Before the Hearings Commissioners
at Christchurch

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in the matter of: a submission on the proposed Hurunui and Waiau River Regional Plan and Plan Change 3 to the Natural Resources Regional Plan under the Resource Management Act 1991

to: **Environment Canterbury**

submitter: **Meridian Energy Limited**

Statement of evidence of Mark Charles Grace Mabin

Dated: 12 October 2012

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CHAPMAN TRIPP

Qualifications and experience

1. My full name is Mark Charles Grace Mabin. I am an environmental scientist with over 25 years of experience, and am employed as a Principal Environmental Scientist at the Christchurch office of URS New Zealand Ltd.

2. I hold the degrees of Bachelor of Science, Master of Science and Doctor of Philosophy from the University of Canterbury. My research training concerned the environments of the braided Rangitata River, Ashburton River, and associated parts of the Canterbury Plains.

3. I have undertaken consulting, research, and university teaching activities in earth surface process regimes in many parts of the world. I have expertise in river sediment transport and geomorphology. I have authored or co-authored research papers and reports including 15 papers in international refereed scientific publications.

4. Over the past ten years I have provided assessments of effects of hydro dams, irrigation takes, and river protection works on large rivers such as the Kawarau and Clutha Rivers (Otago), Waiau River (Southland), Cleddau River (Fiordland), and Canterbury braided rivers including the Tekapo River, Waitaki River, Rakaia River, Waimakariri River, and the Waiau River. This work has involved writing technical reports, and presenting evidence to resource consent hearings.

5. I have read the code of conduct for expert witnesses set out in Environment Court Practice Note 2011, and confirm that I have complied with the code in the preparation of my evidence. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

6. In my evidence I will discuss Ngai Tahu Property Limited's (NTPL) and Meridian Energy Limited's (Meridian's) Balmoral Hydro Proposal (BHP) which, in combination with existing consented and potential future takes (particularly by Hurunui Water Project), would represent a full practical implementation of the Proposed Hurunui and Waiau River Regional Plan's (the Proposed Plan) environmental flow and allocation regime for the Hurunui River. In particular I will address issues related to the effects of the proposed BHP on sediment transport regimes and braided river landforms in the Amuri Reach of the Hurunui River. I note the Proposed Plan seeks to maintain the natural braided character of the Hurunui River.

7. I prepared a report[1] to help inform an Assessment of Environmental Effects (AEE) supporting proposed consent applications for the principal water consents for the BHP. I have used the work undertaken for that report as the basis of the evidence provided here.

8. My overall conclusion is that while the proposed allocation regime in the Hurunui River would have the potential to slightly depower the river in its bed load sediment transporting flow bands, the river in its present condition is undersupplied with bed load material and the small reductions in sediment transporting floods will not detectably affect the river. It will be able to continue to carry its normal bed and suspended sediment loads. Therefore, the allocation regime can be implemented in a manner that has no adverse effect on the Hurunui River's ability to transport and deposit sediment, or its ability to form and maintain its braided river fairway.

9. My evidence is divided into the following sections.

   9.1 The proposed Environmental Flow and Allocation Regime as supported by NTPL and Meridian;

   9.2 The methodology I have used to inform my opinions;

   9.3 Sediment transport in the Hurunui River, covering both suspended sediment and bedload sediment transport, and braided river landforms;

   9.4 The effects of a fully realised Environmental Flow and Allocation Regime via irrigation development and the proposed BHP on sediment transport and braided river landforms; and

   9.5 Summary and conclusions.

PROPOSED ENVIRONMENTAL AND ALLOCATION REGIME

10. It is my understanding that NTPL and Meridian generally support that Environmental Flow and Allocation Regime for the Hurunui River in the Proposed Plan, apart from the requirement to provide storage greater than 20 million cubic metres in the catchment to secure access to the "C" allocation block. My assessment below will be on the basis that the "C" block is available for either irrigation and/or hydro.

11. The proposed Plan allocation regime is in three blocks as follows:

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[1] *Balmoral Hydro Project: Assessment of Potential Effects on Sediment Transport in the Waiau River.* URS New Zealand report prepared for Meridian Energy Ltd. 9 August 2012. 33p.

11.1 A Block Minimum Flow at Mandamus: 10 – 15 m^3/s

A Block Allocation: 6.2 m^3/s

B Block Gap Size: 0 – 5 m^3/s

B Block Minimum Flow at Mandamus: 19 – 27 m^3/s

B Block Allocation: 10 m^3/s

C Block Minimum Flow: 29 – 37 m^3/s

C Block Allocation: 33 m^3/s

12. The total allocation across the three blocks is 49.2 m^3/s and NPTL and Meridian's Balmoral Hydro Project would take a maximum of 15 m^3/s of this subject to its relative priority position in the allocation regime.

Balmoral Hydro Project

13. Meridian's Balmoral Hydro Project (BHP) is described in detail by other witnesses. For my purposes it will suffice to briefly note the following.

13.1 The BHP take will affect up to a 28 km reach of the Hurunui River as it flows through the Amuri Reach in the southern part of the Amuri Basin. The intake will be at or near the existing Balmoral Irrigation Scheme (BIS), which is owned and operated by the Amuri irrigation Company, and is located just downstream of the Mandamus – Hurunui River confluence. The outfall will be upstream of the Dry Stream confluence.

13.2 The maximum rate of take would be 15 m^3/s, and this would occur when Hurunui River flow as it enters the Amuri Reach is equal to or greater than 27 m^3/s in winter, or 30 m^3/s in summer. Below these flows the hydro take would progressively reduce as required by the relative position of the BHP take within the allocation regime, and it would cease entirely at a river flow of ~11 m^3/s.

13.3 Under the flow and allocation regime in the Proposed Plan with more than 20 million cubic metres of storage in the Hurunui catchment, the hydro take would be occurring on average for between 78% and 91% of the time, or 285 to 332 days per year. Averaged over a year the take would be between 7.4 m^3/s and 11 m^3/s, depending on the extent of irrigation development.

13.4 While the BHP would be a run-or-river scheme, there will be some short-term flow variations within the scheme such that the maximum rate of discharge back to the river would be 18 m^3/s.

METHODOLOGY

14. In forming my opinions, I have reviewed and used information from a variety of technical reports prepared in relation to the Hurunui River, and sediment transport in other Canterbury rivers, including the Waiau River as documented in my other brief of evidence. I have applied this understanding to my own knowledge of the Hurunui River.

15. I have also made use of topographic maps and aerial photography in the MapToaster software, and examined aerial photography available on the Environment Canterbury website and satellite images viewed on the Google Earth and Bing Maps web sites. I have analysed Hurunui River synthetic flow data provided by Pattle Delamore and Partners (PDP) and flow data from the Mandamus gauging station on the Hurunui River operated by NIWA. My analyses have used HillTop and EXCEL software.

HURUNUI RIVER

16. The Hurunui River has a moderately large catchment area covering some 2,670 km^2 of North Canterbury. It is 145 km long, draining from mountains along and just to the east of the Main Divide of the Southern Alps, and flows through foothill ranges, inland basins and hill country to the coast about 11 km south of Cheviot.

17. The river has a gravel bed through most of its length, and has a variety of channel forms including narrow rocky gorges, single thread channels, and multi-thread channels with significant braided reaches.

18. An important feature of the Hurunui River is the 18.5 km^2 of lakes that occur in the upper catchment. The largest is Lake Sumner (13.8 km^2) and this along with the other lakes has an important effect on the river's hydrological regime as it attenuates flood peaks, and acts as a sink for bedload sediment inputs and a partial sink for suspended sediment inputs from 40% of the upper catchment area of the Hurunui River.

19. The BHP would be located on the Hurunui River in the Amuri Basin, between 42 km and 70 km upriver from the coast. This basin covers about 840 km^2, with a small part in the north draining to the Waiau River, while and most of it drains to the Hurunui River via significant tributaries like the Pahau River, Dry

Stream, and the Waitohi River. The Hurunui River flows generally eastwards through the southern part of the basin. In this 33 km reach it is flanked on the north by alluvial plains and terraces currently largely covered by the Balmoral Forest, to the southwest by farmed alluvial plains and terraces, and to the south by the Lowry Peaks range of hills.

20. Hurunui River flow is monitored at NIWA Site 65104 (Mandamus) in a gorge just upstream of the Amuri Basin. The gauge is 1.4 km upstream of the proposed BHP intake, and 0.7 km upstream of the Mandamus – Hurunui River confluence. To take account of the extra flow delivered by the Mandamus River, PDP have developed a synthetic Hurunui River flow record for the period June 1972 to May 2011. PDP have also modelled this flow series to take account of several irrigation take and BHP take scenarios that I will refer to. I note that Mr Woods has used this same database in preparing his evidence on the hydrology of the Hurunui Catchment.

21. All of the flow data I will refer to in my evidence is mean daily flow taken from the PDP synthetic flow record, unless otherwise noted.

22. In Table 1 I list the key flow characteristics for the Hurunui River for the period 1972 – 2011.

Table 1: Summary Hurunui River flow statistics (1972 – 2011)

Maximum instantaneous flow*	1,145 m^3/s
Maximum mean daily flow	805 m^3/s
Mean annual flood	423 m^3/s
Mean flow	58.6 m^3/s
Median flow	43.8 m^3/s
Minimum flow	11.3 m^3/s

* Measured at the Mandamus gauge on 27th December 1957

23. The landform characteristics of the Amuri Reach are generally similar to other Canterbury multi-thread gravel bed rivers. However, this reach of the Hurunui River is probably less braided than is typical for other rivers. I illustrate it in Figure 1, which is from aerial photographs dated 2nd November 2004.

24. The river fairway width is highly variable, but shows a general increase downstream from about 550 m near the intake to over 750 m at the outfall. Overall it varies in width from 200 m to 1,040 m. The higher parts of the fairway are rarely covered by floodwaters and can be well vegetated with grass, scrub and willow trees. The more frequently flooded parts of the

fairway comprise bare gravel, and makes up 50% to 70% of the total fairway width, varying from 130 m to 670 m across.

25. Surface relief across the fairway is small, and I estimate there is generally less than 4 m of height difference between the highest and lowest points, and fairway slope varies between 5.1 and 6.3 m/km. The D_{50} (median) grainsize of the gravel and sand alluvium is ~25 mm, while the channels are typically armoured with a surface layer of cobbles 65 mm to 85 mm in diameter.

26. The fairway is typical of a gravel bed river and consists of one or more interlaced channels that separate gravel bars and islands with varying levels of generally sparse vegetation cover. The arrangement of the channels and bars can be highly mobile, changing completely with the passage of large floods, while channels can migrate across the fairway even during periods of low flow. These river landforms are a focus of my assessment and their general characteristics are as follows.

27. Although usually referred to as a braided river, the Amuri Reach of the Hurunui River has significant sections with only one or two low flow channels where it is not a truly braided river. There are four sub-reaches along the Amuri Reach as described in Table 2. These data are based on sampling the fairway characteristics at one kilometre intervals along the reach.

Table 2: Amuri Reach landform characteristics

Sub-reach	# Braid Channels	Notes
0 – 14 km	1 – 3	Intake is at 0.7 km. Slope ~5m/km.
14 – 19 km	4 – 5	Braided sub-reach. Slope ~6m/km.
19 – 23 km	1 – 3	State Highway 7 crosses at 20.5 km. Slope 6m/km.
23 – 32 km	4 – 7	Braided sub-reach. Outfall at 28.7 km. Slope 6m/km.

28. In the Amuri Reach only about 14 km is truly braided, and most of this is downstream of the State Highway 7 bridge.

29. The channels that carry the Hurunui River non-flood flow vary in width from a few metres to over 60 m. At higher flows more braid channels become active, until they start to merge in floods and their numbers reduce. Channels can be continuous as they branch and re-join, or they can start/stop in groundwater seeps/soaks. They are typically shallow, often less than 0.5 m, but can be incised 2 – 3 m below the higher parts of the fairway.

30. In non-flood flow the channels are moderately swiftly flowing runs, with some shorter, shallower, and more swiftly flowing riffles. Slow flowing pools are not common.

31. The channels flow between gravel bars and islands. There is little real difference between a bar and an island, except for size and vegetation cover. Bars are smaller (typically less than 1 ha) and the gravels are bare or lightly grassed, while islands are larger (several hectares) and somewhat higher so that they are less frequently flooded and therefore support grass, scrub, and even trees.

32. I estimate that the actively flowing channels in the non-braided section of fairway shown in Figure 2 comprise about 20% of the predominantly bare fairway area. In floods a further 35% becomes flowing channel, leaving about 45% of the area as bars and islands.

33. The braided sub-reaches are a little differently arranged. In the sub-reach shown in Figure 3, actively flowing channels cover about 15% of the bare fairway, with flood channels adding a further 25% of fairway area. The bulk of the bare fairway area (60%) is bars and islands.

34. The flood channels become increasingly active during freshes and small-medium floods, and many will be flowing in the FRE3 flood (three times the median flow), which is 132 m^3/s. All braid channels and some bars and islands will be inundated by floods of 400 m^3/s (occurring about once every 2 – 3 years), and much of the fairway will be inundated by floods of 550 m^3/s (occurring about once every 5 years). The fairway becomes fully inundated at about 700 m^3/s and this occurs about once every 20 years.

SEDIMENT TRANSPORT IN THE HURUNUI RIVER

35. A natural function of rivers is to transport sediment. This material can be carried as suspended load and bed load, where suspended load is the clay, silt and fine sand material that is carried along in suspension by the flow, and bedload is the sand and gravel material rolled or bounced along the river bed.

36. Suspended sediment particles are small and require only low flow velocities to keep them in motion. Suspended load is transported at almost all flows, although increases greatly in floods. Bed load material is larger and requires higher velocity flows to initiate and maintain sediment transport. While small quantities of bed material can be in motion in low flows, the bulk of this transport occurs in floods. Therefore, when considering bed load transport,

the high velocity flows that occur during flood discharges are the most important.

37. In most rivers, suspended load makes up the bulk of the sediment carried. For example, Hicks (1998, Table 4)[2] lists estimates for bed load in the Waimakariri River varying between 2% and 13% of the total suspended load transported, and for the Hurunui River the bed load estimate is 16.5% of the suspended load.

Suspended load

38. Suspended sediment is supplied from the upper catchment and results from erosion processes on hills and mountain slopes that strip soil and loess material which is then washed into the main river by tributary streams (Hicks and Davies, 1993[3]). The transport of this material in the main river depends on the rate at which it is supplied, rather than the river's ability to transport it. Rivers are well able to transport all the suspended sediment supplied to them.

39. Most of the suspended load is very small sediment particles of clay or fine silt carried along in suspension in the water flow.

40. Data on suspended sediment concentrations in the Hurunui River are available from the NIWA flow gauging site (#65104) on the Hurunui River at the Mandamus flow recording site. From these data I have derived a suspended sediment rating curve using a LOWESS[4] smoothing that gives a reasonable approximation of the relationship between suspended sediment carried and discharge in the river. I show this rating curve in Figure 4.

41. This relationship shows how suspended sediment concentrations increase rapidly as flow increases above about 75 m^3/s. The relationship is descriptive and not causative, in that changes in river flow do not cause changes in suspended sediment concentration. Rather, the suspended sediment arrives in the river carried in hillslope runoff which is itself a driver of changing flow.

42. This means that the allocation of water that may be allowed for under the Proposed Environmental Flow and Allocation Regime would not change the concentration of suspended sediment in the Hurunui River. A take removes

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[2] *Sediment budgets for the Canterbury Coast – a review, with particular reference to the importance of river sediment* NIWA Client Report CHC98/2, ECan Report # U98/12, 85p.

[3] *Erosion and sedimentation in extreme events* pp115-141 *in* Mosley, P. & C.P. Pearson (eds) *Floods and droughts: the New Zealand experience* New Zealand Hydrological Society.

[4] LOcally-WEighted Scatterplot Smoothing using an EXCEL application at http://peltiertech.com/WordPress/loess-smoothing-in-excel/

both water and its suspended sediment load from the river, and there will be no increase (or decrease) in the concentration of suspended sediment in the water column downstream of the intake.

43. The Hurunui River carries a reasonably significant suspended sediment load. Hicks et al[5] have estimated suspended sediment yields for New Zealand Rivers, and they calculate the annual suspended sediment load for the Hurunui River at Mandamus is 0.4 x 10^6 tonnes per year, which is a specific yield of 538 t/km^2/yr. This is rather less than is carried by other Canterbury braided rivers like the Waiau River (1,171 t/km^2/yr), or the Waimakariri River (996 t/km^2/yr) both of whose headwaters are adjacent to the Hurunui River. This lower suspended sediment yield is probably due to the settling out that occurs as the water passes through Lake Sumner.

44. Although suspended sediment is the largest component of a river's solid load, it is rarely of concern for the management of physical aspects of the river channel and floodplain. Of much more importance for these issues are river erosion and aggradation (or sediment build up), and these processes relate directly to the transport of bed load by the river.

Bed load

45. Bed load is the sand and gravel material that is rolled or bounced over the river bed and this type of sediment transport occurs most effectively during flood conditions.

46. As I noted above, bed load usually comprises a small proportion of the total sediment load. Using the estimate in paragraph 37 above, the annual bed load transported by the Hurunui is probably in the order of 66,000 tonnes per year.

47. There is a large body of work on gravel transport in Canterbury braided rivers (e.g. Griffiths (1979)[6], Hicks and Davies (1997)[3], and Duncan and Bind (2008)[7] who all discuss bedload sediment transport in the Waimakariri River). The more recent studies have made use of 2-D hydrodynamic models, and while these are usually directed at ecological matters, they can also be useful

[5] *Suspended sediment yields from New Zealand rivers* Journal of Hydrology (NZ) 50(1): 81 – 142 (2011).

[6] Griffiths, G. (1979) *Recent sedimentation history of the Waimakariri River, New Zealand* Journal of Hydrology (New Zealand) 18(1): 6 – 23.

[7] Duncan, M. and J. Bind (2008): *Waimakariri River bed sediment movement for ecological resetting* NIWA Client Report CHC2008-019, 32 p

in understanding bed load sediment transport. Duncan and Bind (2009)[8] and Jowett (2012)[9] have modelled part of the Waiau River, and Duncan and Shankar (2004, 2007)[10] have modelled part of the Hurunui River in the braided sub-reach downstream of the State Highway 7 bridge. Together these studies provide a useful background for understanding the bedload sediment transport in the Hurunui River.

48. The Hurunui River is a gravel bed river, and the taking of water for the proposed BHP could de-power the river in the Amuri Reach, potentially leading to several effects such as:

- Reduced sediment transport capacity resulting in aggradation of the river bed, and siltation at the river mouth;
- Changes in the fairway landform patterns, braided channels, bars and islands;
- Reduced sediment delivery to the coast; and
- Reduced efficiency and/or effectiveness of infrastructure (for example, irrigation intakes, flood protection works, and bridges).

These potential effects relate directly to sediment transport issues and the physical character of the river channel and floodplain, and my assessment relates only to these issues. Matters related to river ecology and bird habitat, are covered in evidence by other experts.

49. The Hurunui River is typical of many gravel bed rivers in New Zealand where the surface layer of sediment found on the bed is generally larger gravel or cobble sized particles that form an “armour” layer over finer material directly beneath.

50. It is in this condition because the finer gravel and sand material has been transported away downstream, leaving behind the larger particles that will protect the underlying sediment from erosion until there is a flood large enough to move this surface layer. Therefore, this coarse gravel armour layer

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8 Duncan, M. and J. Bind (2009) *Waiau River instream habitat modelling based on 2-D hydrodynamic modelling NIWA Client Report CHC2008-176, 72 p.*

9 Jowett, I (2012) *Instream habitat in the Waiau River and assessment of effects of the Amuri Hydro Project* Jowett Consulting Ltd Report IJ01203, 69 p.

10 Duncan, M. and U. Shankar (2004) *Hurunui River Habitat 2-D Modelling NIWA Client Report CHC2004-011* published as Canterbury Regional Council Report No U04/19*, 72 p.* Duncan, M. and U. Shankar (2007) *Hurunui River Habitat 2-D Modelling: habitat for periphyton NIWA Client Report CHC2007-039* prepared for Canterbury Regional Council, 17 p.

bed condition indicates the river is effectively under-supplied with bed load, and it would transport more bedload if supply from upstream were available.

51. What then are the significant sediment transporting and landforming floods in the river? Three flow levels are important:

51.1 The flow at which sand and fine gravel sediment begins to move across the bed surface armour layer. This is known as the fines flushing or surface flushing;

51.2 The flow at which the bed surface armour layer of larger gravel particles is moved allowing the underlying finer material to be transported. This is known as depth flushing or vertical flushing; and

51.3 The flow that covers the fairway and allows reorganisation of the channel landforms.

52. While the fines flushing flows do mean that sand and fine gravel are being transported, it is the depth flushing and in particular the fairway-inundating floods that will be responsible for re-organisation of the fairway and on-going development of the braid channel, bar and island geomorphology.

53. Duncan and Bind[7,8] show that fines flushing and some depth flushing are theoretically possible even at very low flows. This can have important implications for some biota. However, this is not significant in relation to braided river landforms and overall bed load sediment transport as little of the wetted channel area is experiencing flushing, and very little of the whole fairway is actually affected by these flows.

54. The FRE3 flow (i.e. three times the median flow) has often been used as an indicator flow at which bed sediment movement is occurring, and this is likely to comprise mainly fines flushing and some depth flushing at the river bed.

55. However, while sediment transport is likely to be well underway at the FRE3 flow, it is still confined to the actively flowing braid channels and from the data presented above in paragraphs 33 and 34, I estimate these would only cover about 30% to 35% of the fairway area. Significant bedload transport does not occur until much higher discharges are reached and more of the fairway is inundated.

56. Davies[11], Hicks and Davies[3], and Griffiths[6] have examined this issue in the Waimakariri River, and from their work it is apparent that the most effective bedload transporting flow occurs at discharges that are 2 – 3 times greater than the FRE3 flow when the whole Waimakariri River bed is inundated. I estimate that significant bedload transport in the Hurunui River occurs at about 400 m^3/s which is close to three times the FRE3 flow (~395 m^3/s), and the mean annual flood (423 m^3/s).

57. I have examined aerial photographs and satellite images of the part of the Amuri Reach of the Hurunui River that show the fairway after a variety of flood events. These indicate that a flood of about 550 m^3/s is required for significant changes to occur to braid channel patterns. This event occurs on average about once every five years.

58. The sediment transport that occurs during these large floods will be able to reorganise the fairway landforms of braided channels, bars and islands. The flow that covers the fairway is likely to cause the most widespread change to fairway landforms.

59. Combining the above information, I list the significant flow thresholds for sediment transport in the Hurunui River in Table 3.

60. From these data I interpret that bed load sediment transporting flows which will have a significant effect on fairway braid islands, bars and channels occur in flow bands well above the FRE3 threshold of 132 m^3/s, and this is just above the 130 m^3/s flow at which the BHP intake will have ceased for 48 hours.

Table 3: Hurunui River bedload sediment transporting flows

Median flow	44 m^3/sec	Limited fines and depth flushing may be occurring in some braid channels.
FRE3 'fresh' flow	132 m^3/sec	Fines and some depth flushing occurring in the main braid channels.
Significant bed load transporting flow	400 m^3/sec	All braid channels flowing, and some flow encroaching onto fairway bars and islands. Fines and depth flushing affecting braid channels.
Fairway inundation flow	550 m^3/sec	Much of the fairway inundated. Fines and depth flushing occurring in channels and a less extent on bars and islands.

11 *Modification of bedload transport capacity in braided rivers* Journal of Hydrology (New Zealand) 27(1): 69-72

EFFECTS OF THE PROPOSED BHP FLOW REGIME

61. The take of water from the Hurunui River for hydro generation will reduce flow in the Amuri Reach across all flow bands above the minimum flows in the Proposed Plan such that the overall mean flow will be reduced by between 7.4 m^3/s and 11 m^3/s, assuming no other flow losses or gains through the reach.

62. However, the BHP take would only occur by itself outside of the irrigation season, and so assessment needs to take into account the irrigation takes that would also be occurring during the irrigation season. Therefore, in my evidence below reference to the “BHP take” includes the associated irrigation takes.

63. The potential effects of the BHP water take is assessed in relation to the existing flow regime of the Hurunui River. As identified in the evidence of Mr Woods, a variety of Hurunui River flow regimes were modelled by PDP, each reflecting different mixes of existing and proposed irrigation and hydro takes. Scenario 2a represents the existing flow regime with all consented water takes exercised (which are the 6.2 m^3/s provided for by the “A” allocation block). I have taken this to be the existing environment for the purposes of my assessment.

64. Of the nine flow regimes modelled by PDP, four include a hydro take component and these are identified as Scenarios 2b, 3b, 4b, and 5b. However, Scenarios 4b and 5b are very similar, so I will not separately assess Scenario 5b.

65. I show summary characteristics of the existing flow regime and proposed BHP flow regimes in Table 4. It can be seen that Scenario 3b would have the largest combined effect on the Hurunui mean flow, although it would allow the smallest hydro take for BHP.

Table 4: Hurunui River flow in the Amuri Reach under various BHP and irrigation scenarios

Flow regime	Annual Mean flow downstream of the BHP intake	Average Annual Irrigation take	Average Annual BHP take
Existing flow regime (Scenario 2a)	56.5 m^3/s	2.0 m^3/s	-
Scenario 2b (Existing consented irrigation takes + BHP)	45.5 m^3/s	2.0 m^3/s	11.0 m^3/s
Scenario 3b (Full potential HWP irrigation development + BHP)	39.9 m^3/s	11.3 m^3/s	7.4 m^3/s
Scenario 4b (Stage 1 HWP irrigation development without storage + BHP)	44.9 m^3/s	3.1 m^3/s	10.6 m^3/s

66. In Figure 5, I show flow duration curves for the various scenarios, with flow truncated at 150 m^3/s in order to show the effects more clearly. The flow regime changes will affect all flow bands above the minimum flows as the hydro take is proposed to be possible at all of these flows, apart from short shut downs for 48 hours when Hurunui River flow rises to and beyond 130 m^3/s. However, due to operational constraints it is likely that takes at flows above 130 m^3/s would be restricted due to the high suspended sediment load carried.

67. It can be seen that all take scenarios have similar effects in the flow band between 10 m^3/s and 24 m^3/s. Above 24 m^3/s, Scenario 3b takes more water from the river while the less aggressive Scenarios 2b and 4b have very similar effects.

Effects on suspended sediment transport

68. The reduction in flow through the Amuri Reach is unlikely to have any detectable effect on the Hurunui River's ability to transport suspended sediment.

69. Water entering the BHP intake will be carrying suspended sediment and this will enter the intake in the same proportions as the main flow of the river. A water take removes water and suspended sediment from the river and so does not increase the concentration of suspended sediment in the water that remains in the river.

70. The suspended sediment load will then continue to be carried downstream by the river through the Amuri Reach. The reduced flow will not result in increased deposition by settling out of suspended sediment. Rivers are

effectively not limited in the amount of suspended sediment they can carry so that a reduction in flow does not result in increased deposition.

71. Some deposition of fine sediment does occur as the river discharge declines, but this is a natural process involving the very small quantities of suspended sediment that become trapped at the river margins in small pools of still water between gravel clasts.

72. The water taken for the proposed BHP may pass through a sediment settling pond and storage basins where some settling of suspended sediment is likely to occur. This would reduce the concentration of suspended sediment in the water so that when it is discharged via the scheme outfall back into the Hurunui River, it will generally be a little clearer than the water in the river. This will have no detectable effect on suspended sediment transport processes in the river.

Effects on bed load transport

73. The reduced river flow in the Amuri Reach will affect the bedload sediment transporting flow bands as shown in Table 5.

Table 5: Characteristics of Hurunui River bedload sediment transporting flow events after BHP and irrigation takes (1972 – 2011)

Flow Events	**Frequency** (days/year)	**Mean Duration** (days)	**Mean Separation** (days)
Median flow events (44 m^3/s)			
Scenario 2b (all takes)	14.6	7.8	18.3
Difference from existing flow regime Hydro take component	0.8	-5.2	3.9
Scenario 3b (all takes)	13.0	6.5	22.7
Difference from existing flow regime	-0.9	-6.4	8.4
Hydro take component	-0.3	-2.7	3.3
Scenario 4b (all takes)	14.6	7.5	18.5
Difference from existing flow regime	0.8	-5.4	4.1
Hydro take component	0.7	-4.6	3.1
FRE3 'fresh' flow events (132 m^3/s)			
Scenario 2b (all takes)	6.9	3.0	50.9
Difference from existing flow regime Hydro take component	0.1	-0.5	-0.1
Scenario 3b (all takes)	5.7	2.9	61.4
Difference from existing flow regime	-1.1	-0.6	10.4
Hydro take component	0.1	-0.3	-0.8
Scenario 4b (all takes)	6.8	2.9	51.3
Difference from existing flow regime	0.03	-0.5	0.3
Hydro take component	0.2	-0.5	-1.2
Significant bedload transporting flow (400 m^3/s)			
Scenario 2b (all takes)	0.6	1.4	556
Difference from existing flow regime Hydro take component	-0.03	-0.02	23.2
Scenario 3b (all takes)	0.5	1.4	673

Difference from existing flow regime	-0.15	0.02	140.3
Hydro take component	-0.08	0.01	64
Scenario 4b (all takes)	0.6	1.4	556
Difference from existing flow regime	-0.03	-0.02	23.2
Hydro take component	-0.03	0.01	23
Braided river landform events (550 m^3/s)			
Scenario 2b (all takes)	0.18	1.43	2076
Difference from existing flow regime Hydro take component	-0.03	0.05	250
Scenario 3b (all takes)	0.15	1.50	2491
Difference from existing flow regime	-0.05	0.13	665
Hydro take component	0.0	0.0	0
Scenario 4b (all takes)	0.18	1.43	2076
Difference from existing flow regime	-0.03	0.05	250
Hydro take component	-0.03	0.05	250

74. The BHP take will mainly affect the 11 – 130 m^3/s flow band, but there will a changes in the frequency, duration, and separation between events across most flow bands.

75. Table 5 generally shows that across all scenarios there would be a pattern of reduced event frequency and duration and increased separation between events. However, for the smaller median flow and FRE3 events, frequency would increase in the 2b and 4b Scenarios as events in higher flow bands drop down into these categories. The hydro take component would typically be a little more significant in the 2b and 4b Scenarios, while the irrigation take component would be more significant in Scenario 3b.

76. The changes in the median flow events are unlikely to have a detectable effect on bedload sediment transport as little of the riverbed is affected in these channel-confined events.

77. Bedload sediment transport starts to occur more significantly at higher flows and to take account of this Meridian proposes to shut off the BHP intake for 48 hours when the Hurunui River flow rises above 130 m^3/s. In the existing flow regime >130 m^3/s flow events occur on average 6.8 times per year, with a mean duration of 3.4 days. Nearly half these events (3.4 / yr) last for only 1 – 2 days and so will not be affected by the BHP water take. The three-day events occur in the natural flow regime 1.2 times per year, and they will become 1 day events, while four-day events occur 0.7 times per year, and will become 2 day events.

78. FRE3 events are a more important threshold for bedload sediment transport and occur at 132 m^3/s, which is just above the 48 hour shut-off flow. Table 5 shows there will be a very small increase in the frequency of these events in

Scenarios 2b and 4b, but their average duration will be 0.5 days less. Scenario 3b would reduce the frequency of FRE3 events by a day as well as making them about half a day shorter.

79. These FRE3 events are still confined to the braid channels and sediment movement is likely to be mainly fines flushing. Thus there will be only a minor effect on bedload sediment transport arising from the reduction in these flow events.

80. The most effective flows for bedload sediment transport are likely to occur at around 400 m^3/s. At this flow most braid channels will be carrying swiftly flowing water with fines and depth flushing occurring across much of the channels. From Table 5 it can be seen there will be very little effect on the frequency or duration of these events in any irrigation and/or hydro take scenario. This arises from the 48 hour shut down at 130 m^3/s which means many of these brief infrequent high flow events remain unaffected by the BHP take. Overall, I consider these changes are unlikely to have a detectable effect on bedload sediment transport.

81. The much larger events that result in significant changes in braided river landforms will be a little less frequent under the BHP scenarios, with 13% fewer events under Scenarios 2b and 4b, and 25% fewer events under scenario 3b. There is an apparent increase in the duration of these events, but this arises from the reduced number of events being at the expense of short events while longer events are not affected, resulting in a slight increase in the mean event duration. This highlights the fact that in my analysis of flow regime changes, some of the differences result from the small number of events in PDP's 39 year modelling period and the effects that outlier values have on the calculated means. I therefore consider that the reduction in the high flow regime events will have little overall effect on the bedload sediment transport regime.

82. The above assessment shows that Scenario 3b has the potential to have a slightly greater effect on bedload sediment transport that Scenarios 2b and 4b. However, overall the changes are considered to be small and none of the three hydro take scenarios is likely to have any detectable effect on bedload sediment transport and braided river landforming events.

83. I noted above (paragraph 50) that the Hurunui River is probably under-supplied with bedload sediment and is therefore unlikely to be transporting bedload at its sediment transport capacity. For this reason the river is likely to

be able to absorb these small changes in bedload sediment transporting power without any reduction in the volume of sediment moved. This in turn means there is unlikely to be any detectable change in braided river landforming processes in the Amuri Plains reach of the Hurunui River arising from any of the BHP water take scenarios.

Effects on braided river landforms

84. The natural character of the braided river fairway landforms of channels, bars and islands in the Amuri Reach of the Hurunui River arises mainly from the very large floods that substantially cover the fairway. These are the braided river landforming events that start at about 550 m^3/s and these occur on average about once every five years. Full inundation of the fairway does not occur until floods of about 700 m^3/s that occur on average about once every 20 years.

85. It is unlikely that irrigation or hydro takes would be occurring in these floods as they carry very large suspended sediment loads. If a BHP take were occurring the 15 m^3/s involved would represent less than 3% of the river flow.

86. I therefore conclude that as the BHP take will have only a very minor effect on these large flood events, there will be no detectable changes in braided river landforms.

SUMMARY

87. The Hurunui River carries substantial volumes of suspended and bed load sediment. Suspended load comprises clay, silt and fine sand, while bedload is sand, gravel and larger cobbles. Most of this material is carried by flood flows such that the bulk of suspended load is carried by flows greater than the FRE3 flow, and the bulk of bed load material is carried by flows greater than three times the FRE3 flow.

88. While some bedload sediment transport does occur below the FRE3 flow, this involves mainly sand material and is confined to the flowing channels that cover less than 25% of the fairway area. Thus, this does not play a significant role in fairway landform development.

89. Summarising my assessment of the effects of the proposed Balmoral Hydro Project on sediment transport in the Hurunui River, and fairway braided river landform geomorphology, it is my opinion that the overall effects will be less than minor.

90. As the proposed power scheme reflects the practical full use of the Hurunui River flow and allocation regime in the proposed Hurunui and Waiau River Regional Plan for hydro generation, I similarly conclude that the effects of implementing this regime on sediment transport in the Hurunui River, and fairway braided river landform geomorphology, can be less than minor. I note that this may not apply if large volumes of water are taken and used consumptively.

M.C.G. Mabin
12th October 2012

Figure 1: Aerial photograph of the Amuri Reach of the Hurunui River Image date 2/11/2004, river flow 61 m^3/s. I = intake, O = outfall. Image dimensions 29.5 km by 12.5 km.

Figure 2: Aerial photograph of a non-braided sub-reach at between km 5 and km 7 in Amuri Reach. Image date 2/11/2004, flow 61 m^3/s.

Figure 3: Aerial photograph of braided sub-reach at between km 22 and km 24.5 in Amuri Reach. Image date 2/11/2004, flow 61 m^3/s.

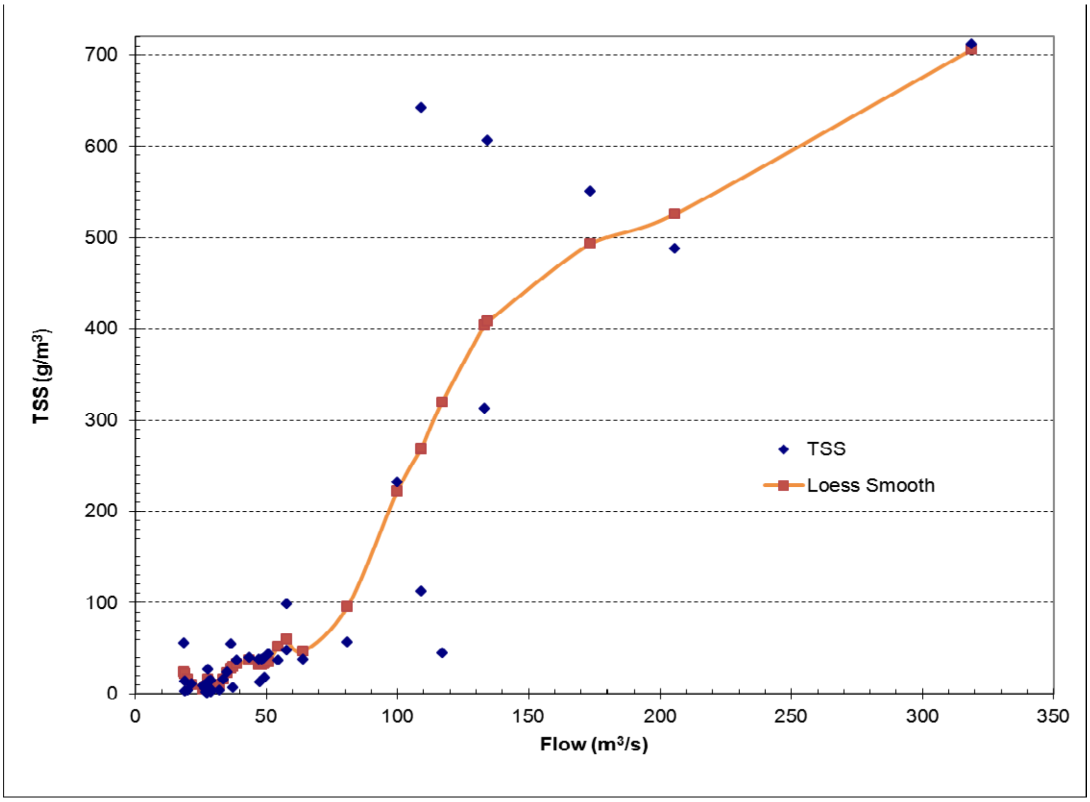

Figure 4: Suspended sediment rating curve for the Hurunui River at Mandamus (TSS = total suspended solids)

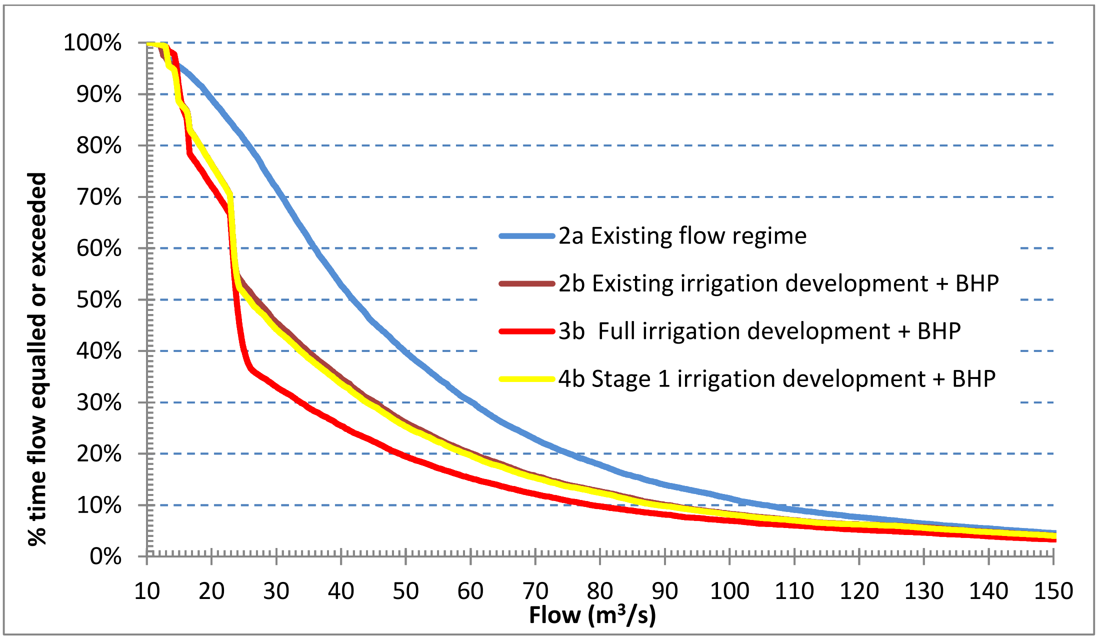

Figure 5: Flow duration curves for the Hurunui River under various modelled take regimes