9.1. Roxburgh Natural Hazards Management

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PURPOSE

[1] To update the Council on the progress with the Roxburgh debris flows hazard management programme.

EXECUTIVE SUMMARY

[2] The Roxburgh area from Coal Creek Flat to north of Ettrick is exposed to alluvial fan hazards, including debris flows, where steep creeks exit the Old Man Range towards the Clutha River.

[3] Debris flows are a rapidly moving slurry of water, sediment, and debris that may occur on alluvial fans with a high impact force. The geological and geomorphic characteristics of the catchments in the Roxburgh area allow for the high sediment yields required for debris flow generation. In conjunction, debris flows are initiated by high-intensity rainfall events driven by thunderstorms, so typically provide little warning time.

[4] A number of debris flow events have been recorded in Roxburgh since at least 1938. Most of these recorded events have resulted in direct impact of debris to either infrastructure or property.

[5] The debris flow events of November 2017 highlighted the significance of the hazard to the Roxburgh community and prompted the contemporary hazard management response. This included channel maintenance, debris flow investigations, and monitoring of the catchments.

[6] Preliminary risk assessments conducted by Golder Associates for the Otago Regional Council (ORC) in 2019 indicated that the risk to life is 'significant' at Pumpstation, Reservoir, and Golfcourse Creeks. These reports also recommended that ORC implement an interim channel monitoring and maintenance plan and conduct a more detailed and spatially comprehensive hazard and risk assessment.

[7] The ORC Natural Hazards team has also identified additional catchments other than those active during 2017 and included these in the work programme scope. This included a prioritisation based on a catchment's geomorphic characteristics, history of debris flows, and the exposure of infrastructure and property to potential flows.

[8] This update paper also describes the Roxburgh debris flows work programme which has two parallel works to be conducted this financial year, these action the key recommendations of the Golder reports:

- An interim channel maintenance and monitoring plan to manage the hazard whilst we conduct further investigations and,
- The detailed hazard and risk assessment for debris flows in the Roxburgh area, which is the key technical study that will inform future management options including potential Central Otago District Council (CODC) spatial planning.

RECOMMENDATION

That the Council:

1) ***Notes*** *this report.*

BACKGROUND

Physical environment and natural hazard overview

[9] The Roxburgh area is highly susceptible to alluvial fan hazards, including debris flows. The focus for this update paper is the area from Coal Creek Flat to just north of Ettrick, including the township of Roxburgh, the orchards of Coal Creek Flat, Dunbarton, and State Highway 8 (SH8) infrastructure west of the Clutha River (Figure 1).

[10] Alluvial fan hazards in the Roxburgh area have previously been mapped by Otago Regional Council (ORC) at a regional scale[1], with follow-up assessments then completed by GNS Science[2] and the ORC Natural Hazards team.[3] This mapping and initial assessments highlighted the exposure of the Roxburgh area to alluvial fan hazards (Figure 1).

[11] Alluvial fans[4] are depositional landforms that occur where creeks exit steep hills or mountains to a valley floor (Figures 2 and 3). Alluvial fans are dynamic landforms, where flows commonly break out of existing channels (avulsion) and travel along alternative pathways across the fan surface.[5]

[12] Flows on alluvial fans can contain a variety of sediment concentrations. These flows range from floods (low sediment concentration) to debris flows (high sediment concentration), with intermediate processes (hyper-concentrated flows and debris floods)[6] that contain a substantial amount of sediment, but less than debris flows.[7]

[13] Debris flows are rapid onset, high-velocity flows that form a slurry of water, debris (e.g., trees, man-made debris), and sediment (including coarse-grained). Debris flows have a

[1] Grindley J, Cox S and Turnbull I, 2009. Otago Alluvial Fans Project. Report by Opus International Consultants Ltd and GNS Science for Otago Regional Council.

[2] Barrell, D., Cox, S., Greene, S., and Townsend, D. 2009. Otago Alluvial Fans Project: Supplementary maps and information on fans in selected areas of Otago. (GNS Science consultancy report; 2009/052).

[3] Woods, R. 2011. Otago Alluvial Fans: High Hazard Fan Investigation. Report prepared by the ORC Natural Hazards team as part of the Alluvial Fans project. 69-75pp.

[4] Also referred to as debris fans depending on their dominant process regime

[5] Barrell, D., Cox, S., Greene, S., and Townsend, D. 2009. Otago Alluvial Fans Project: Supplementary maps and information on fans in selected areas of Otago. (GNS Science consultancy report; 2009/052).

[6] For this update paper, we refer to "debris flows" as a generic term for flows containing a sediment concentration greater than typical flood flows (i.e. also including debris floods and hyper-concentrated flows).

[7] De Haas, T., Lau, C., and Ventra, D. 2024. Debris-Flow Watersheds and Fans: Morphology, Sedimentology and Dynamics. In *Advances in Debris-Flow Science and Practice.* Jakob, M., McDougall, S., and Santi, P. (Eds). Springer Nature Switzerland AG. 9-73pp.

high sediment concentration and are very dense relative to clear water, they also contain coarse sediments (i.e., boulders) (e.g., Figure 4).

[14] Debris flows can pose a significant threat to individuals, property, and infrastructure because of their high impact force, and the fact they may occur with little warning due to triggering by high-intensity rainfall cells (e.g. thunderstorms/cloudbursts) which are difficult to forecast with certainty and are spatially variable.

[15] The Roxburgh area has a history of documented debris flow events since at least 1938, many of which caused significant impacts and disruption, these are summarised in Table 1.

[16] The geomorphic and geological characteristics of the Old Man Range and the Roxburgh area, west of the Clutha River, are the primary drivers for the debris flow susceptibility in the Roxburgh area. Key factors include the high sediment yields of the Creeks that drain the eastern flanks of the Old Man Range, and the relatively small, steep nature of the catchments themselves (Figures 3 and 5).

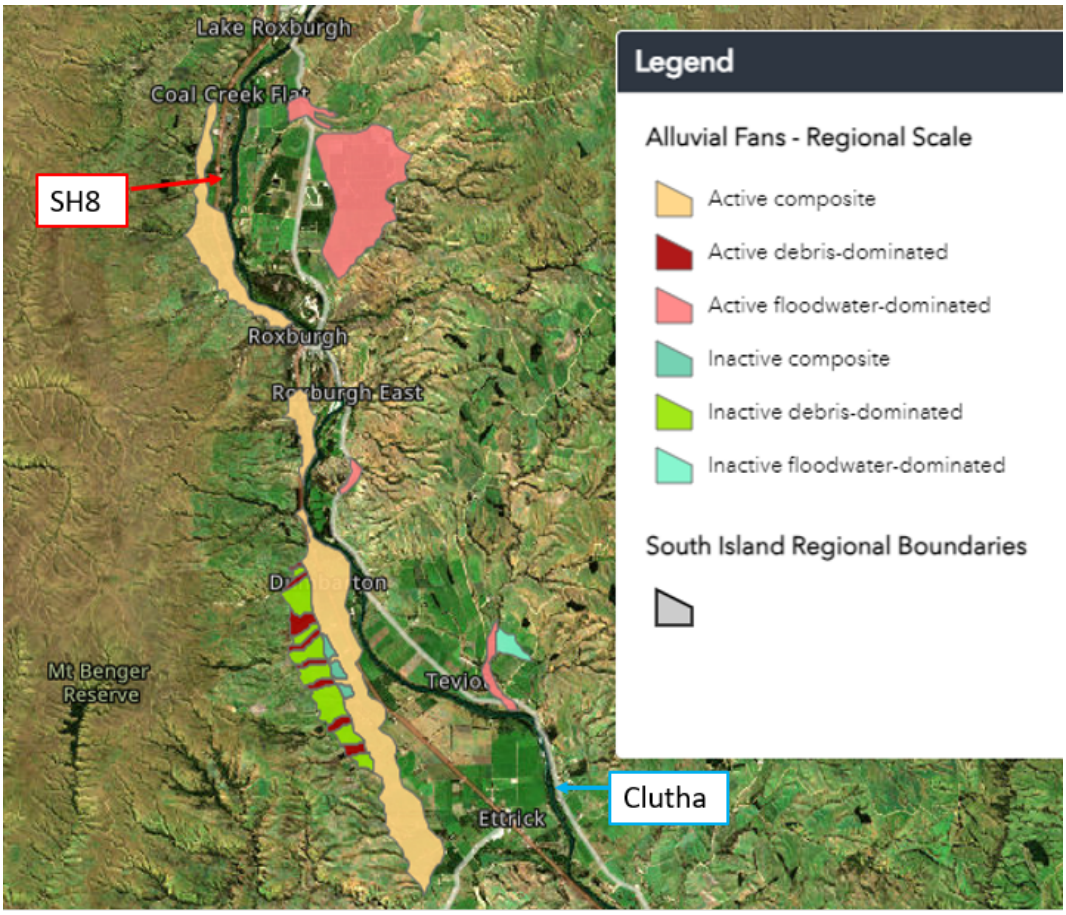

Figure 1: Regional-scale (Otago Alluvial Fans Project) mapping of alluvial fan hazards in the Roxburgh area, this shows the extensive alluvial fan development at the base of the Old Man Range catchments.

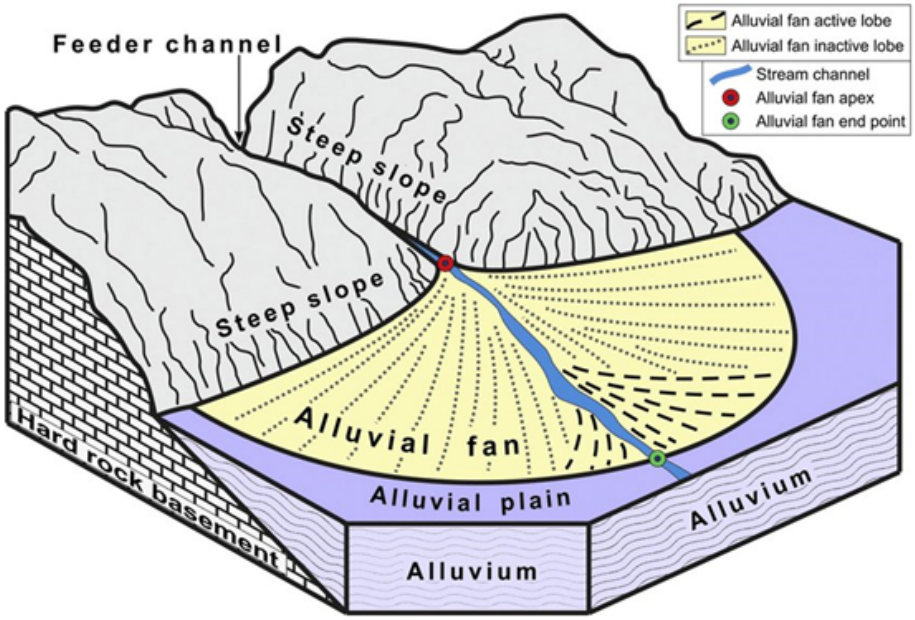

Figure 2: Simplified model of a generic alluvial fan, showing typical fan characteristics.

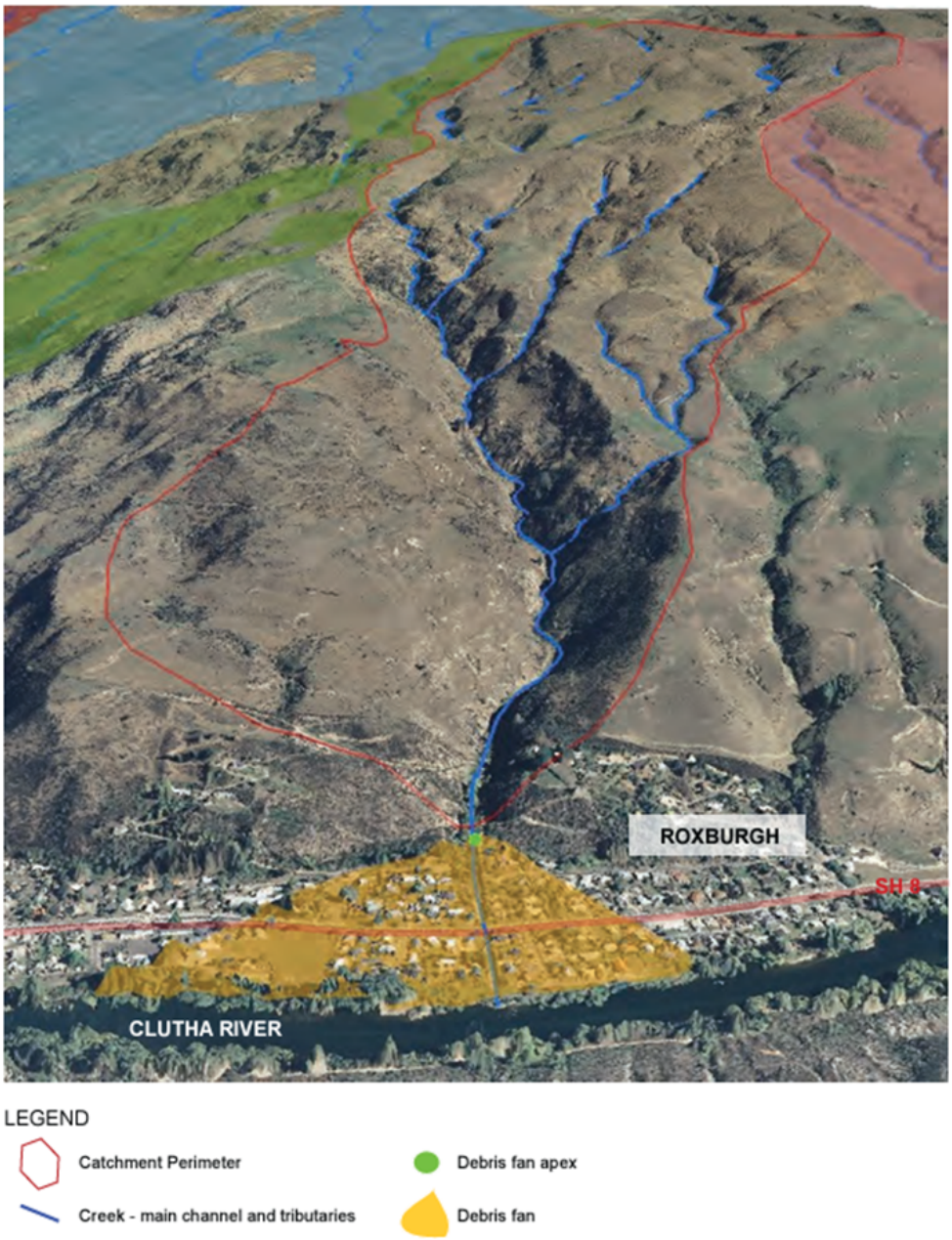

Figure 3: The Reservoir Creek catchment and alluvial (debris) fan[8].

[8] Golder. 2019a. Management and reduction of debris flow risk in Roxburgh, Otago – geomorphological assessment report. Report prepared for Otago Regional Council.

Figure 4: Examples of debris flow deposits from Roxburgh events: top, debris flow at Blackjacks Creek in 2015, and bottom, boulders removed from a debris flow deposit at Blackjacks Creek after the November 2017 events.

Figure 5: Example of a large active landslide in Golfcourse Creek, currently being undercut and eroded by the channel, which likely supplies sediment to a debris flow during an event. This is a typical situation in these catchments.

Past debris flow events in the Roxburgh area

[17] Known debris flow events in the Roxburgh area are described in Table 1. In addition to those listed, likely, numerous lower-magnitude events have also occurred. Where the triggering event for the debris flows has been described, it has been high-intensity rainfall associated with a convection cell.

[18] Following the 1978 event (Figure 6), in the early 1980's, the Otago Catchment Board (OCB) excavated the channel and constructed a concrete-lined channel in the downstream section of Reservoir Creek (from where it exits the valley). The channel structure is designed to rapidly convey floodwaters and debris across the alluvial fan and into the Clutha River. The concrete channel is 200 metres long, 3 metres wide at the base, 9 metres wide at the top, and 2 metres deep (Figure 7).

Table 1: Significant debris flow events on record in the Roxburgh area.

Date	Catchments	Key Impacts
1938	Slaughterhouse Creek and several others adjacent	9 m high debris flow. 2.4 km section of SH8 inundated and orchards severely damaged
1978	Reservoir Creek, Blackjacks Creek, Pumpstation Creek, and Slaughterhouse Creek at least	Direct debris flow impact to dwellings, extensive property damage at Reservoir Creek (Figure 6). Impact to SH8 likely. Prompted the construction of the concrete chute.
1993	Slaughterhouse Creek and Pumpstation Creek at least	Substantial damage to property, orchards, SH8 network (30-ton boulder deposited in middle of road), and power supply cut at Pumpstation Creek
2015	Blackjacks Creek	SH8 inundated with debris (Figure 3).
November 2017	Pumpstation, Reservoir, Golfcourse, Blackjacks, and Stevensons Creek (no direct impact)	Damage to water and power supply, extensive inundation of SH8, property damage by debris and flooding associated with the debris flows (Figures 8-10).

Figure 6: Direct impact of a debris flow at Reservoir Creek, 1978, showing extensive debris deposition, and direct impact to dwellings adjacent to the stream channel.

Figure 7: The Reservoir Creek concrete chute, constructed in the early 1980s.

Figure 8: Impacts of the November 2017 debris flow event at Reservoir Creek, showing the extensive deposition of sediment debris at the confluence with the Clutha River.

Figure 9: Impacts of the November 2017 events at Reservoir Creek, looking upstream of the SH8 bridge.

Figure 10: Impacts of the November 2017 debris flow event at Blackjacks Creek, showing the extensive deposition of sediment debris over State Highway 8.

Debris flow management since the November 2017 events

[19] The magnitude and associated damages of the November 2017 debris flow/flood events prompted a response from the ORC, Central Otago District Council (CODC), and Waka Kotahi NZ Transport Agency (NZTA). Several mechanisms have been employed to address the hazard to date.

[20] ORC commissioned several preliminary hazard assessments. The first was conducted soon after the November 2017 events by GNS Science and described the triggers, dynamics, and impacts of the debris flows[9].

[9] GNS. 2018. Hazard and risk assessment of the Roxburgh debris flows of 26th November 2017. Lower Hutt (NZ): GNS Science. (GNS Science consultancy report; 2018/65).

[21] Two further investigations were conducted by Golder Ltd for ORC in 2019 that provided preliminary geomorphic mapping, culvert capacity calculations, and risk-to-life estimate[10] and a review of possible hazard mitigation concepts for further study[11]. Note that studies by GNS Science and Golder Ltd focused only on the five catchments where debris flows occurred in 2017.

[22] The findings of Golder (2019a) indicated that several SH8 culverts were not up to design standards for clear water. NZTA have since upgraded these culverts with greater capacity (Pumpstation, Golfcourse, and Blackjacks Creeks) but these upgrades may not be sufficient to convey large debris flows. In addition, the Golder (2019a) preliminary risk assessment found the risk to life to be 'significant' at Pumpstation, Reservoir, and Golfcourse Creeks.

[23] In response to debris flow sedimentation into the Clutha River, ORC undertook a preliminary investigation to understand the significance of this sedimentation on flooding and bank erosion hazards.[12] This concluded there would have been a slight increase in flooding hazard, but that these effects would trend back to their pre-November 2017 levels as sediment deposits were eroded over time.

[24] Updates on the ORC investigations and management responses were presented to the ORC Technical committee in January 2018,[13] October 2018 and September 2019.[14]

[25] A series of mitigation works have been conducted to remove the excess sediment deposited by, and since, the 2017 events, as well as some channel armouring. These included emergency works immediately following the events in addition to further works since the events.

[26] Since the 2017 debris flow events, ORC monitoring in the Roxburgh area has included;

- Installation of a rain gauge in the upper reaches of Reservoir Creek, with data available from October 2018. This can indicate high-intensity rainfall in the catchment.
- LiDAR topography and ortho-imagery were captured in 2019 and 2022 for the catchment which experienced debris flows in 2017. Additional LiDAR is being captured in October 2024 to extend coverage further north and south from those initial surveys. These LiDAR surveys provide the necessary data for geomorphic assessment, change detection, and debris flow modelling.

Current work programme

[27] The Golder reports recommended key next steps in the project were to;

[10] Golder. 2019a. Management and reduction of debris flow risk in Roxburgh, Otago – geomorphological assessment report. Report prepared for Otago Regional Council.
[11] Golder. 2019b. Management and reduction of debris flow risk in Roxburgh, Otago – Engineering options report (conceptual design). Report prepared for Otago Regional Council.
[12] Webby G, 2017. Roxburgh – preliminary assessment of flood and erosion hazards in Clutha River. Damwatch Engineering ltd.
[13] Payan J and Mackey M, 2018. November 2017 Roxburgh debris flow. Report to the ORC Technical Committee, 25 January 2018.
[14] Mangoes F and Mackey B, 2019. General Manager's Report to Technical Committee, 11 September 2019.

- Conduct a detailed spatial hazard/risk assessment to inform longer-term options, and to,
- Put in place an interim plan to manage the hazard in the short-term.

[28] The November 2017 events highlighted the significance of the debris flow hazard in the Roxburgh area. However, as demonstrated in this update, the five are not the only catchments where debris flows can occur (Figures 1 and 12).

[29] Staff have identified 22 additional catchments (Figure 10) from the Barrell et al. (2009) mapping and conducted a 'high-level' hazard and exposure analysis to prioritise work for the additional catchments.

[30] To action the key Golder reports recommendations, the current ORC Natural Hazards programme for the Roxburgh debris flows comprises two parallel projects:
- Development of an interim channel monitoring and maintenance plan, and
- Completion of a detailed hazard and risk assessment.

[31] To provide detailed topographic information to inform both these projects, an updated LiDAR survey is being captured to provide topographic data for the full area, as well as a recent survey of channel morphology to inform potential channel maintenance.

[32] ORC Natural Hazard Team have also conducted a helicopter survey of the catchments to assess vegetation recovery rates and their geomorphic state. In addition, staff presented an update on the Roxburgh debris flows work programme at a community meeting in Roxburgh in early July.

Interim channel monitoring and maintenance plan

[33] The purpose of this plan would be to maintain the capacity of the channels to convey high flows during a debris flow event to limit the avulsion of the creeks and any subsequent debris inundation of infrastructure or property. This project is designed to inform ORC Engineering river management and act as an interim plan whilst detailed and spatial hazard/risk assessments are completed. Upon completing these assessments and subsequent planning for further options, a longer-term action plan will supersede the interim monitoring/maintenance project. In addition, the results of further investigations may highlight the need for interim monitoring and maintenance in other creeks in the Roxburgh area.

[34] The ORC Natural Hazards Team has designed a high-level monitoring and maintenance plan, which will be finalised following analysis using the 2024 LiDAR survey.

Detailed hazard and risk assessment

[35] A detailed natural hazard and risk assessment will be carried out primarily to inform potential Central Otago District Council (CODC) spatial planning measures, as well as possible physical mitigation or adaptation options. This risk assessment will include developing an understanding of potential debris flow runouts, and a comprehensive, spatial understanding of the natural hazard risk characteristics. In addition, climate change may impact the magnitude and frequency of debris flows in the future, and this will be considered. CODC has assisted in scope design and will be a part of the evaluation panel for the procurement of this study.

[36] This investigation will comprise of two main stages: 1) hydrogeomorphic modelling (i.e., a detailed hazard assessment) which will map potential debris flow event scenarios in detail and 2) a risk assessment which will include both qualitative and quantitative assessments depending on the results of the modelling stage. The level of detail in the analysis will align with national guidance on landslide and debris flow risk assessment[1516].

[37] The investigation will focus on debris flow hazard and risk from 13 of the 22catchments in the Roxburgh area (Figure 10). These catchments have been identified and prioritised based on factors including their known history of debris flow occurrences, geomorphic indices[17] which indicate susceptibility to debris flow generation, and the exposure of buildings and infrastructure[18].

[38] Procurement of this study is underway. The investigation is anticipated to be completed before the end of the 24/25 financial year.

[39] The study findings will be of value to a range of stakeholders (e.g., ORC, CDEM, CODC, NZTA, and community members).

[15] GNS. 2024. Landslide planning guidance: reducing landslide risk through land-use planning. Lower Hutt (NZ): GNS Science miscellaneous series; 144.
[16] NZGS. 2023. Slope Stability Geotechnical Guidance Series: Unit 1 – General Guidance. New Zealand Geotechnical Society, Draft for Comment.
[17] e.g. Melton ratio, a measure of a catchment's ability to generate debris flows.
[18] Wright, J. 2024b. Roxburgh debris flow catchments prioritisation using morphometrics and hazard exposure analysis. June 2024. Internal Otago Regional Council report.

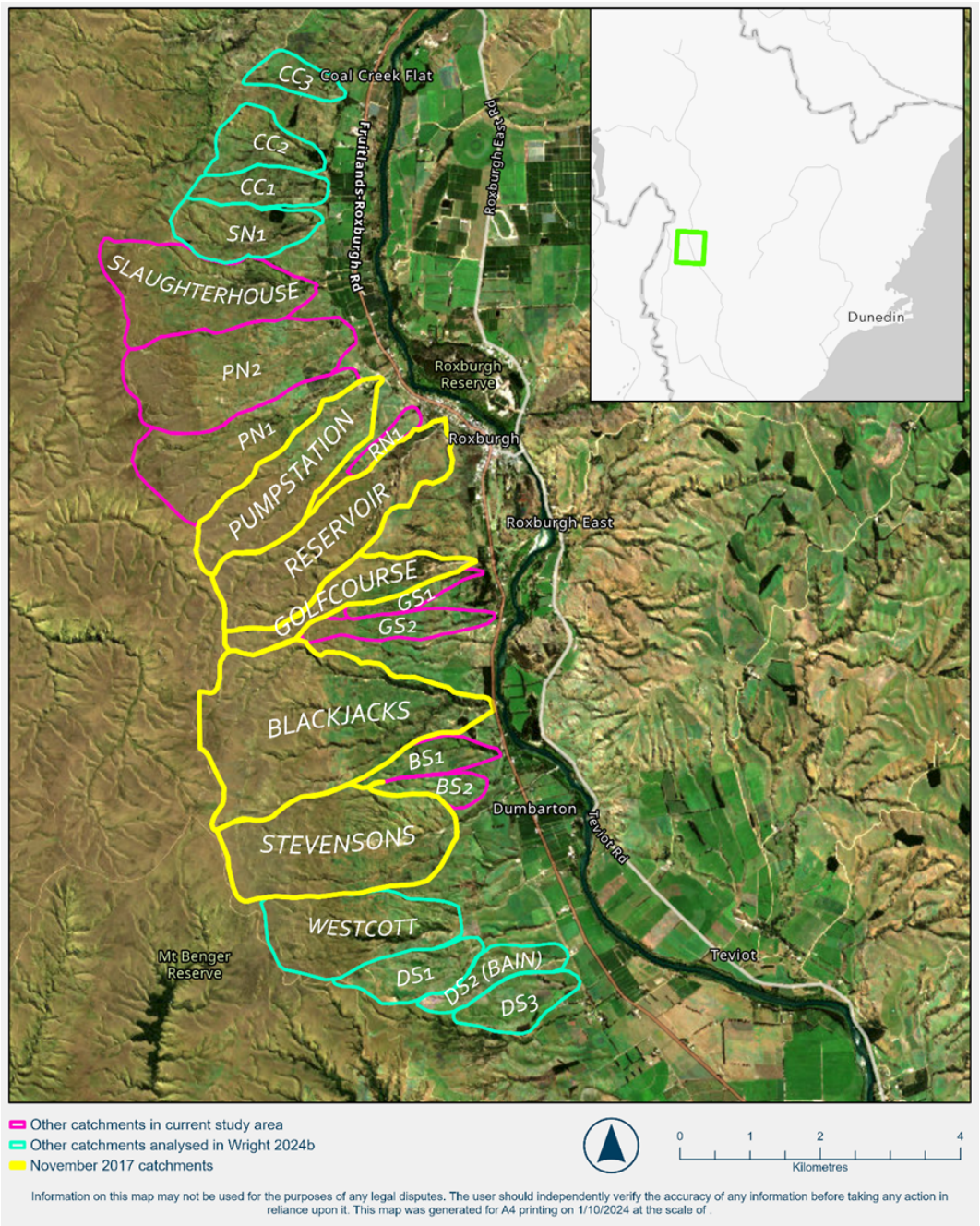

Figure 11: Map of the catchments susceptible to debris flows in the Roxburgh area. Yellow indicates the catchments active during the 2017 events, pink indicates the additional catchments incorporated during this stage of the programme, and blue indicates the other catchments assessed during prioritisation.

DISCUSSION

[40] The Roxburgh debris flow hazard has high potential consequences for the Roxburgh area. This is due to the immediate exposure of property and infrastructure to rapid and dense debris flows that occur with little warning.

[41] Debris flows in the Roxburgh area also occur relatively frequently, as evidenced by the record of past events and the geomorphic characteristics of the fans and catchments. Additionally, climate change may increase the magnitude and/or frequency of debris flow events in the Roxburgh area.

[42] The ORC's natural hazards investigations into the Roxburgh debris flows since the November 2017 events have highlighted the potential significance of the hazard and risk. However, a more comprehensive, detailed, and spatial understanding of the debris flow hazard and risk in the Roxburgh area is required to inform further management of this natural hazard.

[43] The detailed hazard and risk assessment will provide the technical basis to further develop debris mitigation and adaptation for Roxburgh, including any potential CODC landuse planning responses. The work to investigate potential options will be conducted in the 25/26 financial year. The interim monitoring and maintenance plan will allow ORC to manage the debris flow hazard in the meantime.

[44] The results of the detailed hazard and risk assessment will be made available to all interested stakeholders, including CODC, NZTA and the Roxburgh community.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[45] This natural hazards investigation programme will contribute towards the vision statement included in ORC's Strategic Directions: communities that are resilient in the face of natural hazards, climate change and other risks.

[46] The work programme 'Roxburgh Natural Hazards Management Investigations' is specified in the ORC Long-term Plan (LTP) 2024-2034 as key natural hazards work for years 1 to 3 of the LTP.

Financial Considerations

[47] The budget in the 2023/24 Annual Plan provides for the forward work programme described in this paper. The combined budget for the 2023/24 and 2024/25 financial years for the Roxburgh debris flow hazards programme is $150,000 (professional services and staff time).

Significance and Engagement Considerations

[48] ORC Natural Hazards staff presented in July 2024 at a public meeting in Roxburgh, this was to give a summary of debris flow hazards in the area, and to indicate the planned activities which are outlined in this paper.

[49] ORC will develop an engagement Plan for the Roxburgh debris flow hazards programme. The objectives for the first phases of this plan would include;

a. identifying and connecting with partners, affected communities and stakeholders.
b. building community understanding of debris flow hazards and findings of the new hazard and risk investigations.

Legislative and Risk Considerations

[50] The work described in this paper helps ORC fulfil its responsibilities under sections 30 and 35 of the RMA and the Soil Conservation and Rivers Control Act 1941

Climate Change Considerations

[51] Climate change is a factor potentially influencing debris flow hazard and risk, and will be considered in natural hazard and risk assessments.

Communications Considerations

[52] ORC will make all findings from debris flow hazard and risk investigation findings available to the Roxburgh area community and other stakeholders.

NEXT STEPS

[53] There are two key next steps:

- Implementation of the interim monitoring and management plan.
- Commencement of the detailed hazard and risk assessment.

ATTACHMENTS

Nil