Processes creating and maintaining non-estuarine river-mouth lagoons (hapua)

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INTRODUCTION

Hapua are a type of shore-parallel river-mouth lagoon common in New Zealand. Hapua form where gravel-bed rivers emerge onto high wave energy, micro/meso-tidal coastlines. Hapua have highly dynamic outlet channels, which can migrate rapidly alongshore in response to river flows and waves.

Monitoring of the Hurunui Hapua has been conducted since July 2015 to inform better understanding of the key processes affecting hapua morphology and to inform development of a model replicating hapua behaviour. Monitoring has included time-lapse cameras, water level and salinity recorders, and repeat surveys of lagoon and barrier topography. The locations of monitoring instruments in the Hurunui Hapua are shown in Figure 1 and Figure 2, below.

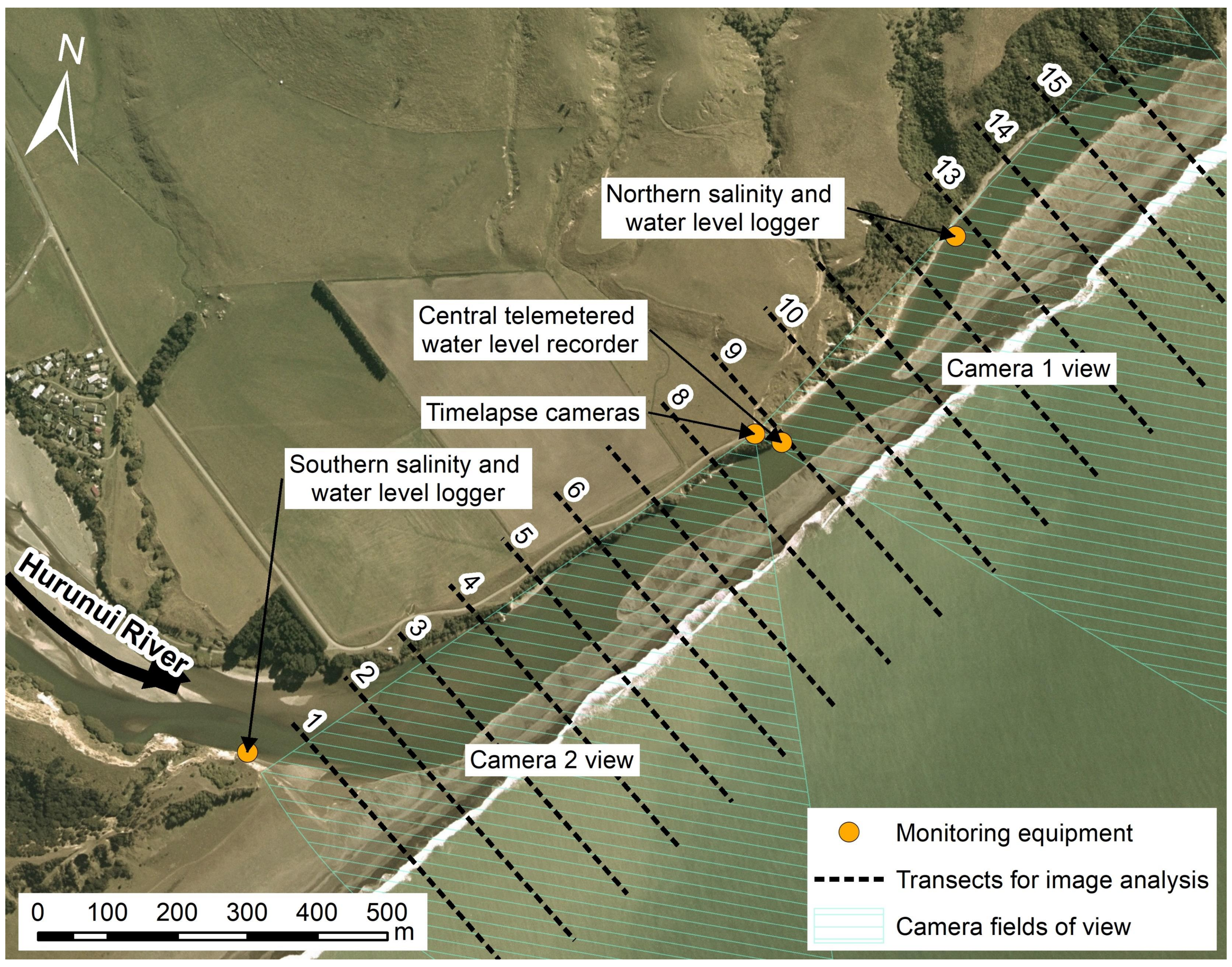


Figure 1: Hurunui Hapua monitoring stations and transects used for analysis of lagoon width

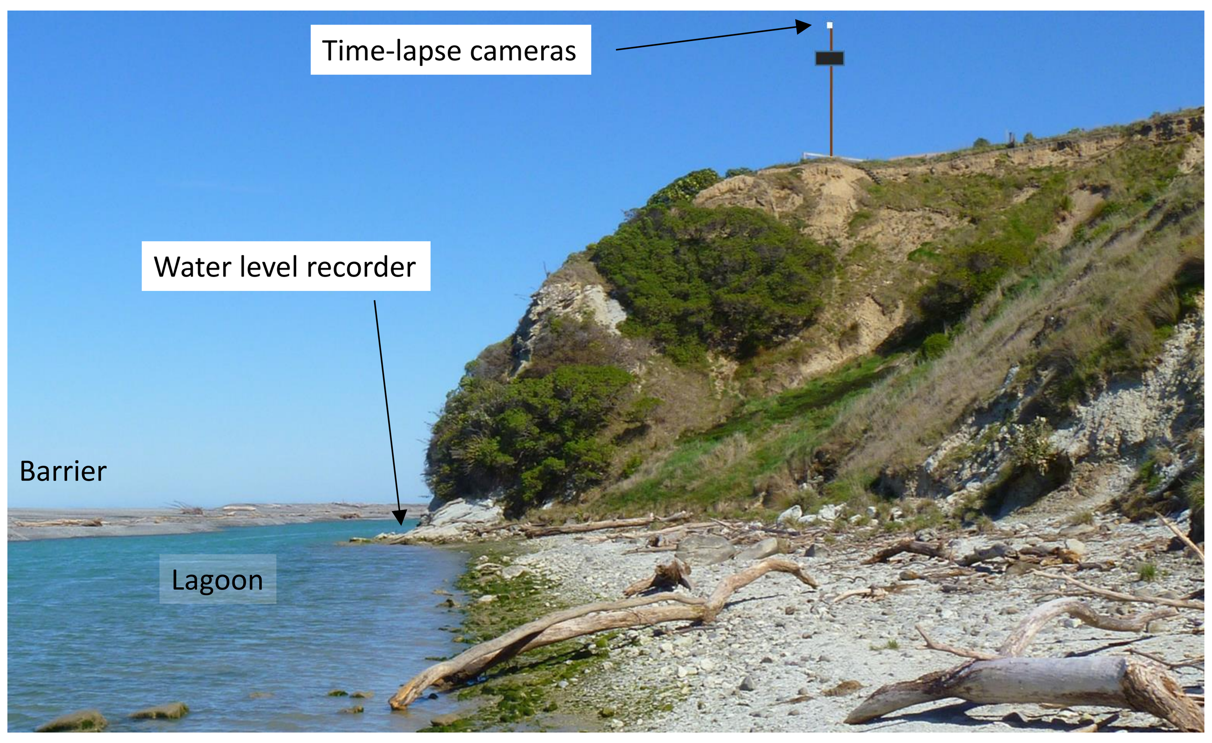


Figure 2: Telemetered cameras and water level recorder installed at the Hurunui Hapua.

Photo looking south west from lagoon backshore at transect 11. Two time-lapse cameras are mounted at the top of an 8 m tall utility pole on the high point of the lagoon backshore cliff. The utility pole also has a satellite antenna (for telemetry) and solar panels (to provide power) mounted onto it. The primary water level recorder is bolted onto an exposed bedrock outcrop at the cliff toe and connects to the same telemetry system.

LAGOON OUTFLOW

Hapua have tidally varying water level but are non-estuarine, i.e. they is no tidal flow reversal. A simple water balance model has been developed for the Hurunui Hapua to quantify lagoon outflow based on lagoon inflow:

River flow (gauged) → Water stored in lagoon (quantified from water level record) → Outlet channel flow (not directly measured)

→ Barrier seepage (Quantified from spot gaugings)

(*outlet channel flow*) = (*river flow*) – (*change in stored volume* + *barrier seepage*)

The calculated lagoon outflow (see top left hand graph in figure 3) shows that the relationship between river flow and outlet channel flow is very strongly impacted by outlet channel morphology. When the outlet channel is short, the lagoon water levels experience large tidal variations and outflows vary from approximately 50% to 150% of river flow. When the outlet channel is extended and constricted, outlet flows become almost constant and lagoon water level stays at an almost constant level, perched 1 m or more above high tide level.

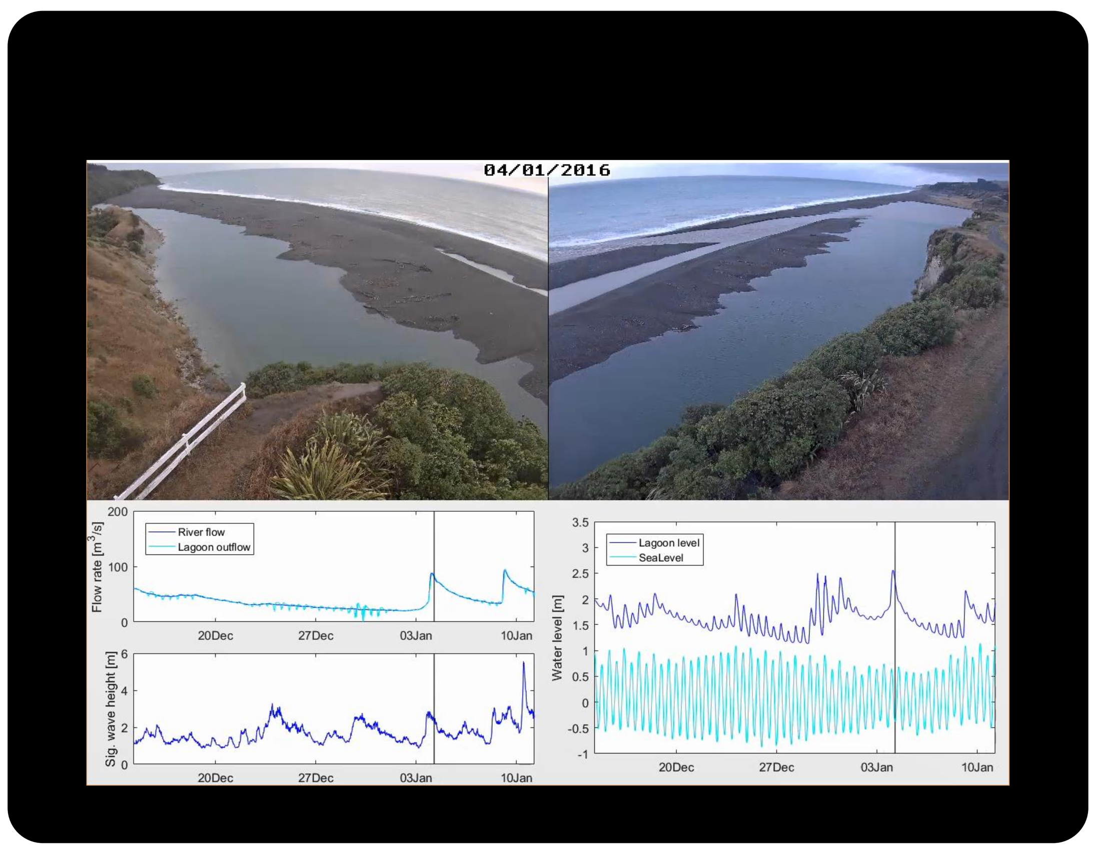


Figure 3: Time-lapse imagery of the Hurunui Hapua with time-linked plots of water level, flow and wave data.

Images were recorded every 15 minutes during daylight hours from two cameras located in the center of the lagoon backshore. In the figure, the left hand image is from camera 1 (looking north east), and the right hand image camera 2 (looking south west). Camera location and fields of view are shown in Figure 1. Below the animated images the plots show river inflow and lagoon outflow (top left), lagoon level and sea level (right), and significant wave height (bottom left).

LAGOON WIDTH

Lagoon width was measured from the time-lapse image data at transects spaced along the length of the hapua (Figure 1). Width was measured by (1) correcting the images for distortion, (2) measuring horizontal and vertical rotation of the camera by identifying static objects in the frame, (3) applying edge detection algorithms to segment the image at the water's edge, (4) projecting the identified water's edge onto a flat plane at the observed water elevation, and (5) intersecting the projected water's edge boundary with the measurement transects.

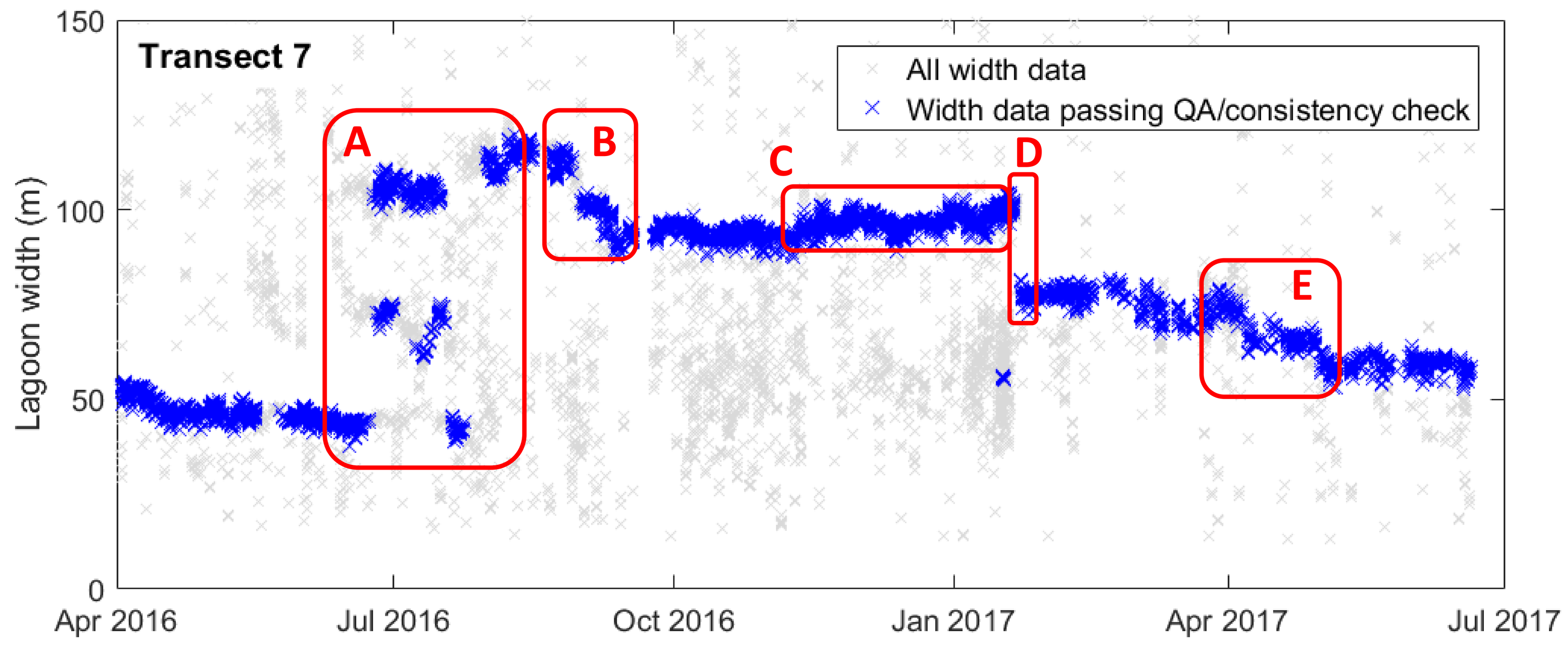
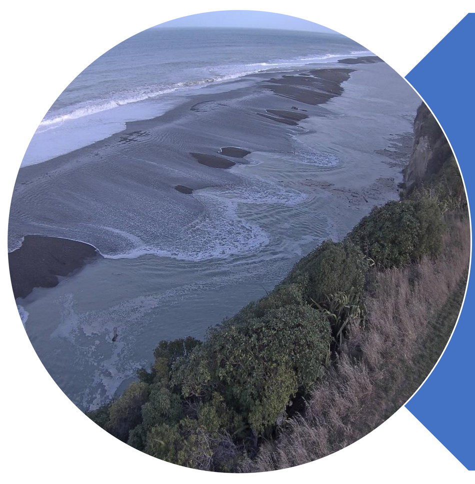


Figure 4: Hurunui Hapua monitoring stations and transects used for analysis of lagoon width. Letters identify periods where width has changed due to identifiable causes – see key processes in boxes below.

Observations from the time-lapse imagery, coupled with the analysis of lagoon width have informed identification and quantification of three key process which control lagoon width (letters refer to figure 5):



Wave overtopping (B, D, E)

Waves overtop the beach barrier washing gravel into the lagoon.

- Primarily driven by waves but sea levels also important.
- Widens barrier and narrows lagoon
- Significant overtopping happens approx. 6 times per year
- Observed complete closure of lagoon at one location

Outlet channel migration (A)

Lagoon outlet channel migrates alongshore. As mouth moves along barrier it 'resets' barrier width and position.

- Complex process driven by interaction of waves (alongshore and cross-shore transport) and river flow
- Widens lagoon
- Approx. 2 years for migration over full length of lagoon

River flood when outlet channel is offset (C)

Freshes and floods which occur when the outlet channel is offset from the river (due to migration) scour the lagoon. If severely constricted even normal flows may cause scour.

- Driven by river flows and outlet channel position
- Widens and deepens lagoon
- Removes deposits from toe of lagoon backshore cliff

NEXT STEPS

The overall goal of this study is to develop a model of hapua behavior which can be used to investigate their response to changing drivers including: flow regime modification (e.g. due to dams or water extraction), sea level rise, and changes to sediment supply. The monitoring and analysis of the Hurunui Hapua is being used to inform model design and to provide a validation dataset to test model performance.