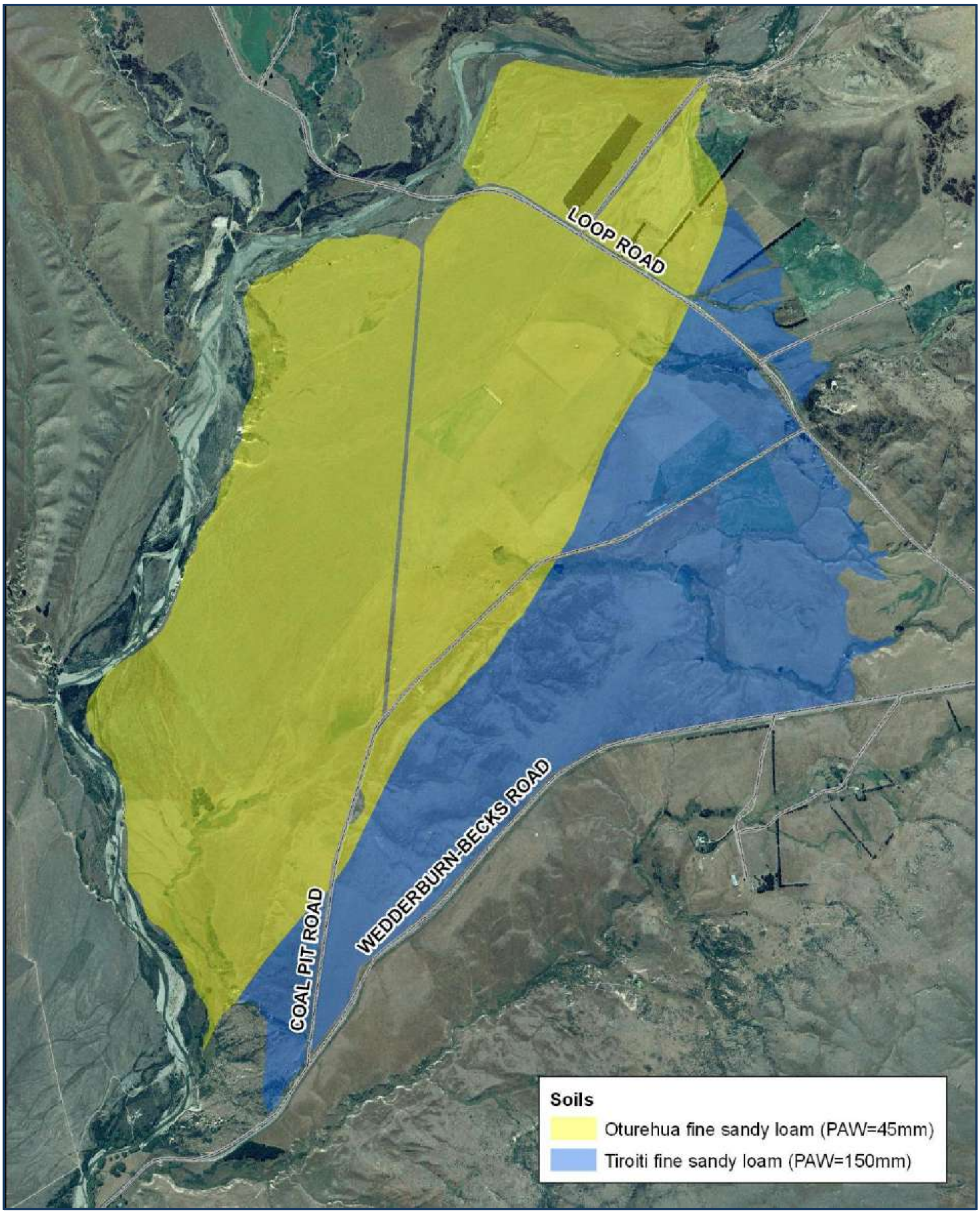
Appendix A: Greenfields supply area



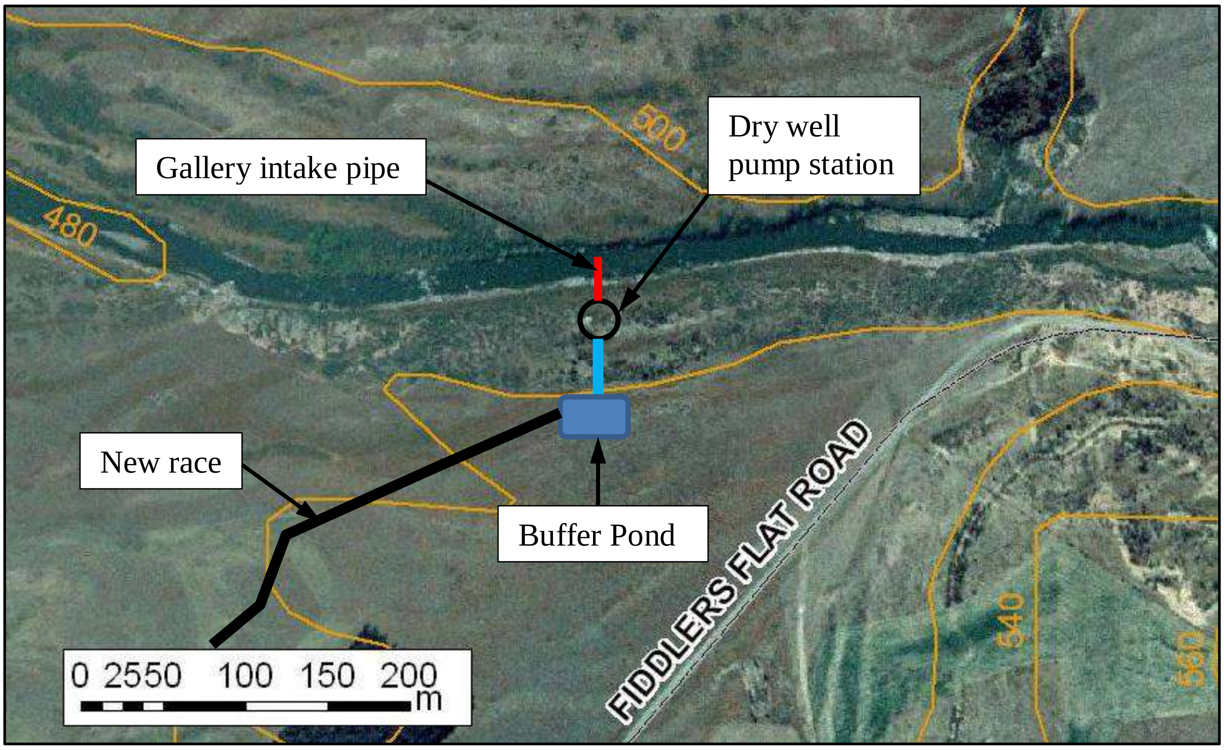
Greenfields supply area

We envisage this area would be supplied both from the High Race, and an additional private take further up the Manuherikia River.

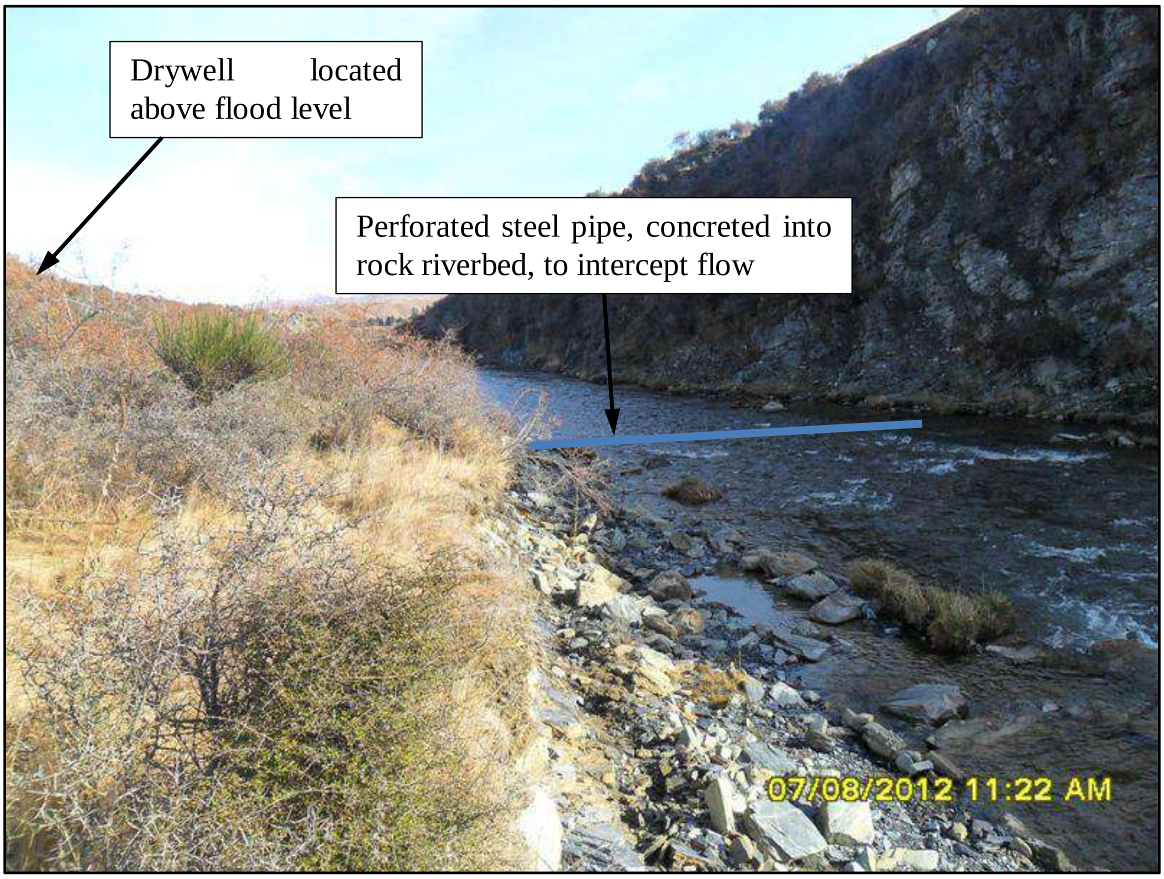


Greenfields soils (Source: Landcare Research 2000)

Greenfields potentially irrigable flats

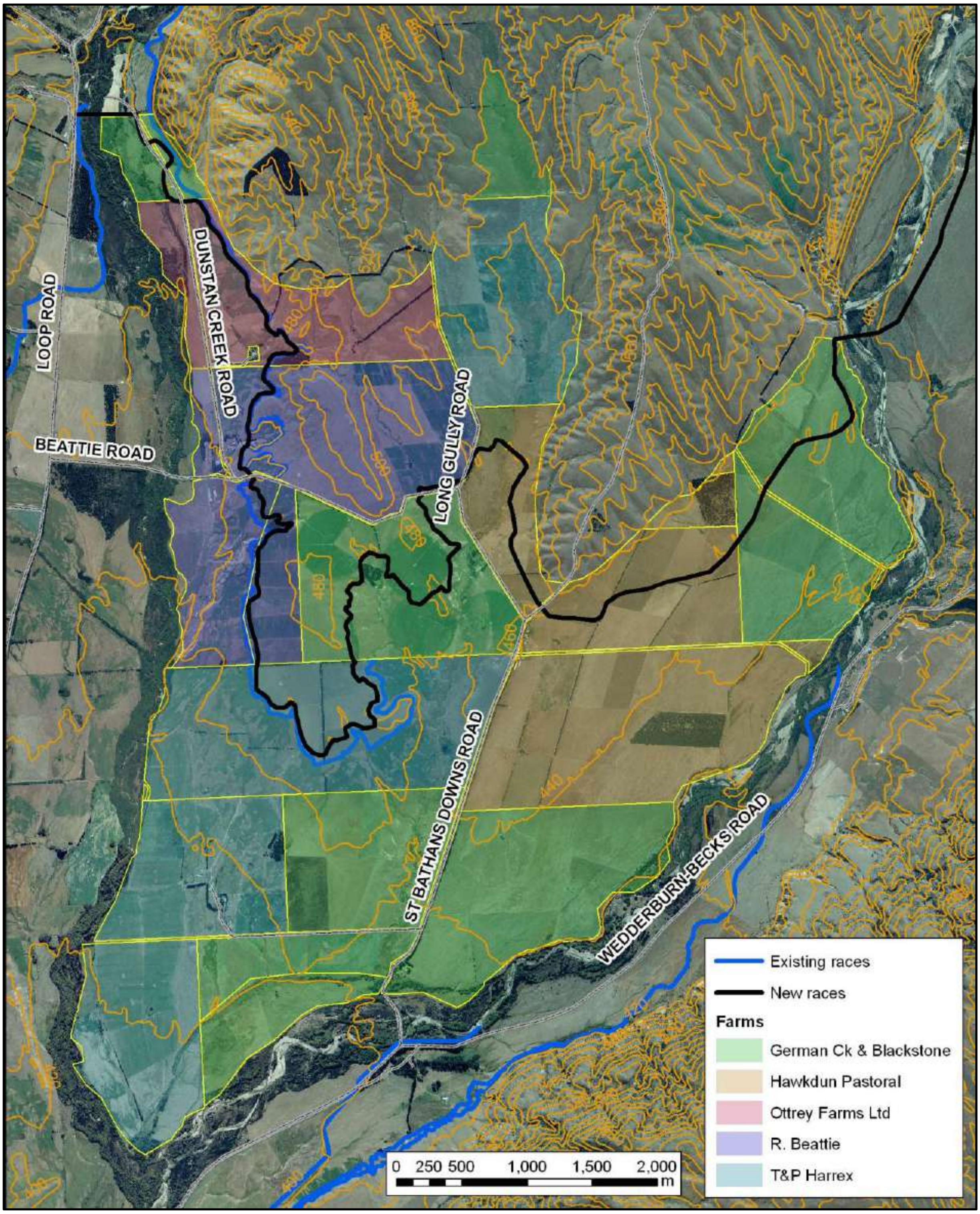


Possible Greenfields high race pump intake site



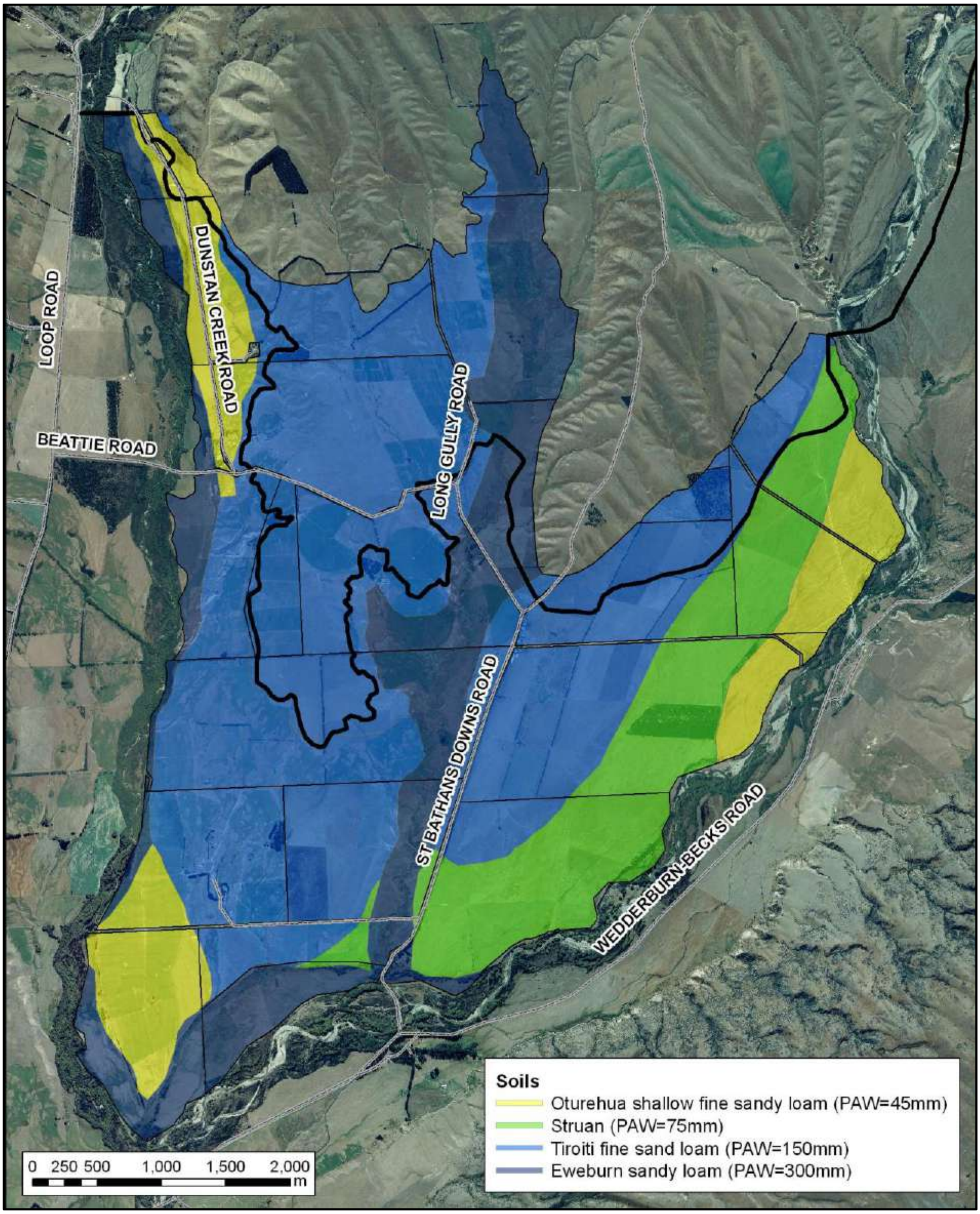
Possible Greenfields high race pump intake site

Appendix B: Downs supply area

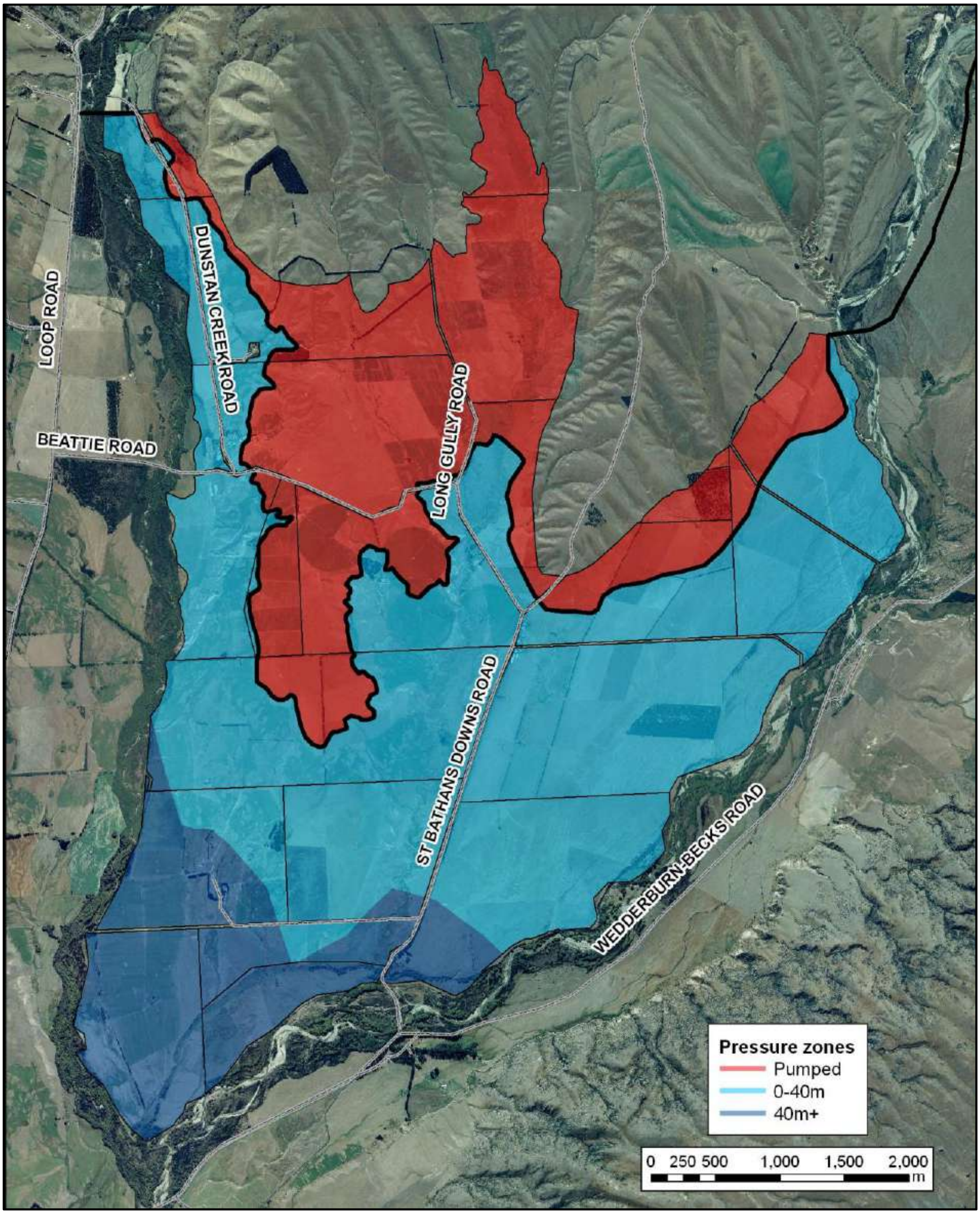


Downs land owners

Most farms border or a close to the High Race, minimising scheme secondary distribution costs.

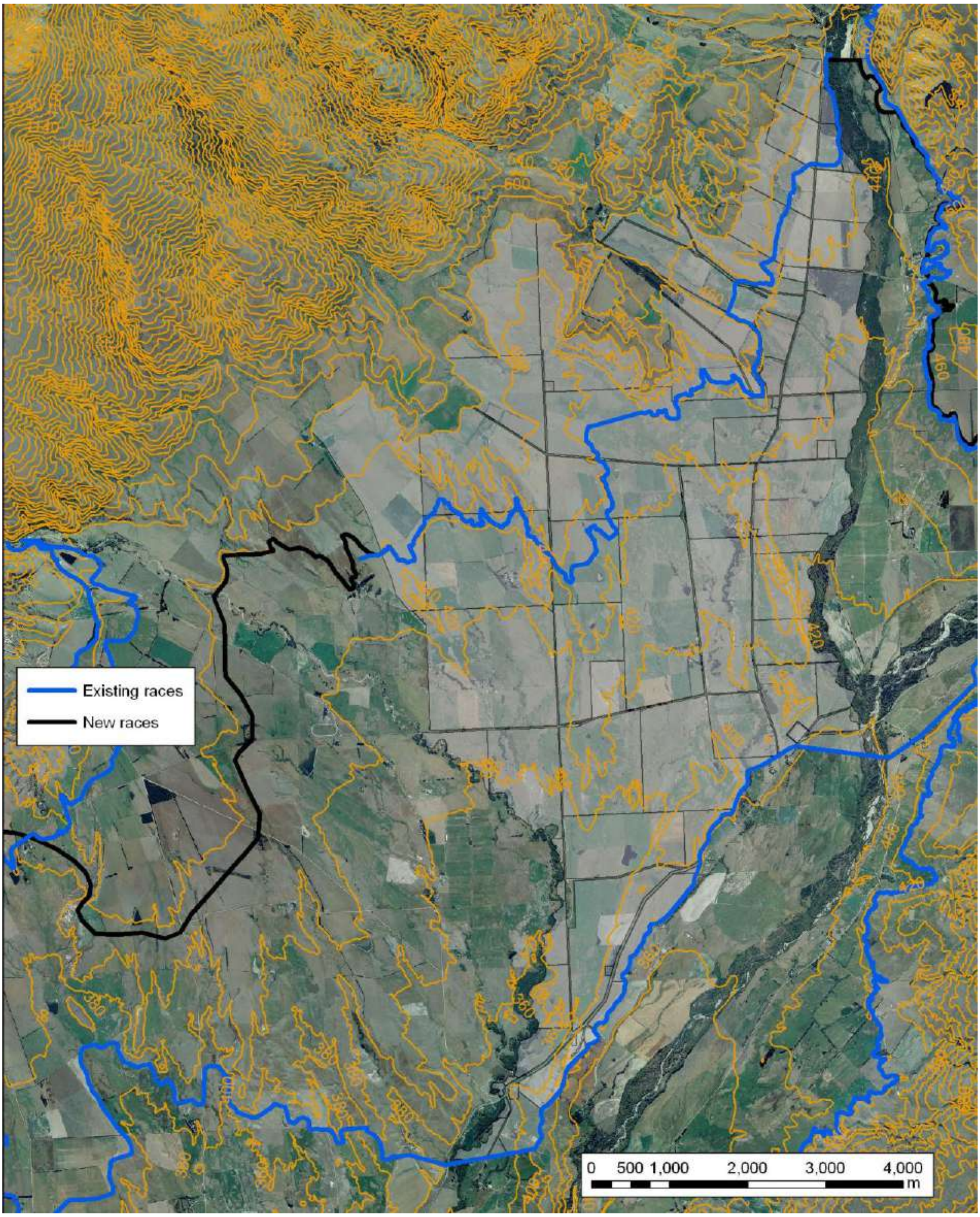


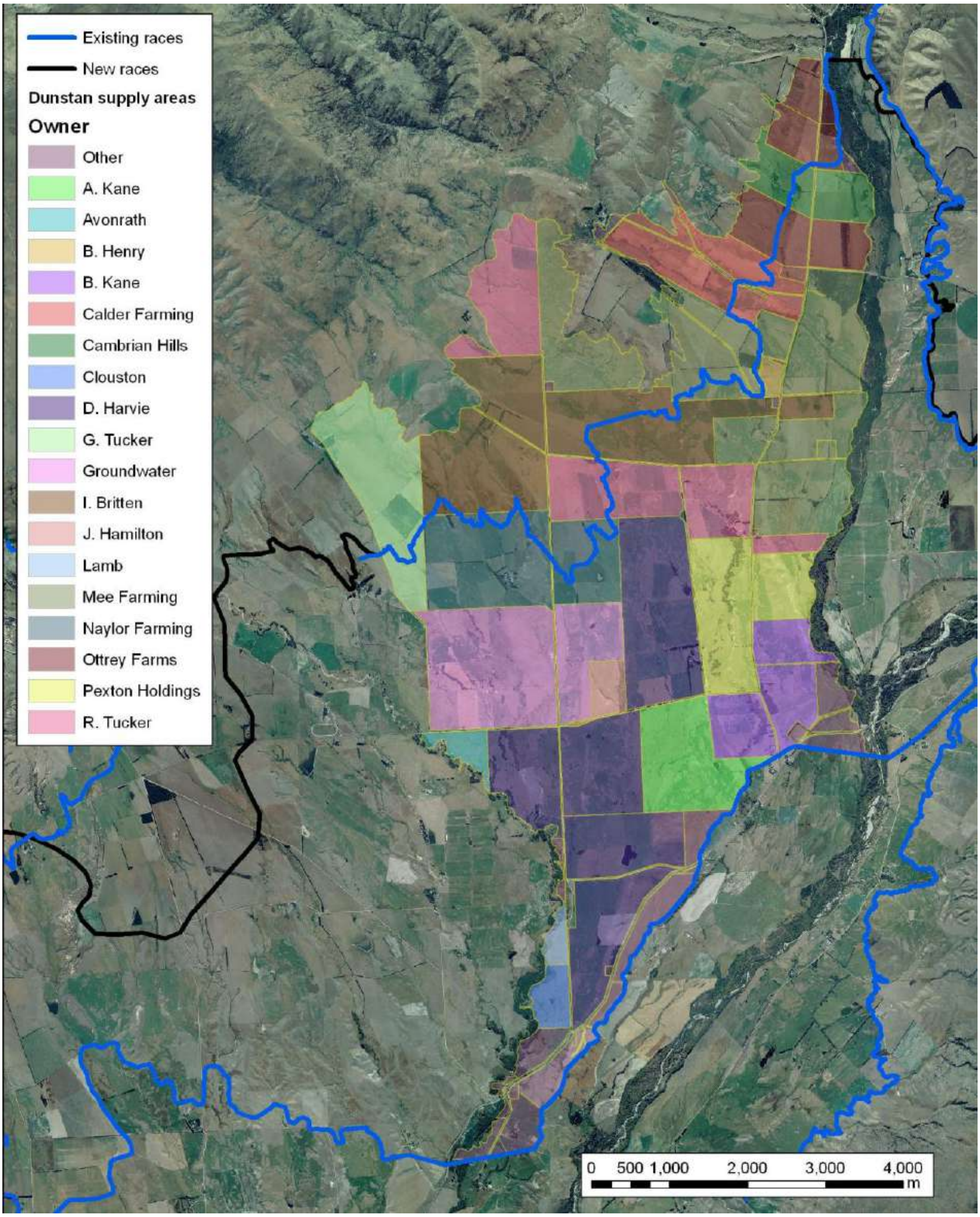
Downs soils (Source: Landcare Research 2000)



Downs pressure zones

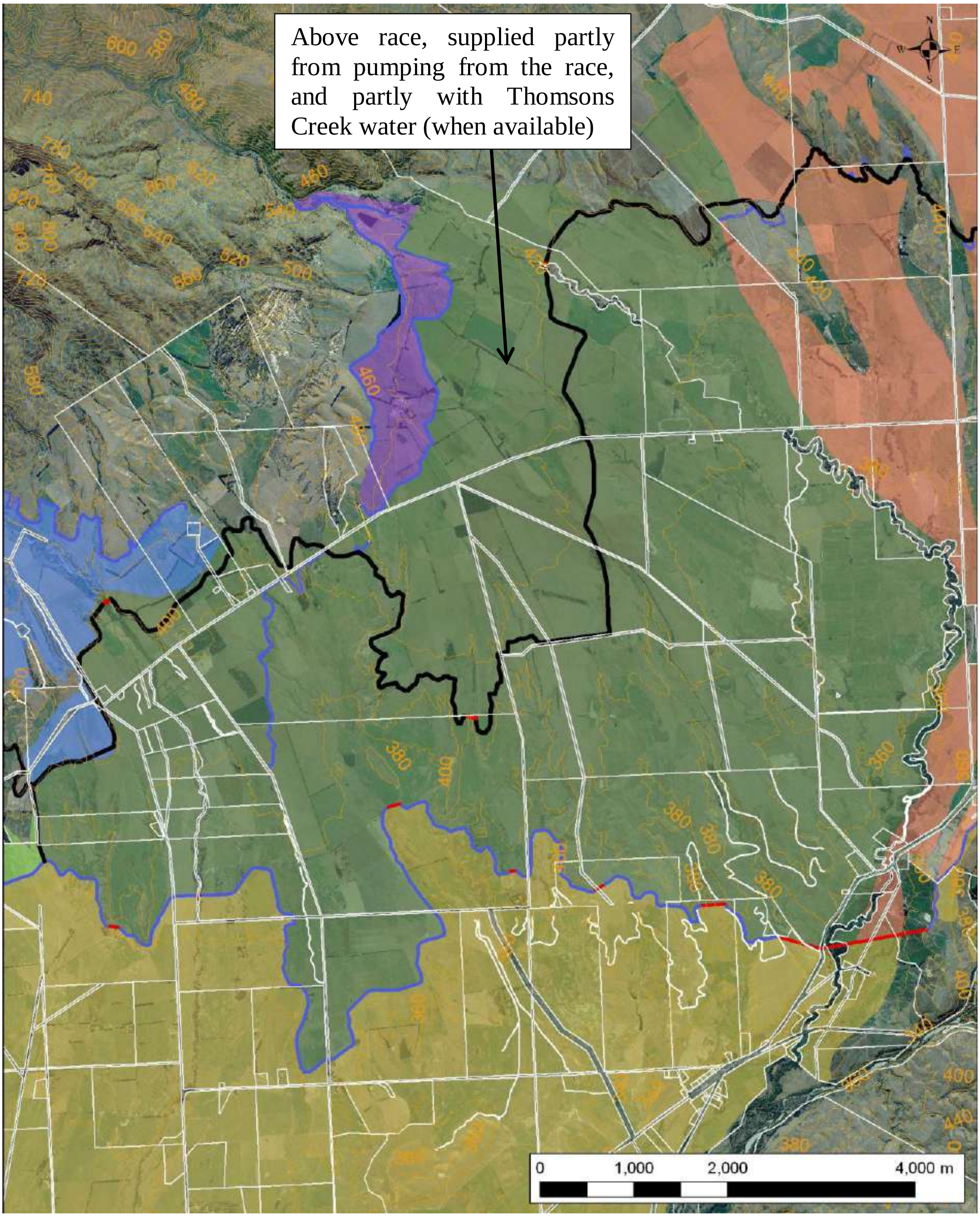
Appendix C: Dunstan supply area

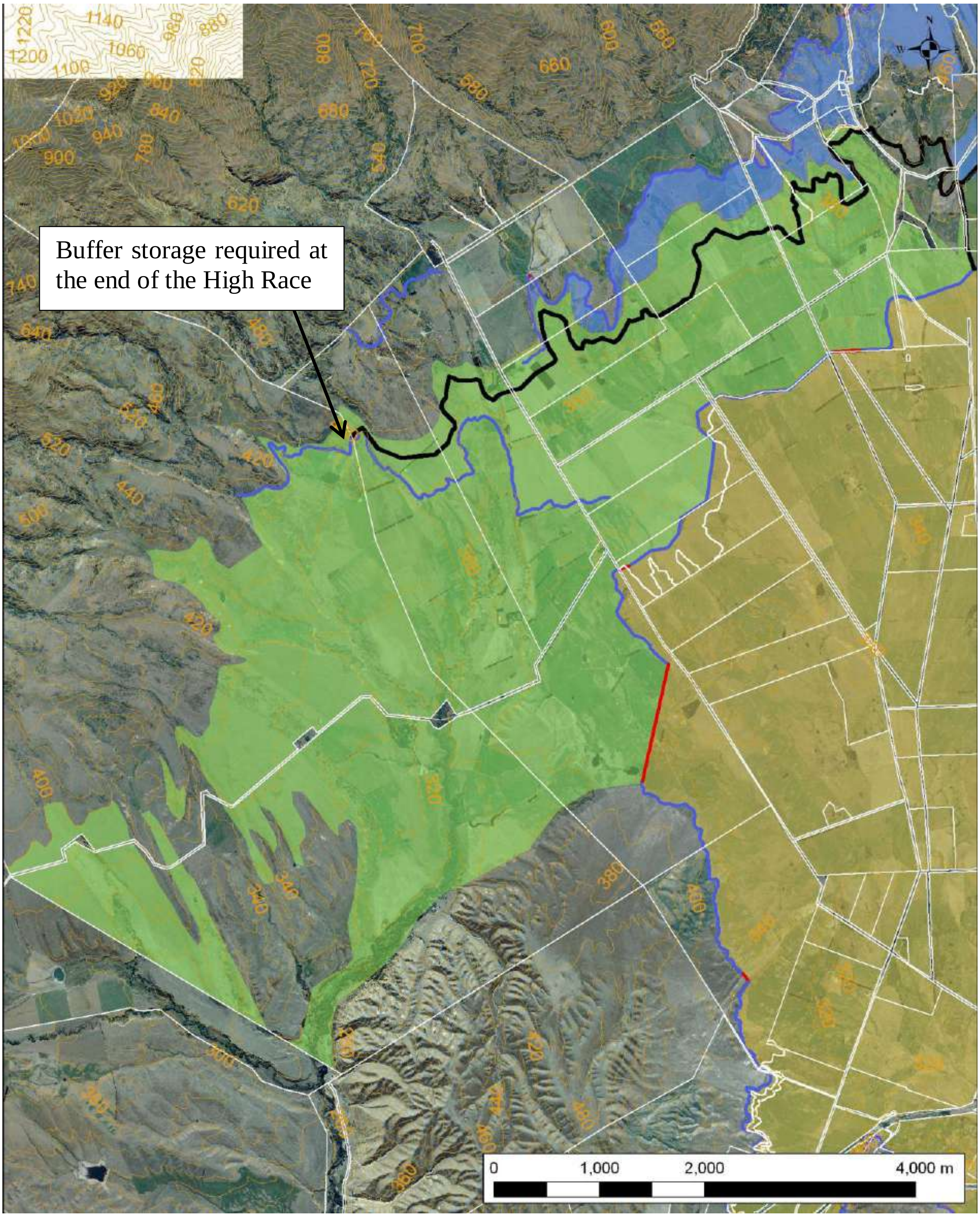




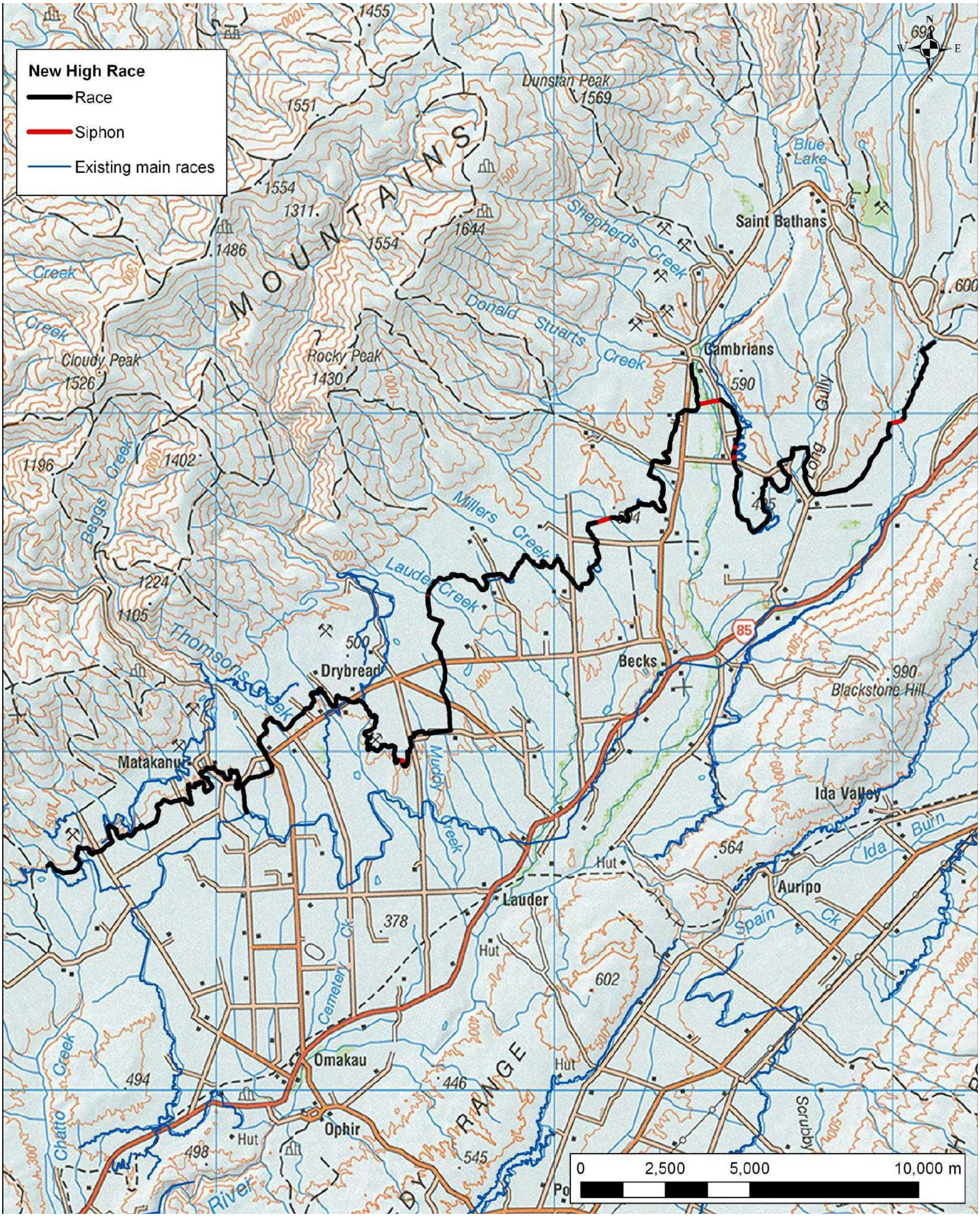
Farms adjacent to and above the Omakau Main Race could either pump from the Main Race, or could be supplied under pressure with a piped supply from the High Race. The Dunstan Area will generally receive partial pipe pressure. Full pressure may be able to be supplied to 30-50% of the area if the higher MWD race alignment was chosen.

Appendix D: Hamilton Road – Matakanui Station supply areas

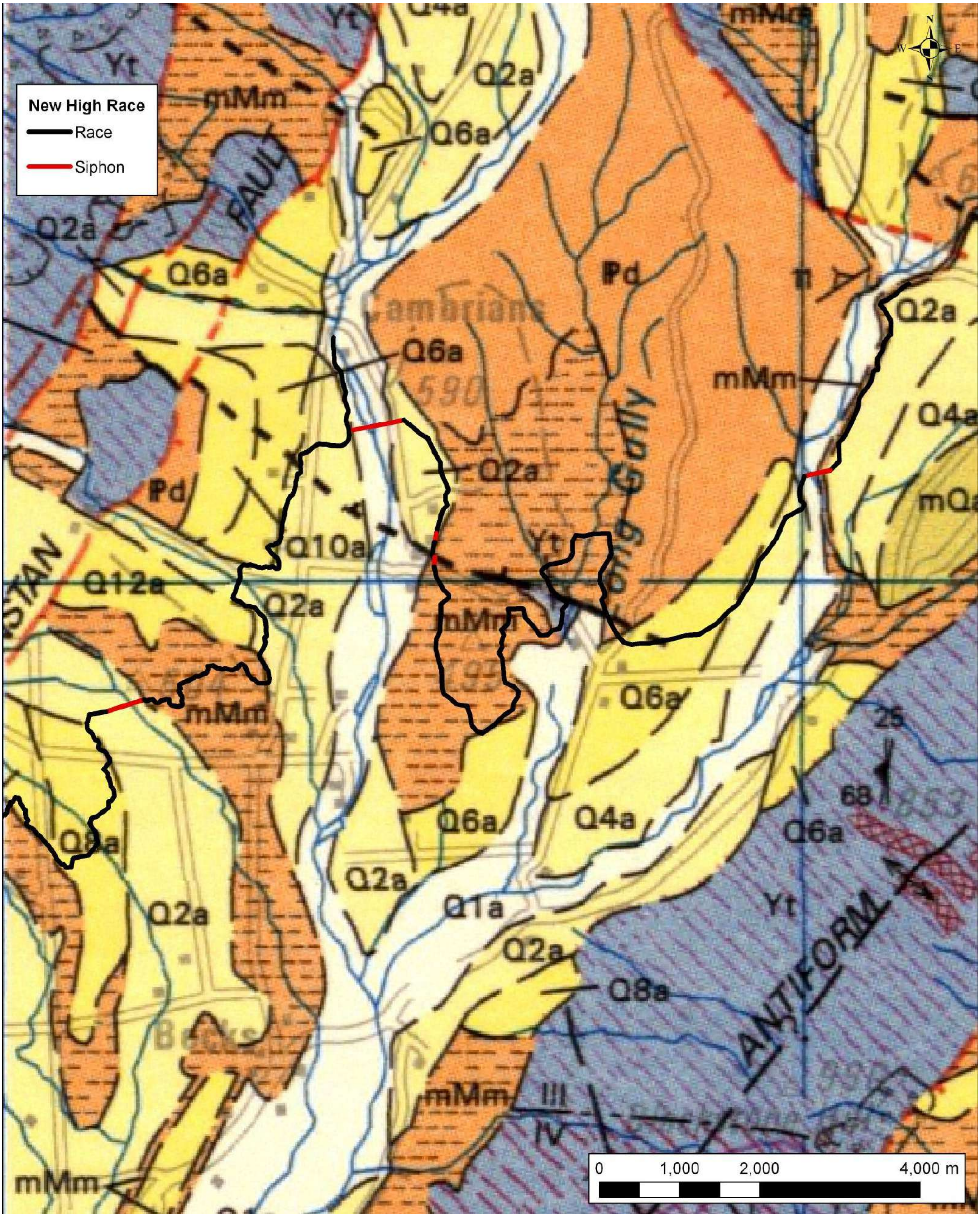



Buffer storage required at the end of the High Race
0
1,000
2,000
4,000 m

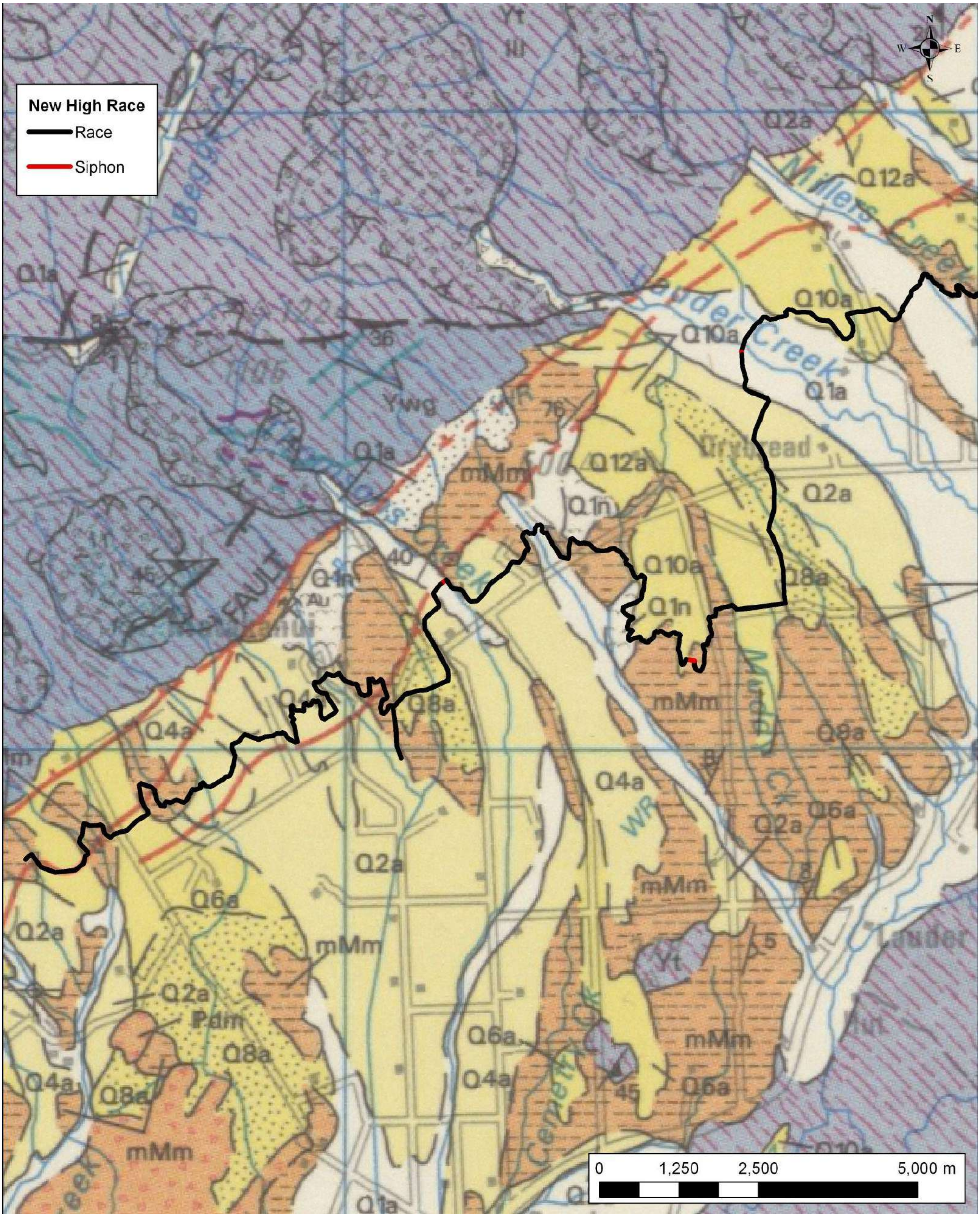
Appendix E: High Race



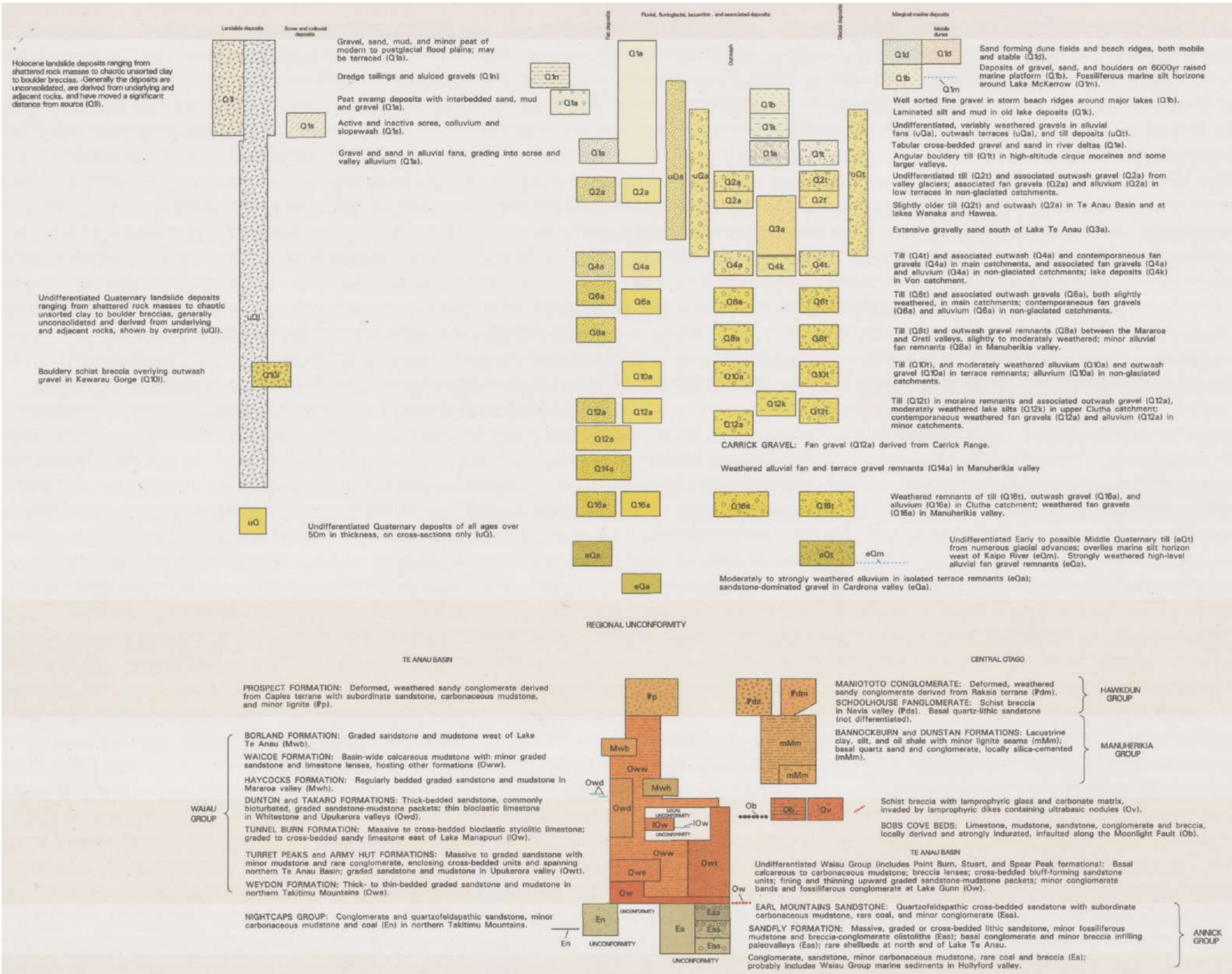
High Race overview



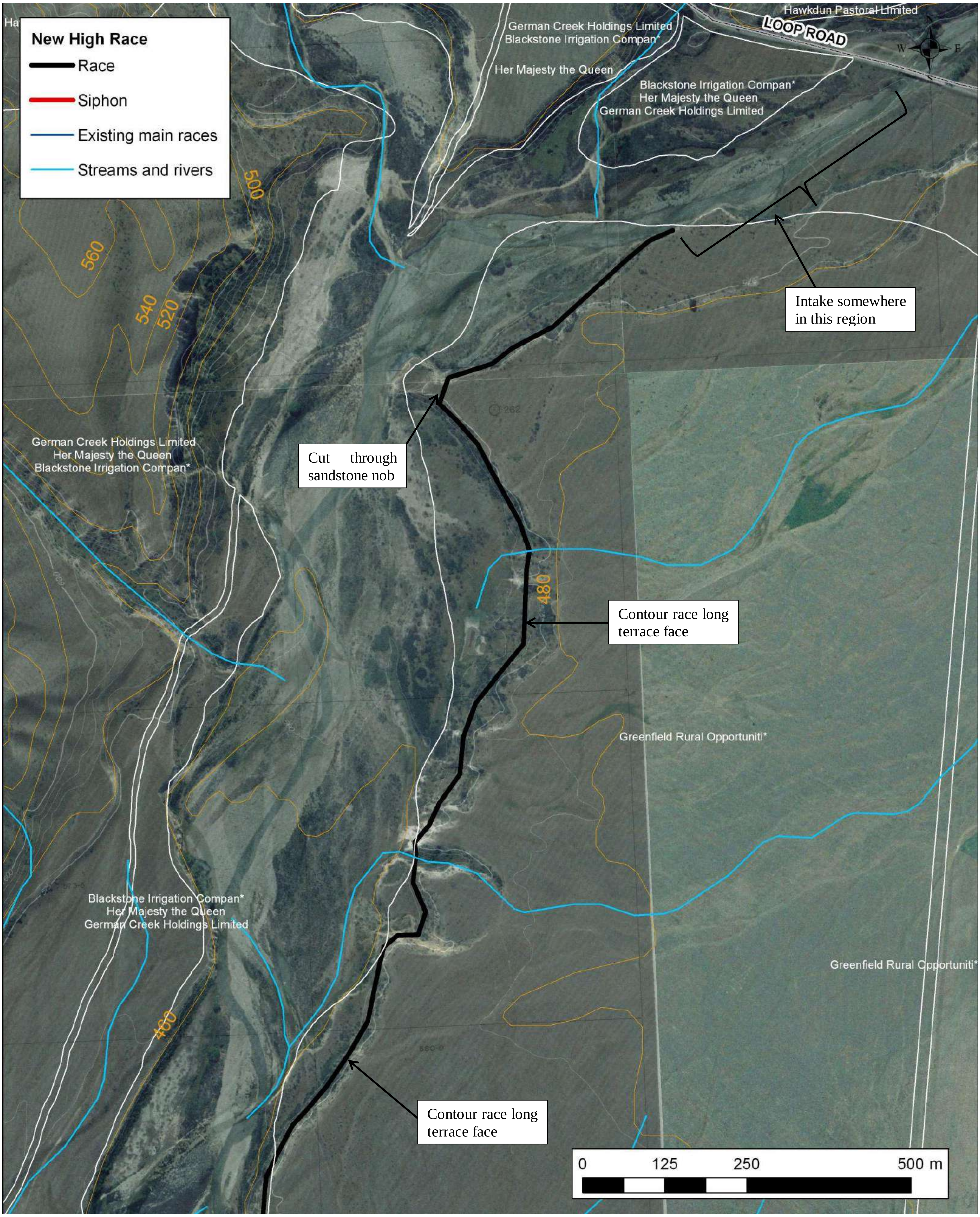
High Race geology – Figure 1



High Race geology – Figure 2

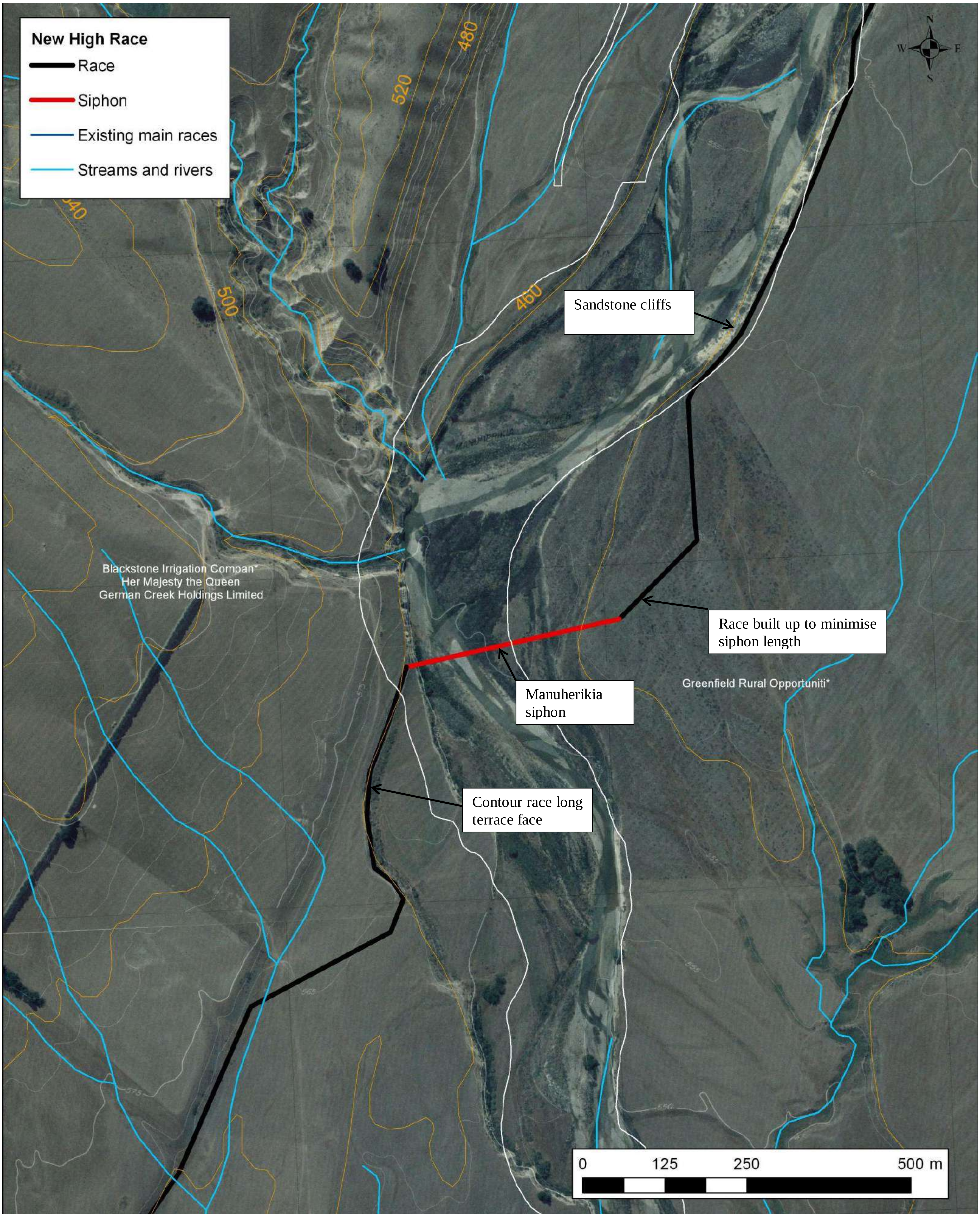


Holocene landslide deposits ranging from shattered rock masses to chaotic unsorted clay to boulder breccias. Generally the deposits are unconsolidated, are derived from underlying and adjacent rocks, and have moved a significant distance from source (Q1l).
Gravel, sand, mud, and minor peat of modern to postglacial flood plains; may be terraced (Q1a).
Dredge tailings and sluiced gravels (Q1n)
Peat swamp deposits with interbedded sand, mud and gravel (Q1a).
Active and inactive scree, colluvium and slopewash (Q1s).
Gravel and sand in alluvial fans, grading into scree and valley alluvium (Q1a).
Sand forming dune fields and beach ridges, both mobile and stable (Q1d).
Deposits of gravel, sand, and boulders on 6000yr raised marine platform (Q1b). Fossiliferous marine silt horizons around Lake McKerrow (Q1m).
Well sorted fine gravel in storm beach ridges around major lakes (Q1b).
Laminated silt and mud in old lake deposits (Q1k).
Undifferentiated, variably weathered gravels in alluvial fans (uQa), outwash terraces (uQa), and till deposits (uQt).
Tabular cross-bedded gravel and sand in river deltas (Q1a).
Angular bouldery till (Q1t) in high-altitude cirque moraines and some larger valleys.
Undifferentiated till (Q2t) and associated outwash gravel (Q2a) from valley glaciers; associated fan gravels (Q2a) and alluvium (Q2a) in low terraces in non-glaciated catchments.
Slightly older till (Q2t) and outwash (Q2a) in Te Anau Basin and at lakes Wanaka and Hawea.
Extensive gravelly sand south of Lake Te Anau (Q3a).
Till (Q4t) and associated outwash (Q4a) and contemporaneous fan gravels (Q4a) in main catchments, and associated fan gravels (Q4a) and alluvium (Q4a) in non-glaciated catchments; lake deposits (Q4k) in Von catchment.
Undifferentiated Quaternary landslide deposits ranging from shattered rock masses to chaotic unsorted clay to boulder breccias, generally unconsolidated and derived from underlying and adjacent rocks, shown by overprint (uQl).
Till (Q6t) and associated outwash gravels (Q6a), both slightly weathered, in main catchments; contemporaneous fan gravels (Q6a) and alluvium (Q6a) in non-glaciated catchments.
Till (Q8t) and outwash gravel remnants (Q8a) between the Mararoa and Oreti valleys, slightly to moderately weathered; minor alluvial fan remnants (Q8a) in Manuherikia valley.
Bouldery schist breccia overlying outwash gravel in Kawarau Gorge (Q10l).
Till (Q10t), and moderately weathered alluvium (Q10a) and outwash gravel (Q10a) in terrace remnants; alluvium (Q10a) in non-glaciated catchments.
Till (Q12t) in moraine remnants and associated outwash gravel (Q12a), moderately weathered lake silts (Q12k) in upper Clutha catchment; contemporaneous weathered fan gravels (Q12a) and alluvium (Q12a) in minor catchments.
CARRICK GRAVEL: Fan gravel (Q12a) derived from Carrick Range.
Weathered alluvial fan and terrace gravel remnants (Q14a) in Manuherikia valley
Weathered remnants of till (Q16t), outwash gravel (Q16a), and alluvium (Q16a) in Clutha catchment; weathered fan gravels (Q16a) in Manuherikia valley.
Undifferentiated Quaternary deposits of all ages over 50m in thickness, on cross-sections only (uQ).
Undifferentiated Early to possible Middle Quaternary till (eQt) from numerous glacial advances; overlies marine silt horizon west of Kaipo River (eQm). Strongly weathered high-level alluvial fan gravel remnants (eQa).
Moderately to strongly weathered alluvium in isolated terrace remnants (eQa); sandstone-dominated gravel in Cardrona valley (eQa).
REGIONAL UNCONFORMITY
TE ANAU BASIN
PROSPECT FORMATION: Deformed, weathered sandy conglomerate derived from Caples terrane with subordinate sandstone, carbonaceous mudstone, and minor lignite (Pp).
WAIAU GROUP
BORLAND FORMATION: Graded sandstone and mudstone west of Lake Te Anau (Mwb).
WAICOE FORMATION: Basin-wide calcareous mudstone with minor graded sandstone and limestone lenses, hosting other formations (Oww).
HAYCOCKS FORMATION: Regularly bedded graded sandstone and mudstone in Mararoa valley (Mwh).
DUNTON and TAKARO FORMATIONS: Thick-bedded sandstone, commonly bioturbated, graded sandstone-mudstone packets; thin bioclastic limestone in Whitestone and Upukerora valleys (Owd).
TUNNEL BURN FORMATION: Massive to cross-bedded bioclastic stylolitic limestone; graded to cross-bedded sandy limestone east of Lake Manapouri (lOw).
TURRET PEAKS and ARMY HUT FORMATIONS: Massive to graded sandstone with minor mudstone and rare conglomerate, enclosing cross-bedded units and spanning northern Te Anau Basin; graded sandstone and mudstone in Upukerora valley (Owt).
WEYDON FORMATION: Thick- to thin-bedded graded sandstone and mudstone in northern Takitimu Mountains (Owe).
NIGHTCAPS GROUP: Conglomerate and quartzofeldspathic sandstone, minor carbonaceous mudstone and coal (En) in northern Takitimu Mountains.
UNCONFORMITY
LOCAL UNCONFORMITY
CENTRAL OTAGO
MANIOTOTO CONGLOMERATE: Deformed, weathered sandy conglomerate derived from Rakaia terrane (Pdm).
SCHOOLHOUSE FANGLOMERATE: Schist breccia in Nevis valley (Pds). Basal quartz-lithic sandstone (not differentiated).
HAWKDUN GROUP
BANNOCKBURN and DUNSTAN FORMATIONS: Lacustrine clay, silt, and oil shale with minor lignite seams (mMm); basal quartz sand and conglomerate, locally silica-cemented (mMm).
MANUHERIKIA GROUP
Schist breccia with lamprophyric glass and carbonate matrix, invaded by lamprophyric dikes containing ultrabasic nodules (Ov).
BOBS COVE BEDS: Limestone, mudstone, sandstone, conglomerate and breccia, locally derived and strongly indurated, infaulted along the Moonlight Fault (Ob).
TE ANAU BASIN
Undifferentiated Waiau Group (includes Point Burn, Stuart, and Spear Peak formations): Basal calcareous to carbonaceous mudstone; breccia lenses; cross-bedded bluff-forming sandstone units; fining and thinning upward graded sandstone-mudstone packets; minor conglomerate bands and fossiliferous conglomerate at Lake Gunn (Ow).
EARL MOUNTAINS SANDSTONE: Quartzofeldspathic cross-bedded sandstone with subordinate carbonaceous mudstone, rare coal, and minor conglomerate (Eaa).
SANDFLY FORMATION: Massive, graded or cross-bedded lithic sandstone, minor fossiliferous mudstone and breccia-conglomerate olistoliths (Eas); basal conglomerate and minor breccia infilling paleovalleys (Eas); rare shellbeds at north end of Lake Te Anau.
Conglomerate, sandstone, minor carbonaceous mudstone, rare coal and breccia (Ea); probably includes Waiau Group marine sediments in Hollyford valley.
ANNICK GROUP



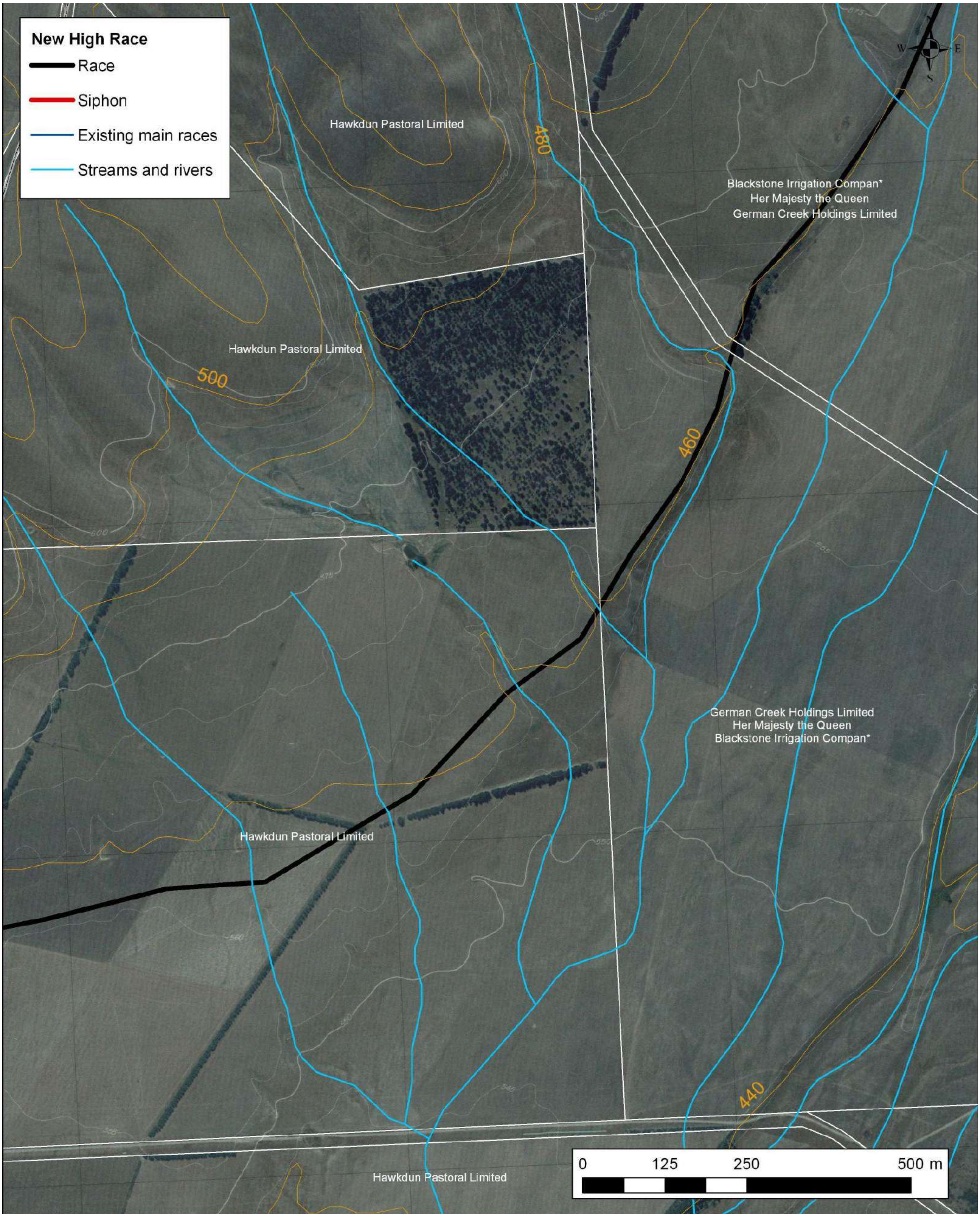
High Race detail – Figure 1

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used. By example, the 575 m contour corresponds to 475 m above mean sea level. Spot heights are recorded to 0.5 m.



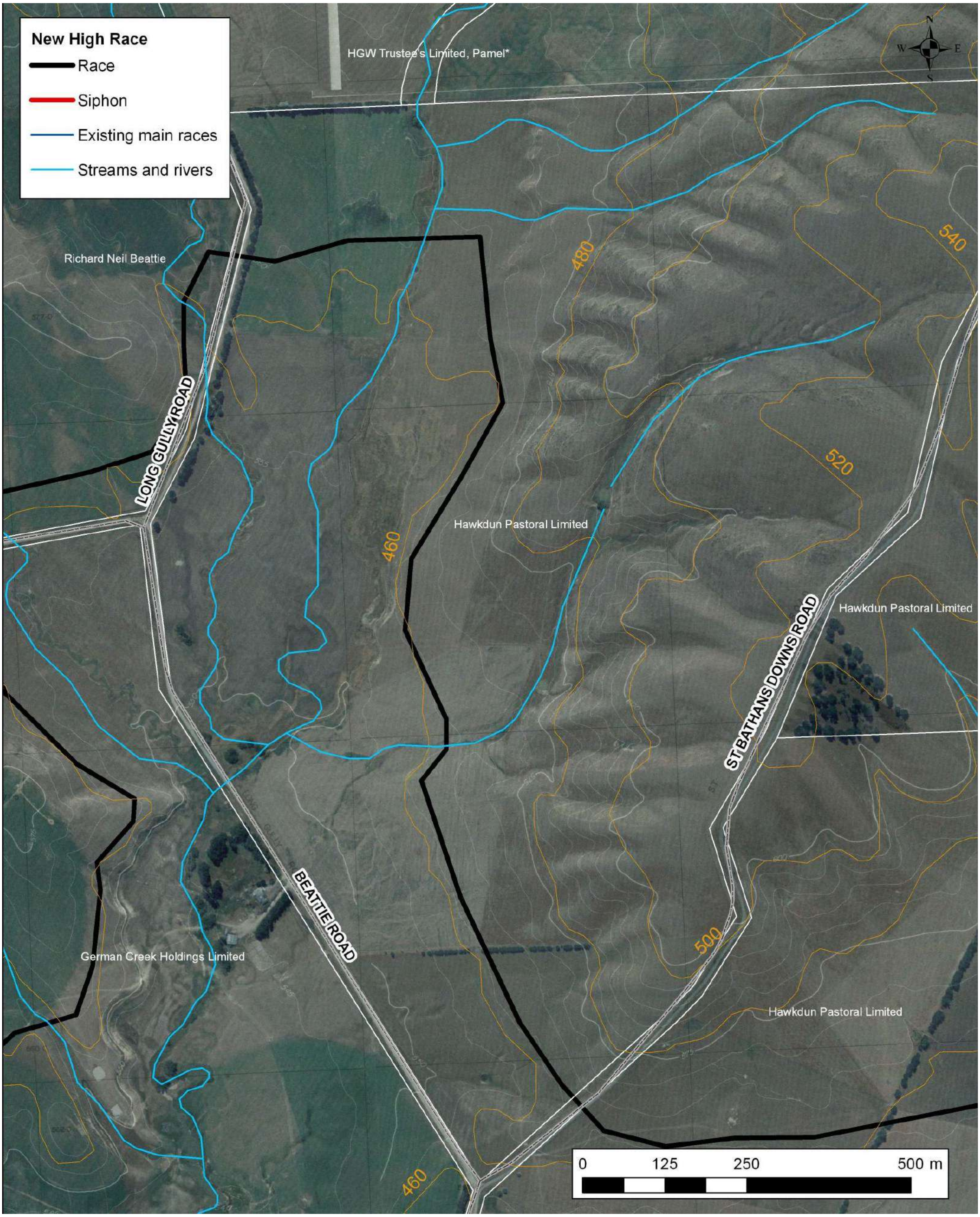
High Race detail – Figure 2

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



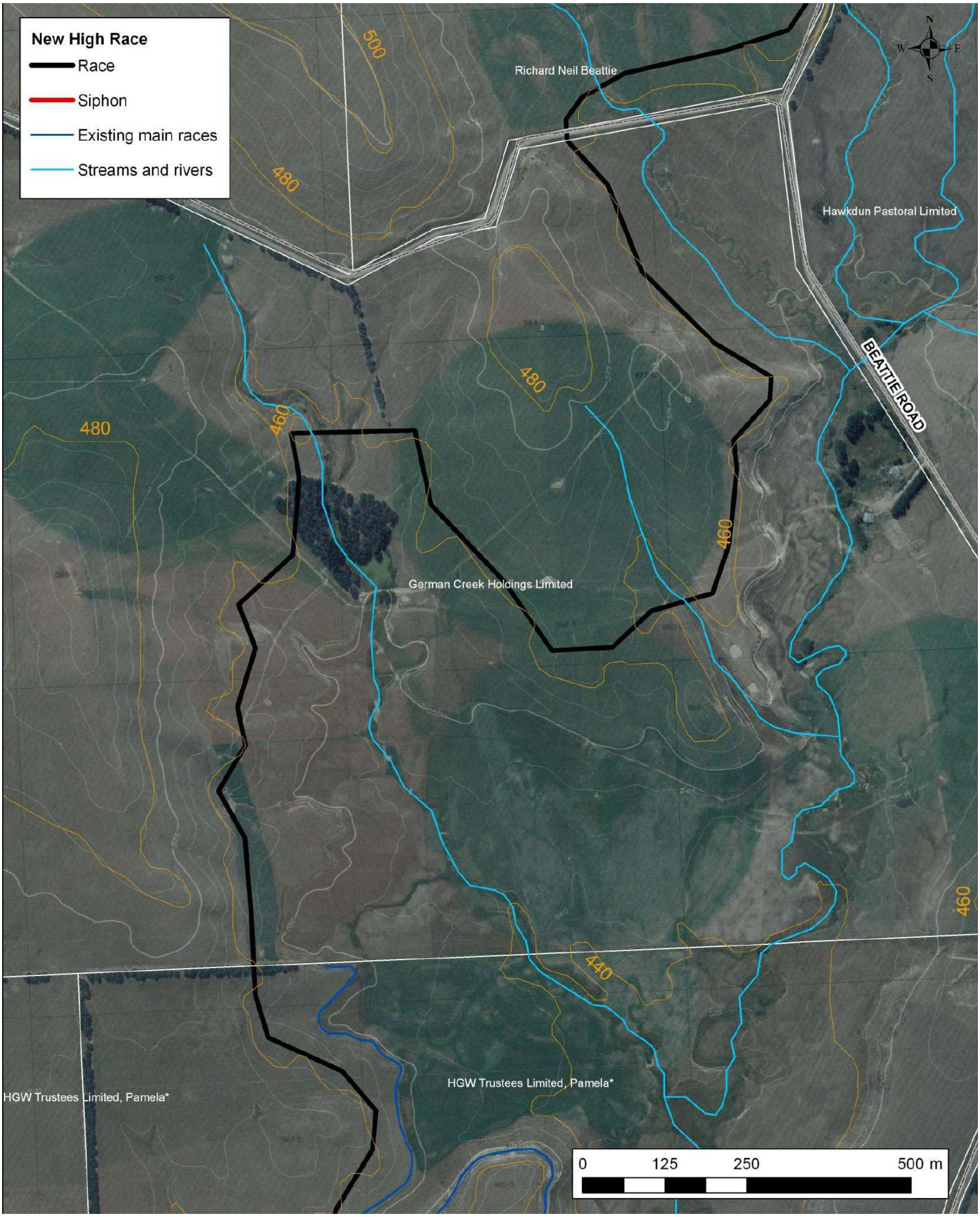
High Race detail – Figure 3

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



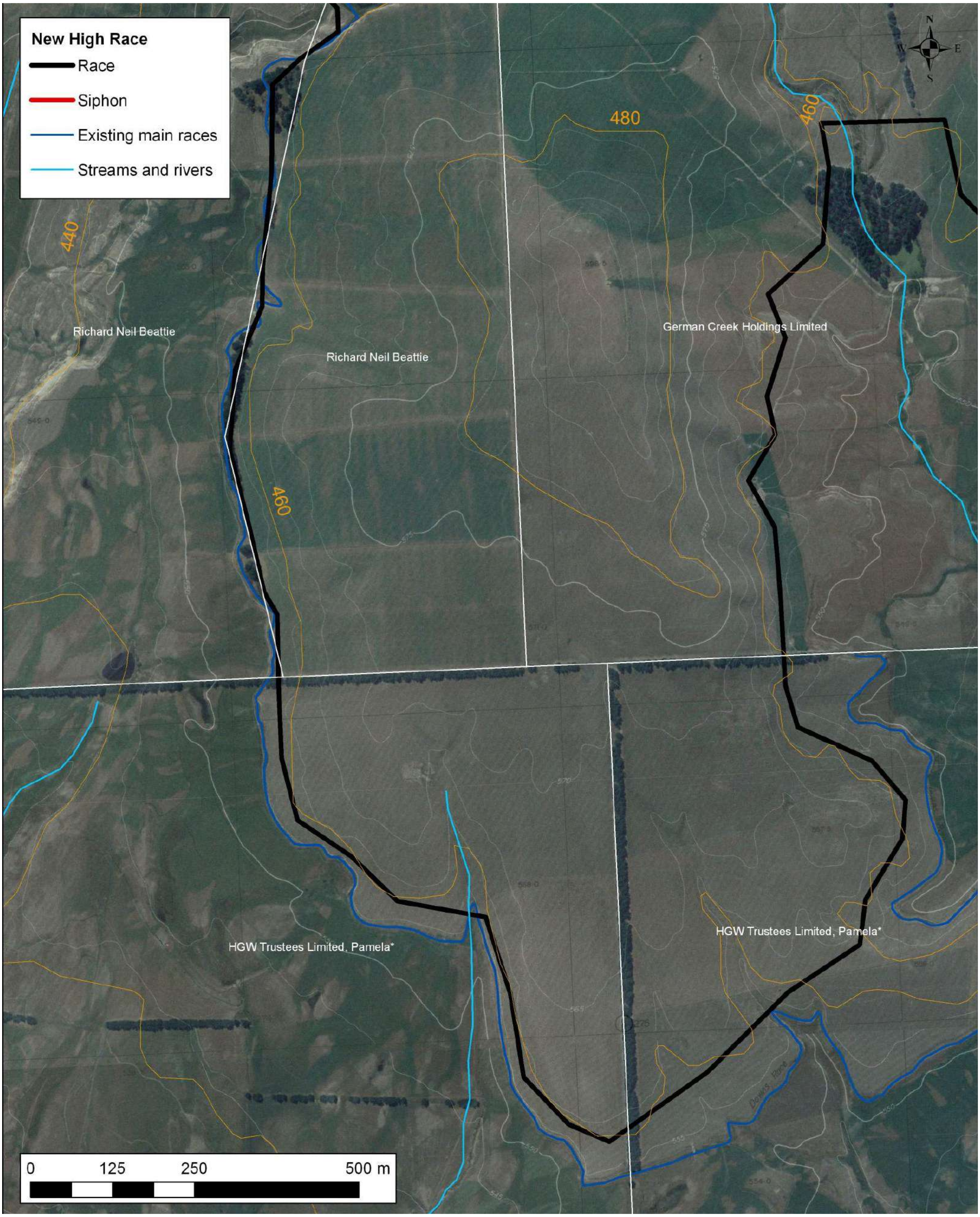
High Race detail – Figure 4

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



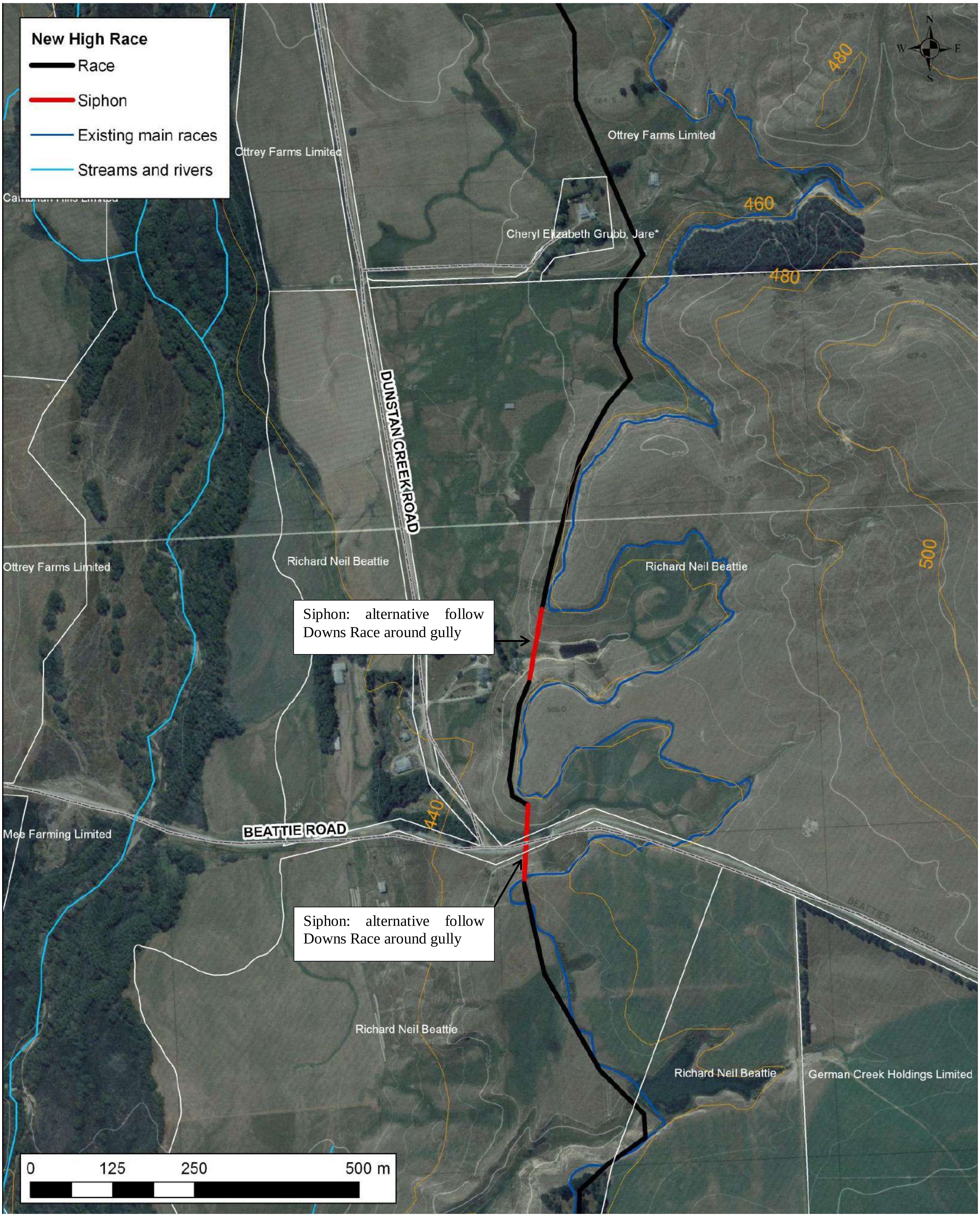
High Race detail – Figure 5

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



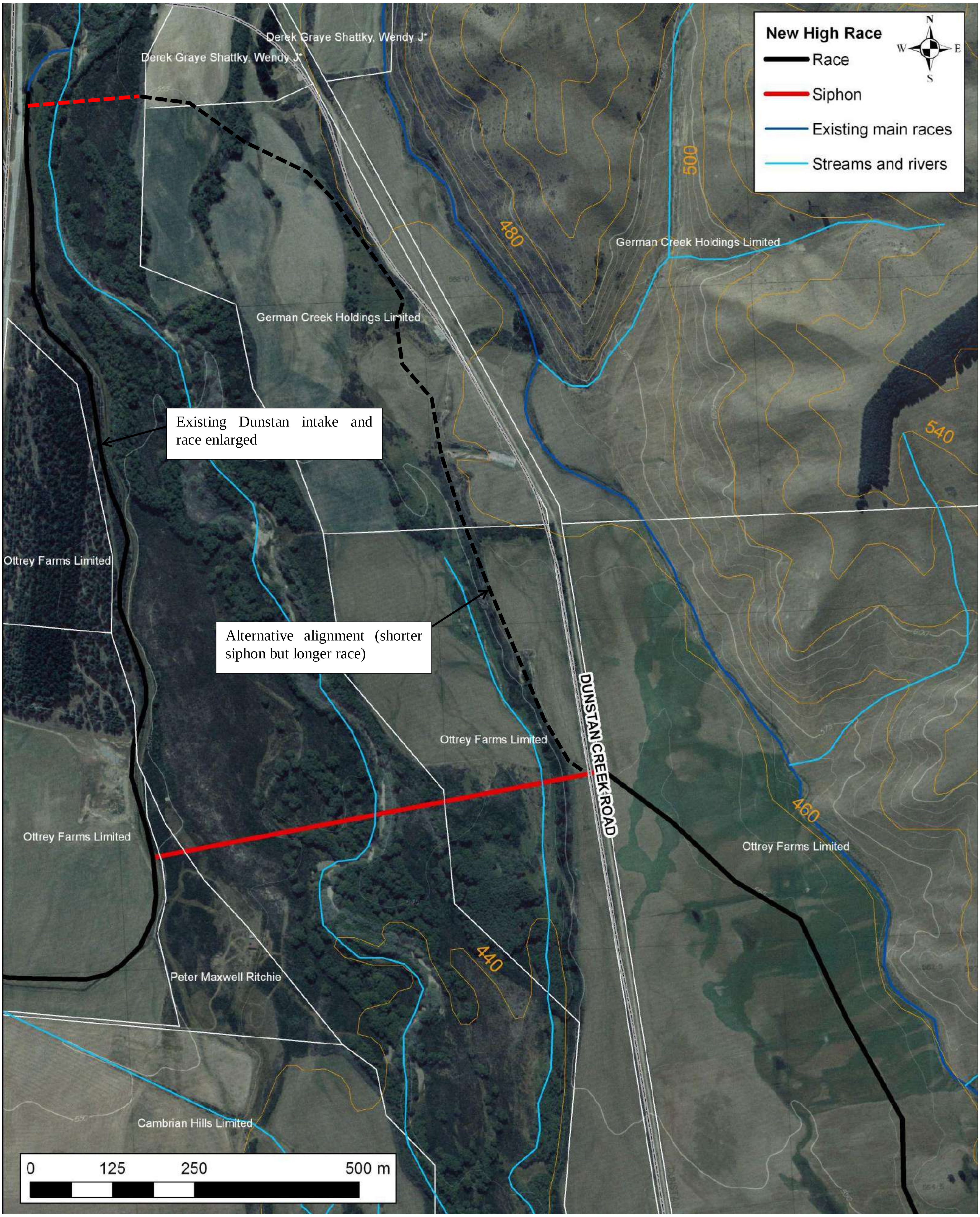
High Race detail – Figure 6

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



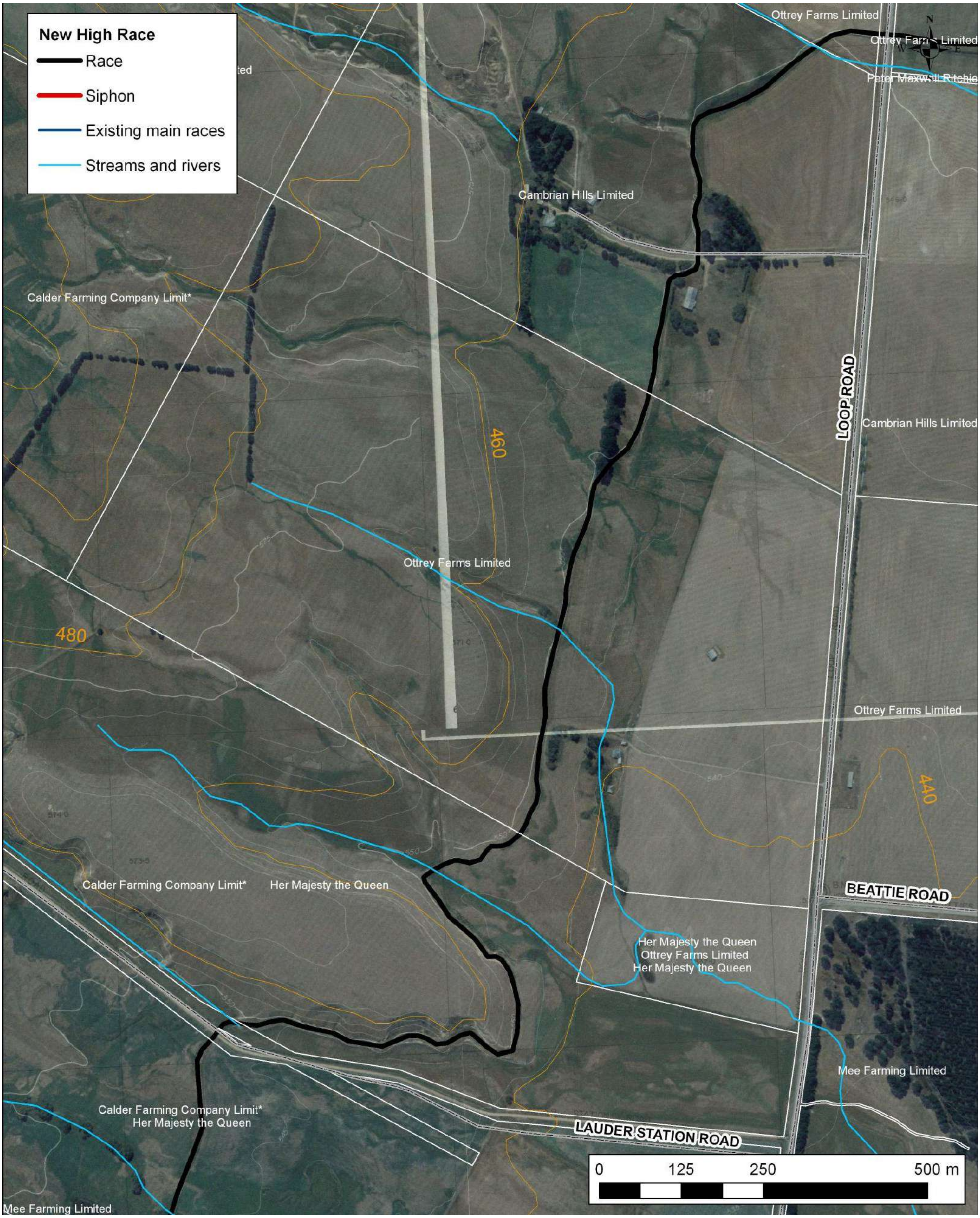
High Race detail – Figure 7

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



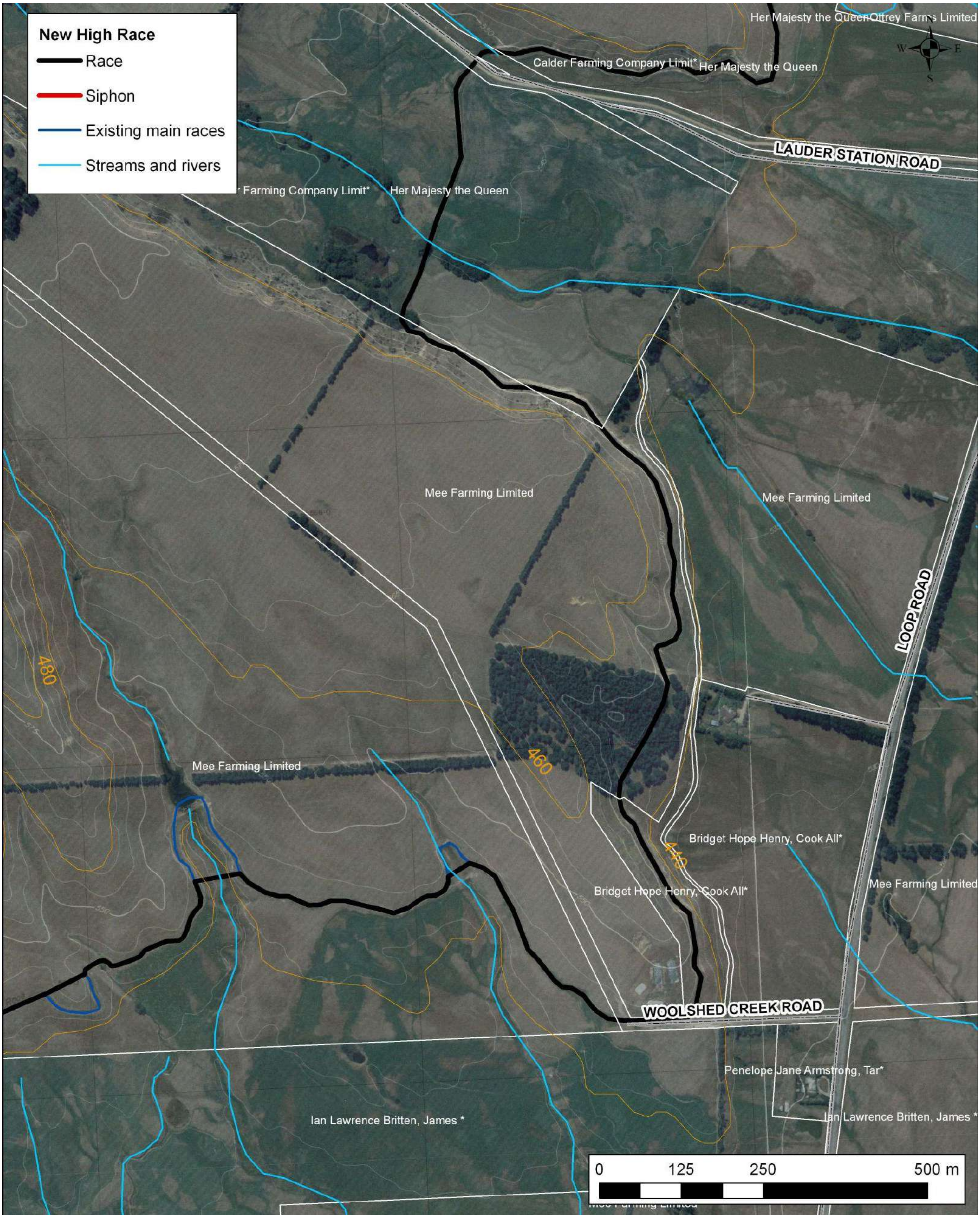
High Race detail – Figure 8

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



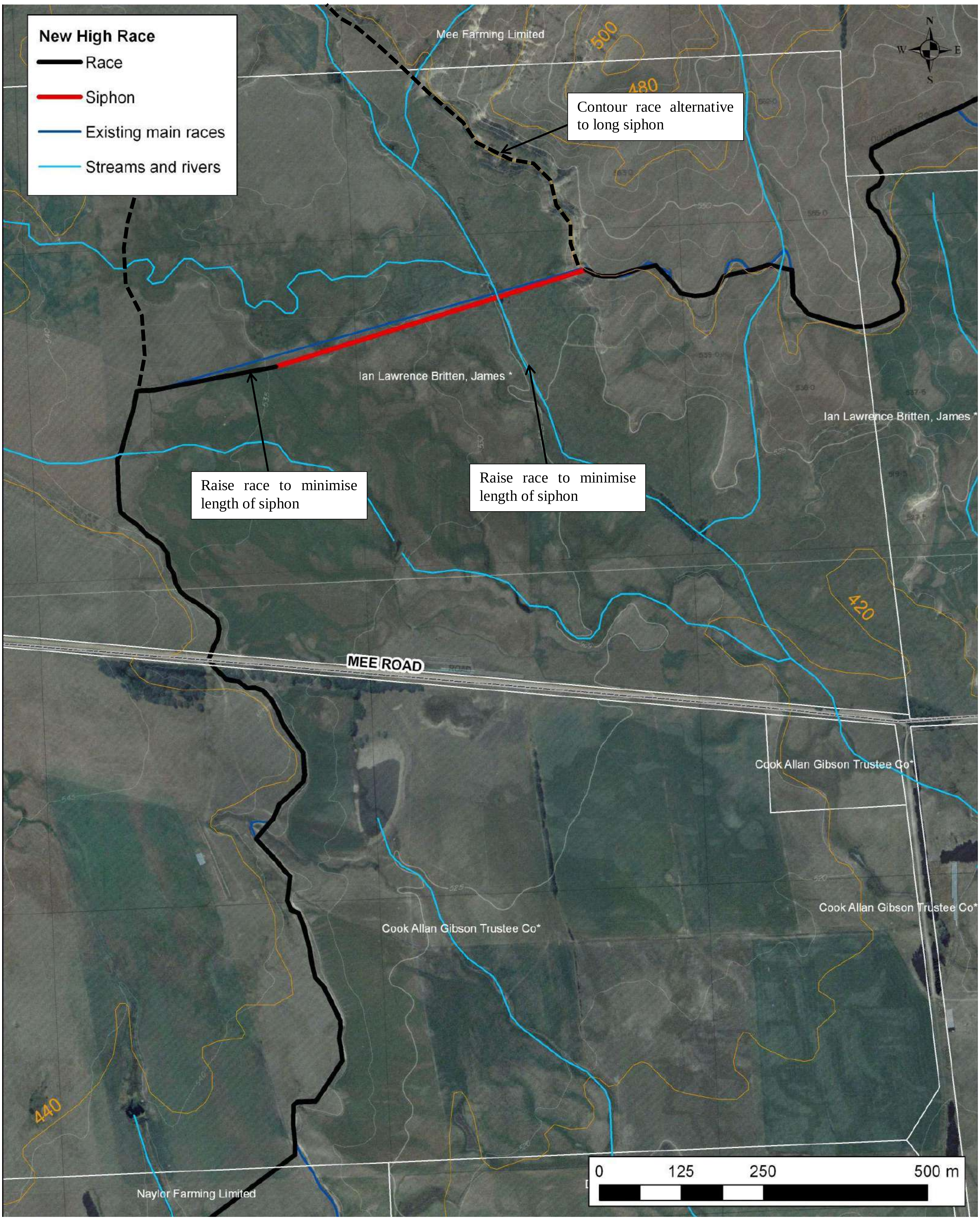
High Race detail – Figure 9

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



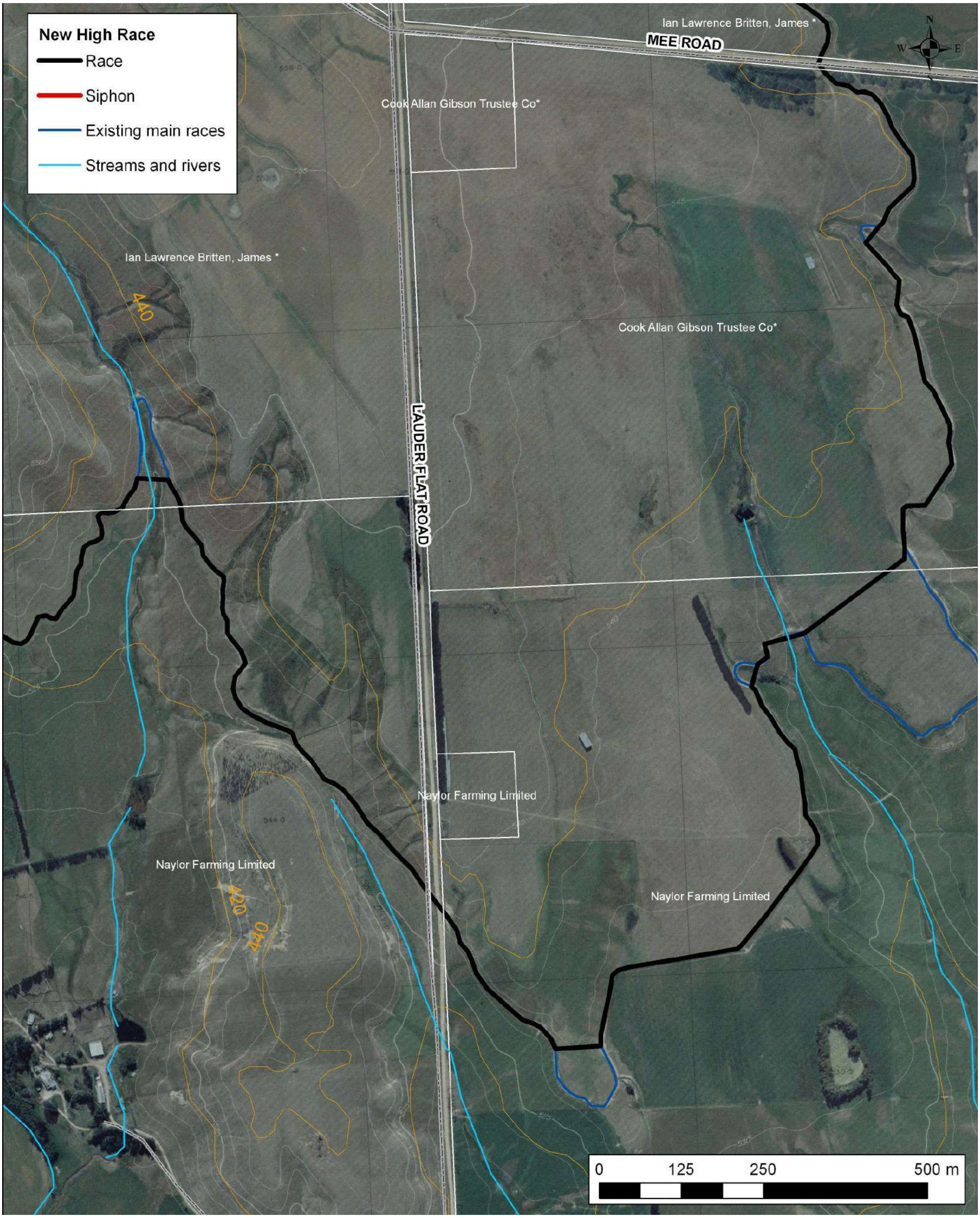
High Race detail – Figure 10

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



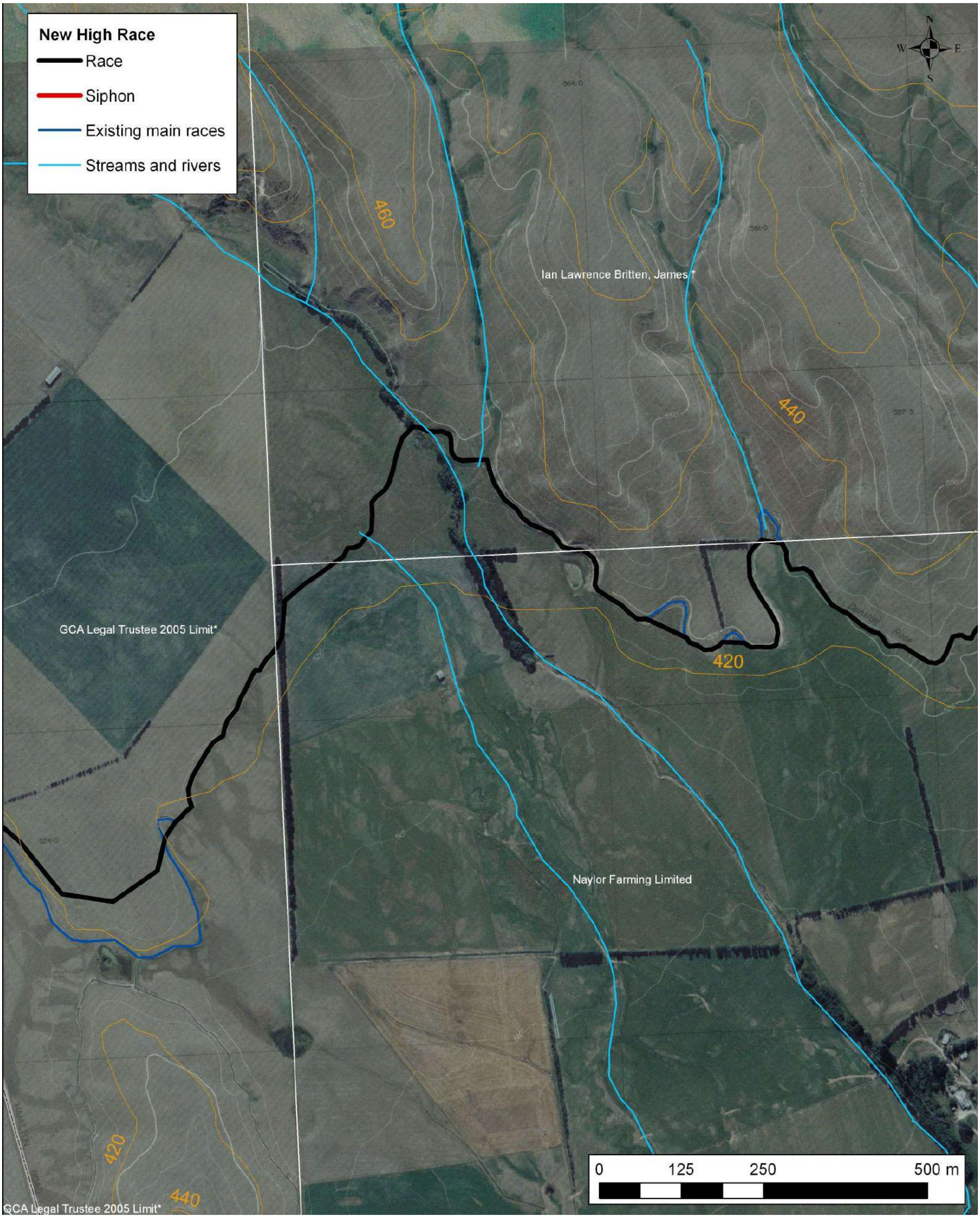
High Race detail – Figure 11

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



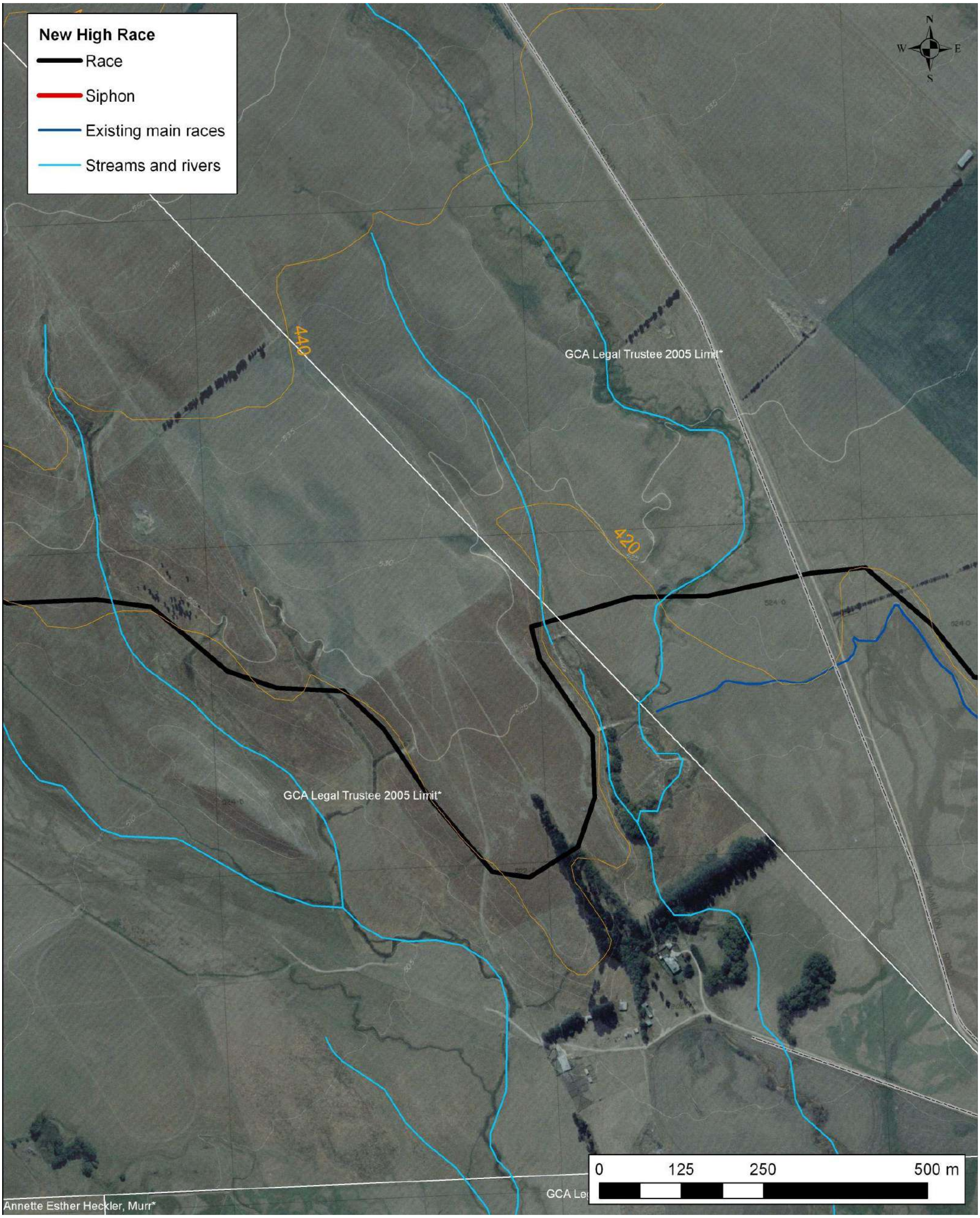
High Race detail – Figure 12

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



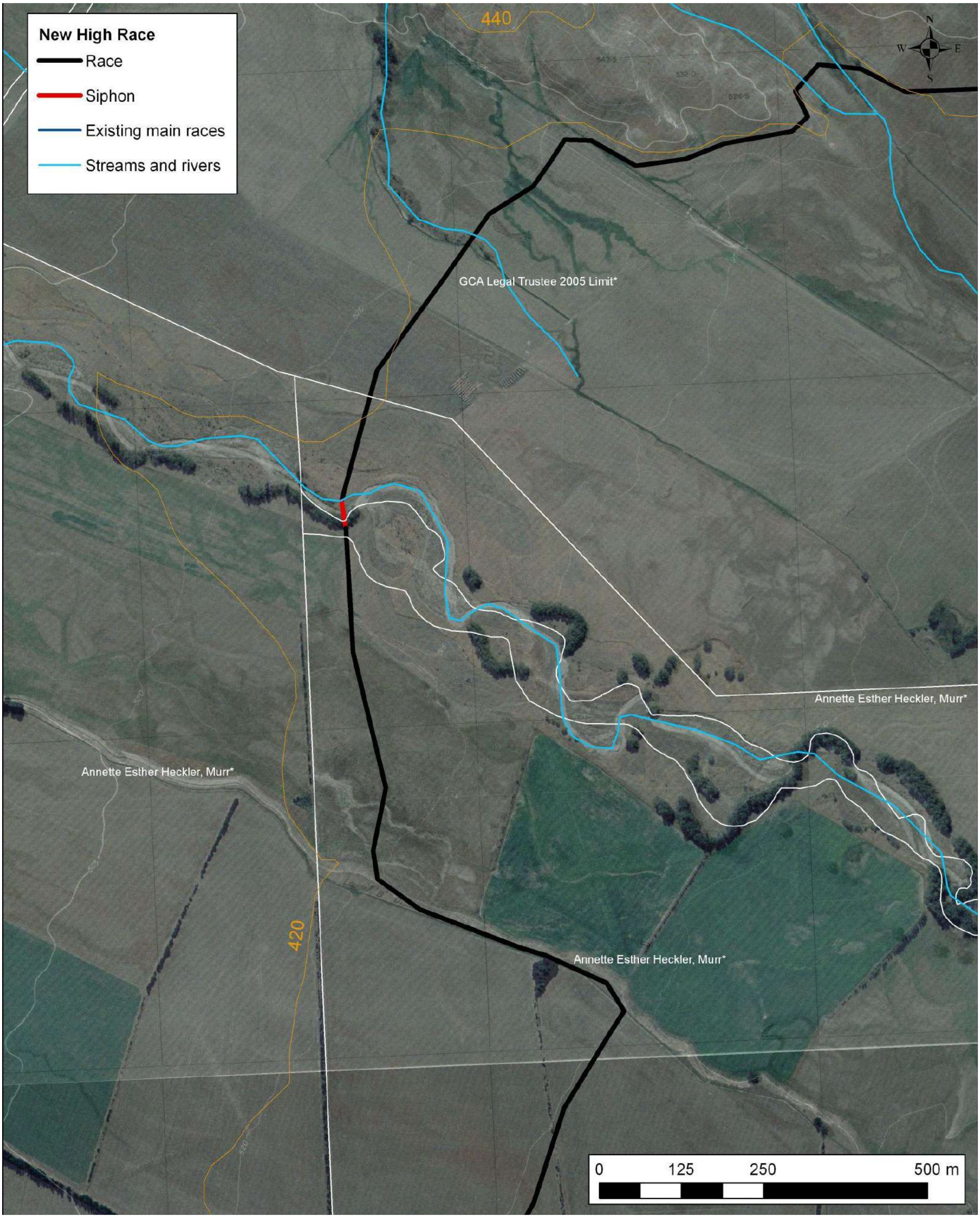
High Race detail – Figure 13

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



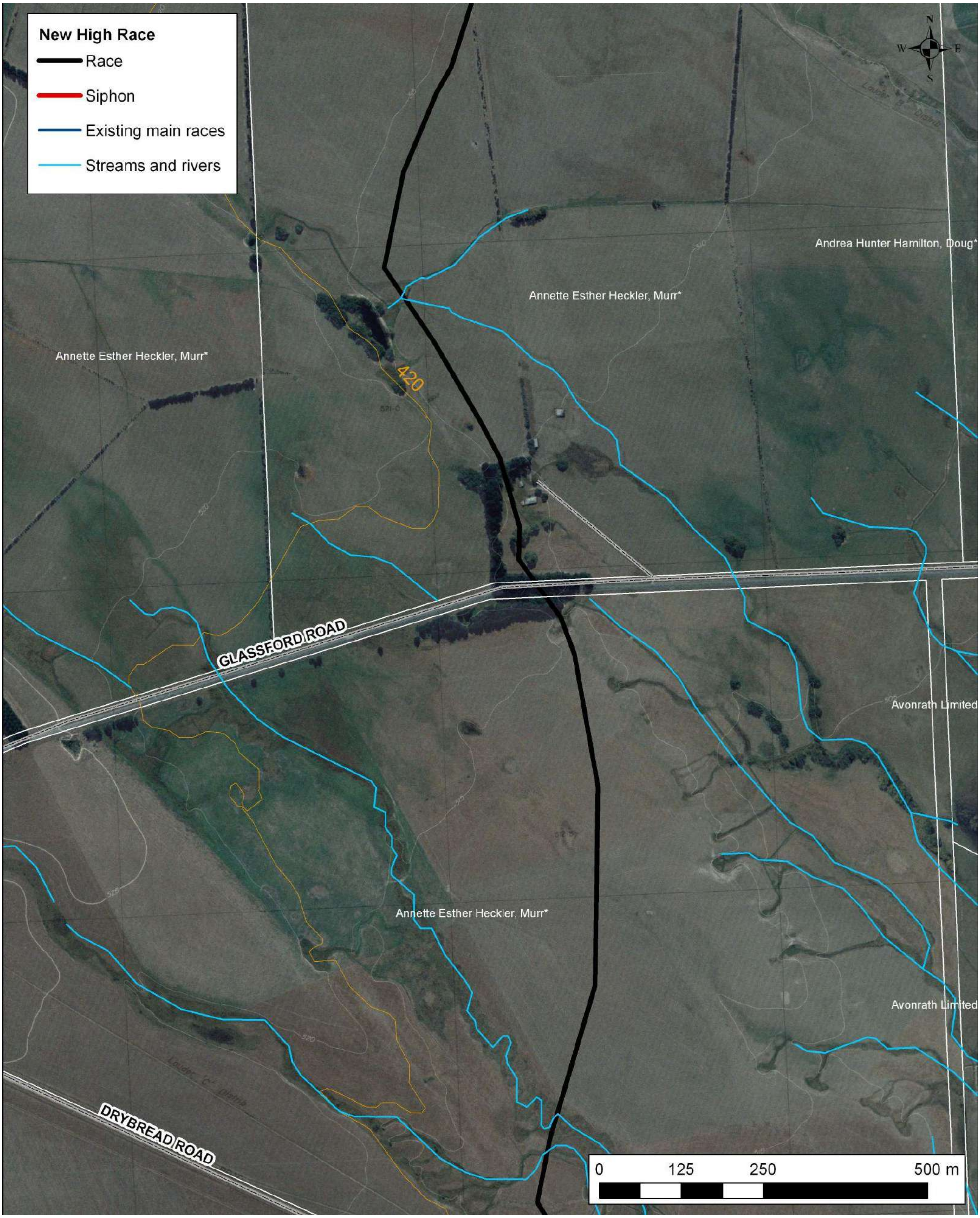
High Race detail – Figure 14

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



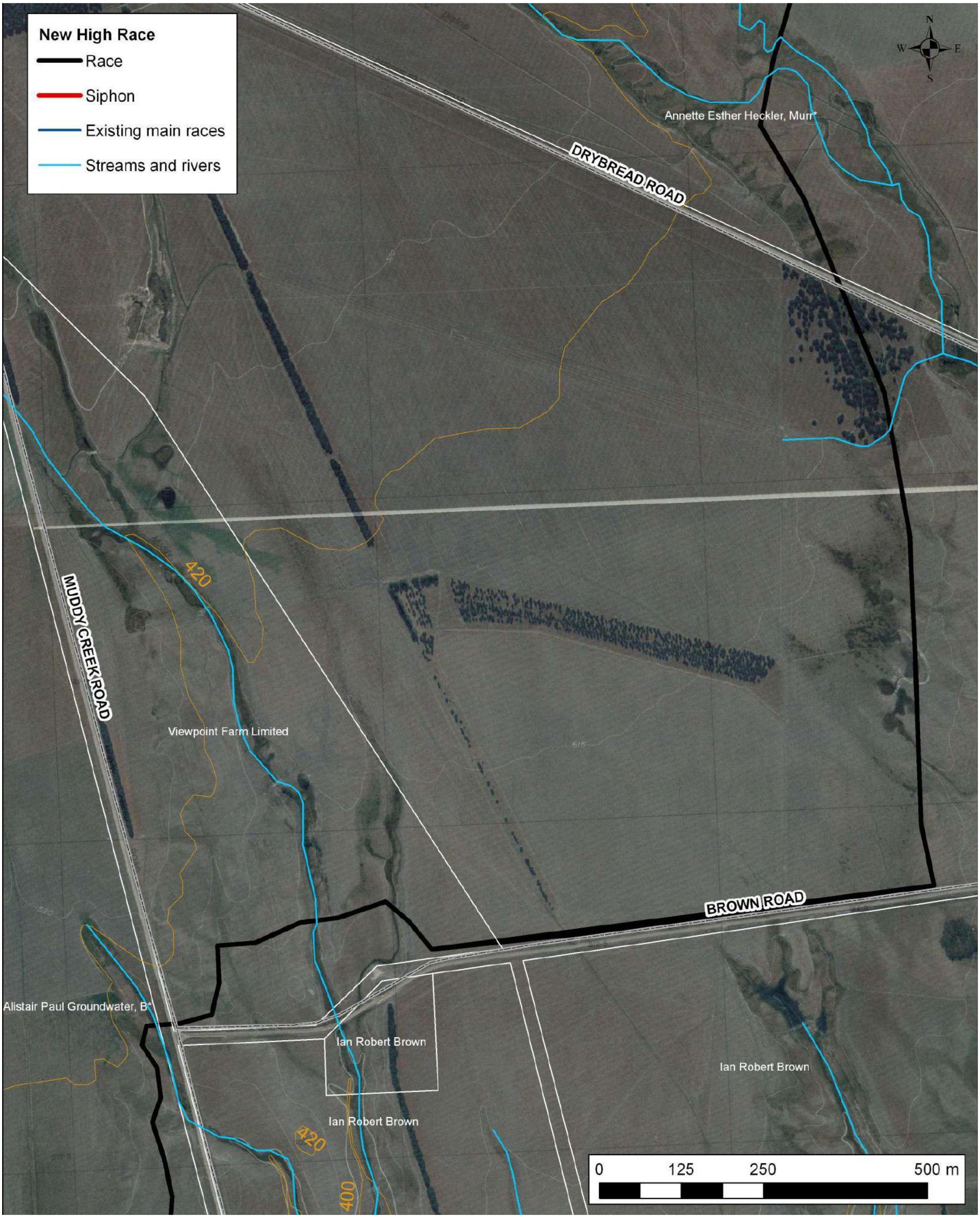
High Race detail – Figure 15

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



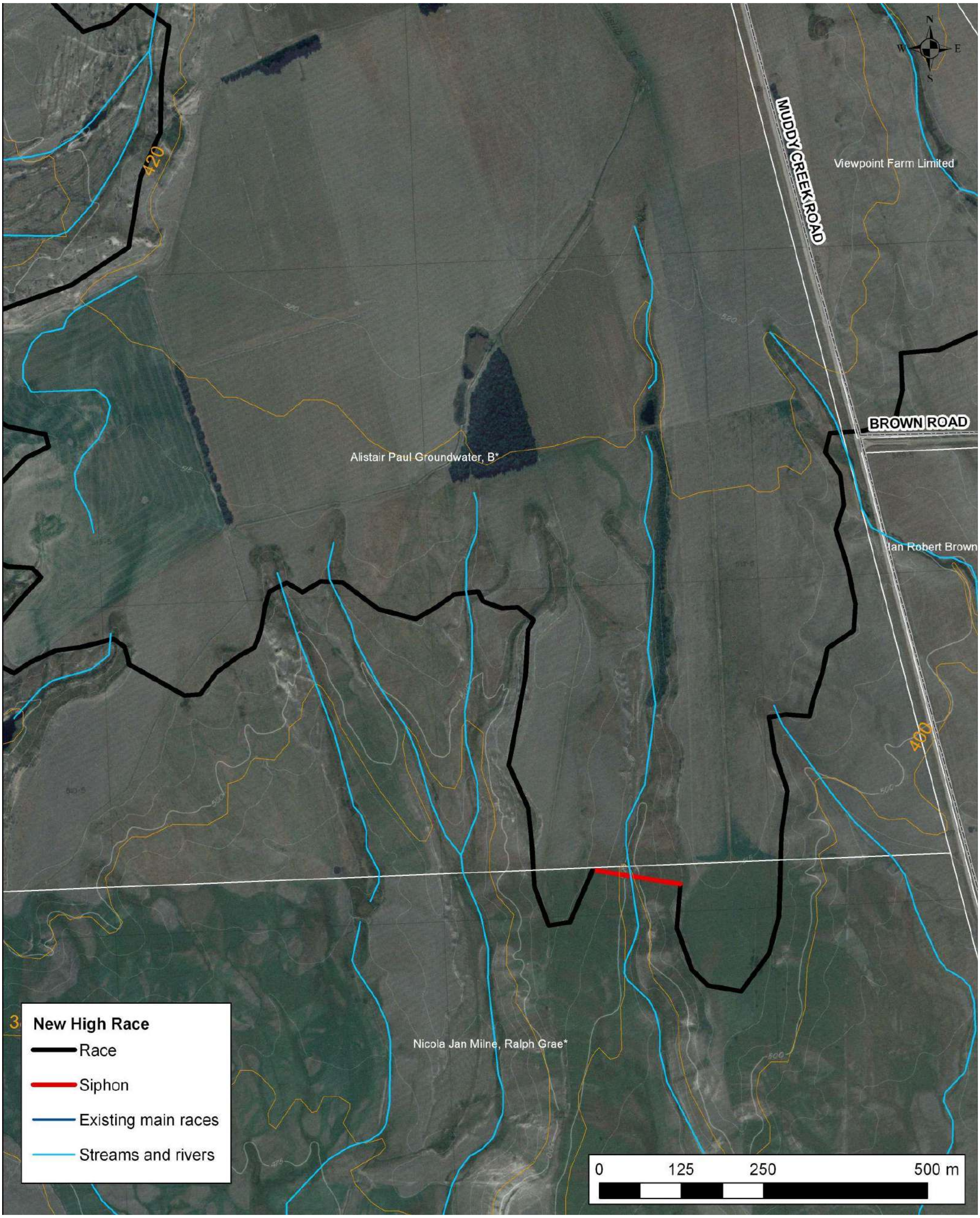
High Race detail – Figure 16

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



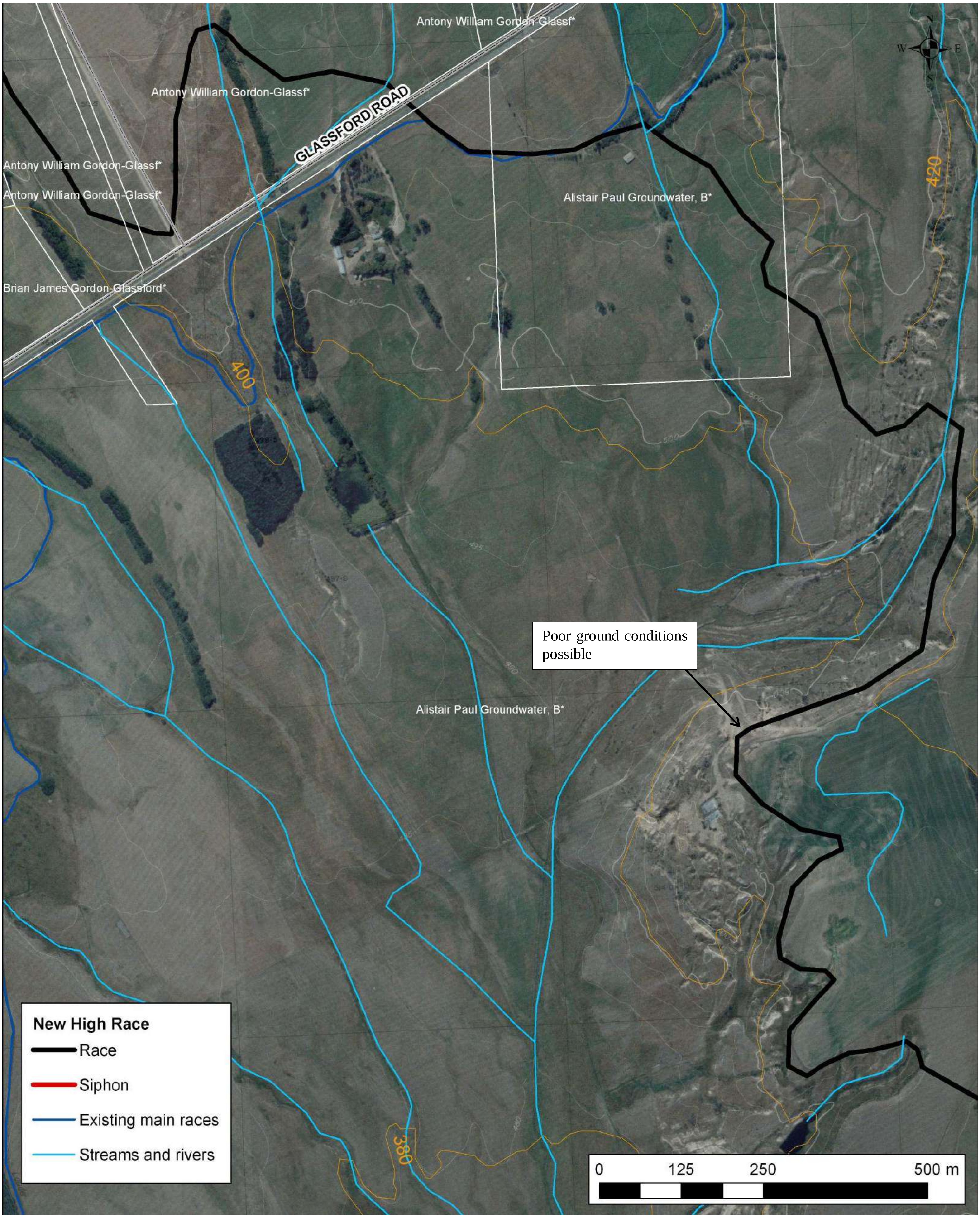
High Race detail – Figure 17

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



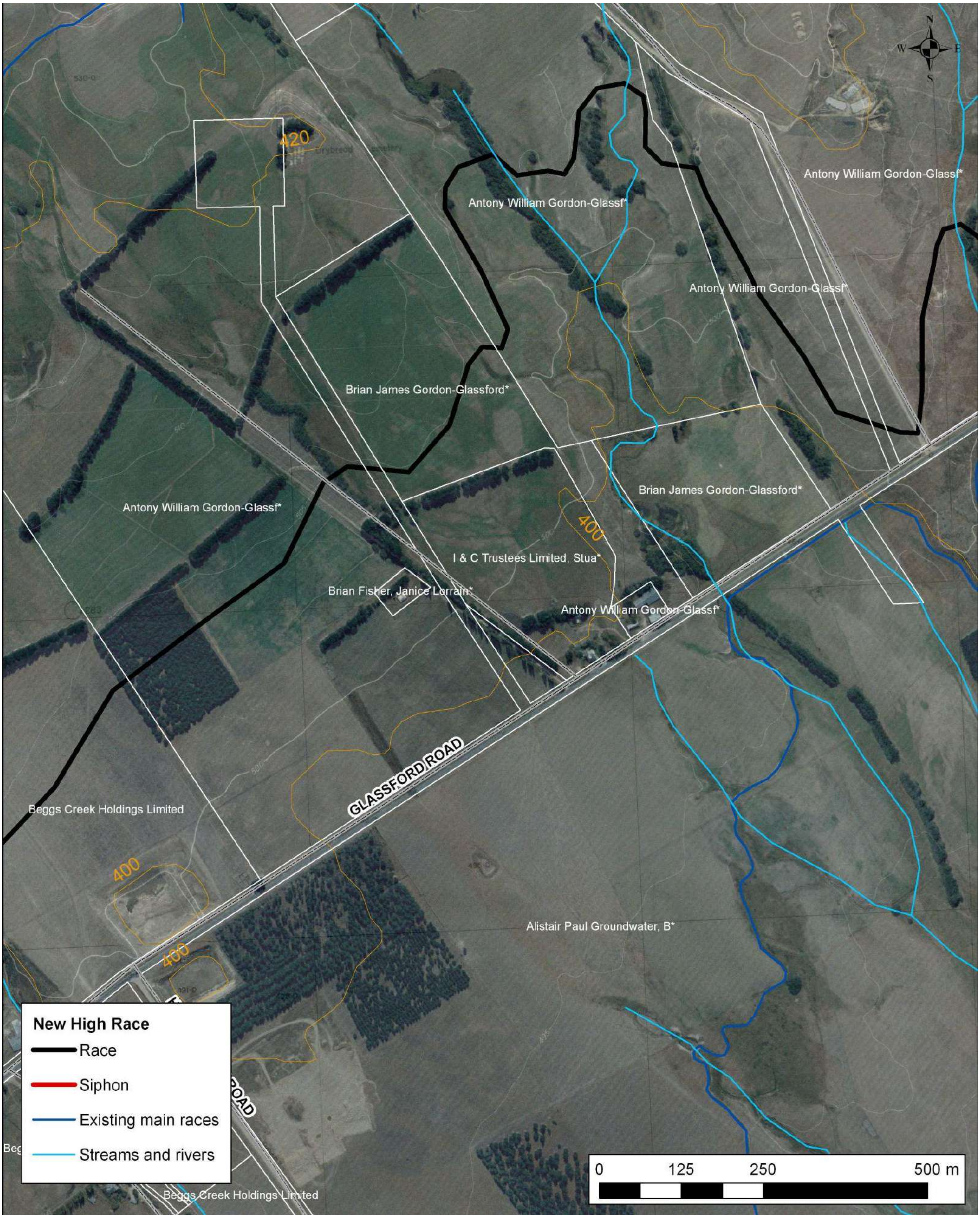
High Race detail – Figure 18

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



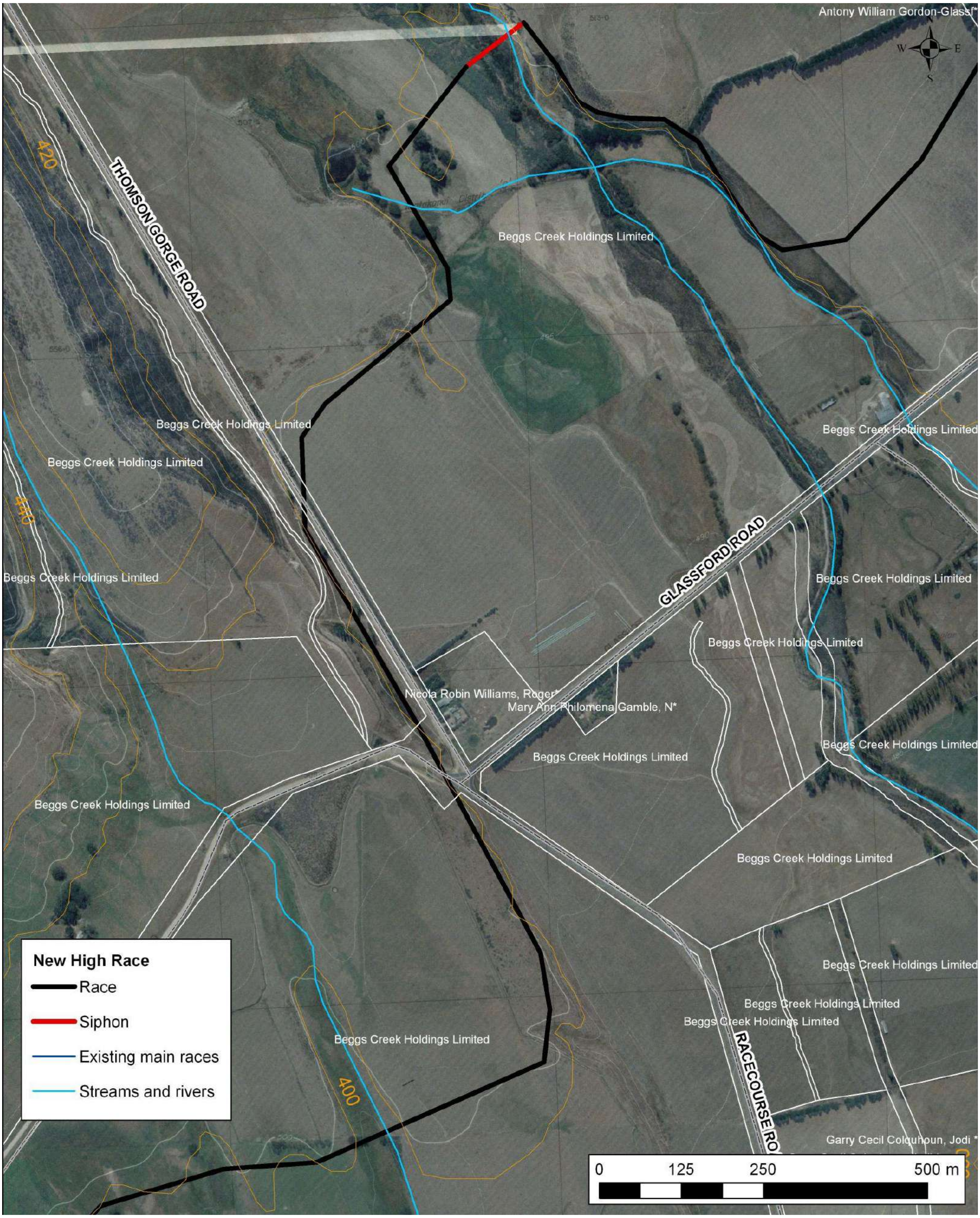
High Race detail – Figure 19

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



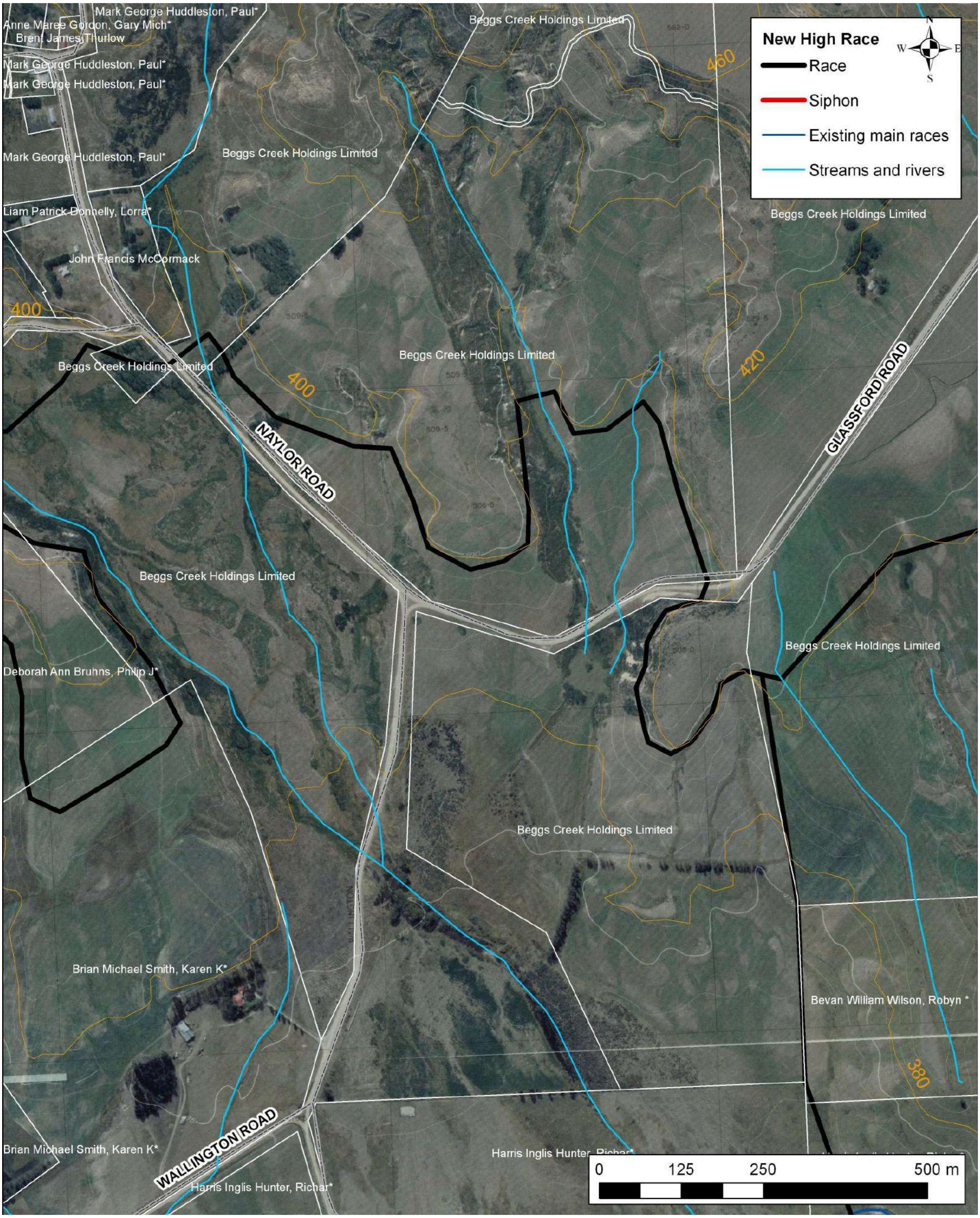
High Race detail – Figure 20

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



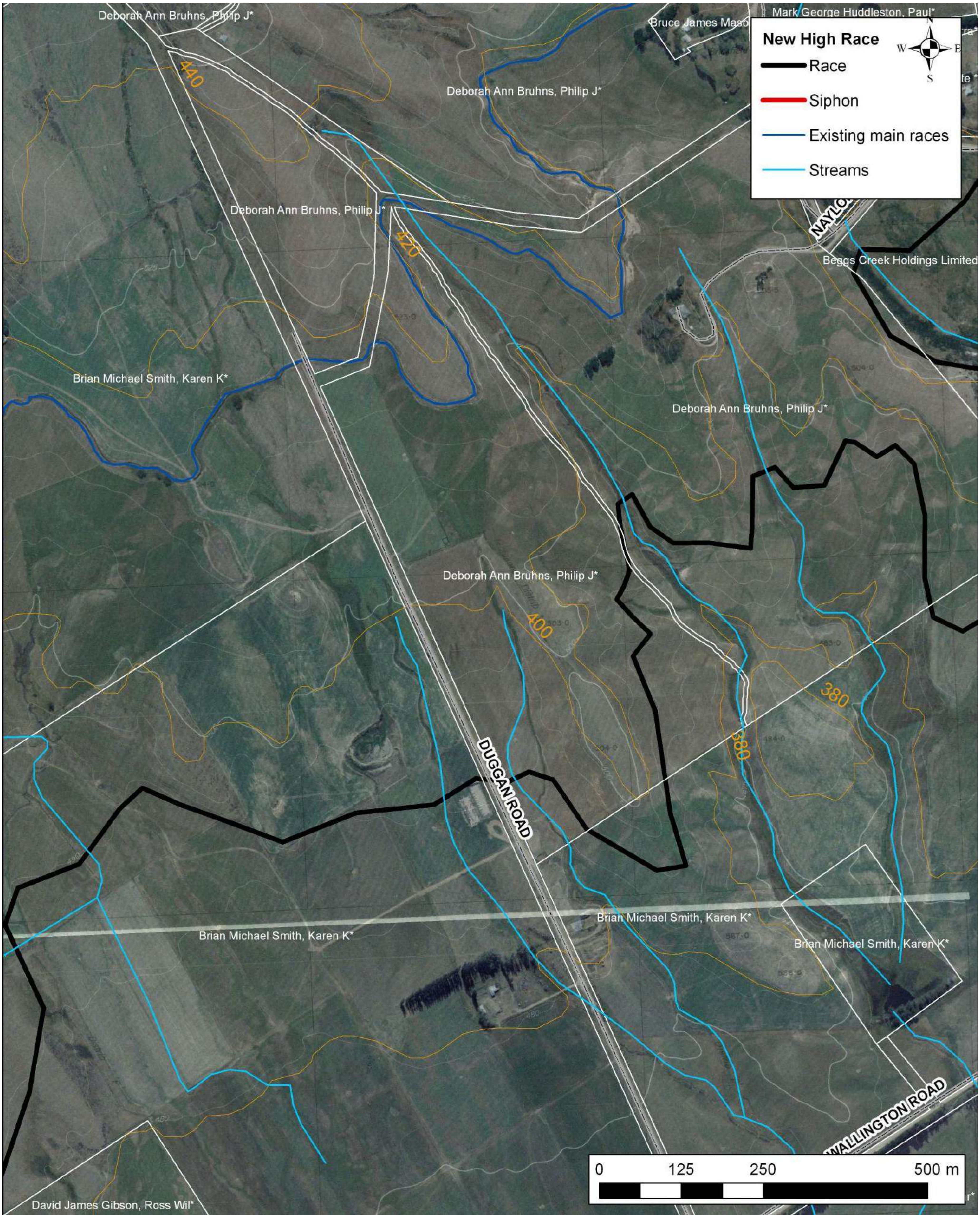
High Race detail – Figure 21

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



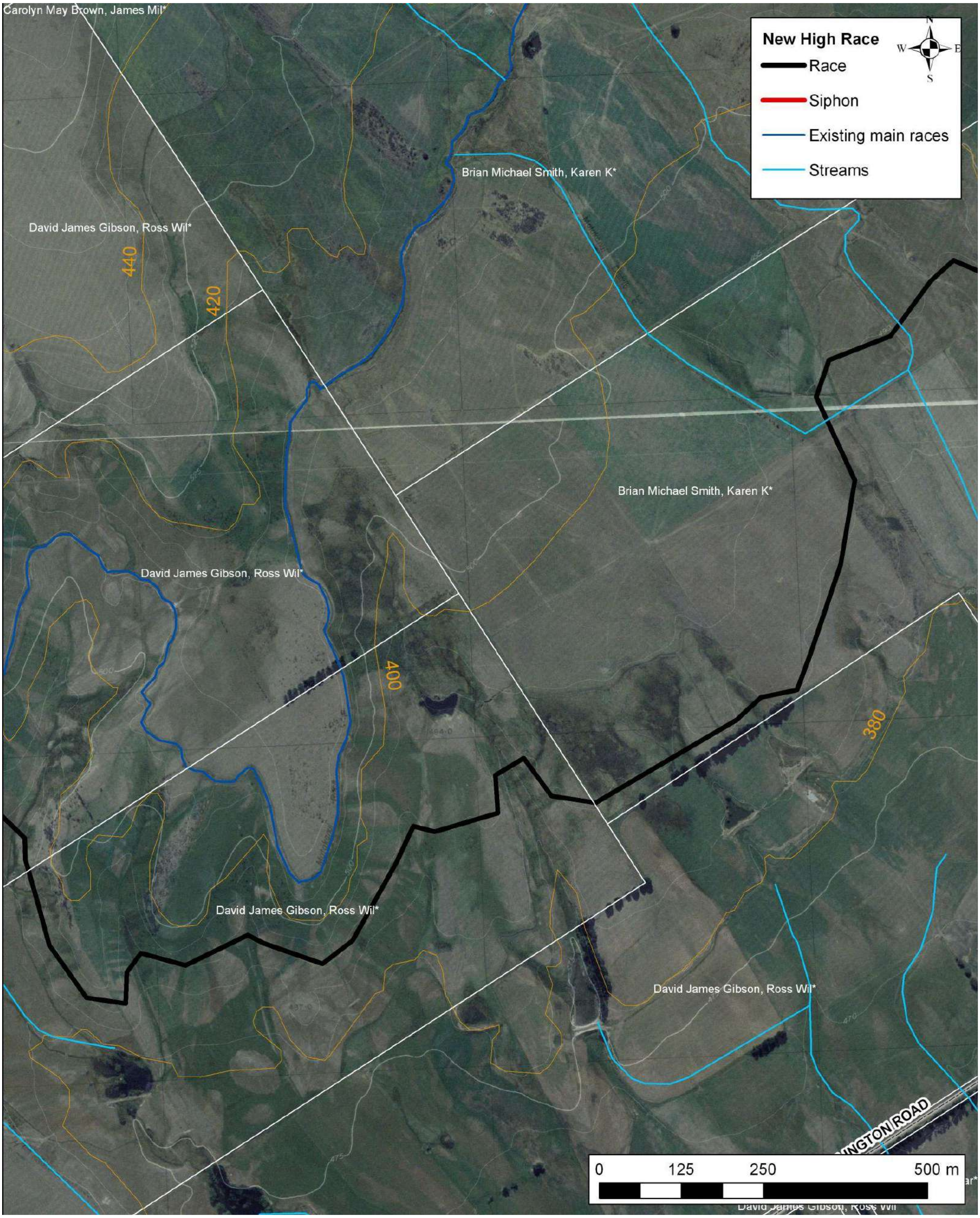
High Race detail – Figure 22

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



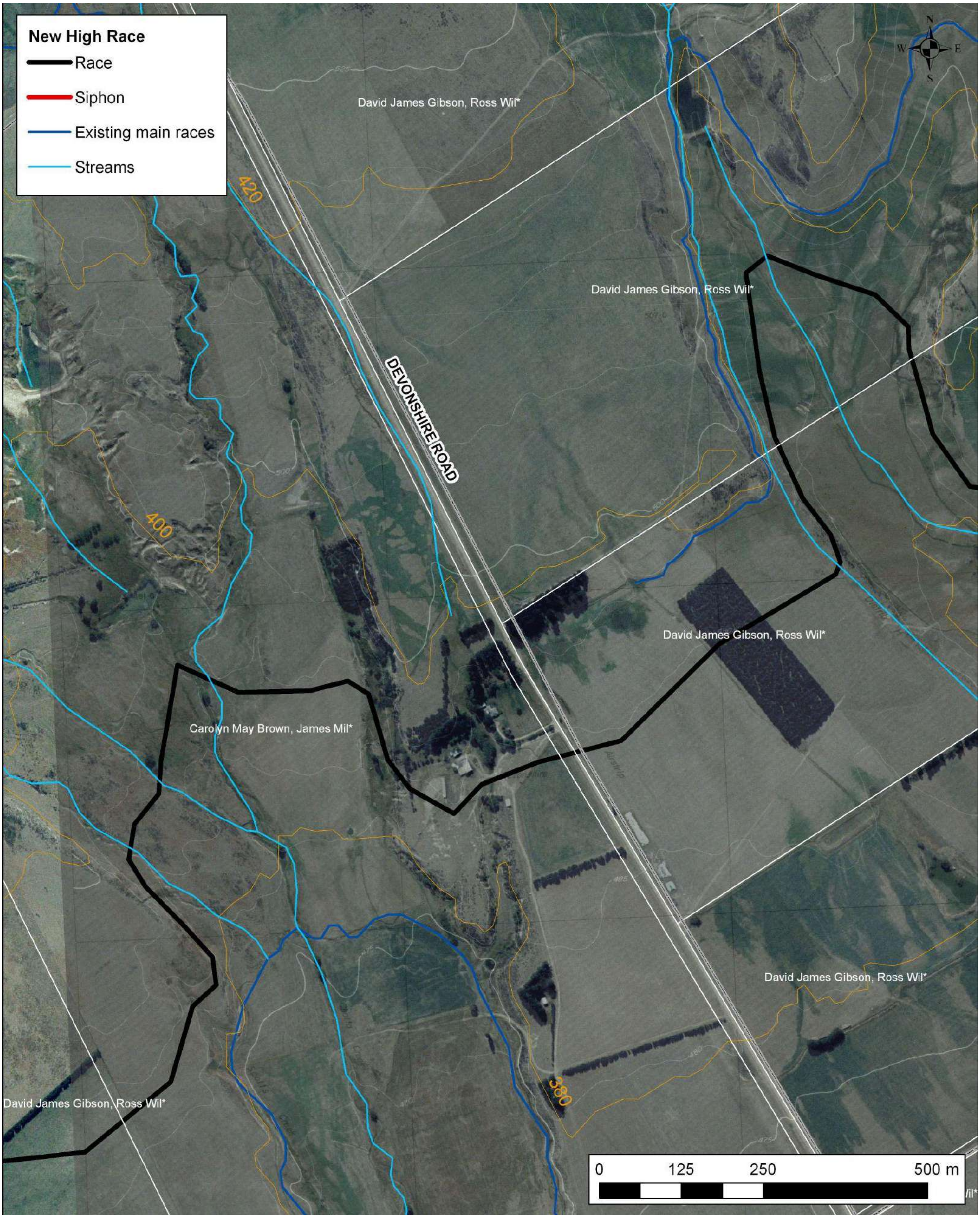
High Race detail – Figure 23

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



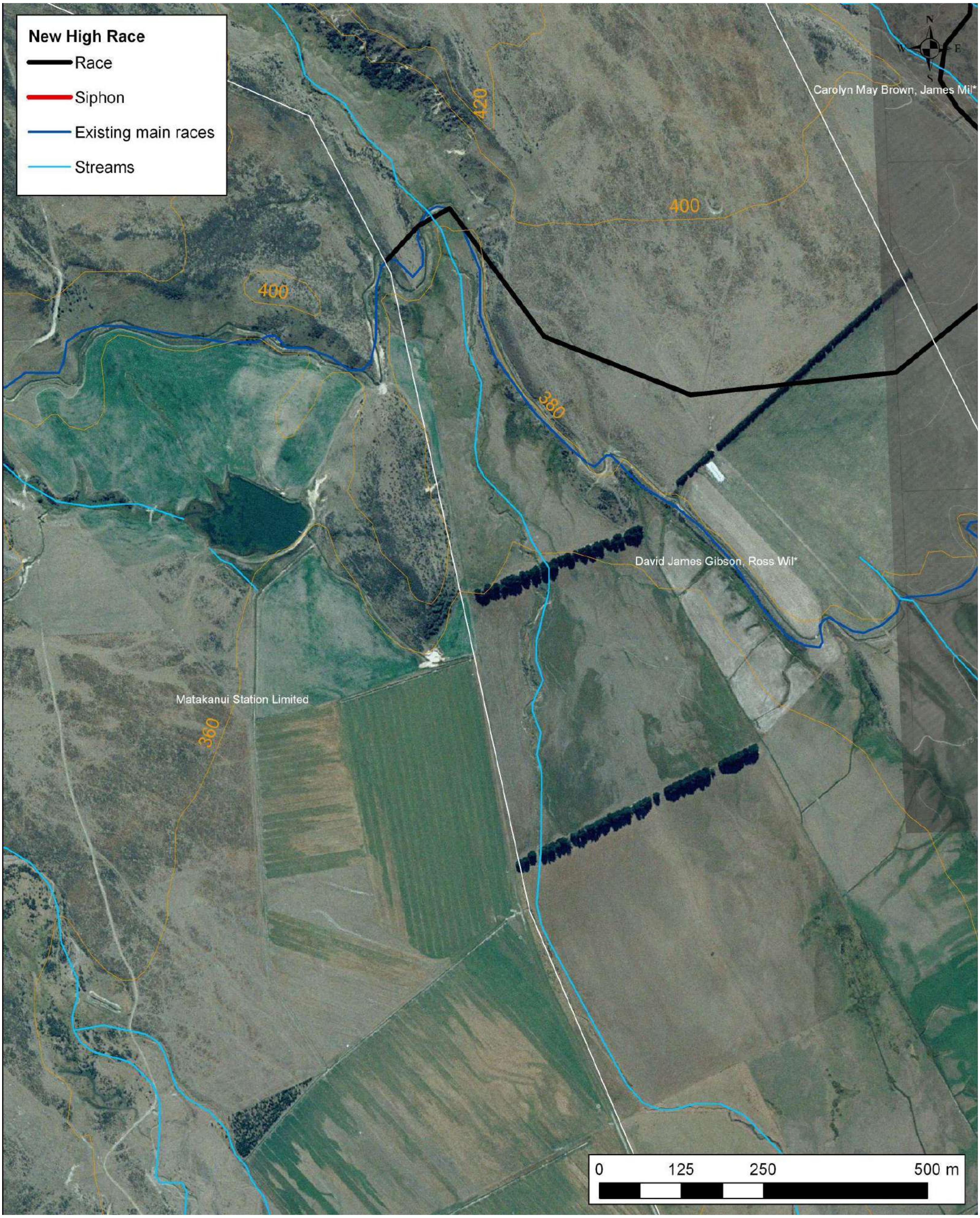
High Race detail – Figure 24

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



High Race detail – Figure 25

5m contours are from MWD aerial photogrammetry from 1976. The Otago datum (100m below M.S.L.) is used.



High Race detail – Figure 26

Appendix F: Engineering costings

Option 1 - 6,500 ha fully irrigated ("do minimum")

Item	Description	Unit	Quantity	Rate	Amount
A	**Engineering (8% of B-F)**	LS	1	$277,200	**$277,200**
B	**Preliminary and General (10% of C-F)**	LS	1	$315,000	**$315,000**
C	**Upgrade Omakau main race**				
C1	Automatic gates at Manuherikia intake	LS	1	$100,000	$100,000
C2	Automatic gates on main races	Num	5	$30,000	$150,000
C3	Line leaky race sections	m	5,000	$50	$250,000
C4	Replace minor leaky siphons	Num	10	$30,000	$300,000
C5	Replace first 1100m of Lauder Siphon. 1.05Ø	m	1,100	$1,000	$1,100,000
C6	Other general repairs and maintainence	LS	1	$200,000	$200,000
	Subtotal				**$2,100,000**
D	**Upgrade Blackstone Race**				
D1	Flow control and automation	LS	1	$50,000	$50,000
D2	Line leaky race sections	m	2,000	$50	$100,000
	Subtotal				**$150,000**
E	**Upgrade Downs and Dunstan Races**				
E1	Flow control, automation and intake upgrades	LS	1	$200,000	$200,000
E2	Line leaky race sections	m	4,000	$50	$200,000
	Subtotal				**$400,000**
F	**Upgrade other schemes**				
F1	Flow control, automation and intake upgrades	LS	1	$300,000	$300,000
F2	Line leaky race sections	m	4,000	$50	$200,000
	Subtotal				**$500,000**
G	**Contingency (20% of A-F)**	LS	1	$648,440	**$648,440**
	TOTAL CAPITAL				**$4,390,640**
	Costs exclude GST				

Scenario 2 - 12,000 ha fully irrigated

Item	Description	Unit	Quantity	Rate	Amount
A	**Engineering (8% of B-K)**	LS	1	$1,125,696	**$1,125,696**
B	**Preliminary and General (10% of C-K)**	LS	1	$1,279,200	**$1,279,200**
C	**High Race - Intake to Manuherikia Siphon**				
C1	2.5m^3/s Manuherikia River gallery intake & automatic gates	LS	1	$500,000	$500,000
C2	2.3-2.5 m^3/s race	m	2,700	$150	$405,000
C3	Earthworks, E/A, downstream of intake	LS	1	$200,000	$200,000
C4	Minor drain and stream crossings (culvert under race)	Num	2	$15,000	$30,000
C5	Farm crossings (box culvert or bridge)	Num	1	$20,000	$20,000
C6	Manuherikia River 1.0 mΦ siphon	m	350	$1,000	$350,000
	Subtotal				**$1,505,000**
D	**High Race - Downs**				
D1	2.3-1.3 m^3/s race	m	14,600	$120	$1,752,000
D2	Minor drain and stream crossings (culvert under race)	Num	15	$12,000	$180,000
D3	Road crossings (box culvert or bridge)	Num	5	$30,000	$150,000
D4	Farm crossings (box culvert or bridge)	Num	10	$15,000	$150,000
D5	Dunstan Creek 0.8mΦ siphon	m	700	$700	$490,000
	Subtotal				**$2,722,000**
E	**High Race - Dunstan Race Upgrade**				
E1	Upgrade Dunstan intake [incl. automatic gates] (3.0m^3/s)	LS	1	$150,000	$150,000
E2	Dunstan Race upgrade (0-1.5 m^3/s)	m	15,100	$150	$2,265,000
E3	Becks Creek crossing E/O (earthworks and short siphon)	LS	1	$240,000	$240,000
E4	Minor drain and stream crossings (culvert under race)	Num	12	$10,000	$120,000
E5	Road crossings (box culvert or bridge)	Num	5	$25,000	$125,000
E6	Farm crossings (box culvert or bridge)	Num	10	$15,000	$150,000
	Subtotal				**$3,050,000**
F	**High Race - other**				
F1	Buffer storage	m^3	120,000	$5	$600,000
F2	Flow recorder sites	Num	3	$5,000	$15,000
F3	Flow control software	LS	1	$50,000	$50,000
	Subtotal				**$665,000**
	Omakau High Race subtotal				**$7,942,000**
G	**Secondary distribution**				
G1	Farm off-take structures incl. telemetry and flow meter	Num	50	$10,000	$500,000
G2	Dunstan supply area - piped to farm boundary	ha	3,000	$500	$1,500,000
	Subtotal				**$2,000,000**
H	**Upgrade Omakau main race**				
H1	Automatic gates at Manuherikia intake	LS	1	$100,000	$100,000
H2	Automatic gates on main races	Num	5	$30,000	$150,000
H3	Line leaky race sections	m	5,000	$50	$250,000
H4	Replace minor leaky siphons	Num	10	$30,000	$300,000
H5	Replace first 1100m of Lauder Siphon. 1.05Ø	m	1,100	$1,000	$1,100,000
H6	Other general repairs and maintainence	LS	1	$200,000	$200,000
	Subtotal				**$2,100,000**
I	**Upgrade Blackstone Race**				
I1	Flow control and automation	LS	1	$50,000	$50,000
I2	Upgrade race capacity to 450 l/s	LS	1	$100,000	$100,000
I3	Line leaky race sections	m	2,000	$50	$100,000
	Subtotal				**$250,000**
J	**Upgrade other schemes**				
J1	Flow control, automation and intake upgrades	LS	1	$300,000	$300,000
J2	Line leaky race sections	m	4,000	$50	$200,000
	Subtotal				**$500,000**
K	**Contengency/unscheduled items (20% of A-K)**	LS	1	$3,039,379	**$3,039,379**
	TOTAL CAPITAL				**$18,236,275**
	Costs exclude GST, land purchase and easement costs and legal fees				

Scenario 3 - 18,000 ha fully irrigated

Item	Description	Unit	Quantity	Rate	Amount
A	**Engineering (8% of B-L)**	LS	1	$1,857,372	**$1,857,372**
B	**Preliminary and General (10% of C-L)**	LS	1	$2,110,650	**$2,110,650**
C	**High Race - Intake to Manuherikia Siphon**				
C1	5.5m^3/s Manuherikia River gallery intake & automatic gates	LS	1	$850,000	$850,000
C2	5.3-5.5 m^3/s race	m	2,700	$210	$567,000
C3	Earthworks, E/A, downstream of intake	LS	1	$230,000	$230,000
C4	Minor drain and stream crossings (culvert under race)	Num	2	$15,000	$30,000
C5	Farm crossings (box culvert or bridge)	Num	1	$25,000	$25,000
C6	Manuherikia River 1.5 mΦ siphon	m	350	$1,600	$560,000
	Subtotal				**$2,262,000**
D	**High Race - Downs**				
D1	4.3-5.3 m^3/s race	m	14,600	$180	$2,628,000
D2	Minor drain and stream crossings (culvert under race)	Num	15	$15,000	$225,000
D3	Road crossings (box culvert or bridge)	Num	5	$40,000	$200,000
D4	Farm crossings (box culvert or bridge)	Num	10	$20,000	$200,000
D5	Dunstan Creek 1.4mΦ siphon	m	700	$1,400	$980,000
	Subtotal				**$4,233,000**
E	**High Race - Dunstan Race Upgrade**				
E1	Upgrade Dunstan intake [incl. automatic gates] (3.0m^3/s)	LS	1	$150,000	$150,000
E2	Dunstan Race upgrade (3.0 - 4.5 m^3/s)	m	15,100	$150	$2,265,000
E3	Becks Creek crossing E/O (earthworks and short siphon)	LS	1	$260,000	$260,000
E4	Minor drain and stream crossings (culvert under race)	Num	12	$15,000	$180,000
E5	Road crossings (box culvert or bridge)	Num	5	$30,000	$150,000
E6	Farm crossings (box culvert or bridge)	Num	10	$20,000	$200,000
	Subtotal				**$3,205,000**
F	**High Race - Hamilton Rd to Muddy Creek**				
F1	1.8 - 3.0 m^3/s race	m	8,500	$160	$1,360,000
F2	Lauder Creek 1.2mΦ siphon	m	75	$1,100	$82,500
F3	Muddy Creek bywash and Omakau Main Race intake	LS	1	$50,000	$50,000
E3	Minor drain and stream crossings (culvert under race)	Num	7	$12,000	$84,000
E4	Road crossings (box culvert or bridge)	Num	2	$30,000	$60,000
E5	Farm crossings (box culvert or bridge)	Num	5	$20,000	$100,000
	Subtotal				**$1,736,500**
G	**High Race - other**				
G1	Buffer storage	m^3	180,000	$5	$900,000
G2	Flow recorder sites	Num	4	$5,000	$20,000
G3	Flow control software	LS	1	$50,000	$50,000
	Subtotal				**$970,000**
	Omakau High Race subtotal				**$12,406,500**
H	**Secondary distribution**				
H1	Farm off-take structures incl. telemetry and flow meter	Num	80	$10,000	$800,000
H2	Dunstan supply area - piped to farm boundary	ha	3,000	$500	$1,500,000
H3	Dunstan - Muddy Ck supply area - piped to farm boundary	ha	2,500	$500	$1,250,000
	Subtotal				**$3,550,000**
I	**Upgrade Omakau main race**				
I1	Automatic gates at Manuherikia intake	LS	1	$100,000	$100,000
I2	Automatic gates on main races	Num	5	$30,000	$150,000
I3	Line leaky race sections	m	5,000	$50	$250,000
I4	Replace minor leaky siphons	Num	10	$30,000	$300,000
I5	Replace first 1100m of Lauder Siphon. 1.05Ø	m	1,100	$1,000	$1,100,000
I6	Race capacity upgrades to accommodate 1.8 m^3/s from Muddy Ck	m	10,000	$180	$1,800,000
I7	Additional secondary distribution associated with extra flow	LS	1	$500,000	$500,000
I8	Other general repairs and maintainence	LS	1	$200,000	$200,000
	Subtotal				**$4,400,000**
J	**Upgrade Blackstone Race**				
J1	Flow control and automation	LS	1	$50,000	$50,000
J2	Upgrade race capacity to 450 l/s	LS	1	$100,000	$100,000
J3	Line leaky race sections	m	2,000	$50	$100,000
	Subtotal				**$250,000**
K	**Upgrade other schemes**				
K1	Flow control, automation and intake upgrades	LS	1	$300,000	$300,000
K2	Line leaky race sections	m	4,000	$50	$200,000
	Subtotal				**$500,000**
L	**Contengency/unscheduled items (20% of A-L)**	LS	1	$5,014,904	**$5,014,904**
	TOTAL CAPITAL				**$30,089,426**
	Costs exclude GST, land purchase and easement costs and legal fees				

Scenario 4 - 21,000 ha fully irrigated

Item	Description	Unit	Quantity	Rate	Amount
A	**Engineering (8% of B-M)**	LS	1	$2,537,964	**$2,537,964**
B	**Preliminary and General (10% of C-M)**	LS	1	$2,884,050	**$2,884,050**
C	**High Race - Intake to Manuherikia Siphon**				
C1	7.0m^3/s Manuherikia River gallery intake & automatic gates	LS	1	$1,000,000	$1,000,000
C2	6.8-7.0 m^3/s race	m	2,700	$220	$594,000
C3	Earthworks, E/A, downstream of intake	LS	1	$250,000	$250,000
C4	Minor drain and stream crossings (culvert under race)	Num	2	$15,000	$30,000
C5	Farm crossings (box culvert or bridge)	Num	1	$25,000	$25,000
C6	Manuherikia River 1.7 mΦ siphon	m	350	$1,800	$630,000
	Subtotal				**$2,529,000**
D	**High Race - Downs**				
D1	5.8-6.8 m^3/s race	m	14,600	$200	$2,920,000
D2	Minor drain and stream crossings (culvert under race)	Num	15	$15,000	$225,000
D3	Road crossings (box culvert or bridge)	Num	5	$40,000	$200,000
D4	Farm crossings (box culvert or bridge)	Num	10	$25,000	$250,000
D5	Dunstan Creek 1.6mΦ siphon	m	700	$1,600	$1,120,000
	Subtotal				**$4,715,000**
E	**High Race - Dunstan Race Upgrade**				
E1	Upgrade Dunstan intake [incl. automatic gates] (3.0m^3/s)	LS	1	$150,000	$150,000
E2	Dunstan Race upgrade (4.5-6.0m^3/s)	m	15,100	$180	$2,718,000
E3	Becks Creek crossing E/O (earthworks and short siphon)	LS	1	$300,000	$300,000
E4	Minor drain and stream crossings (culvert under race)	Num	12	$15,000	$180,000
E5	Road crossings (box culvert or bridge)	Num	5	$40,000	$200,000
E6	Farm crossings (box culvert or bridge)	Num	10	$20,000	$200,000
	Subtotal				**$3,748,000**
F	**High Race - Hamilton Rd to Matakanui**				
F1	2.5 - 4.5 m^3/s race	m	22,100	$160	$3,536,000
F2	Lauder Creek 1.4mΦ siphon	m	75	$1,300	$97,500
F3	Thomsons Creek 1.1mΦ siphon	m	75	$1,000	$75,000
E3	Minor drain and stream crossings (culvert under race)	Num	19	$15,000	$285,000
E4	Road crossings (box culvert or bridge)	Num	8	$30,000	$240,000
E5	Farm crossings (box culvert or bridge)	Num	15	$20,000	$300,000
	Subtotal				**$4,533,500**
G	**High Race - Matakanui to Matakanui Stn**				
G1	0.5-1.0m^3/s lined race	m	12,500	$140	$1,750,000
G2	Minor drain and stream crossings	Num	9	$10,000	$90,000
G3	Road crossings (box culvert or bridge)	Num	4	$25,000	$100,000
G4	Farm crossings (box culvert or bridge)	Num	10	$15,000	$150,000
	Subtotal				**$2,090,000**
H	**Link race**				
H1	1.5 m^3/s lined race (high grade)	m	800	$200	$160,000
H2	Automatic gates	LS	1	$40,000	$40,000
	Subtotal				**$200,000**
I	**High Race - other**				
I1	Buffer storage	m^3	200,000	$5	$1,000,000
I2	Flow recorder sites	Num	5	$5,000	$25,000
I3	Flow control software	LS	1	$50,000	$50,000
	Subtotal				**$1,075,000**
	Omakau High Race subtotal				**$18,890,500**
J	**Secondary distribution**				
J1	Farm off-take structures incl. telemetry and flow meter	Num	100	$10,000	$1,000,000
J2	Dunstan supply area - piped to farm boundary	ha	3,000	$500	$1,500,000
J3	Dunstan - Matakanui supply area - piped to farm boundary	ha	4,000	$500	$2,000,000
J4	Matakanui - Matanui Station supply area - piped to farm boundary	ha	2,000	$250	$500,000
	Subtotal				**$5,000,000**
K	**Upgrade Omakau main race**				
K1	Automatic gates at Manuherikia intake	LS	1	$100,000	$100,000
K2	Automatic gates on main races	Num	5	$30,000	$150,000
K3	Line leaky race sections	m	5,000	$50	$250,000
K4	Replace minor leaky siphons	Num	10	$30,000	$300,000
K5	Replace first 1100m of Lauder Siphon. 1.05Ø	m	1,100	$1,000	$1,100,000
K6	Race capacity upgrades to accommodate 1.5 m^3/s link race flow	m	10,000	$160	$1,600,000
K7	Additional secondary distribution associated with extra flow	LS	1	$500,000	$500,000
K8	Other general repairs and maintainence	LS	1	$200,000	$200,000
	Subtotal				**$4,200,000**
L	**Upgrade Blackstone Race**				
L1	Flow control and automation	LS	1	$50,000	$50,000
L2	Upgrade race capacity to 450 l/s	LS	1	$100,000	$100,000
L3	Line leaky race sections	m	2,000	$50	$100,000
	Subtotal				**$250,000**
M	**Upgrade other schemes**				
M1	Flow control, automation and intake upgrades	LS	1	$300,000	$300,000
M2	Line leaky race sections	m	4,000	$50	$200,000
	Subtotal				**$500,000**
N	**Contengency/unscheduled items (20% of A-M)**	LS	1	$6,852,503	**$6,852,503**
	TOTAL CAPITAL				**$41,115,017**
	Costs exclude GST, land purchase and easement costs and legal fees				