General distribution and characteristics of active faults and folds in the Hurunui District, North Canterbury

D.J.A. Barrell D.B. Townsend

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EXECUTIVE SUMMARY

This report presents a general outline of the locations and character of active geological faults and folds in the Hurunui District. A fault is a fracture within the rock of the Earth's crust, along which movement has occurred. Commonly, strain builds up in the rock of the Earth's crust, and is released suddenly by a slip event (rupture) on a fault, causing an earthquake. Folds represent bending or buckling of rock, and commonly form above an underlying fault.

A fault or fold is termed 'active' where it has moved in the geologically–recent past, in particular where the movement has been sufficiently large to have emerged at the ground surface, forming offset and breakage of the ground (fault) or buckling or tilting of the ground (fold). Old landforms of uniform character, such as river terraces formed during the last ice age which ended about 18,000 years ago, are well suited for revealing the presence of active faults or folds, because they may be old enough to have experienced several rupture events and display large offsets or buckles. In areas of younger landforms, the land surface may be younger than the most recent fault or fold movements, and the presence and location of any active faults or folds may be 'concealed' from view. In this way, we can recognise active faults or folds in some places (e.g. where there are ice age river terraces), but elsewhere we may be uncertain whether or not they are present (e.g. on young river floodplains).

Regional geological mapping has detected 36 areas of active faults or folds at the ground surface in Hurunui District. This report is accompanied by Geographic Information System (GIS) datasets, showing the locations of the recognised active faults and folds. In some places, it is clear beyond doubt that a feature is an active fault or fold, but in others, the evidence is less certain. Levels of certainty in the recognition of active faults and folds are included in the datasets, as are estimates of average slip rates and recurrence intervals for each fault, in relation to Ministry for the Environment guidelines.

The nature of hazards posed by active faults has recently been demonstrated on the Canterbury Plains during the 2010 Darfield Earthquake that resulted in ground-surface rupture, and sideways land shift, on the Greendale Fault. The 1888 North Canterbury Earthquake, centred west of Hanmer Springs, was associated with very similar phenomena on the Hope Fault. Three other historic large earthquakes centred in the district, in 1901, 1922 and 1948 caused shaking damage, but no fault-rupture ground deformation was identified as a result of those earthquakes.

The main hazards associated with active faults or folds include: (i) local epicentres for large earthquakes, and (ii) the effects of sudden ground surface offset or buckling which may result, for example, in the destruction or tilting of buildings in the immediate vicinity of the fault or fold. The landform geological record shows clear evidence for prehistoric deformation at many locations within Hurunui District, and highlights that it would be prudent to treat these active fault or fold features as potentially hazardous. Based on available estimates of the amounts of deformation over time, the Awatere Fault and Hope Fault in the northwestern part of the district are the most active features in the district. Faults in the mid- to southern parts of the district appear to be somewhat less active, but there is a large number of them.

The active faults and folds of the Hurunui District have, for the most part, been mapped at a regional scale. Information presented in this report and in the accompanying GIS layer is intended to highlight those areas potentially affected by active fault or fold hazards, and may help to target locations for any further investigations that may be deemed necessary. This report provides the most up-to-date information available on the locations and nature of active faults and folds in Hurunui District. Within the last 20 years, detailed fault mapping has been undertaken at Hanmer Springs township and Mt Lyford village, sufficient for fault hazard avoidance zonation to be undertaken. However, elsewhere in the district, where this report highlights the definite or likely presence of active faults or folds, more detailed site-specific investigations of faults should be undertaken before any fault hazard avoidance zoning is attempted.

1.0 INTRODUCTION

The geologically-active nature of New Zealand reflects our position astride the mobile boundary between two large slabs (plates) of the Earth's crust (Fig. 1). The forces involved in plate movement are immense and cause the rock of the Earth's crust to buckle (fold) and fracture (fault) in the general vicinity of the boundary between the plates. The plate boundary in the South Island is marked, at the ground surface, by a series of major faults that extend from Marlborough through North Canterbury, then merge onto a single major feature, the Alpine Fault, which runs along the western margin of the Southern Alps to the Fiordland region.

In the central South Island from about Arthur's Pass south to Fiordland, most of the plate movement is concentrated on the Alpine Fault. The movement is predominantly sideways, with the western side of the fault moving northeast, and the eastern side moving southwest as well as a little bit upwards, which has produced the Southern Alps. The technical term for a sideways-moving fault is 'strike-slip', while a fault where the movement is mostly up-down is called 'dip-slip'. In the northeastern South Island, including the Hurunui District, a substantial part of the plate movement is taken up on a series of large strike-slip faults east of the Alpine Fault. Movement is also accommodated on a variety of faults and folds within the ranges and basins of coastal North Canterbury.

Although the movement along the plate boundary is continuous, and can be measured by ground and satellite (GPS) surveying, rock of the Earth's crust is remarkably elastic and can accommodate a lot of bending before letting go and breaking suddenly (rupturing) along a fault, causing an earthquake. On large faults, the break may be big, and extend up to the Earth's surface, causing sudden offset and breakage (faulting), or buckling and warping (folding), of the ground surface, and generating a large earthquake. The 2010 Darfield Earthquake has provided a good example of the nature and effects of a large, ground-surface-rupturing earthquake on a geological fault (e.g. Barrell et al. 2011) (Fig. 2).

In favourable settings, prehistoric fault offsets or fold buckles of the ground may be preserved by way of distinctive landforms, and these landforms are key to identifying the locations of active faults and folds. In New Zealand, an active fault is commonly defined as a fault that has undergone at least one ground-deforming rupture within the last 125,000 years or at least two ground-deforming ruptures within the last 500,000 years. An active fold may be defined as a fold that has deformed ground surfaces or near-surface deposits within the last 500,000 years. Unfortunately, there are few reliable 'clocks' in the natural landscape, and for practical purposes, it is common to identify as active any fault or fold that can be shown to have offset or deformed the ground surface, or any unconsolidated near-surface geological deposits (Figs. 2 & 3). This practical approach for identifying active faults or folds is used on most geological maps published in New Zealand, and is followed in this report. It is also common to assess the significance of hazards associated with an active fault or fold by estimating how often, on average, it has undergone a ground-deforming rupture or deformation event. The average recurrence interval is a primary consideration in Ministry for the Environment guidelines for planning land-use or development near active faults (Kerr et al. 2003).

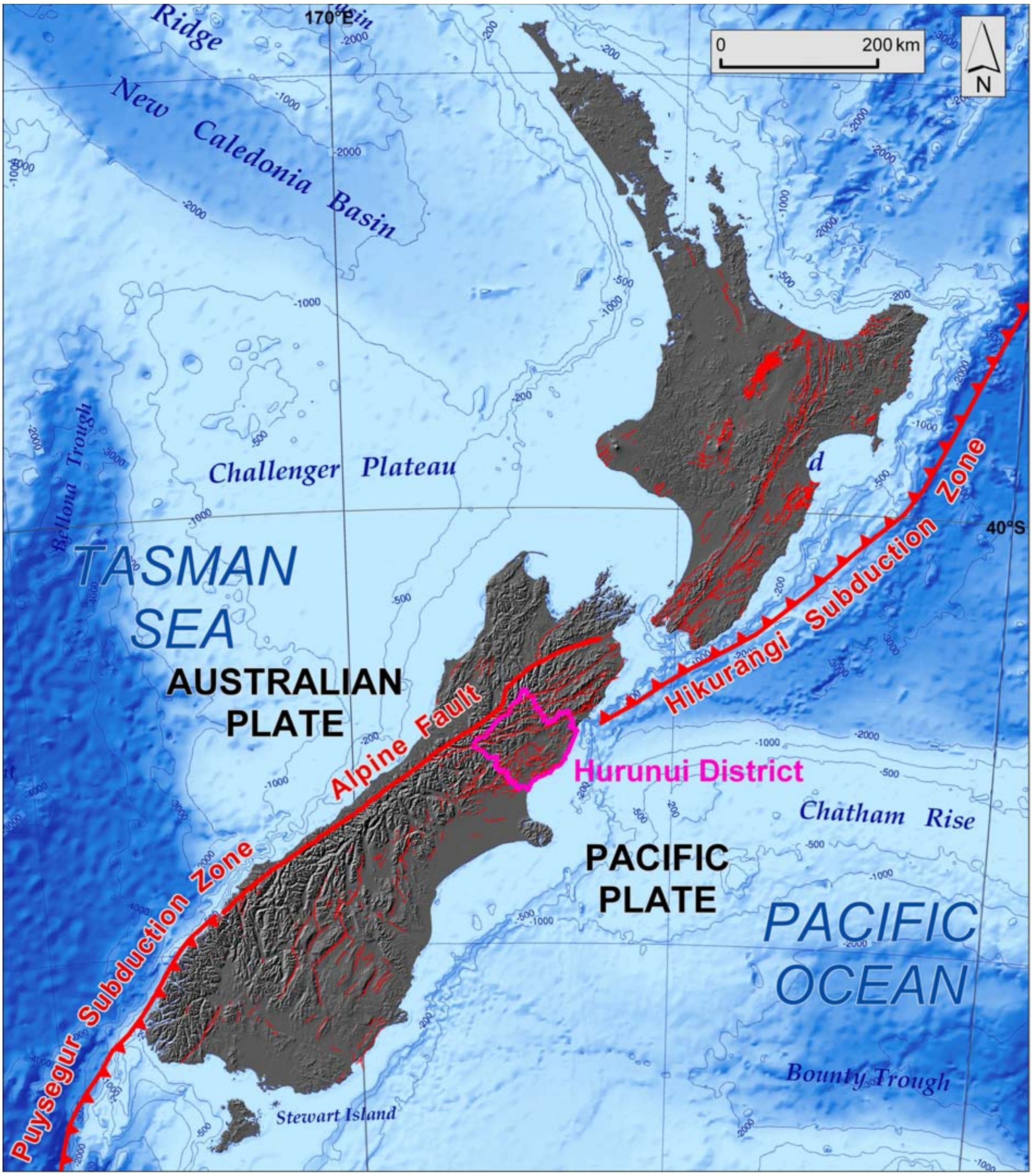


Figure 1 The tectonic setting of the Hurunui District. The junction between the Australian and Pacific plates of the Earth’s crust passes through New Zealand, with the Pacific Plate pushing westward against the Australian Plate. The Hikurangi Subduction Zone marks the place where the rocks of the Pacific Plate slide west under the North Island, while at the Puysegur Subduction Zone, the rocks of the Tasman sea floor slide east under the southwestern South Island. In between is a sideways tear, the Alpine Fault. Although most of the plate movement is concentrated at the subduction zones and the Alpine Fault, there is a wider zone of deformation, marked by numerous active faults, shown by thin red lines (from New Zealand Active Faults Database (NZAFD)). The Hurunui District lies in the midst of this wider zone of tectonic deformation. The offshore image is the New Zealand Continent map (GNS Science) showing shallower water in light blue and deeper water in darker blue. Bathymetric contours are in metres below sea level.

Figure 2 A: A fence offset sideways by ~2.4 m of strike-slip rupture on the Hope Fault at Glynn Wye during the 1888 North Canterbury Earthquake (Photo: A. McKay, GNS Science CN4852). B: A fence offset sideways by ~4.5 m of strike-slip rupture on the Greendale Fault during the 2010 Darfield Earthquake (Photo: N.J. Litchfield). Half-arrows either side of the fault indicate the direction of movement. In both cases, the movement is 'right-lateral', sometimes called 'dextral'. This means that to an observer, the ground on the far side of the fault has shifted sideways to the right. The effect is the same regardless of which side of the fault the observer is standing. The other type of strike-slip movement is 'left-lateral', sometimes called 'sinistral', but is not common in New Zealand.

There are many active geological faults and folds recognised in the Canterbury region. As part of ongoing improvements in the recognition and mitigation of natural hazards, Environment Canterbury engaged the Institute of Geological and Nuclear Sciences Limited (GNS Science) to summarise the state of knowledge regarding active geological faults and folds in the Hurunui District (see Fig. 6). This report presents that summary, and forms a companion to similar reports commissioned for the Ashburton District (Barrell & Strong 2009) and Mackenzie District (Barrell & Strong 2010).

The information in this report is intended to assist local authorities in delineating the general areas of the Hurunui District that are subject to active fault and fold hazards.

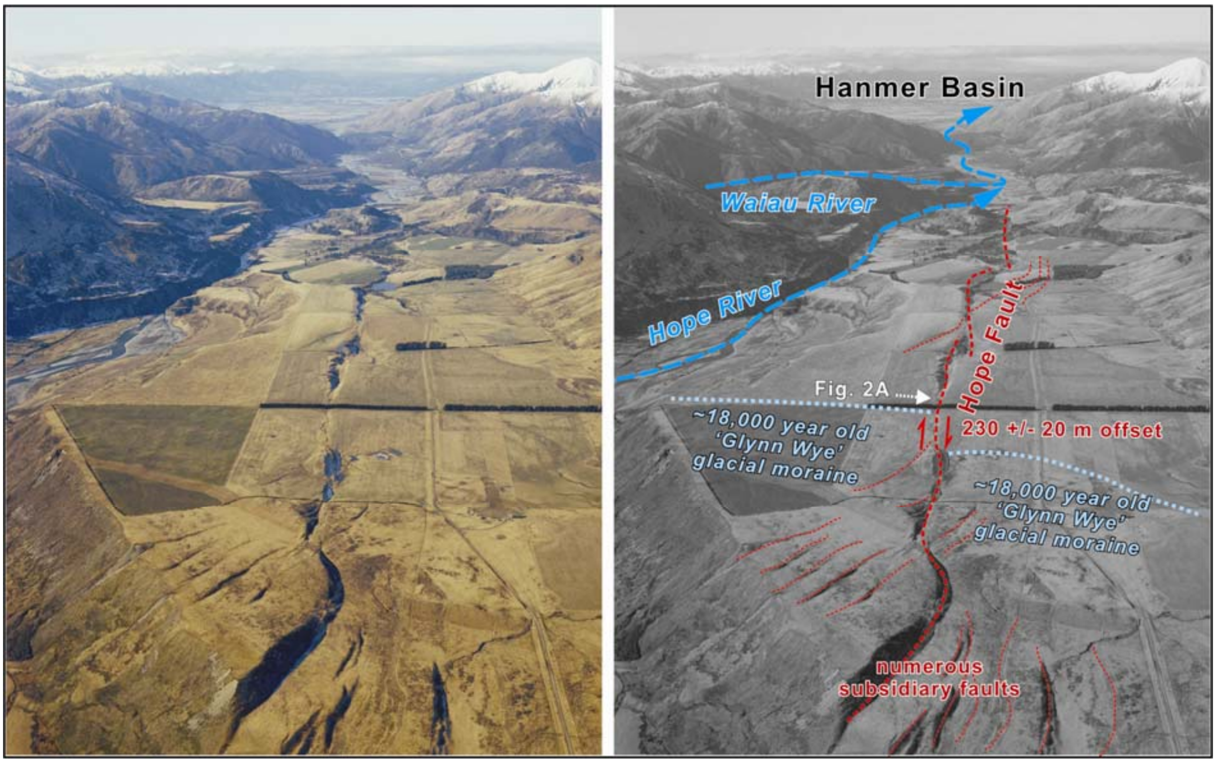


Figure 3 Aerial view looking east along the Hope Fault at Glynn Wye, Hope River valley. The fault trace is accentuated by a dusting of snow persisting on shaded areas along the fault (Photo: D.L. Homer, GNS Science CN3602/26).

2.0 INFORMATION SOURCES

This summary draws largely upon regional-scale geological mapping, compiled in digital format as part of the GNS Science 1:250,000 scale QMAP (Quarter-million scale MAP) project, represented in the Hurunui District by the Kaikoura map (Rattenbury et al. 2006), as well as the Greymouth map (Nathan et al. 2002) in the western part of the district, and the Christchurch map (Forsyth et al. 2008) towards the south. Some more detailed studies have contributed to the generalised information shown on these maps and their underlying Geographic Information System (GIS) databases. Those studies, where relevant, are identified in Table 2 of this report. Additional detailed information on active faults is contained in the New Zealand Active Faults Database (NZAFD – see reference list).

This report comprises an office-based review of existing information, with a scope of work that did not include site investigations. However, both authors have previously undertaken geological investigations in the Hurunui District, including ground-based reconnaissance inspections or interpretation of aerial photographs, of the active faults and folds identified in this report (Rattenbury et al. 2006; Forsyth et al. 2008). Unpublished observations made during that work are included in the interpretations within this report, with extended description of some aspects contained in Appendix A.

3.0 GEOLOGICAL OVERVIEW

3.1 Rocks and landforms

In North Canterbury, including Hurunui District, the oldest underlying rock (basement rock) consists mainly of hard sandstones and flaky mudstones, commonly called greywacke and argillite respectively, with a few bands of volcanic rock. These ancient rocks, of Triassic to Early Cretaceous age (between 250 and 100 million years old) were buried by a blanket of younger sedimentary rocks (cover rocks) including coal measures, quartz sands, marine mudstones, limestones and gravelly conglomerates. The cover rocks range in age from about 85 million to about 1 million years old. Collectively, the basement and cover rocks constitute what may be called ‘bedrock’. The cover rocks provide useful reference markers for identifying faults and folds. The well-developed sedimentary layering readily shows offsets due to faulting, while the tilting of these layers may reveal the effects of folding. In many of the ranges of the Hurunui District, uplift and erosion has stripped away much of the cover rock blanket, exposing the underlying basement rock. The cover rocks are preserved around the flanks of many of the ranges in the central to eastern parts of the district, and beneath many of the broad valleys and basins, such as the Culverden Basin and the Omihi valley.

The youngest deposits of the district are unconsolidated sediments. These are the result of uplift and erosion of the ranges and mountains during the latter half of the Quaternary Period (from about 1 million years ago to the present day) that produced voluminous sediment that has been laid down in the basins and valleys, on top of the basement or cover rocks. A major feature of the Quaternary Period has been a cycle of large-scale natural shifts in global climate, with periods of generally cool conditions (glaciations, or ‘ice ages’) separated by periods of warmer climate (‘interglaciations’), such as that existing today. In the last 500,000 years or so, an ice age has happened, on average, at least once every 100,000 years. During an ice age, ice was not everywhere, but rather the climate cooled enough to allow glaciers to form, or expand greatly, in some of the cooler and wetter places, such as in the Southern Alps. Sea level is linked to glaciation/interglaciation cycles. During ice ages, so much water became locked up in ice sheets that formed on Europe and North America that the level of the sea dropped. At the peak of the most recent ice age, about 20,000 years ago, sea level was at least 120 m lower than it is now. As Northern Hemisphere ice sheets melted, sea level rose, stabilizing at its present level about 7000 years ago. The last time the sea was as high as it is now was during the last interglacial period, about 125,000 years ago.

Erosion and deposition has been greatly influenced by episodes of glaciation in the hinterland during ’ice ages’, when debris-laden glacier ice flowed off the Southern Alps into the upper reaches of the Hurunui, Hope, Waiau and Clarence rivers (Barrell 2011). Lakes Sumner, Taylor, Sheppard, Guyon and Tennyson lie in troughs hollowed out by ice age glaciers. Glacier meltwater spread vast volumes of river sediment out though the basins and towards the coast. In addition, snowlines and treelines were many hundreds of metres lower than they are today. The lack of trees aided erosion in the hills and mountains, and promoted build-up of river and stream sediments in the valleys and basins. During ice ages, the inland parts of the Hurunui District were a harsh environment, with the bleakness enhanced by dust storms of river silt that was picked up from floodplains by the wind and blanketed on terraces and hillslopes. These yellow-brown windblown silt deposits, known as loess, are common on old high terraces and foothills.

The last ice age ended about 18,000 years ago (e.g. Alloway et al. 2007), and was followed by warming climate, retreat of glaciers from the headwaters of the major rivers, the spread of woody vegetation and the stabilisation of hill slopes. As a result of the improved slope stability, the river systems were no longer choked with sediment, and began to cut down into their valley floors, leaving flights of terraces. The confinement of rivers to narrower courses across the basins and broad valleys led to large areas of ‘fossil’ ice-age river beds being preserved, such as the Waipara & Kowai plains, Masons Flat and the Balmoral, Amuri and Emu plains of the Culverden Basin. These landforms, although youthful in a geological sense, are old enough to have been affected by some of the most recent active fault and fold movements. Areas of younger landforms or deposits, such as steep, eroding hill slopes, young river terraces and floodplains and accumulating fans of stream sediment at the mouths of valleys and gullies, are commonly younger than the most recent fault movements or fold growth. These younger landforms, either as a result of burial or erosion, ‘conceal’ the locations of faults or folds.

Close to the coast, wave-cut shore platforms were formed during past episodes of interglacial climate (with sea level about the same as it is today). In places where the land is being uplifted, these former sea-bed areas have been raised, and preserved as distinctive coastal terraces. There are good examples near Motunau Beach, Hurunui Mouth, Gore Bay and Conway Flat. These coastal terraces are relatively old landforms, ranging from about 125,000 years old to perhaps as much as 330,000 years old, and therefore are well suited for showing the long-term effects of fault movements or fold growth.

3.2 Recognition of active faults and folds

The key evidence for recognising active faults or folds is the offset or buckling of landforms or young geological deposits. This is seen most clearly on old river terraces or river plains, where the original channel and bar patterns of the former riverbed are ‘fossil’ landforms dating from when the river last flowed in that location. Topographic steps or rises that cut across such river-formed features could not have been created by the river, and therefore result from subsequent deformation of the ground. As long as factors such as landsliding can be ruled out, these topographic features may confidently be attributed to fault or fold movements (Figs. 2 to 4). Note that in the captions accompanying the photos of Hurunui district faults in this report, sufficient information is given so that an interested reader would be able to go to the location where the photo was taken, and examine the feature first-hand.

In this report, and the accompanying GIS dataset, we distinguish between the style of active deformation, whether predominantly by **fault** offset of the ground (fault scarp), or whether by folding (buckles, tilts or flexures) of the ground. Folds are subdivided into ‘one-sided folds’, or **monoclines**, and ‘two-sided folds’, either up-folds (**anticlines**) or down-folds (**synclines**) (Fig. 5).

Figure 4 A view northwest towards a ~3 m high fault scarp, traversed by Creans Road ~260 m southeast of the Hewetts Road intersection. The ground surface here, southwest of the Hurunui River and about 13 km north-northwest of Hawarden, is part of the ~18,000 year old Balmoral Plain formed by the Hurunui River. This well-expressed fault, part of the Hurunui Peak fault zone (Fig. 6, feature 12), is classed as ‘definite’ because it cuts across ‘fossil’ Hurunui River channels, although these are not visible in this image. Photo: D.J.A. Barrell.

Two end-members of fault type are shown in Figure 5, a dip-slip fault which has up-down movement, and a strike-slip fault which has horizontal (sideways) movement. In practice it is not uncommon for a fault to display a combination of both types of movement; such faults are called ‘oblique-slip’, and have movement that is partly up-down and partly sideways. Most dip-slip faults are inclined (i.e. are not vertical), and there are two basic types of movement. Where the rock on the upper side of the inclined dip-slip fault shifts upwards along the fault, it is called a reverse fault, and results from compressional forces. Where the rock on the upper side of the inclined dip-slip fault shifts downwards along the fault, it is called a normal fault, and results from tensional forces.

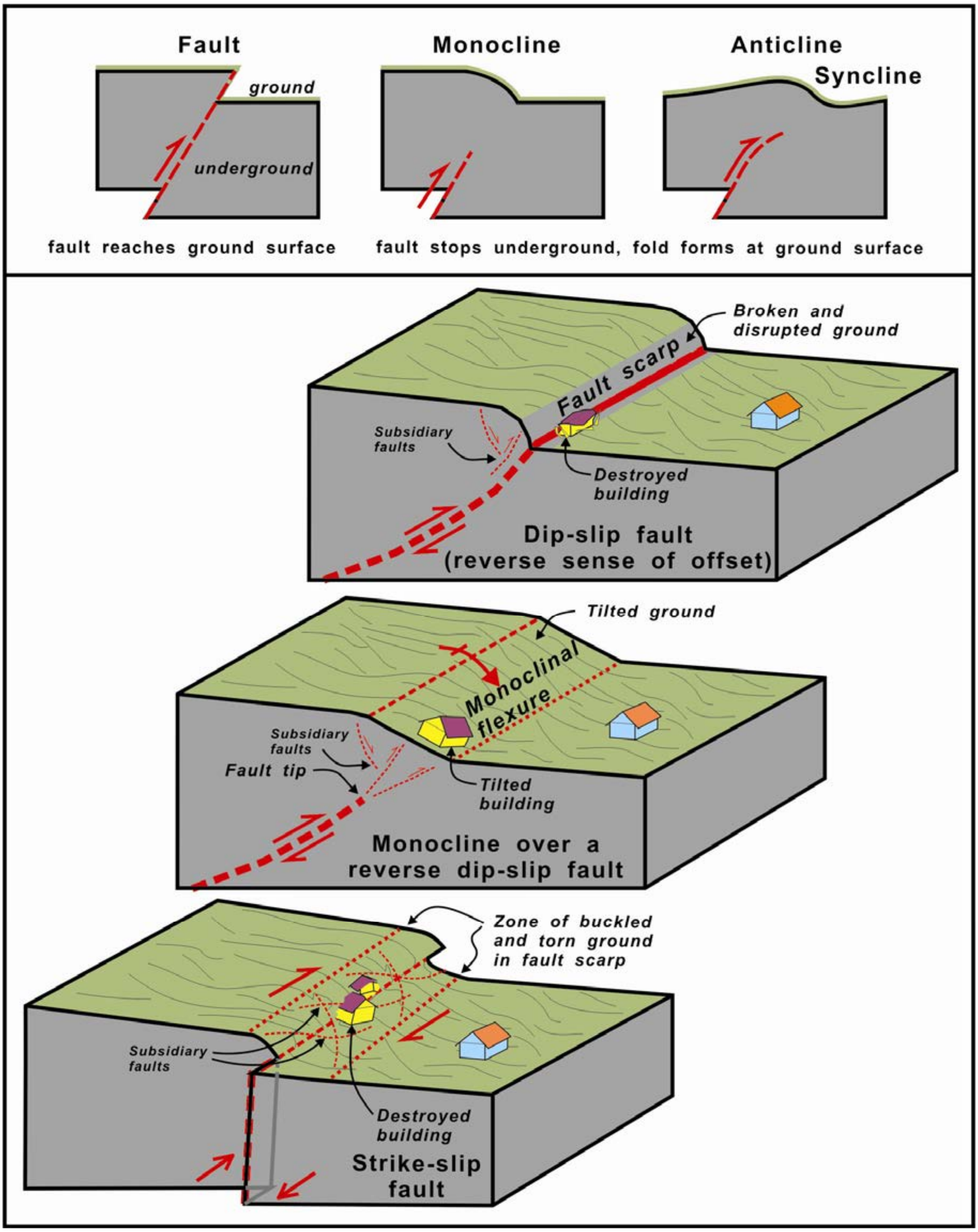


Figure 5 Diagrams illustrating styles of active faults and folds. The diagrams illustrate general concepts rather than actual details, and are not drawn to an exact scale. Upper panel: Cross-section (vertical slice) diagrams illustrating an active fault, active monocline and active anticline and syncline. Most folds are, as shown here, thought to have formed over faults whose ruptures have not made it all the way to the ground surface. Lower panel: perspective block diagrams showing typical ground-surface expressions of faults and monoclines. The diagrams include hypothetical examples of effects on buildings of a future fault rupture or monocline growth event. See text for further explanation.

The fault and fold styles illustrated in Figure 5 are idealised examples. They do not show the full range of variations and complexity that may exist (for example, see Fig. 3 and also Fig. 10). Indeed, to find such simple examples in nature would be an exception rather than a rule. The steepness of inclination (dip) of the fault may vary considerably (Fig. 5). Where a fault has a gentle dip (i.e. is closer to horizontal than vertical), each successive movement commonly results in the upthrown side ‘bulldozing’ outward, over-riding the ground and encroaching over anything in its immediate vicinity. The destroyed building in Figure 5 attempts to convey some impression of the bulldozer effect.

There is rarely an exact distinction between a fault and a monocline at the ground surface. Fault scarps are commonly associated with some buckling of the ground and near-surface layers, particularly on the upthrown side of the main fault scarp (Fig. 5; also see Fig. 10). In some cases, part of the fault movement may have broken out on a series of smaller subsidiary faults in the vicinity of the main fault. In the case of monoclines or anticlines, subsidiary faults may also occur over buried faults that underlie these folds, resulting in small ground surface offsets (e.g. Kelson et al. 2001). The important message is that on any active fault or fold, there commonly are elements of both faulting and folding close to the ground surface. The amount of deformation due to faulting, relative to the amount expressed as folding, may vary over short distances.

In practice, where the zone of ground deformation is quite narrow, we interpret it as a fault, and where it is broad, we interpret it as a fold (e.g. monocline) (see Fig. 5). The only way to determine the accuracy of this interpretation is to excavate a trench across the deformed zone to try and see whether, or to what extents, the near-surface deposits have been offset, or merely folded. Sometimes, natural exposures in stream banks provide the necessary information. This highlights a key issue; without detailed work involving examination of what lies within the first few metres beneath the ground surface, we can at best only make informed guesses about the exact locations, form and likely future consequences of fault or fold activity.

It is common to find some surprises as a result of more detailed geological examinations of active faults or folds. For example, a broad fault scarp, that we would expect to include a considerable amount of folding may, upon excavation, turn out to have a well-defined fault offset with very little folding. This could occur because after a surface deformation event, natural landscape processes tend to smooth-over the effects. For instance, a steep face of bare broken ground in a fault scarp will settle, subside, and compact due to factors such as rainstorms, frost heave, and soil formation. Over longer periods, wind-blown dust emanating from river beds tends to accumulate most thickly in hollows and depressions, further smoothing any irregularities produced by fault offset of the ground.

An important message is that while landforms provide important clues as to the general location of active faults or folds, many details of these features which may be relevant to land-use, development and hazard mitigation cannot be obtained without more detailed site-specific investigations.

4.0 DISTRIBUTION AND CHARACTERISTICS OF ACTIVE FAULTS AND FOLDS IDENTIFIED IN HURUNUI DISTRICT

A regional-scale map of the active faults and folds identified so far in the Hurunui District is presented in Figure 6. Descriptions of the typical characteristics of active faults and folds and syntheses of the mapping categories in this report are presented in Table 1, while Table 2 summarises the main features of the recognised active faults or folds in Hurunui District.

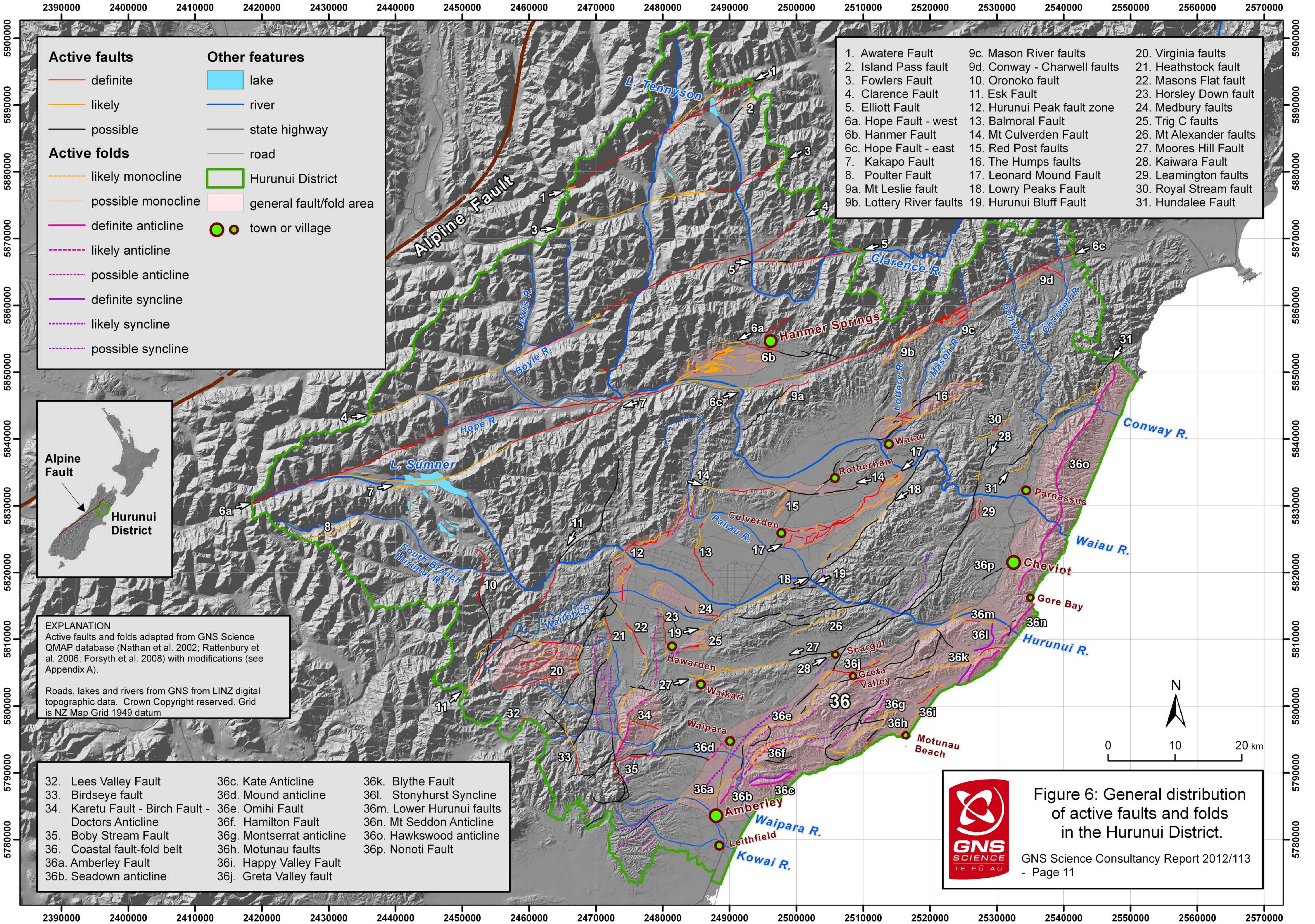
The original information on active faults and folds is extracted from the QMAP dataset (Nathan et al. 2002; Rattenbury et al. 2006; Forsyth et al. 2008). For this report, we have re-examined the existing mapping and made a number of additions and refinements to the mapping of active faults and folds. We have also made amendments to the datasets (see Appendix A) with the addition of three data fields (also known as ‘attributes’):

- HDC_name (local names for the mapped features)
- Certainty (see below)
- Surf_form (see below)

By and large the names correspond to those in the New Zealand Active Faults Database (NZAFD), which in the Hurunui District is closely related to the QMAP dataset. The main departure in the datasets accompanying this report is that we have applied local names to some of the fault or fold features. In places where no name has previously been given to active fault/folds, we have applied a representative name taken from nearby named topographic features (e.g. The Humps faults). Where names are informal, fault or fold are in lower case type, while for formally-published names, a capital ‘F’ is used.

For the purposes of illustration and discussion, in places where several active fault or fold features lie close to one another, we have grouped them together under one name. In total, we have identified 36 individual or grouped active fault/fold features (Fig. 6).

In the Certainty field, we have designated as ‘**definite**’ those features that can only be explained by active faulting or folding. We designate as ‘**likely**’ those features that are most probably due to faulting or folding, but where we cannot rule out other origins such as having been formed by erosion. In instances where we have some reason to suspect the presence of an active fault or fold, but cannot say for sure either way because, for example, the landforms are unsuitable (e.g. too young) to have preserved any direct evidence of young movement, we designate such features as ‘**possible**’. The purpose of the Certainty field is to indicate our level of confidence in the interpretation of the deformation features. Features identified as ‘possible’ should not be treated as delineated active faults or folds unless investigated further. They are identified to highlight areas that are worth a closer look with regard to the possible existence of active faults or folds.



1. Awatere Fault
2. Island Pass fault
3. Fowlers Fault
4. Clarence Fault
5. Elliott Fault
6a. Hope Fault - west
6b. Hanmer Fault
6c. Hope Fault - east
7. Kakapo Fault
8. Poulter Fault
9a. Mt Leslie fault
9b. Lottery River faults
9c. Mason River faults
9d. Conway - Charwell faults
10. Oronoko fault
11. Esk Fault
12. Hurunui Peak fault zone
13. Balmoral Fault
14. Mt Culverden Fault
15. Red Post faults
16. The Humps faults
17. Leonard Mound Fault
18. Lowry Peaks Fault
19. Hurunui Bluff Fault
20. Virginia faults
21. Heathstock fault
22. Masons Flat fault
23. Horsley Down fault
24. Medbury faults
25. Trig C faults
26. Mt Alexander faults
27. Moores Hill Fault
28. Kaiwara Fault
29. Leamington faults
30. Royal Stream fault
31. Hundalee Fault

32. Lees Valley Fault
33. Birdseye fault
34. Karetu Fault - Birch Fault - Doctors Anticline
35. Boby Stream Fault
36. Coastal fault-fold belt
36a. Amberley Fault
36b. Seadown anticline
36c. Kate Anticline
36d. Mound anticline
36e. Omihi Fault
36f. Hamilton Fault
36g. Montserrat anticline
36h. Motunau faults
36i. Happy Valley Fault
36j. Greta Valley fault
36k. Blythe Fault
36l. Stonyhurst Syncline
36m. Lower Hurunui faults
36n. Mt Seddon Anticline
36o. Hawkswood anticline
36p. Nonoti Fault

EXPLANATION
Active faults and folds adapted from GNS Science QMAP database (Nathan et al. 2002; Rattenbury et al. 2006; Forsyth et al. 2008) with modifications (see Appendix A).

Roads, lakes and rivers from GNS from LINZ digital topographic data. Crown Copyright reserved. Grid is NZ Map Grid 1949 datum

Figure 6: General distribution of active faults and folds in the Hurunui District.

Table 1: Categories and terms used in this report to describe active faults and folds in the Hurunui District

Category	Characteristics	Certainty	Surface form	Nature of evidence	Fault complexity (based on definitions in Kerr et al. (2003))
Active fault	Deformation predominantly in the form of breakage and offset of the ground surface. This is presumed to occur in sudden events accompanied by a large earthquake. May also include some monoclinal or anticlinal folding	definite	well expressed	Sharp step in ground surface that cannot be attributed to other geological factors (e.g. river erosion or landslide movement)	Well-defined deformation
		definite	moderately expressed	Poorly-defined step(s) in ground surface that cannot be attributed to other geological factors	Well-defined or distributed deformation
		definite	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby definite active fault	Uncertain deformation
		likely	well expressed	Sharp step(s) in the ground surface that cannot readily be attributed to other geological factors	Well-defined deformation
		likely	moderately expressed	Poorly-defined steps in the ground surface that cannot readily be attributed to other geological factors	Uncertain deformation
		likely	not expressed	No surface expression, but lies along trend from nearby likely active fault	Uncertain deformation
		possible	moderately expressed	Coincides with a definite or likely fault in bedrock, along trend from nearby definite or likely active fault; includes steps or topographic features that may possibly relate to fault activity, but other origins are reasonably likely.	Uncertain deformation
		possible	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby likely or possible active fault	Uncertain deformation
		possible	unknown	No known surface expression, but likely that evidence for/against activity may be found on further investigation	Uncertain deformation
Active monocline	Deformation predominantly in the form of tilting, buckling or warping of the ground surface. Growth of the fold is presumed to occur in sudden events accompanied by a large earthquake. May also include some subsidiary fault offsets	definite	well expressed	Broad step or rise in ground surface that cannot be attributed to other geological factors	Distributed deformation
		definite	moderately expressed	Poorly-defined broad step(s) or rise in ground surface that cannot be attributed to other geological factors	Distributed deformation
		definite	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby definite or likely active monocline	Uncertain deformation
		likely	moderately expressed	Broad steps or rises in the ground surface that cannot readily be attributed to other geological factors	Uncertain deformation
		likely	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby likely active monocline	Uncertain deformation
		possible	moderately expressed	Coincides with a definite or likely monocline in bedrock, or a broad rise of uncertain origin, along trend from nearby definite or likely active monocline	Uncertain deformation
		possible	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby likely or possible active monocline	Uncertain deformation
		possible	unknown	No known surface expression, but likely that evidence for/against activity may be found on further investigation	Uncertain deformation
Active anticline or syncline	Deformation expressed mainly as a broad arch in the ground surface. Growth possibly occurs in sudden events accompanied by a large earthquake. May include subsidiary fault offsets or monoclines	definite	well expressed	Broad arch in ground surface that has clearly defined limits, and which cannot be attributed to other geological factors	Distributed deformation
		definite	moderately expressed	Poorly-defined broad arch in the ground surface that cannot be attributed to other geological factors	Distributed deformation
		definite	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby definite active anticline	Uncertain deformation
		likely	moderately expressed	Poorly-defined broad arch in ground surface that cannot readily be attributed to other geological factors	Uncertain deformation
		likely	not expressed	No surface expression (i.e. evidence concealed or eroded away) but lies along trend from nearby likely active anticline	Uncertain deformation
		possible	moderately expressed	Poorly-defined broad arch in ground surface that may possibly, on account of its position and form, be due to active folding	Uncertain deformation
		possible	unknown	No known surface expression, but likely that evidence for/against activity may be found on further investigation	Uncertain deformation

Definite = clear evidence for the existence of an active fault or fold
Likely = good reason to suspect the existence of an active fault or fold
Possible = some reason to suspect the existence of an active fault or fold

Well expressed = likely to be able to be located to better than +/- 50 m in site-specific investigations
Moderately expressed = likely to be able to be located to better than +/- 100 m in site-specific investigations
Not expressed = able to be located only by large-scale subsurface site-specific investigations
Unknown = probable that evidence for or against an active feature would be found in targeted site-specific investigations

Table 2: Summary of evidence and estimated deformation characteristics of active faults and folds recognised in the Hurunui District (see text for explanation)

Name	**Observed characteristics**	**References**	**Deformation estimates**						
Lower case last term (e.g. fault) = informal name. Upper case (e.g. Fault) = name previously published	**Geologic evidence**	**Most comprehensive published information on fault/fold activity**	**Basis of estimates**	**Estimated age of deformed landform** (years before present)	**Estimated vertical deformation of landform** (m)	**Calculated average vertical slip rate** (mm/yr)	**Implied long-term average recurrence interval (RI - years) of deformation event, assuming 2 m vertical deformation per event*** (see notes on last page of table)	**Nominal 67% uncertainty in RI (years) **** (see notes on last page of table)	**Implied range of RI Classes** (following Kerr *et al*. 2003)
1. Awatere Fault Zone	Major strike-slip fault extending from Westland to offshore of northeast Marlborough. Definite and likely faults.	Mason & Little (2006); Mason et al. (2006); also see NZAFD.	field inspection & surveying; airphoto interpretation; regional geologic mapping.	Predominantly horizontal movement; detailed studies of the fault in Marlborough indicate an average slip rate of ~6 mm/yr (Mason et al. 2006a) and average recurrence interval of ~900 years (Mason et al. 2006b). The 1848 Marlborough Earthquake (Mw ~7.5) occured on the eastern part of the Awatere Fault and produced an average horizontal ground offset of ~5 m (Mason & Little 2006).					I
2. Island Pass fault	Likely and possible faults.	Rattenbury et al. (2006); this report.	regional geologic mapping; airphoto interpretation.	18,000	2	0.1	18,000	5,940	V-VI
3. Fowlers Fault	Likely and definite faults.	Kieckhefer (1979); Rattenbury et al. (2006).	field inspection; airphoto interpretation; regional geologic mapping.	Predominantly horizontal movement; Kieckhefer (1979) reported approximately 25 m of offset on landforms judged to be 'post-glacial' (i.e. less than about 18,000 years old). Van Dissen et al. (2003) assigned a recurrence interval in the range 2,000 to 5,000 years; we use that value in this report.					II
4. Clarence Fault	Major strike-slip fault extending from Westland to northeast Marlborough. Definite and likely faults.	Kieckhefer (1979); Rattenbury et al. (2006); Van Dissen & Nicol (2009).	field inspection; airphoto interpretation; regional geologic mapping.	Predominantly horizontal movement; detailed studies of the fault in Marlborough indicate an average slip rate of ~4 mm/yr and average recurrence interval of ~1700 years, an average horizontal offset of ~7 m per earthquake, and the most recent ground-surface rupture earthquake was between ~1700 and ~1900 years ago (Van Dissen & Nicol 2009). We provisionally assume that these vaules are applicable to the (western) section of the fault that crosses the Hurunui District.					I
5. Elliott Fault	Likely and definite faults.	Kieckhefer (1979); Rattenbury et al. (2006).	airphoto interpretation; field inspection.	Predominantly horizontal movement; Van Dissen et al. (2003) assigned a recurrence interval in the range 2,000 to 5,000 years; we use that value in this report.					II
6. Hope Fault Zone 6a - western section 6b - Hanmer Fault 6c - eastern section	Major strike-slip fault extending from Westland to offshore of northeast Marlborough. Definite and likely faults. Hanmer Basin is a down-dropped area in the step-over between the western and eastern sections; Hanmer Fault is part of the down-drop zone.	6a: Cowan (1990); Cowan & McGlone (1991); Langridge & Berryman (2005). 6b: Wood et al. (1994); Langridge et al. (2008). 6c: Langridge et al. (2003).	field inspection & surveying; airphoto interpretation; regional geologic mapping.	**6a**: Predominantly horizontal movement; detailed studies indicate that the western section has a slip rate of between ~8 and ~13 mm/yr and average recurrence interval of between ~150 and ~500 years (Cowan & McGlone 1991; Langridge & Berryman 2005). The 1888 North Canterbury Earthquake (M_w ~7.0 to ~7.3) occurred on a ~30 km long part of the western section, between the Hanmer Basin and the Boyle River, and offset fences by between ~1.5 and ~2.6 m (Cowan 1991). The size and significance of this earthquake was similar to the 2010 Darfield Earthquake on the Greendale Fault. **6b**: The Hanmer Fault has a mix of vertical and horizontal movement (normal-dextral). At least 10 m of vertical offset has accumulated in the past ~12,500 years. Recent trenching investigations and radiocarbon dating indicate a total slip rate of between ~1 and 3 mm/yr, and recurrence interval of ~300 to 600 years (Langridge et al. 2008). **6c**: Studies indicate that the slip rate on eastern section of the fault is as much as ~25 mm/yr, with average offset per event of ~6 m, and recurrence interval of ~200 to ~300 years (Langridge et al. 2003).					6a: I 6b: I 6c: I
7. Kakapo Fault	Definite and likely faults.	Yang (1991); Berryman & Villamor (2004).	field inspection & surveying; airphoto interpretation; regional geologic mapping.	Predominantly horizontal movement; Following reduction of the mapped extent of the fault by Berryman & Villamor (2004), the key site for information on past earthquakes is the Kakapo Brook terraces (Yang 1991). Adopting an age of ~18,000 years for the oldest of the offset terraces gives a slip rate of ~4 mm/yr; assuming average offset per event of ~3m (based on observed Hope Fault offsets in the 1888 earthquake) implies a recurrence interval of ~800 years.					I
8. Poulter Fault	Definite and likely faults.	Berryman & Villamor (2004).	field inspection; airphoto interpretation; regional geologic mapping.	Partly un-healed ground-surface rents, associated with as much as ~4 m of horizontal movement, suggest that rupture of the Poulter Fault generated the M_w ~7.0 1929 Arthur's Pass Earthquake. A spur, likely to be at least 18,000 years old, that shows a ~40 m horizontal offset, implies a horizontal slip rate of ~2 mm/yr or less, and recurrence interval for ~4 m offset events of ~2,000 years or more.					I-II
9. Faults southeast of the eastern section of the Hope Fault. 9a: Mt Leslie Fault 9b: Lottery River faults 9c: Mason River faults 9d: Conway-Charwell faults	Definite and likely faults.	9a - 9d: Rattenbury et al. (2006); 9b & 9c: Eusden et al. (2000); 9c: Hancox et al. (2006); 9d: Eusden et al. (2005a,b).	field inspection; airphoto interpretation; regional geologic mapping.	The Hancox et al. (2006) investigation of Lottery River faults indicated slip rates in the range of 0.05 to 0.2 mm/yr, and recurrence intervals ≥6000 years. Similar values are assumed for other faults in this group. RI Class in the range of II to IV is assumed. The reason for mapping many of these faults as 'likely' is that it seems possible that some are the expressions of slope instability movements rather than fault movement.					III-IV

Name	**Observed characteristics**	**References**	**Deformation estimates**						
Lower case last term (e.g. fault) = informal name. Upper case (e.g. Fault) = name previously published	**Geologic evidence**	**Most comprehensive published information on fault/fold activity**	**Basis of estimates**	**Estimated age of deformed landform** (years before present)	**Estimated vertical deformation of landform** (m)	**Calculated average vertical slip rate** (mm/yr)	**Implied long-term average recurrence interval (RI - years) of deformation event, assuming 2 m vertical deformation per event*** (see notes on last page of table)	**Nominal 67% uncertainty in RI (years) **** (see notes on last page of table)	**Implied range of RI Classes** (following Kerr *et al*. 2003)
10. Oronoko fault	Definite and likely fault offsetting hill slopes. Possible extension to the south on a fault mapped in bedrock.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
11. Esk Fault	Definite and likely faults; possible extension northeast of the Hurunui River.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
12. Hurunui Peak fault zone	Definite and likely faults. Equates in part to West Culverden Fault Zone of Pettinga et al. (2001). Revised name adopted from a nearby geographic feature (Hurunui Peak).	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	8	0.4	4,500	3,015	I-IV
13. Balmoral Fault	Definite and likely faults.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
14. Mt Culverden Fault	Definite and likely faults. Likely moncline to east.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	10	0.6	3,600	2,412	I-IV
15. Red Post faults	Likely faults.	Rattenbury et al. (2006).	airphoto interpretation; regional geologic mapping.	Faults parallel to bedding in cover rocks, in downland terrain. There is no age context for the land surface and slip rates and recurrence intervals cannot be estimated.					?
16. The Humps faults	Definite, likely and possible faults; possible extension northeast of Mason River; possible extensions across the Waiau valley towards the west side of the Rotherham Downs.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	65,000	10	0.2	13,000	8,710	III-VI
17. Leonard Mound Fault	Definite and likely faults.	Armstrong (2000); Campbell et al. (2005); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	18,000	10	0.6	3,600	2,412	I-IV
18. Lowry Peaks Fault	Likely, definite and possible faults.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	65,000	10	0.2	13,000	8,710	III-VI
19. Hurunui Bluff Fault	Likely and possible faults.	Litchfield et al. (2003); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	Indications near Hurunui village of a possible component of horizontal movement. 1 m high scarp on ~18,000 year old terrace at western end of fault is probably a minimum for the fault as a whole. We provisionally assume as much as 5 m offset in the last 18,000 years, which gives a slip rate of ~0.3 mm/yr, implies a recurrence interval for ~2 m offset events of 7,200 +/- ~4,800 years, and RI Class in the range II-V.					II-V
20. Virginia faults	Definite, likely and possible faults; five distinct faults in this area, identified in the dataset as Waitohi Fault, Virginia fault, Leaseman fault, Madrid Hill fault and Double Tops fault.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	Features visible in aerial photos suggest predominantly right-lateral horizontal movement. On each fault the offset of hill slopes, assumed age 18,000 years, is probably no more than 5 m or so. This implies horizontal slip rate of ~0.3 mm/yr on each fault.					II-V
21. Heathstock fault	Definite and likely faults.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	6	0.3	6,000	4,020	II-IV
22. Masons Flat fault	Definite and likely faults.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	3	0.2	12,000	8,040	III-VI
23. Horsley Down fault	Definite and likely faults and monocline.	Campbell et al. (2005); Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	6	0.3	6,000	4,020	II-IV

Name	Observed characteristics	References	Deformation estimates						
Lower case last term (e.g. fault) = informal name. Upper case (e.g. Fault) = name previously published	**Geologic evidence**	**Most comprehensive published information on fault/fold activity**	**Basis of estimates**	**Estimated age of deformed landform** (years before present)	**Estimated vertical deformation of landform** (m)	**Calculated average vertical slip rate** (mm/yr)	**Implied long-term average recurrence interval (RI - years) of deformation event, assuming 2 m vertical deformation per event*** (see notes on last page of table)	**Nominal 67% uncertainty in RI (years) **** (see notes on last page of table)	**Implied range of RI Classes** (following Kerr *et al*. 2003)
24. Medbury faults	Definite, likely and possible faults.	Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	2	0.1	18,000	12,060	IV-VI
25. Trig C faults	Definite and likely faults and anticlines.	Litchfield et al. (2003); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	The faults are identified by steps on hill slopes that are most likely due to fault offset, although other explanations are possible. These uncertainties coupled with a lack of clear age context for the land surface means that slip rates and recurrence intervals cannot be estimated.					?
26. Mt Alexander faults	Possible and likely faults.	Litchfield et al. (2003); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	18,000	2	0.1	18,000	12,060	IV-VI
27. Moores Hill Fault	Likely and possible faults.	Litchfield et al. (2003); Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
28. Kaiwara Fault	Possible and likely faults.	Warren (1995); Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	Likely faults comprise benches on hill slopes that may be due to fault offset, although other explanations are possible. These uncertainties coupled with a lack of clear age context for the land surface means that slip rates and recurrence intervals cannot be estimated.					?
29. Leamington faults	Definite faults.	Rattenbury et al. (2006).	airphoto interpretation; regional geologic mapping.	Faults parallel to bedding in cover rocks, in downland terrain. There is no age context for the land surface and slip rates and recurrence intervals cannot be estimated.					?
30. Royal Stream fault	Likely and definite faults.	Warren (1995); Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
31. Hundalee Fault	Likely and possible faults.	Warren (1995); Rattenbury et al. (2006); this report.	airphoto interpretation; regional geologic mapping.	Topographic features that are classed as likely faults are mostly on eroded slopes, remote from the age context offered by river or stream terraces. Slip rates and recurrence intervals cannot be estimated.					?
32. Lees Valley Fault	Definite fault. Most of the fault lies in Waimakariri District, only the northern tip extends into Hurunui District.	Forsyth et al. (2008).	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
33. Birdseye fault	Definite, likely and possible faults.	Forsyth et al. (2008); this report.	airphoto interpretation; regional geologic mapping.	18,000	2	0.1	18,000	12,060	III-VI
34. Karetu Fault - Birch Fault - Doctors Anticline	Definite, likely and possible faults and fold.	Wilson (1963); Nicol & Campbell (2001); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	Karetu Fault has complex surface expression; offset of river terraces in Ohuriawa Gorge is identified in this report, of perhaps 2 m on low-level terraces, whose ages are uncertain. The Birch Fault scarp crosses downland to hill country and slip rates and recurrence intervals cannot be estimated.					?
35. Boby Stream Fault	Definite, likely and possible faults. Some earlier maps (e.g. Wilson 1963) use the name 'Bobys Creek Fault'.	Wilson (1963); Nicol & Campbell (2001); Campbell et al. (2005); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	The fault is considered to have oblique horizontal-vertical slip. Campbell et al. (2005) concluded that the offset terraces in the mid-Waipara gorge indicate ~9 m of fault movement. They infer a very young age for this set of terraces (<1,000 years). We consider that the very young ages (several hundred years) proposed for the incised terraces of the Waipara by Nicol & Campbell (2001) are equivocal; landscape and soil maturity considerations make ages of several thousands of years more likely. For comparison with other faults in this report, we adopt an age of ~18,000 years and 5 m in order to calculate a slip rate of ~0.3 mm/yr, and recurrence interval in the range of ~1500 to ~12,000 years.					II-V

Name	**Observed characteristics**	**References**	**Deformation estimates**						
Lower case last term (e.g. fault) = informal name. Upper case (e.g. Fault) = name previously published	**Geologic evidence**	**Most comprehensive published information on fault/fold activity**	**Basis of estimates**	**Estimated age of deformed landform** (years before present)	**Estimated vertical deformation of landform** (m)	**Calculated average vertical slip rate** (mm/yr)	**Implied long-term average recurrence interval (RI - years) of deformation event, assuming 2 m vertical deformation per event*** (see notes on last page of table)	**Nominal 67% uncertainty in RI (years) **** (see notes on last page of table)	**Implied range of RI Classes** (following Kerr *et al*. 2003)
36. Coastal fold-fault belt	Definite, likely and possible faults and folds. Coastal terraces, the remains of former shore platforms, have been uplifted on the seaward side of this belt. Faults and folds are identified geologically by the buckling or offset of bedrock layers, but it is far from certain whether these large-scale geological features are currently active. In this report we recognise an anticline as active if the highest ground is on the axis of the upfold, and drainage is mostly off either side of the axis. On this basis, the Seadown and Kate Anticlines are active, as are the Montserrat anticline north of about Motunau River, the Mt Seddon and Hawkswood anticlines, and the Stonyhurst Syncline. South of Motunau, the Cass/Montserrat anticline has relatively low topography on its axis, and it is judged inactive (Forsyth et al. 2008). Further explanation is provided below under Motunau faults.	Wilson (1963); Carr (1970); Ota et al. (1984); Rattenbury et al. (2006); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	Overall, former shorelines judged to be ~125,000 years old have been elevated to as much as ~100 m along much of the coastline. This implies an uplift rate of as much as ~0.8 m/yr. Hypothetically speaking, were this uplift the result of successive earthquakes, each of which caused say 2 m of uplift, a maximum recurrence interval for such events is ~2,500 years. Ota et al. (1984) describe evidence for at least 12 m of uplift of coastal deposits over the past ~8,500 years. These data imply an uplift rate of ~1.5 mm/yr, and under a scenario of 2 m uplift per event, a maximum recurrence interval of ~1,400 years. It has been suggested that on the Conway coast, adjacent to the highest part of the Hawkswood Range, the uplift rates may be larger, at ~2 mm/yr (Ota et al. 1996), than farther south along the coast.					I-IV
36a. Amberley fault	Likely faults and monoclines.	Forsyth et al. (2008).	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
36b. Seadown anticline	Definite anticline.	Wilson (1963); Forsyth et al. (2008); this report.	airphoto interpretation; regional geologic mapping.	140,000	60	0.4	4,667	3,127	I-IV
36c. Kate Anticline	Definite anticline.	Wilson (1963); Forsyth et al. (2008); this report.	airphoto interpretation; regional geologic mapping.	125,000	65	0.5	3,846	2,577	I-IV
36d. Mound anticline	Likely anticline. The map shows that the Boby Stream Fault possibly extends to the Mound anticline, as suggested by Kirkaldy et al. (1963).	Wilson (1963); Nicol et al. (1994); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	18,000	2	0.1	18,000	12,060	IV-VI
36e. Omihi Fault	Likely and possible faults.	Wilson (1963); Rattenbury et al. (2006); Forsyth et al. (2008); this report.	airphoto interpretation; regional geologic mapping.	A lack of well-defined landform offsets on the line of the fault means that slip rates and recurrence intervals cannot be estimated, other than to presume that the slip rate is low and recurrence interval long. A fault offset recorded in sediments exposed in a cliff on the eastern side of Omihi River (Nicol et al. 1994) is close to the line of the Omihi Fault but is a southeast-striking bedding-parallel fault within Kowai Formation rather than the Omihi Fault proper.					?
36f. Hamilton Fault and Cass Anticline	Likely faults and anticline.	Wilson (1963); Forsyth et al. (2008); this report.	airphoto interpretation; regional geologic mapping.	These are assigned as likely, due to the relatively low, deeply eroded topography of the anticline axis, which is surprising if it is a locus of active uplift. In addition, the existence of the large-displacement Hamilton Fault makes it surprising that the anticline is still active, as one would expect the deformation to be concentrated on the emergent fault. We entertain as a significant possibility the idea that this fault/fold couplet is an old structure, and that the coastal range is being uplifted by newly evolving faults/folds whose locations are not yet clearly identified. For the Hamilton Fault and Cass Anticline, a lack of well-defined landform offsets on the line of the fault/fold means that slip/growth rates and recurrence intervals cannot be estimated with any confidence.					?

Name	Observed characteristics	References	Deformation estimates						
Lower case last term (e.g. fault) = informal name. Upper case (e.g. Fault) = name previously published	**Geologic evidence**	**Most comprehensive published information on fault/fold activity**	**Basis of estimates**	**Estimated age of deformed landform** (years before present)	**Estimated vertical deformation of landform** (m)	**Calculated average vertical slip rate** (mm/yr)	**Implied long-term average recurrence interval (RI - years) of deformation event, assuming 2 m vertical deformation per event*** (see notes on last page of table)	**Nominal 67% uncertainty in RI (years) **** (see notes on last page of table)	**Implied range of RI Classes** (following Kerr *et al*. 2003)
36g. Montserrat anticline	Likely anticline.	Wilson (1963); Carr (1970); Yousif (1987); Barrell (1989); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	This fold is assigned as likely, because the axis coincides with high topography and streams drain off to either side of the axis. A lack of well-defined landforms across the line of the fold means that growth rates and recurrence intervals cannot be estimated.					?
36h. Motunau faults	Definite and likely faults and monoclines in the coastal hills between Waipara and Hurunui rivers. Near Motunau, we suggest that seaward-dipping faults have elevated the eastern limb of the Cass/Montserrat anticline, producing uplifted coastal terraces, while also accounting for relatively low, deeply eroded topography farther inland near the Cass/Montserrat anticline axis (Barrell 1989). This style of faulting is seen on the Happy Valley Fault at Motunau Beach.	Carr (1970); Barrell (1989); Rattenbury et al. (2006); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	Suspected main faults: landform age ~125,000 years, uplift amount ~100 m, average vertical slip rate 0.8 mm/yr, recurrence interval for assumed 2 m uplift event ~2500 +/- ~1,670 years, RI Class I-III.					II-VI (representative value for most of these faults)
36i. Happy Valley fault	Definite and likely faults; likely monocline.	Carr (1970); Barrell (1989); Rattenbury et al. (2006); Forsyth et al. (2008); this report.	field inspection; airphoto interpretation; regional geologic mapping.	125,000	20	0.2	12,500	8,375	III-VI
36j. Greta Valley fault	Definite and likely faults.	Rattenbury et al. (2006).	field inspection; airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
36k. Blythe fault	Definite and likely faults.	Rattenbury et al. (2006).	airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
36l. Stonyhurst Syncline	Definite syncline.	Carr (1970); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	250,000	120	0.5	4,167	2,792	I-IV
36m. Lower Hurunui faults	Definite and likely faults.	Carr (1970); this report.	field inspection; airphoto interpretation; regional geologic mapping.	18,000	5	0.3	7,200	4,824	II-V
36n. Mt Seddon Anticline	Definite anticline.	Carr (1970); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	125,000	100	0.8	2,500	1,675	I-III
36o. Hawkswood anticline	Definite anticline.	Ota et al. (1984); Warren (1995); Ota et al. (1996); Rattenbury et al. (2006); this report.	field inspection; airphoto interpretation; regional geologic mapping.	Age estimates for uplifted terraces at the Conway coast give two options for defomation rates. Estimate 1 (Ota et al. 1996): Tarapuhi Terrace age ~105,000 years, uplift amount ~160 m, average vertical uplift rate 1.5 mm/yr, recurrence interval for assumed 2 m uplift event ~1,300 +/- 880 years, RI Class I-II. Estimate 2 (Ota et al. 1984; Rattenbury et al. 2006): Tarapuhi Terrace age ~330,000 years, uplift amount ~160 m, average vertical uplift rate 0.5 mm/yr, recurrence interval for assumed 2 m uplift event ~4,120 +/- 2,760 years, RI Class I-IV.					I-IV
36p. Nonoti Fault	Possible fault.	Yetton (1993); this report.	field inspection; airphoto interpretation.	Landforms interpreted to be due to faulting were mapped by Yetton (1993). In this report we consider that these landforms are more likely due to river action, rather than faulting. Classified as a 'possible' fault.					?

NOTES

* Deformation of 2 m per event is arbitrarily assumed, for the purpose of placing these features in the context of the Kerr et al. (2003) RI classification. See text for further discussion

** In order to highlight the arbitrarily assumed deformation value, a nominal error of plus/minus two-thirds of the RI value (~67%) is applied

RI Class definitions
I ≤2000 years
II >2000 years to ≤3500 years
III >3500 years to ≤5000 years
IV >5000 years to ≤10,000 years
V >10,000 years to ≤20,000 years
VI >20,000 years to ≤125,000 years

Many of the active faults and folds have been identified only using aerial photographs, or in reconnaissance walkover, and their geometries and locations as depicted in the QMAP-based datasets are very generalised. At the scale of QMAP, none is located more accurately than plus or minus (+/-) 100 m, at best. The Surf_form field provides a preliminary estimate of how well defined the surface expression of these features is likely to be, were they to be subjected to a detailed, site-specific, examination. For features that are '**well expressed**', we predict that they should be able to be located to better than +/- 50 m. Those that are identified as '**moderately expressed**' should be able to be located to better than +/-100 m. Those labelled as '**not expressed**' are not expected to have any physical expression on the ground, because they lie in areas of landforms that are probably younger than the most recent deformation. Features that are '**unknown**' may be found to have evidence for activity if subjected to investigation. The purpose of the Surf_form field is to assist in the planning and targeting of future investigations aimed at a more rigorous characterisation of active fault/fold hazard, should any further work be proposed. For example, features designated as 'well expressed' are likely to be able to be mapped and delineated more quickly, and to a greater degree of precision, than are features identified as 'moderately expressed'.

The Hurunui District, due to its proximity to the plate boundary, has a large number of active faults and folds. Most of the known active faults in the northwestern part of the district, including the Awatere, Fowlers, Clarence, Hope and Kakapo faults (Fig. 6), have predominantly strike-slip movement. These sideways-moving faults have a right-lateral sense of movement. This means that to an observer standing on one side of the fault, the other side of the fault has moved to the right (e.g. Fig. 2). Senses of movement on active faults elsewhere in the district are not well established. Many have dip-slip movement (Figs. 7 to 9) but whether or not some also have strike-slip movement is uncertain. The Hanmer Fault (Fig. 6, feature 6b), is in part a dip-slip normal fault (Wood et al. 1994), but also has a component of strike-slip movement (Langridge et al. 2008).

Table 1 includes preliminary correlations to the fault complexity classification of Kerr et al. (2003). Table 2 includes preliminary estimates of the deformation characteristics of the active faults and folds, based on estimated amounts of deformation of landform features of specific age. For the major strike-slip faults, where the deformation is mainly horizontal, we have adopted deformation rates from published studies (as described with text, rather than estimated numbers, in Table 2). For the remainder, we have estimated the heights of fault scarps or fold arches. These heights represent an approximation of the amounts of vertical deformation. If the faults are dip-slip, this is a good measure of overall deformation, but if the faults have a component of strike-slip movement, the scarp height will represent a minimum value for the overall deformation. The ages estimated for landforms are based on generalised inference and assumed correlations to climatic (glacial/interglacial) events (from Barrell et al. 2011). For river or glacier landforms attributed to the most recent ice age, we adopt an age of 18,000 years (Figs. 7 & 8). Similar landforms or deposits attributed to the early phase of the last ice-age are assigned an age of 65,000 years, while those of the previous ice-age are assigned an age of 140,000 years. An age of 250,000 years is assigned to landforms/deposits of the next oldest ice age. In the coastal fault-fold belt, there are remnants of uplifted former shore platforms, thought to have been formed during past episodes of interglacial climate. The most extensive of the uplifted terraces is attributed to the peak of last interglacial period, for which we adopt an age of 125,000 years.

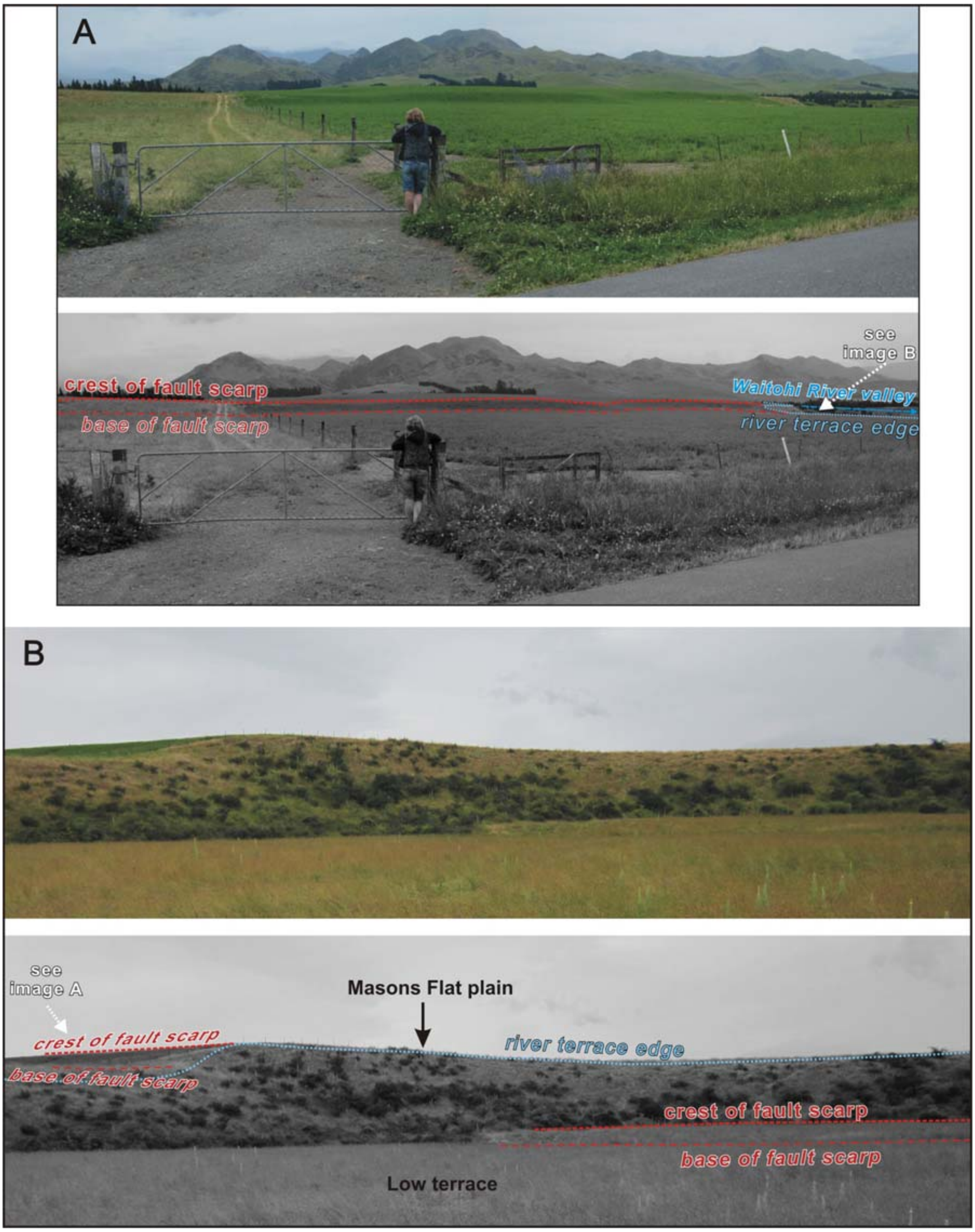


Figure 7 A: A view west-northwest from Powers Road, ~960 m north of the Lake Sumner Road intersection, towards a ~3 m high fault scarp within the Hurunui Peak fault zone (Fig. 6, feature 12). Here, ~10 km northwest of Hawarden, the ground surface is the ~18,000 year old Masons Flat plain, this sector of which was formed by the Waitohi River. B: This view west from Powers Road, ~1280 m north of Lake Sumner Road and ~280 m south of the Waitohi River bridge, reveals that the fault scarp is only ~1 m high on a low, relatively young, terrace of the Waitohi River. This shows that the most recent ground-rupture earthquake on this fault involved no more than ~1 m of vertical movement, and that the ~3-m high scarp on the Masons Flat plain (forming the skyline) is the product of at least two ground-surface rupturing earthquakes since ~18,000 years ago. Photos: D.J.A. Barrell.

All of these ages are no more than very generalised 'ballpark' estimates. The amounts of vertical deformation were estimated according to the methods listed in Table 2. Features examined only in aerial photos, or on the ground but from some distance away, are assigned a nominal height of either 2 m or 5 m. Using these estimated values, we calculate a long-term average vertical slip rate for each fault. In places where the fault/fold features comprise several closely-spaced parallel strands (see Fig. 6), we added the heights together to produce a cumulative total. Where the features are widely spaced or had little overlap between them, we just used the height of the highest or most prominent strand of the fault or fold features. In the latter case, the calculated slip rate is a minimum value for the overall fault/fold feature.

Figure 8 A view southeast from Isolated Hill Road, ~1.6 km east-northeast of the St Leonards Road intersection, towards a ~6 to 8 m high fault scarp, or possibly a monoclinal flexure, that is part of the Leonard Mound Fault (Fig. 6, feature 17). Here, ~6 km east of Culverden, the ground surface in the fore- and middle ground is the ~18,000 year old Amuri Plain formed by the Waiau River. During the time when the Waiau River last flowed through this area, 18,000 or more years ago, river action eroded and trimmed the side of St Leonards hill, the crest of which is marked by the river terrace edge symbol. This hill has been pushed up to its present elevation as a long-term result of repeated movement on the Leonard Mound Fault. Only the most recent movements, those that have offset the Amuri Plain surface by between ~6 and ~8 m on the strand of the fault seen in this view, are well preserved in the landscape. The action of the Waiau River has eroded away whatever details of the fault scarp existed prior to ~18,000 years ago. Ponds along the base of the fault scarp are natural features resulting from growth of the fault scarp having impeded surface runoff down the Amuri Plain. Photo: D.J.A. Barrell.

Figure 9 A view south from Kermode Street towards part of Waikari township, medical centre building on the right. The broad ~3 m high step running right-left in front of the buildings is thought likely to be a fault scarp, or possibly a monoclinal flexure, associated with the Moores Hill Fault (Fig. 6, feature 27), A feature such as this could be investigated by trenching to establish whether it is in fact a fault, or of some other origin, such as a stream-trimmed terrace margin. Photo: D.J.A. Barrell.

The Ministry for the Environment guidelines (Kerr et al. 2003) provide a framework and methodology to assist in avoiding or mitigating the risks associated with development of land (especially building) on or close to active faults. The relative significance of active fault hazards is quantified by means of the Recurrence Interval (RI) of ground-surface deforming rupture of an active fault. The RI represents an estimate of how much time, on average, has elapsed between successive surface ruptures of any particular fault. Because RIs are typically a few hundred years for the ‘most active’ faults, and as much as several thousands of years for other faults, the geological record of deformation of young deposits and landforms is the main source of evidence for defining a RI for a particular fault. However, detailed information is needed in order to define a reliable RI value.

An important quantity for estimating the RI is the amount of movement that occurs on a fault during a ground-surface rupturing earthquake event (single-event displacement, or SED). To use the example of the Hurunui Peak fault zone at Powers Road (Figs. 6 & 7; Table 2), this strand of the fault has offset a river plain landform, of estimated age ~18,000 years, by ~3 m vertically. We know that the fault has offset an adjacent lower terrace by about 1 m vertically. This means that the most recent ground-surface rupturing earthquake on this strand of the fault produced a vertical offset of no more than ~1 m. In other words the SED of that earthquake was no more than ~1 m vertically.

If we run a hypothetical scenario that the deformation of this low terrace was achieved in one earthquake, and that this was a typical offset on this strand of the fault at this location, it implies that three earthquakes produced the ~3 m offset on the ~18,000 year old river plain. This implies a RI of no more than 6,000 years (18,000 years ÷ 3 m x 1 m). If, however, this strand of the fault were to be investigated in detail and if ages could be determined for offset events, by applying geological dating methods such as radiocarbon, it might be shown that the first 1-m offset occurred several thousand years after 18,000 years ago, and that the most recent 1-m offset occurred several thousand years ago. By this scenario, a RI of ~3500 years is quite plausible for this strand of the fault. This scenario illustrates that detailed investigation may be worthwhile for a fault where it is important to determine the RI, for the purposes of land-use planning or engineering design.

Of the various methods for estimating the SED on a particular fault, the best is to excavate a trench across the scarp of the fault in question, and make measurements of the deformed deposits (i.e. site-specific investigation). However, there are other, less direct, methods, such as those described by Wells & Coppersmith (1994) who used a catalogue of observed earthquake events worldwide to define formulae for estimating SED values, based on, for example, the mapped length of a fault[1]. A disadvantage of the catalogue-estimation approach is that the length of a fault may be uncertain. To illustrate this with the Hurunui Peak fault zone, the length of definite or likely faults/folds comprising the Hurunui Peak fault zone is about 15 km. However, if this fault zone is linked southwest with, for example, the Heathstock fault and Virginia faults (Fig. 6, features 21 and 20), then the total length would be about 45 km. The Wells & Coppersmith (1994) formula implies a maximum SED of 0.8 m for a 15 km long fault, increasing to 1.4 m for a 45 km long fault. Either value is broadly compatible with the observations at Powers Road, outlined above.

For most faults in the Hurunui District, no estimates of fault SED have been made to a good level of confidence. For the purposes of this report, we follow the approach described in similar reports for Ashburton District (Barrell & Strong 2009) and Mackenzie District (Barrell & Strong 2010), and use 2 m as a working first approximation for SED on active faults and folds in Hurunui District (except for the major strike-slip faults and faults with no suitable landforms for calculating a slip rate – see Table 2). It is unlikely that this approximation will be a good representation for all faults in the district, but we consider that it enables comparative assessments of active fault and fold hazards, pending better-constrained site-specific data on faults and folds.

Assuming that each surface rupture or deformation event involves 2 m of vertical deformation, we have estimated an indicative average recurrence interval for deformation events on each active fault/fold feature listed in Table 2. For this calculation we divide the landform age by the landform offset, and multiply by 2 m. These generalised estimates are intended only as a general indication of deformation characteristics. For this reason we have given a nominal +/- 67% error on the recurrence interval estimates (see Table 2). Except for some of the major strike-slip faults, none of the age or deformation estimates presented here is based on detailed site-specific investigations, which are a prerequisite for earthquake

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[1] For this example, we have used the Wells & Coppersmith (1994) regression for maximum single event displacement (MD) based on length of surface fault rupture (SRL), where log(MD) = -1.38 + 1.02*log(SRL). Strictly speaking, the MD value represents 'net' slip on a fault; in the example here, we assume the slip is entirely vertical.

geology and paleoseismology assessments. The estimates in this report merely indicate a provisional range of recurrence intervals that may be expected for these faults and allow these faults/folds to be placed in context with the Kerr et al. (2003) guidelines.

The GIS layers of active folds (HDC_folds) and active faults (HDC_faults) accompanying this report are derived from the QMAP dataset, with modifications. These modifications include addition of some previously unmapped features and the reclassification of some features. New features in the dataset may be identified by an absence of data attributes in the QMAP database fields, which have been retained in these GIS layers (Appendix A). Additional commentary on the mapping of several of the fault/fold systems, especially where the mapping presented here differs notably from previous mapping, is provided in Appendix A.

The information in this report is more comprehensive than that currently (May 2012) in the NZAFD. The information in this report also builds on and refines information presented by Pettinga et al. (2001), Van Dissen et al. (2003) and Stirling et al. (2008, 2012), and references therein. The GIS datasets incorporate detailed mapping of the Hanmer Fault at Hanmer Springs (Yetton 1993, Yetton, 2004; Langridge et al. 2008), and the Hope Fault at Mt Lyford village (Hancox et al. 2006). Yetton (1993) proposed the existence of an active fault near Cheviot (Nonoti Fault). However, we consider that the landform that was interpreted by Yetton (1993) as a fault scarp is more likely to have formed by river and stream action, rather than by faulting, and so we have assigned it a certainty of ‘possible’.

5.0 IMPLICATIONS FOR HAZARDS

Since European settlement of the Hurunui District area, only the 1888 North Canterbury Earthquake is known to have caused ground-surface fault rupture. Three other large, locally damaging, historic earthquakes greater than magnitude 6 have been centred in the district, the 1901 Cheviot Earthquake, 1922 Motunau Earthquake and 1948 Waiau Earthquake (Downes 1995), but these did not, as far as is known, produce ground-surface fault rupture. The geological record and landforms show clear evidence for many zones of geologically-recent (though pre-dating European settlement) fault and fold deformation of the ground surface. This highlights that it would be prudent to treat the active fault or fold features of the Hurunui District as potentially hazardous.

Figures 2, 5 and 10 illustrate examples of the types of ground-surface deformation hazards that may arise from active faults or active monoclines, noting that at any location, elements of both faulting and folding may be present within a deformation zone. In general, faults and monoclines present the most focused forms of ground deformation, in regard to direct rupture or significant tilting of the ground surface. Such effects may occur in a sudden event. Active anticlines are likely to present a much lesser level of ground surface deformation hazard with regard to buildings, but may pose relevant hazards to developments such as canals or power stations (e.g. by tilting the ground). Furthermore, the presence of active folds suggests that there may be an underlying active fault at depth that may potentially generate a local, large, shallow earthquake, were it to rupture.

The geological estimates presented in this report indicate that the major strike-slip faults in the northwestern part of the district, particularly the Awatere and Hope Faults, are the most active features in the district, with average recurrence intervals of less than 1,000 years, and perhaps as little as ~200 years for the eastern section of the Hope Fault (Table 2). South of the Hope Fault, the mapped faults and folds have comparatively lower rates of deformation, with an average recurrence interval on each fault/fold system of the order of several thousands of years, but there are many sets of faults and folds. Speaking hypothetically, if there were 20 separate fault/fold systems, each of which has its own pattern of behaviour, and on average each fault/fold system had a recurrence interval for ground-deforming earthquake rupture of, say, 2,000 years, then on average one may expect one of them to rupture in any 100-year period. In summary, there are many active faults in the Hurunui District and every reason for authorities and residents to be prepared for the occurrence of ground-surface rupturing fault movements, and resulting large, locally damaging earthquakes, within the district, over future decades to centuries (Stirling et al. 2008).

Figure 10 Fault scarp formed on the Chelungpu Fault during the magnitude 7.6 Chi-Chi Earthquake, Taiwan, 1999. The disrupted running track shows damage typical of a reverse fault ground-surface rupture, which is well expressed on the brittle surface (note the smoother rupture across grass behind). This location lies on a stream terrace that is younger than the previous rupture event on the fault, so that there was no scarp here before the earthquake. This example illustrates the sorts of effects that can be expected on active reverse faults of the Hurunui District the next time any particular fault experiences a surface rupture earthquake. Photo and information from Kelson et al. (2001).

We emphasise that the mapped delineation of the active faults and folds of the Hurunui District presented in this report has been done at a regional scale (1:250,000). The level of precision is not adequate for any site-specific assessment of hazards (e.g. planning for building or other infrastructure developments), except for the information in the dataset obtained from detailed studies at Hanmer Springs township (Yetton 1993, Yetton 2004, Langridge et al. 2008) and Mt Lyford village (Hancox et al. 2006), which is at a level suitable for fault hazard avoidance zonation. In addition, many of the fault/fold features that have been mapped have not yet proven to be active faults or folds. For features classed as ‘likely’, or ‘possible’, it would be highly desirable to prove one way or the other whether they are hazardous active faults/folds, before undertaking any hazard planning, zonation or mitigation in respect to these features.

We reiterate that the information presented in this report, and the accompanying GIS layers, is primarily intended for indicating general areas where there may be an active fault ground-deformation hazard to look for, and where site-specific investigations may be necessary prior to development.

We make the following general comments and recommendations in relation to active fault ground-deformation hazards in the Hurunui District:

a) Of the larger villages and towns, Hanmer Springs, Mt Lyford, Waiau, Rotherham, Culverden, Hawarden and Waikari lie very close to known or suspected active faults.

b) We recommend that detailed site-specific investigations be undertaken as part of a resource consent application or plan change if and when development (other than normal residential housing) is proposed on or near potential faults in Hawarden, Waikari, Rotherham and Culverden.

c) With regard to lifelines, or major infrastructure, rupture of either the Hope Fault, or the Mt Culverden Fault, would cut the Lewis Pass highway (State Highway 7) until repairs could be made. A rupture of the Mt Culverden Fault may severely disrupt the irrigation scheme canal from the Waiau River. Rupture of the Amberley Fault, depending on establishing first whether it in fact is an active fault, and second the exact location the fault trace, would most likely cut the South Island Main Trunk Railway, and State Highway 1, with no detours available until repairs are done, as the fault rupture may well disrupt the only other road access on Reserve Road and Douglas Road, up either side of the Kowai River. Thus rupture of the Amberley Fault may well temporarily isolate much of the Hurunui District from the Amberley and Christchurch areas. These are just some of the most adverse examples of lifeline disruptions that could impact on emergency management in Hurunui District in the event of a local ground-surface fault rupture. Identification of specific vulnerabilities, and development of contingency plans, would be advantageous for streamlining first-response emergency management and disaster recovery in the event of a major ground-surface rupturing earthquake in the Hurunui District.

6.0 CONCLUSIONS

1. Regional geological mapping has identified a large number of active faults and folds (monoclines and anticlines) in the Hurunui District. In total, 36 areas of known or suspected active faults and/or folds are delineated.
2. A GIS dataset of information on the active faults and folds accompanies this report. For each mapped fault and fold, we include an attribute ‘certainty’ to indicate our level of confidence in the mapping of the feature, whether ‘definite’, ‘likely’ or ‘possible’. We also include a classification of ‘surface form’, whether ‘well expressed’, ‘moderately expressed’, ‘not expressed’ or ‘unknown’. The surface form classification indicates how easy it is to pinpoint the location of the fault or fold feature on the ground.
3. We have summarised, in Table 2, what exists in the way of geological evidence for the degree of activity of each feature. Average slip rate is a common way to compare the level of activity of a fault or fold. This can also be expressed as an average recurrence interval for deformation events, aided by some assumptions. The recurrence interval estimates provide a linkage to Ministry for the Environment active fault planning guidelines.
4. The recurrence interval estimates indicate that the major strike-slip faults in the northwestern part of the district (Awatere and Hope faults) are the most active faults in the Hurunui District. The central to southern part of the district has fault/folds that each appears to have a relatively long recurrence interval, but collectively there are many of them.
5. The information presented here is not sufficiently precise for site-specific hazard assessment. Instead, the information is intended to highlight those areas potentially affected by active fault or fold hazards, and may help to target site-specific investigations required prior to development, and allow identification of lifeline vulnerabilities and emergency management response plans.

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APPENDIX 1 SUPPLEMENTARY INFORMATION

A-1: GIS layers

The GIS layers referred to in this report and contained on the accompanying CD consist of the following shapefiles:

- HDC_faults.shp
- HDC_folds.shp

The original attribute fields for active faults and folds are extracted from the QMAP ‘seamless’ dataset, sourced from map data published as QMAP Greymouth (Nathan et al. 2002), QMAP Kaikoura (Rattenbury et al. 2006) and QMAP Christchurch (Forsyth et al. 2008). In order to make clear the linkage between the QMAP dataset and the amended dataset prepared as part of this project, all the attributes of the QMAP dataset are retained, without modification, in these shapefiles. For this report, all amendments are contained within three additional data fields:

- HDC_name (local names for the mapped features)
- Certainty (see report text)
- Surf_form (see report text)

The newly added faults and folds mapped as part of the work described in this report are identifiable by the lack of any QMAP attributes. All the data have been compiled at a regional scale (1:250,000) and the locations of active faults and folds are +/- 100 m at best. An exception is that the results of detailed mapping at the Hanmer Fault at Hanmer Springs, and Mason River faults at Mt Lyford have been incorporated into these datasets. The geographic coordinate system for the data is New Zealand Map Grid 1949.

Note that some apparent inconsistencies exist between the QMAP ‘Activity’ field and the ‘Certainty’ field defined in this report. For the purposes of this data set, the ‘Certainty’ field supersedes the QMAP ‘Activity’ field. Also, the datasets contain QMAP faults and folds that show evidence for late Cenozoic activity, such as where cover rocks have been displaced against basement rocks, but where there is no physical evidence for geologically-recent offsets or deformation (i.e. of young deposits or the ground surface). These faults and folds are denoted in the ‘Certainty’ and ‘Surf_form’ fields as ‘not classified’. The purpose of retaining them is to highlight the location of major geological structures, and in cognisance that future work may demonstrate that their status should be revised to ‘active’.

A-2: Commentary on some fault/fold areas in Hurunui District

Awatere Fault (feature 1, Fig. 6): We have designated the mapped northern branch of the Awatere Fault near Lake Tennyson as ‘likely’, due to its poor surface expression in the landscape. The NZAFD includes an array of ridge rents on the western side of the crest of St James Range southwest of Lake Tennyson. We have not included these in the dataset presented here.

East of Lake Tennyson, indications of surface scarps in the vicinity of a north-trending fault mapped in bedrock in QMAP have led us to designate the fault as 'likely' active, and we have informally named it 'Island Pass fault' (feature 2, Fig. 6).

Fowlers Fault (feature 3, Fig. 6): Evidence for ground-surface offsets is not convincing west of Waiau River, so the fault is coded as 'likely' in this area. We identified several previously unreported fault scarps using aerial photos in the area southeast of Lake Guyon, and these faults are included in the dataset as 'likely'. We have mapped additional detail of well-expressed scarps in the vicinity of the Clarence River.

Clarence Fault (feature 4, Fig. 6): We have used QMAP linework with a few refinements, notably adding some interconnections between traces. There appears to be a subtle trace on valley floor fans in the Boyle valley just downstream of Lewis confluence – this has been mapped as 'likely'.

Hope Fault – west (feature 6a, Fig. 6): We have adopted the detailed mapping of Langridge and Berryman (2005) for the Hurunui segment of the fault, west of the Glynn Wye moraine terraces, while mapping east of there is from QMAP, based on Cowan (1990).

The NZAFD shows an inferred fault crossing the Waiau River about 5 km upstream of the Hope confluence. Examination of aerial photos reveals definite and likely traces, which have been mapped as 'Hoff Stream fault'.

Hope Fault – west and Hanmer Fault (features 6a and 6b, Fig. 6): We have added two likely connections between the Hope Fault – west and the array of faults in the western part of the Hanmer Basin. This complicated splay of faults was mapped in detail by Wood et al. (1994). In examining the existing datasets, we found that the digitising of these faults from the map presented by Wood et al. (1994), and which formed the basis for the NZAFD and QMAP linework, was done from a poorly-georeferenced copy of the map. The dataset presented in this report for this area of splayed faults has been re-digitised from a more accurate rectification of the Wood et al (1994) map. Note that because many of these faults mapped by Wood et al. (1994) lie close to the trends of natural stream channelling and terracing on that part of the Hanmer Plain, most are classified here as 'likely', where it seemed possible that they are river-formed features rather than fault scarps. In the course of this work, a previously-unrecognised fault was detected and mapped near Woodbank Road, west of Chatterton River.

The mapping of the Hanmer Fault at Hanmer Springs has been updated according to detailed mapping and surveying provided by Environment Canterbury. In addition, the position of the Hanmer Fault both west and east of the township has been mapped in greater detail than in any existing datasets, using detailed aerial photos (~ AD 1950). The western sector of the fault within hill country is classified as 'likely' because it is possible that the surface feature mapped is a landslide scarp rather than a fault scarp.

East of Dog Stream, we have replaced the QMAP traces with a more generalised 'definite, moderately expressed' trace. The existing traces from QMAP are retained in the dataset as 'not classified'. A bedrock fault in the QMAP dataset near The Hossack station has been made a possible continuation of Hanmer Fault, with a possible connector. We extended the fault as far east as head of the landslide beside The Hossack homestead.

A short segment of active fault shown in NZAFD just west of Percival River is from the original 1:250,000 NZAFD dataset, and is not shown by Wood et al. 1994 or QMAP. We have retained this as 'possible, not expressed'. It is difficult to tell, due to forest cover, whether or not a fault scarp is present.

Hope Fault – east (feature 6c in Fig. 6): The sector of the fault in Hanmer Forest northwest of Hanmer River has been mapped as likely, as it is not visible in imagery due to forest cover. We have amended some details of the form and location of fault scarps on terraces near The Hossack.

Kakapo Fault (feature 7, Fig. 6): A fault mapped on the southwest side of Lake Sumner is very difficult to discern on ice-smoothed bedrock, so is coded as ‘likely’. That section of the fault from Lake Sumner up Evangeline Stream into the South Branch of Kakapo Brook is coded as ‘likely’, because no surface trace is preserved in the valley, even though this sector of the fault was mapped an ‘accurate, active’ on QMAP Greymouth by Nathan et al. (2002).

At east end of Dismal Valley, we amended some details of the concealed trace – making part of it moderately expressed. We also made amendments to the positions of fault traces in the lower reaches of Kakapo Brook.

Poulter Fault (feature 8, Fig. 6): We have shown the mapped scarps (Berryman & Villamor 2004) as ‘definite, well expressed’, and the remainder as ‘likely’, to highlight that the mapped fault is largely interpolated across forest hill terrain between the mapped definite scarps.

Mt Leslie fault (feature 9a, Fig. 6): We have applied this informal name to definite and likely fault scarps south of Hanmer Basin. To the southwest, a bedrock fault in Broom Stream that thrusts Torlesse rocks over the Marble Point limestone outlier is mapped as ‘possible’, and informally named Broom Stream fault. There are hints of scarps in the saddle near the head of Broom Stream.

Lottery River faults (feature 9b, Fig. 6): QMAP active faults on the southeast bank of Lottery River have been grouped as ‘Lottery River faults’, and designated ‘likely’ because they could potentially be attributed to slope instability.

Mason River faults (feature 9c, Fig. 6): Detailed mapping at Mt Lyford village by Hancox et al. (2006) has been included in the datasets, with some adjustments to linework in the area for a couple of km north of Mt Lyford village, to show some more detail of faulting. Scarps that may conceivably be due to slope instability rather than faulting are designated ‘likely’.

Hurunui Peak fault zone (feature 12, Fig. 6): A variety of names has been applied to these features, including Waitohi Downs Fault (QMAP, from Mould 1992: University of Canterbury MSc thesis), and West Culverden Fault Zone (Pettinga et al. 2001), which included structures on the range-front south of the Waitohi River. To avoid confusion with structures that are only identified here as ‘possible’, we have encompassed the active faults approximating the range-front from about Waitohi River northwards as Hurunui Peak fault zone, taking the name from a nearby hill.

Included in the fault zone, for geographic convenience, is a north-trending definite fault scarp running up the true left bank of the lower part of Pahau River gorge. This feature is informally called ‘Hughs Gully fault’ within the dataset. It is extended as ‘likely’ along-strike on a contrast in bedrock type, and a few notched spurs.

Across all the strands of the Hurunui Peak fault zone, the overall vertical offset is judged to be as much as ~10 m on the assumed 18,000 year old alluvial plain. We have identified the adjacent sector of the Waitohi Fault west of the Hurunui River as ‘likely’, though cannot see any convincing surface evidence for extending an active fault south-southwest down the Waitohi Fault as shown on QMAP.

Balmoral Fault (feature 13, Fig. 6): This north-south fault scarp was first mapped on the Hurunui 1:250,000 geological map of Gregg (1964). Our additions to the QMAP dataset include a bump in a fan several hundred metres west of Balmoral homestead, and a likely connection between this and the main scarp to the south. We also added a connection north to a north-east-trending definite scarp crossing the Pahau River fan and continuing, less clearly expressed, on the foot of the range north of the Pahau River.

Mt Culverden Fault (feature 14, Fig. 6): This feature, lying on the north side of the Mt Culverden ridge, does not for the most part cross fans, but is evident as steps in range-front streams and in fairly young colluvial sheets at the range-foot. The form of the trace indicates low angle of dip towards southeast (i.e. a thrust fault). Along strike to east, several features on the terraces near Mouse Point suggest a strong likelihood that it continues that way as a warp. These include the sidling of Countess Stream down the terrace sequence, and some dead-end stream channels which pond water, but lack discernible outlets in a southeast direction. North of Mt Culverden this fault has significant vertical offset, of the order of 10 m on ~18,000 year old surfaces.

At about Mouse Point, there are two possible extension directions for this structure, one northeast towards Rotherham and the other east across the Amuri Plain. Northeast towards Rotherham, there are some potentially suspicious landforms. Most channels and terraces edges of the Waiau River are sinuous, but there is one remarkably straight terrace edge extending southwest from the centre of Rotherham village that is marked in the dataset as a ‘possible’ fault. At the southwest end of where this feature ceases to be evident as a terrace edge, there is some suggestion, visible in air photos, that former Waiau channels may extend up and over a rise in the ground, and so we have mapped a possible monocline. Assuming there is some merit in this interpretation, we have mapped a possible concealed fault extending northeast along the foot of the river escarpment on the west margin of the Rotherham downs.

Suspicious landforms extending east from Mouse Point may be river terrace edges of the Waiau, or they may be fault scarps; they are close to the trend of river channelling, so may be river-cut, but there are some odd anomalies in their form. They are mapped as ‘possible’ active faults. It was a very difficult decision as to whether to classify these as ‘likely’ or ‘possible’. We decided that a little stronger evidence was desirable before according them a status of ‘likely’. These features certainly should be investigated if any significant infrastructural development is planned in this area.

Red Post faults (feature 15, Fig. 6): Two scarps that appear to lie parallel to bedding in the cover rocks in the hills northwest of Red Post Corner have been identified as ‘likely, moderately expressed’. The southeasternmost scarp in particular is very subdued.

The Humps faults (feature 16, Fig. 6): A complicated series of fault scarps occurs in this this area. Several that are additional to those in QMAP and the NZAFD have been added, based on detailed aerial photo interpretation, and some connections drawn between discontinuous scarps. We have drawn some possible faults heading down valleys towards the Rotherham downs, to highlight that if one were looking for connections between fault systems, one option well worth exploring would be to extend The Humps fault structures west past Rotherham towards the Mt Culverden Fault. Close to the active fault scarps, the bedrock faults mapped on QMAP Kaikoura are retained, mapped as ‘possible’.

Included for geographic convenience at the north end of The Humps faults area is a fault in hill country in the Leader River headwaters mapped as active in QMAP dataset. We have classified it as ‘likely’.

Leonard Mound Fault (feature 17, Fig. 6): Some detail has been added to this prominent fault system, over what is in the QMAP and NZAFD datasets. We have added several previously unrecognised scarps, particularly at the northeastern end of the system, extending almost as far as the Hurunui River, based on topographic maps and aerial photos.

There, a series of faults runs northeast from the Leonard Mound Fault, as previously mapped. Their recognition is in places somewhat uncertain because their trends in part lie close to fluvial channel trends on the Amuri Plain. There are several places where the faults definitely displace fluvial channels, whereas those steps that are less than 100% unequivocal are mapped as ‘likely’. It is remarkable that these features do not seem to have been mapped before. Gregg’s (1964) map shows the main feature we now map as a fault as a gully and QMAP Kaikoura maps some young (Holocene) alluvium ponded along it. Another ‘likely’ fault lies parallel to it but a few hundred metres farther southeast. For the fault as a whole, vertical offset is at least several metres on the Amuri Plain surface, maybe as much as 10 m if all the traces are added together. This is the same sort of order as the previously mapped (Armstrong 2000; Rattenbury et al. 2006) sector of the Leonard Mound Fault to the southwest, so correlation of the two as a single structure seems reasonable. This extension gives an overall strike length of at least 20 km for Leonard Mound Fault.

Close to the St Leonards – Nukiwai ridge, some previously mapped active fault strands have been downgraded to ‘likely’, because it is possible that they are in part river-trimmed features (see Fig. 7 in the report).

Lowry Peaks Fault (feature 18, Fig. 6): We have applied the terminology of Pettinga et al. (2001) and Litchfield et al. (2003) to name the western margin of the Lowry Peaks Range the Lowry Peaks Fault. We have identified the main mapped fault as ‘possible’. However, 1 km southeast of Lowry Peaks homestead is a definite scarp on a fan at the range-front, and a couple of ‘likely’ scarps on the fans of the next stream to the southwest and to the northeast. We have drawn ‘likely, not expressed’ connections between them. They are not very fresh, compared to the Leonard Mound Fault traces. There are quite a few of these discontinuous degraded scarps northeast along the range. Youngest aggradation fans (Holocene?) don’t seem to be affected. Few scarps are evident NE of the main branch of a stream draining just northeast of Kilsyth homestead – it seems possible that any geologically young deformation may have stepped back to the range-front, and thus be eroded away or obscured by colluvium.

Hurunui Bluff Fault (feature 19, Fig. 6): The structure as mapped by Litchfield et al. (2003) and on QMAP has been extended to the southwest to include a sharp step, only ~1 m high, that is crossed by SH7, 4 km west-southwest of Hurunui village, and we added a likely extension a farther 1 km west-southwest. We added some detail to the Hurunui Bluffs Fault at Hurunui village. There are some suspicious landforms resembling terrace edges here, but with irregularity that suggests that they may be fault scarps. However, because these features are all closely parallel with fluvial channelling on the terraces, we have mapped them as ‘likely’ rather than ‘definite’. On one of these suspicious landforms, there is a visual suggestion, seen in aerial photos, of a right-lateral strike-slip component of offset.

To the northeast of Hurunui village, we have shifted the QMAP ‘approximate’ fault trace slightly northwest to lie at the edge of the river valley, and called it ‘not expressed’. A lack of any scarps here, even though there is a flight of degradational terraces, suggests that this is a low slip rate fault, with few if any Holocene surface rupture events.

At Hitchen Hills, near the Hurunui River’s exit from the Culverden basin, a step on a high terrace seems to have been interpreted as a scarp, however as it is not evident on higher older land surfaces along strike to the east, it seems more likely that the step is a river terrace. Accordingly we have identified this strand as ‘possible’.

Virginia faults (feature 20, Fig. 6): A number of active faults in this area are grouped together as the ‘Virginia faults’ for ease of geographic description. Some of these features are shown on QMAP, but we have identified several previously undetected faults, using aerial photos, and refined the positions and details of some of those shown in QMAP. We have applied informal names to several of the individual faults, including: (i) ‘Virginia fault’, a very sharp east-west trending scarp along Virginia Road that has offset or impeded the drainage of every gully or stream it crosses; (ii) ‘Leaseman fault’, an east-west scarp crossing the valley of Leaseman Stream, and; (iii) ‘Madrid Hill fault’, a fairly sharp, 5 km-long, east-northeast striking scarp near Madrid Hill. The Virginia and Madrid Hill fault scarps have a degree of sharpness that suggests late Holocene movement and, on the latter fault, evidence for at least one previous late Quaternary event, judging by greater scarp height on older landforms. Both look to have predominantly right-lateral strike-slip offset. A very subtle series of scarps, possibly thrust faults, are named as the ‘Double Tops fault’. The Waitohi Fault, whose existence is known from bedrock mapping, shows clear scarps in the south, but these become progressively less well expressed proceeding north into the North Waipara catchment. There is little convincing evidence for surface scarps on the Waitohi Fault north of the Virginia fault – except for one sector mapped as ‘likely’, the remainder of ground surface irregularities are most likely to be slope collapse features, and it is mapped as ‘possible’. In particular, even farther north at Waitohi River, the bedrock trace of the Waitohi Fault is mapped as passing under, and does not displace, the ~18,000 year old aggradation surface, which itself is deformed by several metres at the Hurunui Peak fault zone, 2 km farther east.

Heathstock fault (feature 21, Fig. 6): This is the only convincing active fault along the prominent range-front that marks the west margin of the Waipara-Culverden basin. Much of this range-front has been mapped as a bedrock fault, the Mt Arden Fault, but the only identifiable late Quaternary deformation is towards its northern end. At Virginia Road, Heathstock fault has an arcuate, but rather diffuse, scarp several metres high, suggestive of a thrust fault, displacing the fan of the North Branch Waipara River where the fan grades out to the Masons Flat alluvial plain.

Masons Flat fault (feature 22, Fig. 6): We have mapped additional subtle scarps off the northern end of this north-northwest striking fault, which extends from the ranges west of Hawarden across Masons Flat.

Horsley Down fault (feature 23, Fig. 6): This name is applied informally to a series of fault scarps/monoclines extending from Hawarden township north along the foot of the Horsley Down ridge. We have added a small extension to the southern end of the feature shown in the QMAP dataset, to indicate the direction towards which we think it is likely to continue southward.

About 2 km east of the Horsley Down fault is a north-northeast-trending topographic lineament, that may be tectonic, or simply a depositional feature, such as a line of sand dunes. It is mapped as ‘possible’.

Medbury faults (feature 24, Fig. 6): A previously unrecognised west-striking fault scarp on terraces west of Waitohi River near Hurunui village, with northerly downthrow of about 1.5 m, is informally named ‘Dalzells Road fault’. In aerial photos it can be traced west for only ~2 km to Ginders Road, beyond which it may be obscured by younger alluvium of the Waitohi River. Nearby, north of Medbury Road near Hillview farm, there is distinct north-trending step, down to the east, that appears to displace fluvial channels, that due to its shortness, is assigned as ‘likely’. What appears to be a change in ground surface texture, trending north-west, near Medbury, is mapped as a ‘possible’ fault. Its nature and origin are unclear.

An arcuate fault, informally named ‘Bishells Road fault’, is mapped near The Peaks. It is classified as ‘likely’, because it does not seem inconceivable that it may be a composite river-cut feature. It is included with the areal grouping of ‘Medbury faults’ purely for geographic and descriptive convenience – no tectonic connection is necessarily implied.

Trig C faults (feature 25, Fig. 6): We have applied the name of Litchfield et al. (2003) and extended the QMAP lines as ‘likely’, to match better the extent of these features mapped by Litchfield et al. (2003), and mapped two anticlinal warps at the southwest end of this structure. We also mapped an east-northeast-trending scarp, downthrown to the south, on the north face of the ridge about 2 km to the north of the main Trig C faults, which we include within the Trig C grouping for geographic convenience.

Mt Alexander faults (feature 26, Fig. 6): In the vicinity of the Hurunui River, the surface scarp appears to be fairly subtle, so we have classed it as ‘likely’. Working from the QMAP dataset of these faults, segments of the faults mapped as ‘active, accurate’ we have designated ‘moderately expressed’, while QMAP-classified segments of ‘concealed’ or ‘approximate’ are denoted here as ‘not expressed’. To the southwest, we have identified the mapped bedrock fault traces as ‘possible’. Where the southwest branch of the bedrock fault (Scargill Creek Fault) crosses Scargill Creek, there is a change in terrace height that looks compelling as tectonic. Litchfield et al. (2003) made the same interpretation, although noted that fluvial erosion may have influenced the preservation and appearance of the scarp. Accordingly, we have mapped it as ‘likely’. The western part of the Mt Alexander Fault, about 5 km north of Mt Alexander, is shown as ‘active’ in the QMAP dataset. There is little compelling surface evidence for this interpretation, at least as far as can be seen in aerial photos, and Litchfield et al. (2003) did not describe any evidence for surface offsets. Accordingly, to highlight elements of the QMAP interpretation, we have designated those short portions of the fault mapped as ‘accurate’ as ‘likely’, while denoting other segments as ‘possible’.

The NZAFD shows as active a fault mapped in bedrock by QMAP, extending northeast from the Hurunui River from just east of Hydowns farm to the Kaiwara valley, crossing Glen Jon Stream. We can see no convincing evidence in aerial photos to suggest Quaternary activity, so have denoted this fault as ‘possible, uncertain’.

Moores Hill Fault (feature 27, Fig. 6): Although Litchfield et al. (2003) noted that no fault scarps had been found along this fault, we consider that west of Kinver farm, which itself lies 7 km west of Scargill village, there are sufficient step-like topographic anomalies to warrant, in our opinion, designating the western sector of the Moores Hill Fault as ‘likely’. We have designated as ‘moderately expressed’, those few sectors shown as ‘approximate’ or ‘accurate’ in the QMAP dataset. As most of the fault is mapped as concealed, our approach highlights that there are relatively few well-preserved scarps on the fault. We have retained the eastern sector of the fault, to where it approaches the Kaiwara Fault, as ‘possible’.

Near Waikari, we’ve applied an informal name of ‘Waikari fault’ to that sector of the Moores Hill Fault structure, encompassing the steps at the toes of fans through the Waikari township, and followed the interpretation of Litchfield et al. (2003) by extending this fault east-northeast for ~ 4 km around the northern foot of low hills in Mt Brown Formation rocks, near Waikari cemetery and merging it against the main Moores Hill Fault. We’ve called it likely, moderately expressed. The steps on fans at Waikari (see Fig, 6 of the main report), if fault scarps rather than some type of stream erosion feature, appear to have an en-echelon arrangement, and peter out at the western end of Waikari township.

Kaiwara Fault (feature 28, Fig. 6): We have named the northern section ‘Kaiwara Fault – north’, and attributed as ‘likely’ a couple of uphill facing scarps just north of the Waiau River. We cannot discount that they are simply strike ridges in bedrock, but because they were shown as late Quaternary (i.e. ‘active’) fault traces on the geological maps of Gregg (1964) and Warren (1995), we considered that it was worth highlighting these features. However, they have no along-strike continuity, in an area where the landscape along the range-front is fairly mature, with smooth slopes and broad gullies that we would expect to have preserved surface fault deformation, had any occurred in the geologically-recent past.

‘Kaiwara Fault – south’ is named from southwest of the Waiau River all the way to Scargill. We have mapped it as ‘possible’, because there are no convincing, or even mildly compelling, fault scarps, or any surface-faulting-related features that we can discern. Eroded topography commensurate with different types and hardness of bedrock seems a sufficient explanation.

Leamington faults (feature 29, Fig. 6): Just to the south of the Waiau River, these two scarps on downlands lying southeast of the Kaiwara Fault escarpment have a similar appearance to the ‘Red Post faults’ near Culverden. We therefore think it probable that they are bedding-plane slip faults in the cover-rock sequence, on a fairly mature landscape of uncertain, but possibly considerable, age.

Royal Stream fault (feature 30, Fig. 6): In the lower Leader basin, a fault scarp near Royal Stream shown on QMAP has a correlative to the northeast, crossing the terraces of the next stream. We have mapped other likely scarps, based on topographic steps, with possible connections. To the south, the scarps do not seem to continue south across downland terrain, which should show surface deformation had there been any, so we have suggested that the fault most likely extends west up Castely Stream.

Hundalee Fault (feature 31, Fig. 6): The main evidence for the Hundalee Fault being an active fault is a several-metre-high step crossing a Conway River terrace on the north side of Fernihurst bridge, and troughs on the slope a little farther north. We mark it as ’likely’ because it is not inconceivable that the terrace-step feature is the result of river-trimming against hard beds within the cover-rock sequence, and the troughs are incipient scarps of a lateral-spreading landslide.

Along the mapped line of the fault north of Fernihurst and west of SH1 Conway Bridge, there is a broad plateau landform on which we would expect to see a fault scarp preserved prominently, if the sharp step at Fernihurst is in fact a relatively young fault scarp. North of the Conway, the terrain along the mapped line of the fault is deeply eroded and unstable, but we have identified several topographic–step landforms, that look rather like fault scarps, in that area, mostly just off the mapped line of the fault; we have denoted these steps as ‘likely’, but the fault, as positioned in the QMAP dataset, is otherwise shown as ’possible’.

South of the Conway River at Fernihurst, an arcuate step 20 to 30 m high is regarded as a Hundalee Fault scarp (Warren 1995; Rattenbury et al. 2006), but we have classified it as ‘likely’, because this feature may at least in part be an erosional feature, or related to bedrock lithology. Similarly, active traces mapped by Warren (1995) near the Leader River bridge may conceivably be erosional/bedrock structural features.

Karetu Fault – Birch Fault – Doctors Anticline (feature 34, Fig. 6): On the Karetu Fault, the fault scarps have an opposite sense of throw to the bedrock thrust fault. As depicted on QMAP, we consider it probable that these scarps relate to bedding-slip faults in the east limb of the MacDonald Syncline, and are unrelated to the Karetu Fault. Accordingly, parts of the Karetu Fault not coinciding with the fault scarps are labelled ‘possible’. We have designated the Doctors Anticline as a definite and likely active anticline, but not MacDonald Syncline because its form cannot readily be seen in the topography.

Boby Stream Fault (feature 35, Fig. 6): We have illustrated in the dataset the QMAP interpretation that the scarp on the Grey Fault relates to rupture of the Boby Stream Fault, because the scarp has the opposite sense of throw to that expected for the Grey Fault.

Despite the topographic prominence of the Mt Grey block, there is no direct independent evidence that the Mt. Grey Fault (also known as the Grey Fault – Wilson 1963; Gregg 1964; Forsyth et al. 2008) is currently active. It is established by unpublished mapping that the Mt. Grey Fault is a west-dipping thrust or reverse fault (DD Wilson, field sheets for Wilson (1963); H. Cowan, PhD thesis), but the surface fault scarp along the eastern flank of Mt Grey is up to the east. The outcrop exposure documented by Cowan et al. (1996) shows that the surface offset is along a steeply west-dipping fault with a normal component of offset. In other words the surface scarp is not developed on the west-dipping Mt. Grey Fault. The prominence of the surface scarp and the consideration that it is only traceable north as far as the Boby Stream Fault is why we think it very likely that this scarp is associated with a fault interlinked with the Boby Stream Fault and has been involved in Boby Stream Fault Holocene ruptures. For this reason, the Mt Grey Fault, and Janet Fault to the southwest, are assigned as ‘possible’ active faults.

Coastal fault-fold belt (feature 36, Fig. 6): An east-west striking topographic step about 2 km north of Amberley is interpreted to be a fault scarp (Forsyth et al. 2008), here identified as the Amberley Fault (feature 36a). However, there is a possibility that this step is a river-cut terrace edge, and so the Amberley Fault is identified as ‘likely’. A trenching investigation would be needed to establish whether or not it is an active fault.

Close to Amberley, there is reason to think that the bedrock fold axes approximate late Quaternary axes, because the drainage divides are aligned closely with the fold axial traces. These include the informally-named Seadown anticline (feature 36b), and the Kate Anticline and Teviotdale Syncline (feature 36c). We have extrapolated the Seadown anticline feature tentatively to the north along the Cass Anticline as a ‘likely’ active anticline.

Designations of activity for the Omihi Fault (feature 36e) and Hamilton Fault (36f) are discussed in Table 2. In Greta Valley, we have assigned an informal name of Greta Valley fault to the fault scarp mapped by Rattenbury et al. (2006). At the southwest end of this fault, we have extended a likely fault some distance southeast down a structure identified in the QMAP dataset as the Kaiwara Fault, which we have renamed here the Kaiwara Fault – southeast. Northeast of the junction of these two faults, ~2 km west of Greta Valley township, we have identified the Kaiwara Fault – southeast as ‘possible’. The fault scarp on the saddle on Motunau Beach Rd we have named ‘Cave Creek fault’, after a nearby watercourse.

Beyond the northern end of the Omihi Fault, we have in the dataset named the faulted southeast margin of Greta Valley the ‘Centre Hill fault’. Southwest of Greta Valley township, we have marked it as ‘likely moderately expressed’, as there are suspicious steps along the range-front. Southwest of Spye, where it goes into hill country, it is marked as ‘likely, not expressed’. From Greta township north, there are no steps at the range-front fault so we have just designated it as ‘possible’.

We note that the greywacke axis of Centre Hill is much dissected, and substantial stream valleys drain both north and south roughly parallel to the axis. Although structurally it approximates a faulted anticline, the drainage trends give nothing to suggest that it is actively growing, and in fact it looks like there is a pretty old landscape developed on this feature. We therefore have not mapped it as an active fold.

Motunau faults (feature 36j): As is also explained in Table 2, we took the step of inferring faults under the base of the limestone band on the seaward edges of the coastal range. This is to account for the flights of coastal terraces on the seaward slopes, some of the highest elevations of the coastal range, and fairly undissected topography there. This contrasts with the lower-lying, deeply dissected topography inland, including on the axis of the Cass Anticline south of the Motunau River. If growth of the anticline was the cause of the uplift of these mid-Quaternary coastal terraces, then the highest topography should be on the fold axis.

In the Blythe valley, we have identified the fault mapped on the basis of bedrock relationships as Blythe fault (feature 36k). Its eastern sector is shown as ‘definite’, because there are steps crossing high-level alluvial fans. Towards the west there is, at one location, a step at the margin of the valley that looks almost certainly like a fault displacement, but we have chosen to identify this sector of the fault as ‘likely’ as it could conceivably be the toe thrust of an incipient landslide.

In the lower reaches of the Hurunui valley, downstream of SH1, we have added several faults that were described by Carr (1970), and referred to them collectively as ‘Lower Hurunui faults’ (feature 36m), as well as the broad folds defined by folded old terrace surfaces, also from Carr (Stonyhurst Syncline and Mt Seddon Anticline, features 36l and 36n). We have also added a fault scarp that crosses Hurunui Mouth Road ~1 km northwest of Hurunui Mouth village.

We have drawn a generalised active anticline axis along the highest ground on the crest of the Hawkswood Range. A lack of known faults at the margins of the range, the flight of coastal terraces on its seaward flank, and the point that the drainage divide is broadly symmetrical with the range axis implies definite grounds for regarding this as an active anticline.

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