Lake Coleridge Project – Coastal processes at Rakaia River mouth

Rakaia River mouth

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Executive Summary

This report presents a brief description of the coastal geomorphology of the Rakaia River mouth, and an assessment of the physical environmental effects of possible alterations of the operation of the Coleridge Hydro-Electric Power Scheme (HEPS) as a result of the proposed Lake Coleridge Project (the Project).

The Rakaia River flows into a coastal lagoon known as a hapua, separated from the sea by a narrow sand and gravel barrier. Commonly there is one outlet to the sea, but the position of this outlet changes in relation to changes in fluvial and oceanic processes and sediment transport along the coastal barrier.

This report is based on an assessment of existing literature of the Rakaia River mouth geomorphology and an appreciation of the issues related to the physical processes of the area gained from this reading, field visits to the river mouth and attendance of a workshop hosted by Environment Canterbury in June 2010 where concerns relating to the river mouth and hapua were discussed.

The physical environment of the Rakaia River mouth is dominated by the hapua lagoon and dynamic geomorphological change of the outlet channel position and form in relation to changes in the river flows, sediment transport in the river and along barrier beach, and the wave energy on the ocean shore. The area is subject to natural hazards of flooding and associated with erosion of the riverbanks, hapua shore and the coastline. It is thought that these hazards have been exacerbated by historical changes to the water flows in the river resulting from water abstraction in the Rakaia catchment.

Development of the water resources of the river have the potential to increase flooding at the river mouth hapua, could cause protracted closure of the mouth and could accentuate coastal erosion.

Snapshots of the long-term state of the Rakaia River mouth do not show coastal or hapua shoreline erosion. However, anecdotal information describes an increase in flooding of the hapua, especially when a medium flood event on the river occurs after a prolonged period of low flows. In addition, the Rakaia River mouth was reported to have closed after low flows and heavy seas in early 2010. This is the first reported closure of the Rakaia River mouth.

Monitoring of water levels and flows in the Rakaia River do not show clear patterns of change in flow at the Rakaia River mouth in relation to day-to-day fluctuations in discharge from the Coleridge HEPS. There has also been no monitoring or assessment of existing data to clearly determine the causes of flooding in the Rakaia hapua. It is likely that the hazards experienced at the Rakaia Huts are a result of a combination of processes including marine and fluvial energy levels and natural and artificial variability in the river flows.

From the modelling of the Project scenarios, the Lake Coleridge Project will have no noticeable effects on the magnitude or frequency of flood events, or in the effect of low flow events on the hapua processes.

1. Introduction

1.1 Purpose of the report

This report presents a brief description of the coastal geomorphology of the Rakaia River mouth, and an assessment of the physical environmental effects of possible alterations of the operation of the Coleridge Hydro-Electric Power Scheme (HEPS). In particular, the physical character of the river mouth hapua is described, and issues relating to opening and closing of the mouth and coastal erosion processes are discussed.

The Rakaia River mouth is similar in morphology to most river mouths of the braided rivers on the Canterbury coast. The main channels flow into a coastal lagoon separated from the sea by a narrow sand and gravel barrier. Commonly there is one outlet to the sea, but the position of this outlet changes in relation to changes in fluvial and oceanic processes and sediment transport along the coastal barrier. Maori refer to this type of lagoon as a ‘hapua’. Kirk and Lauder (2000) adopted this name to distinguish this type of lagoon from other kinds of coastal lagoon and from estuaries.

The Coleridge HEPS is situated between Lake Coleridge and the Rakaia River, and utilises natural lake storage, augmented by diverted inflows from the Harper and Wilberforce Rivers, at the western end of the lake catchment, and the Acheron River via Coleridge Stream at the eastern end of the catchment. Water from the lake travels down two intake tunnels on the south-eastern shore of the lake to the Coleridge Power Station adjacent to the Rakaia River. The Coleridge HEPS officially commenced operation in 1914. The Wilberforce Diversion opened in 1977 and was the final modification to the catchment contribution to the lake. The Coleridge HEPS has an energy production capacity of approximately 270 GWh per year.

TrustPower Ltd (TPL) currently operates the Coleridge HEPS. During normal operation of the Coleridge HEPS, approximately $26m^3/s$ is drawn from Lake Coleridge and released to the Rakaia River, 86km from the river mouth.

TPL are proposing to modify operation to provide irrigation and additional power generation via the Lake Coleridge Project (the Project) as described in the Project AEE. In summary, on completion, the Project will include a new canal from Lake Coleridge to supply irrigators on the north (left) and south banks of the Rakaia. Electricity will be generated along the canal and any excess water not required for irrigation will be returned to the river at the Highbank HEPS.

The following sub-sections discuss the methodology of assessment employed for this report. Section 2 presents a description of the existing physical geomorphology and process environment of the Rakaia River mouth and hapua. Section 3 defines thresholds to be protected. Section 4 presents a description of the Project, while Section 5 addresses the effects of the Project on the physical Rakaia River mouth and hapua processes. Section 6 presents conclusions.

1.2 Background and assessment methodology

This report is based on an assessment of existing literature of the Rakaia River mouth geomorphology through research by staff and students of the University of Canterbury, academic and technical papers on the area and describing the functional processes of hapua and the Rakaia River mouth, and an appreciation of the issues related to the physical processes of the area gained from this reading, field visits to the river mouth and attendance of a workshop hosted by Environment Canterbury (ECan) in June 2010 where concerns relating to the river mouth and hapua were discussed. In particular, work by Kirk (1991), Hart (1999), Kirk and Lauder (2000), McHaffie (2010) and Steenson (2010) have provided background for this report. The presentation by Bill Southward (a long-standing resident of the Rakaia settlement) at the ECan workshop, his recollections, photographs and research work have proved valuable in providing background information on the process environment and associated issues to residents and users of the hapua.

Kirk (1991) presents a description of the interaction between fluvial and marine processes as controls of the lagoon size and river mouth opening on mixed sand and gravel beaches. He uses the Rakaia River hapua as an example of these process relationships and how they can be affected by potential and actual modifications to the river flow by activities such as hydropower generation and the abstraction of water for irrigation. He notes "*Water resource development on the river has the potential to increase freshwater flooding adjacent to the mouth, to cause protracted closure of the mouths and to accentuate coastal erosion*." Identification of whether these adverse changes to the river mouth will occur forms the basis for assessing the potential environmental effects of the Project.

1.3 Reports relied on for the assessment

Kirk (1991), Kirk and Lauder (2000) and Hart (1999, 2007, 2009a, 2009b) describe the general process relationships of hapua against which the Rakaia River hapua and mouth system have been assessed. McHaffie (2010) and Steenson (2010) present recent research results on changes to the river mouth geomorphology and management of the Rakaia hapua environment respectively. McHaffie investigates changes to the Rakaia River mouth and hapua as determined from aerial photographs of the area from 1952 to 2004. Steenson presents an assessment of Integrated Coastal Management of the Rakaia Huts area, based on interview with residents and ECan staff.

Hydrological modelling of the project has been used as a basis of the changes that may affect the shore processes and morphology. Reports by Beca Infrastructure (2011) and Tonkin and Taylor (2010) contain the modelling methodology and results.

1.4 Rakaia Hapua and rivermouth workshop

A workshop coordinated by ECan provided an opportunity for residents and scientists to discuss environmental concerns and the scientific database relating to the Rakaia River mouth and hapua area and the Rakaia Huts settlement. The workshop included presentations from Bill Southward, scientists and managers from ECan, NIWA and the University of Canterbury. The topics discussed included:

- Historical perceptions of flow regimes and flooding
- Thinning and movement of the gravel barrier between the hapua and the ocean
- Flow budgets
- Groundwater interaction
- Water Conservation Order, consents and allocations
- Sediment supply and transport
- Mouth opening mechanisms and engineering management options
- Water quality monitoring
- Salmon life stages and migration

It was recognised by the Project team members that changes to the use or operation of the Coleridge HEPS would be seen as relevant to those with interests in the Rakaia Huts and the lower reaches of the river (Beca Infrastructure 2011).

PART A: EXISTING ENVIRONMENT

2. Physical Character of the Rakaia River Mouth and Hapua

2.1 General character

The Rakaia River has a catchment area of approximately 2600 km², and flows from the Southern Alps to the Canterbury Bight. Inland from the coast, the river diverges into two channels around Rakaia Island. The main channel flows to the south of the island, while the Little Rakaia flows to the north. The two channels flow into the hapua and have a common outlet to the sea.

Figure 1 shows the Rakaia River mouth and hapua as of July 2009. The barrier between the sea and the hapua comprises a mixture of sands and gravel. It is generally narrow, and is formed by transport of sediment along the shore by wave swash. The dominant sediment transport is to the north, so the barrier forms as a spit with the southern end wider than the middle and distal end. However, the barrier can also contain a series of inherited features, giving the appearance of overlapping longitudinal ridges.

Although the Canterbury Bight is supplied with new sediment from the Rangitata, Ashburton and Rakaia Rivers, it is in a state of long-term chronic erosion (Kirk, 1991). The Canterbury Regional Council Coastal Environment Plan put the general rate of erosion as about 0.5 to 1.0 m per year. At the South Rakaia Huts the erosion rate between 1991 and 2009 was approximately zero, while at the North Rakaia Huts the shore has prograded (moved seaward) by about 4 to 5 m over the same time period. This is an effect of the river mouth and barrier variability, and is not representative of the general character of the coast. Over the period between 1991 and 2009, the shore just north of the huts prograded at about 0.3 m per year. This is likely to be more representative of the effect of sediment transport along the shore and sediment supply from the river than the progradation rate at the huts (pers com Bruce Gabites, ECan coastal scientist).

The total sediment load of the Rakaia River is about 5 million tonnes per year, of which about 580,000 tonnes is bedload (NIWA WRENZ website). Kirk (1991) refers to the river as 'small' as the sediment load delivered to the coast is insufficient to counteract the erosion forces of the high-energy shoreline.

Figure 1 Google Earth image capture of Rakaia Hapua and lower section of Rakaia River

The river mouth position and size is controlled by the interaction of river flows with the barrier morphology and marine energy. During floods the barrier is breached opposite the main river channel and flows directly into the sea. During medium to low flow conditions the river outlet can migrate in response to littoral drift of sediments. This results in deflection and elongation of the mouth to the north. This is shown in Figure 2. The position and channel morphology of the outlet changes under these conditions. Under prolonged low flow conditions it is possible for the mouth to close. The first recorded occurrence for the Rakaia River was in 2010.

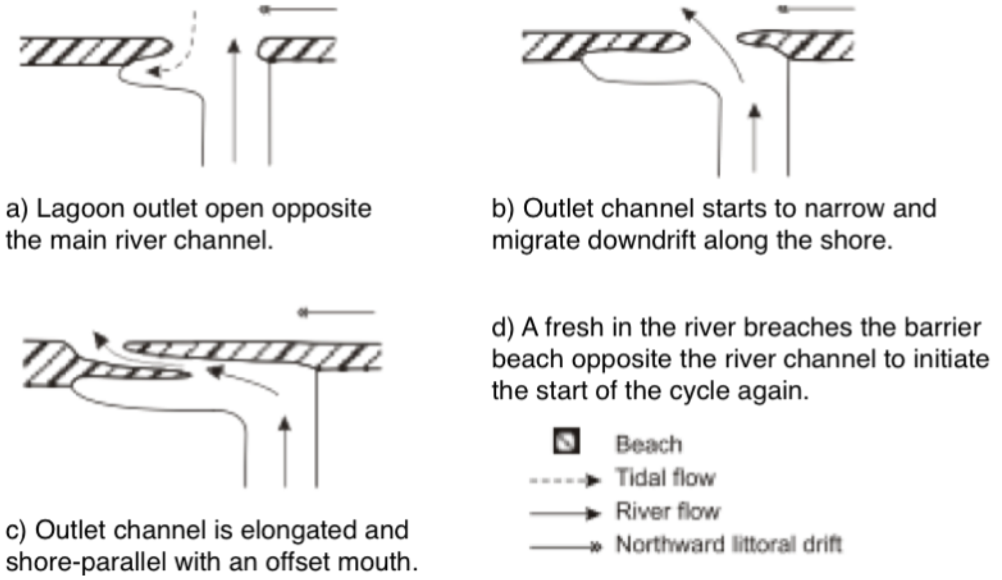


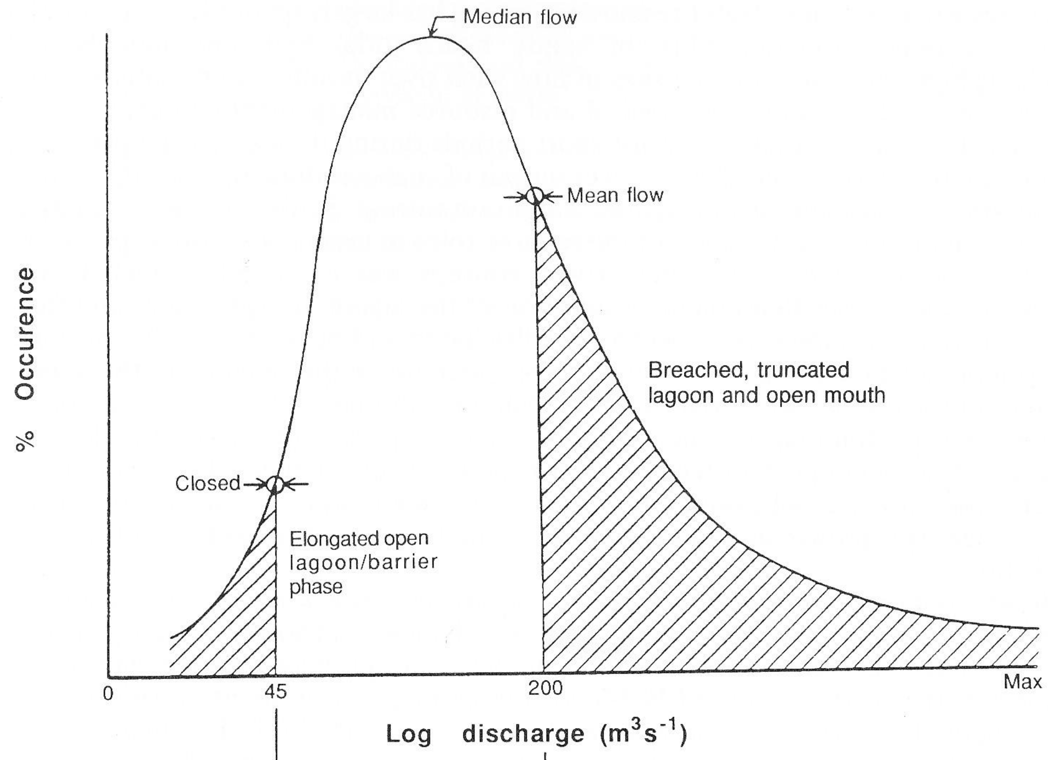
Figure 2 Cycle of river mouth behaviour (after Todd 1992, 212)

The hapua has no tidal inflow, but is influenced by tides due to changes to the hydraulic head at the outlet. The rising tide reduces the permeability of the gravel barrier, and reduces percolation of water through the barrier. This can raise the water level in the hapua. As the tide drops, the hydraulic head increases and there can be greater flow of water through the barrier and through the outlet channel.

River-born sediment can bypass or be temporarily trapped in the hapua. Under low to medium flows sediment is trapped inside the hapua. During floods, the sediment is pushed out to the coast and coarse material is deposited resulting in the growth of a sub-tidal delta. Kirk (1991) noted that the hapua acts as a source of coastal sediments during and immediately after high river flows, and traps sediment during moderate to low flows. The river flows are therefore linked to the outlet flow and position, and to sediment supply to the coast.

Kirk (1991) summarised the process relationships and incorporated them into a descriptive model of the Rakaia River mouth system as shown in Figure 3. In this model, at very low river discharges the lagoon is closed to the sea behind an intact barrier, throughflow is minimal and siltation occurs in the lagoon. At more frequent, moderate discharges the lagoon has a single, open, migratory outlet to the sea, throughflow is low, coarse sediments are stored in the lagoon-barrier complex while fines are delivered to the coast. During high-flow, flood conditions the barrier is breached in one or more locations, opening the river mouth directly to the sea and truncating the lagoon while large volumes of sediment are delivered to the adjacent coast. The threshold for such a breach at the Rakaia hapua, 200 m^3s^{-1}, represents the mean annual discharge of this river.

Large storm waves have the ability to close hapua outlets at the same time as they overtop the barrier, increasing lagoon water levels so that a new outlet is breached as the hydraulic head between lagoon and sea increases on the falling tide. This mechanism is termed ‘storm breaching’ to differentiate it from breaches initiated by river floods (Hart 1999). Storm breaching is believed to be an important but unpredictable control on the duration of closures at moderate to low river flow levels in smaller hapua-type lagoons but may also affect the outlet behaviour for the Rakaia River.



River flow	Low	Moderate	High (floods)
Throughflow	Minimal	Low	High in breach phase
Mouth stability	Closed	Open to sea. Mouth migrates northward	New mouth formed by breaching. Sometimes multiple mouths
		Offset either south or north, usually to north	Deltas formed to seaward by injection of gravels to lagoon
Lagoon	Closed	Open to sea; elongates northward	Truncated. Much of low flow lagoon becomes backwater
Sedimentation	Siltation in closed lagoon (sink)	Reworking of fines sink for coarse sediments	Active source of coarse sediments to lagoon and beach
		Source/sink of fines	Scour of land adjacent to channels

Figure 3 Descriptive model of mixed sand and gravel hapua/spit/barrier processes. Threshold values are set for the Rakaia as functions of river discharge (Source: Kirk 1991, Figure 6).

2.2 Changes to the Rakaia hapua

McHaffie (2010) investigated changes to the Rakaia hapua since 1952 from an examination and GIS analysis of aerial photographs from 1952, 1966, 1975, 1998/99 and 2004. She found that the ocean shoreline and the seaward shore of the hapua moved seaward over the study period. However, the position of both shores retreated landward between 1952 and 1975, before moving seaward. There was also accretion of the inland shoreline of the hapua over the total period.

The average width of the barrier beach was about 50 m. However, the width varied along the shore for each time snapshot, and the width varied over the total time period. The barrier was widest at the time of the 1966 photograph, and narrowest at the time of the 2004 photograph.

The surface area of the hapua water body decreased by about 24.5% between 1952 and 1966, and then remained stable at around 600,000 m^2 for the remaining photographs. McHaffie attributed the difference to seasonal variation as the 1952 photograph was taken in autumn and the others during spring and summer.

It was not possible for McHaffie to ascertain the validity of Kirk's 1991 model of the hapua behaviour due to the narrow range of antecedent river flow conditions relative to the aerial photographs. However she did conclude that the changes were contrary to the net retreat of the ocean shore and the inland shore of the hapua proposed by Kirk. McHaffie suggested that a reason for this may be that there have been changes in the sediment load of the river or there has been a change in the distribution of sediment load between the main and Little Rakaia channels. Her main finding was that the effects of human modifications to the Rakaia River flow regime that were proposed by Kirk were not evident from the aerial photograph analysis.

Anecdotal evidence presented by Steenson (2010) counter the findings of the aerial photograph snapshots. Residents of Rakaia Huts have observed changes to the hapua environment. These include damage to structures on the inland shoreline of the hapua due to shoreline erosion and flooding, increased flooding events after prolonged low-flows in the river, decreased sediment sizes on the barrier beach and closure of the river mouth.

At present there has been no quantitative link between changes in the flow regime and the observed events at the hapua. There have also been no studies that identify the proportional effects of different causative agents of fluctuations in water level and flow records. Therefore the effects of the Coleridge HEPS have not been separated from other effects such as irrigation extraction from the river or groundwater extraction from the aquifers near the river.

2.3 Rakaia Huts

The Rakaia Huts area is a known moa hunting site and is of special interest to Te Taumutu Runanga and Te Runanga o Ngai Tahu. Te Taumutu Runanga (2003) note "*Ngai Te Ruahikihiki ki Taumutu are the primary kaitiaki (guardians) of the Te Waihora catchments* *within which the Rakaia Huts are located*." Te Taumutu Runanga has developed specific policies that apply to earthworks and sewage disposal at the huts.

Early European activity was based around fishing quinnat salmon and whitebait (Graham and Chapple 1965). The area of the huts was subdivided in 1924. The area still contains a number of fishing huts, holiday homes and a campground.

3. Key Thresholds to be Protected

With reference to the National Water Conservation (Rakaia River) Order 1988, the Rakaia River mouth area and hapua are not noted specifically. However Clause 3 declares that the Rakaia River and its tributaries include and provide for an outstanding natural characteristic in the form of a braided river. The river mouth area and hapua exhibit natural characteristics of braided rivers and especially represent the characteristics of hapua that are found on these types of river in New Zealand. The geomorphology and processes at work are similar to the Ashburton and Hurunui River mouths and hapua in Canterbury, and to the Waiau River mouth and hapua in Southland.

It is therefore relevant that the natural characteristics of the river mouth and hapua be maintained. It should be noted that these processes include dynamic change to the river mouth form and position, periods of low and high flows in the river, flooding of the hapua and low-lying hinterland, periods when the physical system is dominated by oceanic processes (waves, currents and alongshore sediment transport), and periods when the physical system is dominated by fluvial processes. In assessing the effects of the Project, the existing dynamic character of the area has been considered.

PART B: THE PROPOSAL

4. The Project

The Project AEE presents a standardised description of the TrustPower proposal. The proposal seeks to change the National Water Conservation (Rakaia River) Order 1988 to enable water stored in Lake Coleridge to be used for irrigation of the Canterbury Plains and for further hydroelectric power generation. In particular, the proposal will facilitate a change in the way TrustPower currently operates the Coleridge and Highbank Hydroelectric Power Schemes to allow storage and use of 'winter' water for irrigation.

The hydrological effects of the proposal are of particular relevance to the assessment of the proposal on the Rakaia River mouth and hapua. Tonkin and Taylor (2010) and Beca (2011) discuss the hydrological effects of proposed changes to the operation of the Coleridge HEPS in detail. They found that changes to the flows from the Coleridge HEPS are difficult to ascertain from the background 'noise' in the flow regime in reaches of the river downstream of the SH1 bridge (22km from the mouth). Long durations of cessation of flow from the Coleridge HEPS are visible in water level records downstream of SH1. However, changes in the release from the Coleridge HEPS are masked by other fluctuations in the water level record. Further hydrological analysis of time-series data is required to assess the likelihood of increased duration of low flow events at the river mouth.

The actual effects of the existing operation of the Coleridge HEPS cannot be assessed in detail with the existing flow duration curve data. However, the effects of day-to-day operations appear to be masked by other variability in the flow and water level records for the reach of the river downstream of SH1.

PART C: EVALUATION

5. Assessing the Effects of Changes to the Flow Regime

The links between river flows and the hapua and river mouth outlet state described by Kirk (1991) are recognised in the potential for integrated management of Canterbury rivers by ECan (ECan 2010 Draft Regional Policy Statement, Policy 8.3.2 Preservation of the natural character of the coastal environment). There is debate in the literature as to the general validity of approach (Hart 2009a, McHaffie 2010, Steenson 2010), and there is a paucity of monitoring and data on the hydrological flows, sediment movement and geomorphological changes over time from which to test Kirk's model (Figure 3). However, the principles behind the model, and the process interactions are sound.

The greatest effect on the hapua dynamics due to water abstraction from the river catchment is during medium flow conditions. During these conditions, changes to the hapua barrier are dominated by changes in the breaking wave environment. Longshore drift of sediment results in the migration along the shore of the outlet channel (generally to the north), elongation and narrowing of the barrier. Offset of the outlet to the north for prolonged periods can result in erosion of the barrier beach to the south and wave penetration to the landward shore of the hapua near the Rakaia Huts. If the outlet closes, the flooding risk to the hapua hinterland increases.

It is noted in the Beca (2011) report that an increase in water levels during prolonged periods of low flow raises concerns of flooding for residents of Rakaia Huts. The residents have associated the antecedent high water level state with increased flooding during moderate flood events, or events that historically would not result in flooding around the Rakaia Huts.

It is unclear from the hydrological modelling results (Tonkin and Taylor 2010, Beca 2011) whether the Project will increase the duration of low flows periods at the hapua, or whether the effects of changes in flow due to the Project will attenuate downstream to be negligible at the river mouth. In the Beca report, it is noted that there will be a perception of increased flood risk. The report suggests "*a key element of the Project hydrological analysis will need to be time-series data as flow duration curves will not provide the level of detail required*." That view is supported in light of the process dynamics of the Rakaia hapua. Without the detailed information, the effects of the Project proposal on flooding at the hapua cannot be assessed further than noting that separation of effects of the different types of human modification to the water volume in the Rakaia River is not possible at this time.

With regard to sediment supply from the river, Beca 2011 note "*Changes in the flow regime may alter the total supply in the short-term as upstream river morphology adjusts to the revised regime but in the medium- to long-term the supply of material is not expected to change significantly*." This conclusion is consistent with the findings of Mabin (2007) in assessing the effects of the Central Plains Water Scheme, "*as the affected flow bands carry only a very small amount of suspended sediment, and the reduced flow in these flow bands would result in an undetectable change in fine sediment transpo*rt."

The differences in flows shown by the Tonkin and Taylor modelling of the Project are small, and do not affect the higher magnitude events that transport all of the available sediment size ranges in the river. Therefore, the Project should not result in changes to the sedimentation of the hapua or transfers of sediment to the coast through the Rakaia River mouth.

6. Conclusions and Recommendations

The physical environment of the Rakaia River mouth is dominated by the hapua lagoon and dynamic geomorphological change of the outlet channel position and form in relation to changes in the river flows, sediment transport in the river and along barrier beach, and the wave energy on the ocean shore. The area is subject to natural hazards of flooding and associated with erosion of the riverbanks, hapua shore and the coastline. It is thought that these hazards have been exacerbated by historical changes to the water flows in the river related to water abstraction in the Rakaia catchment.

Kirk (1991) developed a model to illustrate the interaction between fluvial and marine processes including sediment transport in the river and along the coast, wave energy and changes in river flows (shown in Figure 3). He found that fluvial processes dominate the river mouth behaviour on the Rakaia River. He noted that development of the water resources of the river has the potential to increase flooding at the river mouth hapua, could cause protracted closure of the mouth and could accentuate coastal erosion.

McHaffie (2010) found that snapshots of the long-term state of the Rakaia River mouth do not show coastal or hapua shoreline erosion. This is confirmed by ECan coastal monitoring for the Rakaia River mouth section of the Canterbury Bight. However anecdotal information describes an increase in flooding of the hapua, especially when a medium flood event on the river occurs after a prolonged period of low flows. In addition, the Rakaia River mouth was reported to have closed after low flows and heavy seas in early 2010.

Monitoring of water levels and flows in the Rakaia River do not show clear patterns of change in relation to day-to-day fluctuations in discharge from the Coleridge HEPS. There has also been no monitoring or assessment of existing data to clearly determine the causes of flooding in the Rakaia hapua. It is likely that the hazards experienced at the Rakaia Huts are a result of a combination of processes including marine and fluvial energy levels and natural and artificial variability in the river flows.

From the modelling of the Project scenarios to date, the Lake Coleridge Project will have no noticeable effect on the magnitude or frequency of flood events. Smaller flood will continue to increase the water level inside the hapua and are unlikely to directly cause the barrier to open opposite the main river channel. Larger flood events will still result in the river breaching the barrier opposite the main channel. There will also be no noticeable change to the effects of low flow events.

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