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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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 Limited.

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 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, Waiau River (Southland), Cleddau River (Fiordland), and Canterbury braided rivers including the Tekapo River, Waitaki River, Rakaia River, Waimakariri River, and the Hurunui 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.

Scope of Evidence

6. In my evidence I will discuss Meridian Energy Limited's (Meridian's) Amuri Hydro Proposal (AHP) which, in combination with existing consented and potential future takes, would represent a full implementation of the Proposed Hurunui and Waiau River Regional Plan's (the Plan's) allocation regime for the Waiau River. In particular I will address issues related to the effects of the AHP on sediment transport regimes and braided river landforms in the Emu/Amuri Plains reach of the Waiau River.

7. My overall conclusion is that the proposed allocation regime relates to flows in the Waiau River that do not carry appreciable quantities of either bed load or suspended load sediments. Thus the allocation regime will have no

detectable adverse effect on the Waiau River's ability to transport and deposit sediment, or its ability to form and maintain its braided river fairway.

8. My evidence is divided into the following sections.

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

   8.2 The methodology I have used to inform my opinions;

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

   8.4 The effects of a fully realised Environmental Flow and Allocation Regime on sediment transport and braided river landforms; and

   8.5 Summary and conclusions.

PROPOSED ENVIRONMENTAL AND ALLOCATION REGIME

9. It is my understanding that Meridian generally supports the Environmental Flow and Allocation Regime in the proposed Hurunui and Waiau River Regional Plan (the proposed Plan), apart from the proposed provision for a B Block Gap Size of two cubic metres per second (m^3/s). My assessment below will be on the basis that this B Block gap is not in place.

10. The proposed Plan allocation regime for the Waiau River is in three blocks as follows:

    10.1 A Block Minimum Flow: 20 m^3/s

    A Block Allocation: 18 m^3/s

    B Block Gap Size: 2 m^3/s (this is not supported by Meridian)

    B Block Minimum Flow: 40 m^3/s

    B Block Allocation: 11 m^3/s

    C Block Gap Size: 0 m^3/s

    C Block Minimum Flow: 51 m^3/s

    C Block Allocation: 42 m^3/s

11. The total allocation across the three blocks is 73 m^3/s and Meridian's Amuri Hydro Project would take a maximum of 50 m^3/s of this subject to its relative priority position in the allocation regime.

Amuri Hydro Project

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

12.1 The AHP take will only affect a 29 km reach of the Waiau River as it flows through the Emu/Amuri Plains at the northern end of the Amuri Basin. The intake will be at or near the existing Amuri Irrigation Company intake just downstream of the Leslie Hills Road bridge, and the outfall will be 1 – 2 km downstream of the State Highway 70 bridge near Waiau township.

12.2 The maximum rate of take would be 50 m^3/s, and this would occur when Waiau River flow as measured upstream at Marble Point was in the band between ~70 m^3/s and 210 m^3/s. At river flows below 70 m^3/s, the hydro take would progressively reduce as required by the relative position of the AHP take within the allocation regime, and it would cease entirely at a river flow of ~20 m^3/s.

12.3 Given the river flow and allocation regime, the hydro take would be occurring on average for ~85% of the time, or 309 days/year. Averaged over a year the take would be ~31 m^3/s.

METHODOLOGY

13. In forming my opinions, I have reviewed and used information from a variety of technical reports prepared in relation to the Waiau River, and sediment transport in other Canterbury rivers as documented in my evidence. I have applied this understanding to my own knowledge of the Waiau River that arises from site inspections, aerial overflight in a light plane, and jet boat access on the river.

14. I have also made use of topographic maps using MapToaster software, Waiau River flow data made available by Environment Canterbury from their Marble Point gauging site, flow analysis using HillTop software, aerial photographs supplied by New Zealand Aerial Mapping, satellite images viewed on Google Earth and Bing Maps web sites.

WAIAU RIVER

15. The Waiau River has a moderately large catchment area covering some 3,300 km^2 of North Canterbury. It is 167 km long, draining from mountains along the Main Divide of the Southern Alps and Spenser Mountains, and flows through foothill ranges, inland basins and hill country to the coast about 9 km northeast of Cheviot.

16. 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 including significant braided reaches.

17. The AHP would be located in the Amuri Basin, about 40 km from the coast. This basin covers about 840 km^2, and most of it drains south to the Hurunui River. The Waiau River flows in a generally easterly direction through the northern part of the basin. In this 30 km reach the river is flanked on the north by the Emu Plains, and the Amuri Plains to the south.

18. Waiau River flow is monitored at Marble Point, in a gorge just upstream of the Amuri Basin. The gauge is 9 km upstream of the proposed AHP intake. I list the key flow characteristics from this site are listed in Table 1 (for the period 1967 – 2009).

Table 1: Summary Waiau River flow statistics at Marble Point

Maximum instantaneous flow	1,650 m^3/s
Maximum mean daily flow	1,233 m^3/s
Mean annual flood (instantaneous flow)	~1,000 m^3/s
Mean annual flood (mean daily flow)	~730 m^3/s
Mean flow	97 m^3/s
Median flow	72 m^3/s
Minimum flow	19 m^3/s

19. In The Emu/Amuri Plains reach the Waiau River has a mostly braided channel form and I illustrate it in Figure 1 which is from aerial photographs dated 5th December 2000. In Figure 2, I show in detail a 2.8 km long section near the central part of the Emu/Amuri Plains reach that has been identified by Duncan and Bind (see footnote 7 below) as representative of the whole reach. These authors have developed a hydrodynamic model of this section of the channel that I will refer to below.

20. The fairway varies from about 0.5 km to over 2 km across. Slope varies between 3.9 and 5.3 m/km, and the D_{50} (median) grainsize of the gravel and

sand alluvium is 37 mm. Surface relief across the fairway is small, with generally less than 4 m of height difference between the highest and lowest points.

21. The fairway is typical of a braided river and consists of a multiplicity of 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 braided river landforms are a focus of my assessment and their general characteristics are as follows.

22. The braid channels that carry the Waiau River flow vary in width from a few metres to over 200 m. At low flow there tend to be 1 – 2 major channels, and 3 – 4 minor channels. At higher flows more 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 up to 2 – 3 m below the higher parts of the fairway. They are organised into pools, riffles, and runs. Pools are deeper and slower moving, while riffles are short shallow and swift flowing. However, the most common channel form is the run where the water flows in relatively long, moderately swift and moderately deep sections.

23. I estimate that the channels in the section of fairway shown in Figure 2 comprise about 25% of the total fairway area. Floods up to about the FRE3 flow remain largely within the channels, and larger floods begin to spread out over the fairway. (FRE3 = three times the median flow, or 217 m^3/s).

24. The channels flow between gravel bars and islands, and these landforms comprise the bulk (~75%) of the fairway area. 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 consist of bare or lightly grassed gravels, while islands are larger (several hectares) and somewhat higher so that they are less frequently flooded and can therefore support grass, scrub, and even trees.

25. Bar landforms typically start to become flooded above the FRE3 flood (217 m^3/s), and by the mean annual flood about 50% of the fairway is inundated. Full inundation of the fairway when all bars and most islands are underwater

occurs at about 1,400 m^3/s (instantaneous flow) and is relatively infrequent. These bank-to-bank floods occur on average about once every 15 years.

SEDIMENT TRANSPORT IN THE WAIAU RIVER

26. 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.

27. 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 ion 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.

28. In most rivers, suspended load makes up the bulk of the sediment carried. For example, Hicks (1998)[1] estimates that for the Waimakariri River the total bed load transported amounts to between 2% and 13% of the total suspended load transported, while for the Waiau River bed load is estimated to be just 4% of the suspended load.

Suspended load

29. 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, 1997[2]). 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[2]. Rivers are well able to transport all the suspended sediment supplied to them.

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

31. Data on suspended sediment concentrations in the Waiau River are available from the flow gauging data on the Waiau River at the Marble Point flow

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[1] *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.

[2] *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.

recording site. From these data I have derived a suspended sediment rating curve using a LOWESS[3] 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 3.

32. This relationship shows how suspended sediment concentrations increase as flow increases. 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.

33. This means the AHP water take will not change the concentration of suspended sediment in the Waiau River. The take removes 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.

34. Using the rating shown in Figure 3, I calculate that in the flow band between 20 m^3/s and 210 m^3/s, suspended sediment concentrations in the Waiau River would typically vary between about 2 g/m^3 and 586 g/m^3. Major floods can carry several thousand g/m^3 of suspended sediment.

35. Using this rating and the Waiau River flow duration curve for the period 1967 – 2009, I calculate the average annual suspended sediment load is about 1.73 x 106 tonnes per year[4], and of this only 21% is carried by flows up to 210 m^3/s. The proportion of the annual load carried declines rapidly below this flow. For example, less than 5% of the annual suspended sediment load is carried by flows up to the mean flow (97 m^3/s).

36. Thus, the larger flood flows above the flow band affected by the AHP water take are the dominant events that carry suspended sediment in the Waiau River, and this is consistent with other Canterbury braided rivers. For example, Hicks (1998)[1]calculated that in the Waimakariri River only 5.2% of the TSS load is carried by flows less than the mean flow.

37. 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

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

[4] This is similar to, but not exactly the same as the 2.4 x 10^6 tonnes per year calculated by NIWA (2011) using a LOWESS smoothing-based rating calculation (Hicks, D. *et al* Suspended sediment yields from New Zealand Rivers *Journal of Hydrology (NZ)* 50(1): 81 – 142.)

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

38. 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.

39. There is a large body of work on gravel transport in Canterbury braided rivers (eg Griffiths (1979)[5], Hicks and Davies (1997)[2], and Duncan and Bind (2008)[6] who discuss bedload sediment transport in the Waimakariri River). Duncan and Bind (2009)[7] have also modelled part of the Waiau River that would be affected by the AHP. Together, and these studies provide a useful background for understanding the bedload sediment transport in the Waiau River.

40. The Waiau River is a braided gravel bed river, and the taking of water for the AHP could de-power the river in the Amuri/Emu Plains 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 floodplain landform patterns of 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, bird habitat,

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5 Griffiths, G. (1979) *Recent sedimentation history of the Waimakariri River, New Zealand* Journal of Hydrology (New Zealand) 18(1): 6 – 23.
6 Duncan, M. and J. Bind (2008): *Waimakariri River bed sediment movement for ecological resetting* NIWA Client Report CHC2008-019, 32 p
7 Duncan, M. and J. Bind (2009) *Waiau River instream habitat modelling based on 2-D hydrodynamic modelling NIWA Client Report CHC2008-176, 72 p.* Duncan has added sediment transport outputs from this work in a personal communication reported in Olsen, D. *et al* (2011) *Assessment of the Amuri Hydro Project on the Waiau River, North Canterbury* Cawthron Report No. 2011, 129 pp.

fish-ability, visual character and amenity values, and other issues are covered in evidence by other experts.

41. The Waiau 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.

42. 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.

43. The question then arises, what are the significant sediment transporting and landforming floods in the river? Three flow levels are important:

    43.1 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*;

    43.2 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

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

44. 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 and island geomorphology.

45. Duncan and Bind[6,7] show that fines flushing and some depth flushing are theoretically possible even at very low flows, but I consider this to be insignificant 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.

46. For example, the Duncan and Bind[7] model shows that at the median flow (72 m^3/s) the Waiau River could have ~20% of the median flow bed subject to depth flushing. However, the median flow bed covers just 13% of the whole

fairway, so only about 2.5% of the fairway would be experiencing bed load transport.

47. Another approach to estimating bed load transporting flows is through ecological considerations. Clausen and Biggs (1997)[8] have identified through statistical analysis an ecologically significant flood flow for New Zealand rivers that is sufficiently large to disturb the riverbed ecology and prevent aquatic plant and animal communities from fully developing. This disturbance of the river bed organisms results from dislodgement by the force of the current and abrasion by sediment particles moving over the bed, and the turning over of armour layer particles[9].

48. This flow has been quantified as being a flood of a magnitude three times the median flow[7] or the FRE3. I interpret the FRE3 flow to be an indicator that significant fines flushing and some depth flushing is occurring at the river bed. In the Waiau River, the Duncan and Bind[7] model suggests that at the FRE3 flow (217 m^3/s) 70% of the median flow bed would be subject to fines flushing, and 52% of the bed would be subject to depth flushing.

49. 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 these only cover about 20% of the fairway area. Significant bedload transport does not occur until much higher discharges are reached and more of the fairway is inundated.

50. Davies[10], Hicks and Davies[2] and Griffiths[5] 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. However, the Waiau River is somewhat different to the Waimakariri River, having coarser gravel material, and full fairway inundation is much less frequent. Taking these matters into consideration I estimate that significant bedload transport in the Waiau River occurs at 4 – 5 times the FRE3 flow (~1,000 m^3/s).

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[8] *Relationships between benthic biota and hydrological indices in New Zealand streams.* Freshwater Biology 38: 327-342.

[9] Jowett, I.; P. Mosley 2004 *Analysis of instream values.* In Harding, J.; *et al* (eds) *Freshwaters of New Zealand.* New Zealand Hydrological Society and Limnological Society, Christchurch.

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

51. I have examined aerial photographs and satellite images of the part of the Emu/Amuri Plains reach of the Waiau River that was modelled by Duncan and Bind[7]. From these I estimate that the fairway here is about 1.6 km across and it requires a flood of ~1,000 m^3/s for it to be 50% covered. This event has an Annual Exceedance Probability (AEP) of ~0.41% (or an Average Recurrence Interval (ARI) of 1 in 2.5 years). This is close to the flow event known as the Mean Annual Flood that occurs on average once every 2.33 years. To fully inundate the fairway requires a flood of ~1,400 m^3/s, which has an AEP of ~0.065% (ARI = 1 in 15 years).

52. 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.

53. I list the significant flow thresholds for sediment transport in the Waiau River in Table 2.

54. 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 217 m^3/s, and this is well above the 210 m^3/s flow at which the AHP intake will have ceased.

Table 2: Waiau River flood flows

Median flow	73 m^3/sec	Some fines and depth flushing may be occurring in braid channels affecting about 10% of the fairway.
FRE3 'fresh' flow	217 m^3/sec	20 – 25% of fairway inundated. Fines and depth flushing occurring in the main channels across 10 – 14% of the fairway.
Significant bed load transporting flood	1,000 – 1,200 m^3/sec	50 – 80% of the fairway inundated. Fines and depth flushing affecting >80% of the channel area and on some bars.
Fairway inundation flow	1,400 m^3/sec	100% of the fairway inundated. Fines flushing occurring across much of the fairway. Depth flushing occurring in all channels, and across >50% of the fairway.

EFFECTS OF THE PROPOSED AHP FLOW REGIME

55. The take of water from the Waiau River for hydro generation will reduce flow in the Emu/Amuri Plains reach in the 20 – 210 m^3/s flow band such that the overall mean flow after both hydro and irrigation takes and assuming no losses or gains through the reach will be reduced by ~42 m^3/s to 55 m^3/s. The hydro component of this reduction is from 86 m^3/s (ie after irrigation takes) to 55 m^3/s.

Effects on suspended sediment transport

56. The reduction in flow through the Emu/Amuri Plains reach is unlikely to have any detectable effect on the Waiau River's ability to transport suspended sediment.

57. Water entering the AHP intake will be carrying suspended sediment and this will enter the intake in the same proportions as the main flow of the river. An abstractive 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.

58. The suspended sediment load will then continue to be carried downstream through the Emu/Amuri Plains 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.

59. 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.

60. The water taken for the Amuri Hydro Project will pass through a reservoir where some settling of suspended sediment is likely to occur. This will reduce the concentration of suspended sediment in the water so that when it is discharged via the scheme outfall back into the Waiau 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.

61. Meridian has proposed a condition on the consents associated with AHP to mitigate the potential build-up of periphyton during periods of reduced flow. This would entail the AHP ceasing to take water for a period of 24 hours to allow the flow to rise to or above 100 m^3/s, thus allowing the faster velocity

water and its suspended sediment to flush undesirable periphyton growths from the channel bed. The proposed AHP take will not affect the effectiveness of this mitigation measure.

62. In summary, the Amuri Hydro Project water take will not have any detectable effect on the transport and deposition of suspended sediment in the Waiau River.

Effects on bed load transport

63. The reduced river flow in the Emu/Amuri Plains reach will affect the bedload sediment transporting flow bands as shown in Table 3. This shows changes in the frequency, duration and separation of the various bedload transporting flood events.

Table 3 Characteristics of Waiau River bedload sediment transporting flows after Amuri Hydro Project and irrigation takes (1967 – 2009)

Flow Threshold	Frequency	Mean Duration	Mean Separation
Median flow (72 m^3/s) (Difference from natural Marble Point flow)	18.8 / yr (-0.8)	3.4 days (-6.1 days)	17.0 days (+6.8 days)
FRE3 'fresh' flow (217 m^3/s) (Difference from natural Marble Point flow)	9.2 / yr (-0.7)	2.1 days (-0.1 days)	38.5 days (+3.0 days)
Significant bed load transporting flow or Mean Annual Flood (742 m^3/s) (Difference from natural Marble Point flow)	0.5 / yr (0)	1.2 days (0 days)	661.0 days (0 days)

64. The Amuri Hydro Project take will affect the 20 – 210 m^3/s flow band, and there will be a decrease in the frequency and duration, and an increase in the separation between events within and close to this flow band, as shown in Table 3.

65. There will be slightly fewer median flow events, and they will be of considerably shorter duration. However, effects on bedload sediment transport will be minor as these events are very small freshes that cause only limited fines flushing of the channel bed, and isolated depth flushing of short riffles were the bed slope is steep. These events are confined to the flowing braids and do not affect the fairway.

66. The FRE3 events are more important for bedload sediment transport and they occur at flows just above the 210 m^3/s flow threshold when the hydro scheme take ceases. Table 3 shows there will be a decrease of 0.7 events per year, and the mean duration will be reduced by 0.1 days. The hydro take will have ceased before the FRE3 flow level is reached, thus the effects on

frequency, duration and separation of these events do not result from the hydro take itself. Rather, they would occur from the irrigation takes, which the hydrological model assumes will still be operating at flows above 210 m^3/s. In any event, the FRE3 events in the Waiau River are still confined to the braid channels and sediment movement is mainly fines flushing. Thus there will be only a minor effect on bedload sediment transport in these flow events.

67. The most significant bed load transporting flows occur around 1,000 m^3/s. From Table 3 it can be seen there will be no difference in the frequency and duration of these events.

68. The above assessment shows the AHP will have only a minor effect on the bedload sediment transporting regime of the Waiau River in the Emu/Amuri Plains reach. Effects will occur in the smaller sediment transporting floods at the median and FRE3 flow levels. In these events the main sediment movement process is fines flushing, and the effects are confined to the wetted channels that cover only a small part of the fairway. The main bedload sediment transporting flood events (>1,000 m^3/s) will not be affected by the hydro scheme take.

Effects on braided river landforms

69. The natural character of the braided Emu/Amuri Plains reach of the Waiau River arises from the floods that rearrange the fairway landforms of braid channel, bars and islands. This occurs when the fairway is substantially covered by water. Floods greater than about 217 m^3/s (FRE3) are likely to start spreading out of the braid channels and across the fairway, and these occur ~9 times per year. Full inundation of the fairway occurs with floods of ~1,400 m^3/s (instantaneous flow) that occur every ~15 years.

70. These flood events will not be affected by the AHP water take and thus there will be no effects on braided river landforms arising from flow regime changes associated with the hydro scheme.

SUMMARY

71. The Waiau 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 four times the FRE3 flow.

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

73. Summarising my assessment of the effects of the proposed Hurunui and Waiau River Regional Plan flow regime, and the Meridian Amuri Hydro Project on sediment transport in the Waiau River, and fairway braided river landform geomorphology, it is my opinion that the overall effects will be less than minor.

M.C.G. Mabin
12 October 2012

APPENDIX TO THE EVIDENCE OF MARK MABIN – FIGURES

Figure 1: Emu/Amuri Plains reach of the Waiau River. Image dimensions 22 km by 8 km. Flow from left to right.

Figure 2: Sub-reach of the Emu/Amuri Plains reach of the Waiau River (modelled by Duncan and Bind, 2009). Image date: 5/12/2000. Flow left to right, ~50 m^3/s. Image dimensions 2.7 km by 1.9 km.

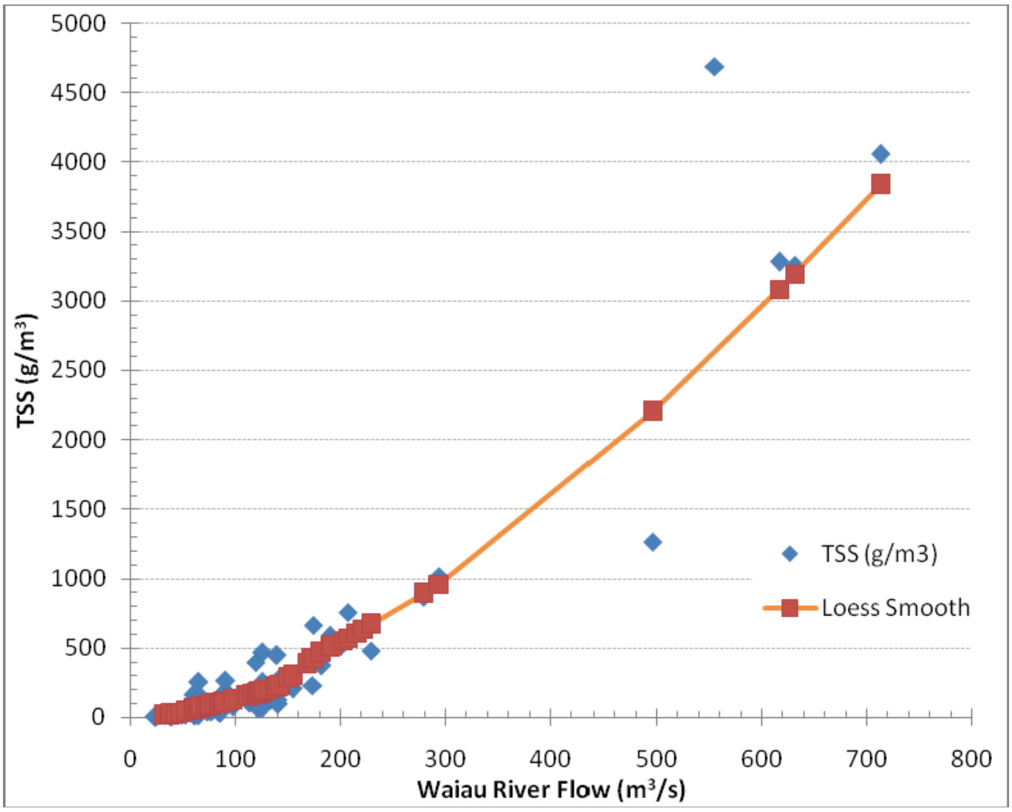

Figure 3: Suspended sediment rating curve for the Waiau River at Marble Point (TSS = total suspended solids)